Lactoferrin and Immunoglobulin Contents in Camel's Milk (*Camelus bactrianus*, *Camelus dromedarius*, and Hybrids) from Kazakhstan

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ABSTRACT

Lactoferrin (Lf) and IgG were estimated in camel's milk from Kazakhstan, where 2 species of camels (*Camelus bactrianus*, *Camelus dromedarius*) and their hybrids cohabit. The concentrations of Lf and IgG were determined according to 3 variation factors: region ($n = 4$), season ($n = 4$), and species ($n = 5$; sample 4 was mixed milk and sample 5 was of unknown origin). The mean values in raw camel's milk were 0.229 ± 0.135 mg/mL for Lf concentration and 0.718 ± 0.330 mg/mL for IgG concentration. The seasonal effect was the only significant variation factor observed, with the highest values in the spring for Lf and in the winter for IgG. The Lf concentration varied in 1-wk postpartum milk from 1.422 to 0.586 mg/mL. The range in IgG concentration was wide and decreased from 132 to 4.75 mg/mL throughout the 7 d postpartum, with an important drop after parturition. In fermented milk, the lactoproteins are generally hydrolyzed. For milk samples from undefined species, discriminant analyses did not allow the origin of the species to be determined. A slight correlation between Lf and IgG concentrations was observed in raw milk. The values were slightly higher than those reported in cow's milk, but this difference was insufficient to attribute medicinal virtues to camel's milk.

Key words: lactoferrin, immunoglobulin, camel's milk, colostrum

INTRODUCTION

The current camel population in Kazakhstan is around 130,000 head (Statistical Agency of the Republic of Kazakhstan, 2006). This country is well known for the cohabitation of 2 species of camels (*Camelus bactrianus* and *Camelus dromedarius*) and their hybrids. Within the Kazakh Bactrian breed, 3 types have

been described according to their geographic distribution: *uralobukeevskii*, *kyzylordinskii*, and *yuzhnokazakhstanskii* (Terenyev, 1975; Konuspayeva and Faye, 2004). For the Dromedary camel, only the Arvana breed, which originated from Turkmenistan, is present in Kazakhstan. Different levels of hybridization have occurred, resulting in a wide range of crossbreeds (Terenyev, 1975).

The consumption of camel's milk, especially in fermented form, is a very old tradition in Kazakhstan. Many beneficial properties are attributed to camel's milk and to a fermented product called *shubat*. It is traditionally used for the treatment of tuberculosis, gastroenteritis, and for many infections, and is also drunk as a tonic (Sharmanov and Dzhangabylov, 1991). These antimicrobial properties of camel's milk and *shubat* can be attributed to substances such as proteins, lipids, and vitamins (Elagamy et al., 1992; Farah, 1993; Elagamy, 2000; Benkerroum et al., 2004; Konuspayeva et al., 2004). Among the milk proteins, lactoferrin (Lf), IgG, lactoperoxidase, lysozyme, and some peptides are the main components that have been implicated (Barbour et al., 1984; Duhaime, 1988). However, the quantity of those components and their overall variability in camel's milk are not well documented. In the present study, we determined the Lf and IgG contents in raw and fermented camel's milk from *C. bactrianus*, *C. dromedarius*, and their hybrids under different seasonal and geographic conditions.

MATERIALS AND METHODS

Sampling Procedure

To obtain the maximum variability, the camel's milk was sampled from 4 different regions at extreme points of Kazakhstan: Almaty, Atyrau, Aralsk, and Shymkent (the maximum distance between the different points was more than 3,500 km) and in 4 seasons of the year. In total, 128 samples were used for quantitative and qualitative determination of the Lf and IgG contents in camel's milk (Table 1). Those samples, collected ran-

Received July 4, 2006.

Accepted August 24, 2006.

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Table 1. Camel raw milk sampling design by region (Almaty, Atyrau, Aralsk, and Shymkent), species, and season

Breed	Almaty (n = 35)				Atyrau (n = 28)				Aralsk (n = 8)				Shymkent (n = 34)			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Bactrian		5	4	3	2	4	7	6	2	1						
Dromedary	4	11	6	2	2	2	1	1	2	1				2	1	
Hybrid														2	2	6
Mixed milk						1	1	1						1	4	
Unknown									1	1			1	4	3	2
Total																105

domly among lactating females on 2 private farms per region, comprised 105 raw milk samples, 6 colostrum samples, and 17 fermented milk samples (*shubat*). The raw milk samples were collected at milking time in Bactrian (n = 37), Dromedary (n = 42), and hybrid (n = 6) animals. In some cases, samples were collected from different species after the whole milking (n = 14; hereafter referred to as “mixed milk”). In 6 cases, information on species origin was not available (hereafter referred to as “unknown”). Bactrian camel's milk samples were from different Kazakh types, as described above. Milk samples from Dromedary camels were from the Turkmen Arvana breed. Hybrid samples involved F₁ or F₂ crossbred animals. Milk samples collected within 8 d of parturition were called colostrum. The colostrum originated from the Almaty region; samples were collected from 6 Dromedaries in the spring only (i.e., in the main calving period for this area, from January to April). *Shubat* samples were collected, like the “mixed milk” samples, by region and season (Table 2). In all cases, milk was obtained by manual milking and kept frozen at -20°C until analysis.

Reference Materials for Laboratory Analysis

Noble Agar was supplied by Difco (Detroit, MI). Bovine serum albumin, trichlo-trifluoroethane, and Freund's complete and incomplete adjuvants were purchased from Sigma-Aldrich (Saint Quentin Fallavier, France). Individual colostrum samples, used for protein purification, were obtained from lactating camels (*C. dromedarius*) at the Experimental Station of the Arid Land Institute of Medenine (Tunisia).

For protein purification, colostrum was first defatted by centrifugation at $2,500 \times g$ for 30 min and diluted 3.5-fold (vol/vol) with distilled water. Caseins were then precipitated by decreasing the pH to 4.2 with 1 M HCl. After centrifugation at $20,000 \times g$ and 4°C for 20 min, the supernatant was dialyzed overnight against 0.02 M Tris-HCl buffer (pH 8.4) and centrifuged at $20,000 \times g$ and 4°C for 30 min.

Purified Proteins

Immunoglobulin G was purified as previously described (El-Hatmi et al., 2006). Briefly, IgG was obtained from camel colostrum by a combination of gel permeation chromatography on Sephadex G200 (Amersham Biosciences, Orsay, France) and ion-exchange chromatography on Q-Sepharose Fast Flow (Amersham).

For the purification of Lf, the third peak obtained by gel permeation chromatography of colostrum whey on Sephadex G200 equilibrated in 0.02 M Tris-HCl buffer

Table 2. Fermented camel's milk (*shubat*) sampling design by region and season

Region	Winter	Spring	Summer	Autumn
Almaty	1	2		1
Atyrau		2	2	2
Aralsk	3			
Shymkent	1	2	1	
Total		17		

(pH 8.6) was passed through a 5-mL HiTrap heparin column (Amersham Biosciences) and equilibrated in the same buffer. Elution was performed at 2 mL/min over a 0 to 1 M NaCl gradient (60 mL) using HPLC equipment (pump 420, detector 430; Kontron Instruments, St-Quentin-en-Yvelines, France). Lactoferrin eluted as a single peak at 0.3 M NaCl. Purity was checked by polyacrylamide gel electrophoresis (12.5% acrylamide) with or without denaturing agents (SDS and mercaptoethanol with heating for 5 min in a boiling water bath).

Polyclonal Antibodies

Rabbits were immunized at monthly intervals by multiple intradermal injections of antigen–adjuvant mixture (Levieux et al., 2005) prepared by emulsifying 1 vol of saline containing 0.5 to 1 mg of purified protein/mL and 1 vol of complete (first injection) or incomplete (booster injections) Freund's adjuvant. Each rabbit received 2 mL of the emulsion. Animals were bled 7 d after each booster injection and the sera were analyzed for antibody activity and specificity by immunoelectrophoresis (Scheidegger, 1955) and single radial immunodiffusion assay (SRID; Mancini et al., 1965). The immunogens used were purified IgG and Lf.

Immunochemical Assay of Proteins

Concentrations of IgG and Lf in individual colostrum and milk samples were determined by the SRID assay using 1.9-mm-thick agar plates containing 1.2% agar in 0.005 M barbital buffer (pH 7.3) and suitable quantities of each specific antiserum, as described by Levieux (1991) and adapted for Lf determination according to Levieux et al. (2005). Circular wells (1.5-mm diameter) were punched out of the gel and filled with 3- μ L aliquots of adequately diluted samples or 3 μ L of purified proteins of known concentration as standards. The purified proteins and samples were diluted in the barbital buffer containing 1% nonimmunized rabbit serum and 1 mg of sodium azide/mL. Plates were incubated in a moist box at 37°C for 15 to 20 h, and the diameter of the ring-shaped precipitates was measured using a magnifying video camera system (Levieux, 1991). Standard curves

were constructed by plotting the diameter of the precipitating ring vs. the square root of the protein concentration. With the diffusion time used, a linear regression was always obtained. Samples and standards were plated in duplicate. The coefficients of variation of the assays were 3 to 5%.

Statistical Analysis

A linear model was tested, with IgG and Lf concentrations as dependent variables. The tested variation factors were region, species, season, and their interactions. The significance level for the variance analysis was set at 0.05. The results are presented as mean $\pm$ standard error. Because the variances were not homogeneous, data were log-transformed to attain a normal distribution of values. The correlation between Lf and IgG was tested using a Pearson correlation. To identify the factors linked to low and high values for IgG and Lf simultaneously, the samples were divided into IgG1 and Lf1 (concentrations below the median values) and IgG2 and Lf2 (concentrations above the median values), giving 4 groups of samples (IgG1/Lf1, IgG2/Lf1, IgG1/Lf2, and IgG2/Lf2). The partitioning into those groups by species, season, and region was evaluated by a χ^2 test. Separate analyses were conducted for raw camel's milk, colostrum, and *shubat*. The R software was used for all statistical analyses (Ihaka and Gentleman, 1996).

RESULTS

Camel Raw Milk Samples

Lf Content. The mean Lf concentration in raw camel's milk was 0.229 ± 0.135 mg/mL. According to geographic factors, the Lf content was higher, on average, in the Shymkent region (Table 3), but the differences were not significant (Table 4). Also, no significant differences were found among species in spite of the higher mean Lf content in hybrids (Tables 3 and 4). The ANOVA showed a significant seasonal effect (Table 4) only for Lf ($P < 0.05$), with the Lf content being higher in the spring (0.271 ± 0.161 mg/mL) than in the autumn (0.176 ± 0.083 mg/mL; Table 4).

Because the seasonal effect was significant, the monthly changes in Lf concentration are shown (Figure 1). Peak Lf concentrations were clearly observed in April (0.294 ± 0.152 mg/mL) and in June (0.312 ± 0.194 mg/mL; $P < 0.05$). The lowest Lf concentrations were observed from July to October (0.190 ± 0.072 mg/mL).

IgG Content. The mean IgG concentration in raw camel's milk was 0.718 ± 0.330 mg/mL. The IgG content was, on average, higher in the Aralsk region (Table 3), but like Lf, the differences were not significant (Table 4). Also, no significant difference was found for species

Table 3. Mean $\pm$ standard error of lactoferrin (Lf) and IgG content (in mg/mL) in camel raw milk according to the region, season, and species

	Region				
Item	Almaty	Atyrau	Aralsk	Shymkent	
Lf	0.209 ± 0.105	0.225 ± 0.148	0.227 ± 0.126	0.254 ± 0.154	
IgG	0.795 ± 0.383	0.605 ± 0.311	0.857 ± 0.196	0.698 ± 0.286	
	Season				
	Winter	Spring	Summer	Autumn	
Lf	0.221 ± 0.124	0.271 ± 0.161	0.214 ± 0.119	0.176 ± 0.83	
IgG	0.849 ± 0.204	0.826 ± 0.427	0.550 ± 0.157	0.659 ± 0.243	
	Species				
	Bactrian	Dromedary	Hybrid	Mixed milk	Unknown
Lf	0.223 ± 0.132	0.209 ± 0.131	0.320 ± 0.255	0.249 ± 0.102	0.273 ± 0.58
IgG	0.638 ± 0.282	0.833 ± 0.375	0.802 ± 0.511	0.598 ± 0.135	0.597 ± 0.66

in spite of the higher mean IgG concentration in the Dromedary (Tables 3 and 4). Similar to Lf, the seasonal change in IgG content was significant ($P < 0.001$), with higher values in the winter (0.849 ± 0.204 mg/mL) than in the summer (0.550 ± 0.157 mg/mL; Table 4). There was a significant interaction ($P < 0.01$) between region and species for IgG concentration, which can be explained by the significantly higher IgG concentration in Dromedary raw camel's milk samples from Aralsk (0.955 ± 0.243 mg/mL) compared with the Bactrian samples from Almaty (0.591 ± 0.128 mg/mL).

The monthly change in IgG concentration is shown (Figure 2). The IgG concentration decreased regularly ($P < 0.001$) throughout the year, with the highest value found in January (0.975 ± 0.132 mg/mL) and the lowest in July (0.511 ± 0.121 mg/mL).

Correlation Between Lf and IgG

The correlation between IgG and Lf concentrations in all raw camel's milk samples was significant ($r^2 = 0.530$, $P < 0.01$). The regression equation was

$$[\text{IgG}] = 421 + 1,295[\text{Lf}] \quad \varepsilon = 281.$$

The number of milk samples from Bactrian and Dromedary camels was sufficient to compare the regression lines (Figure 3). The Pearson correlation coefficient was significant for the Bactrian camel ($r^2 = 0.706$, $P < 0.05$), mainly because of few samples having a high concentration of both Lf and IgG, but not for the Dromedary ($r^2 = 0.327$, NS). However, after omitting a single outstanding point, the Pearson correlation coefficient for the Bactrian camel was still significant ($r^2 = 0.340$, $P < 0.05$).

Based on their concentrations of both Lf and IgG (Table 5), the 4 groups of samples were significantly linked ($P < 0.001$) to some factors: The samples with low concentrations of both IgG and Lf (IgG1/Lf1) were linked to summer milk from the Dromedary at Shymkent, whereas the samples with high concentrations of both IgG and Lf (IgG2/Lf2) were linked to spring milk from the Bactrian at Atyrau. The group IgG1/Lf2 was more frequent in summer milk from the Dromedary, whatever the region, and the group IgG2/Lf1 was more

Table 4. *F*-value and probability level from ANOVA for the lactoferrin (Lf) and IgG contents of camel raw milk.

Factors and their interactions	Lf		IgG	
	<i>F</i> -value	<i>P</i> (> <i>F</i>)	<i>F</i> -value	<i>P</i> (> <i>F</i>)
Region	1.138	0.289	0.472	0.494
Season	5.685	0.019*	12.480	0.001***
Species	1.781	0.185	0.105	0.747
Region $\times$ season	1.330	0.252	2.049	0.156
Region $\times$ species	0.035	0.852	7.275	0.008**
Season $\times$ species	1.064	0.305	1.539	0.218
Region $\times$ season $\times$ species	0.191	0.663	1.102	0.297

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Figure 1. Monthly changes (mean $\pm$ SE) in the lactoferrin (Lf) content of raw camel's milk.

common in spring milk from Aralsk, whatever the species.

Colostrum Samples

Six samples of colostrum were collected, in 2 time repetitions on d 7 after parturition. The Lf concentration varied from 1.422 to 0.586 mg/mL throughout the

Figure 2. Monthly changes (mean $\pm$ SE) in the IgG content of raw camel's milk.

Figure 3. Relationships between the IgG and lactoferrin (Lf) concentrations in Bactrian (■) and Dromedary (□) camel's milk, and regression lines for the Bactrian (—) and Dromedary (---) breeds.

7 d postpartum. This concentration did not decrease as did the IgG concentration, but the quantity was, on average, 0.813 ± 0.311 mg/100 mL (i.e., more than 3 times higher than in milk samples; Figure 4). The range of IgG concentrations in the colostrum samples was wide (from 132.563 to 4.750 mg/mL), with an important decrease after parturition (Figure 5).

Shubat Samples

In total, 17 samples of fermented camel's milk (*shubat*) were collected from different regions and seasons, and were quantified for Lf and IgG contents. However, for some samples the appearance of the ring-shaped precipitate with the SRID technique was indicative of Lf or IgG proteolysis occurring during the fermentation process. Thus, the Lf concentration was determined in 9 samples (values between 0.037 and 0.571 mg/mL) and IgG in 3 cases (values between 0.344 and 0.719 mg/mL).

Table 5. Immunoglobulin G and lactoferrin (Lf) concentration (mg/mL, mean $\pm$ SE) in each group of samples according to the values below (IgG1, Lf1) or above (IgG2, Lf2) the median value

Sample	IgG concentration	Lf concentration
Group IgG1/Lf1	0.513 ± 0.96	0.142 ± 0.42
Group IgG1/Lf2	0.523 ± 0.77	0.270 ± 0.51
Group IgG2/Lf1	0.880 ± 0.323	0.146 ± 0.56
Group IgG2/Lf2	0.942 ± 0.397	0.358 ± 0.174

Figure 4. Changes in the lactoferrin (Lf) concentration in colostrum samples from the Dromedary after parturition.

DISCUSSION

Sampling Procedure

The sampling design aimed to optimize the variability in milk composition according to the main variation factors generally described in the literature: species (single- or double-humped camels and their hybrids), region (including farming practices and feeding systems), and season (including the feeding system and physiological status as the calving period occurred between January and April). However, because of the long distances between regions and harsh conditions in the winter, and because of the specific presence of Bactrian or Dromedary camels in some regions, it was not possible to collect milk samples in some cases and to provide

Figure 5. Changes in the IgG concentration of colostrum samples from the Dromedary after parturition.

Table 6. Concentration of lactoferrin in camel's milk (in mg/mL) according to the literature

Reference	Minimum value	Maximum value
Qian (1995)	2.000	6.000
El-Gawad et al. (1996)	2.480	
Elagamy et al. (1996)	0.020	0.080
Zhang et al. (2005) ¹	2.350	7.280
El-Hatmi (2006)	0.140	0.420
Present results	0.055	0.888

¹Expressed as the percentage of total proteins for the Bactrian camel only.

information for all the cells (species $\times$ region $\times$ season). Thus, our sampling design was unbalanced because of field constraints. Because some cells were not informed or had a limited number of samples, nonsignificant results could have been due to a lack of statistical power and to questionable results.

Laboratory Methods

The methods used in the present study were tested all along the process to control the critical points at each step. The analytical method retained was that of Mancini (1965), as modified by Levieux (1991). For determination, the Lf and IgG proteins were purified by classical methods (ion-exchange chromatography) and then controlled for purity. Rabbits were immunized against camel Lf and camel IgG to obtain polyclonal antibodies. Those antibodies were tested by the method of Ouchterlony (Mancini et al., 1965) with standard solutions of proteins and also other milk proteins to see whether the polyclonal serum presented another immunity activity to other proteins. The specificity of the anti-Lf-camel and anti-IgG-camel activity was tested with controlled bovine polyclonal antibodies. Finally, the polyclonal serum was tested by immunoelectrophoresis (Levieux et al., 2005; El-Hatmi et al., 2006). After these tests, the methods used were determined to be adequate to describe variations in the Lf and IgG concentrations.

Lf Concentrations in Milk and Colostrum

The Lf concentration increased in spring milk. The main reason could be a better quality of pasture from March to June, but no data are available in the literature on the effect of feeding on camel's milk composition. Most of the animals sampled in the spring were probably at the beginning of lactation, when the protein content in milk is generally higher.

Some studies of the Lf content in camel's milk have shown different concentrations of this protein (Table 6). However, the authors have used different methods

for quantitative analyses and different units, and sometimes the analytical methods have not been clearly described. Thus, comparisons with our data were quite difficult most of the time, and some results could be debatable.

For example, to determine the Lf concentration in Bactrian camel's milk, Zhang et al. (2005) used SDS-PAGE and densitometry. All the results are presented as the percentage of total proteins. According to the authors, Lf represented between 2.35 and 7.28% of the total protein in the milk. Those results are quite different from our findings. Indeed, related to the total protein content of the Bactrian milk samples (results not presented), the Lf concentration represented 0.121 to 1.33% of total protein (mean = $0.424 \pm 0.217\%$). More generally, the Lf concentration in Bactrian camel's milk has rarely been studied. Our results showed that there was no significant difference between the Bactrian and Dromedary species. The Lf concentration seemed, on average, very high in milk from hybrids, but the variability was also more important than in pure species and the difference was not significant. In fact, the hybrid population was very heterogeneous. In Kazakhstan, 2 hybridizing schema are described (*Kurt-Nar* and *Kez-Nar*) according to the male sex in the Bactrian $\times$ Dromedary cross (Terenytev, 1975). In our sampling, no information on the hybridizing schema and generation (F_1 , F_2 , or F_3) was available.

Elagamy (2000) used laboratory methods similar to ours but did not refer to the same authors as those cited here. The Lf concentration in Dromedary camel's milk reported by Elagamy (2000) was somewhat lower than our results (0.170 vs. 0.209 mg/mL). According to recent results from El-Hatmi et al. (2006) using the same method as in the present study, the Lf concentration in Dromedary camel's milk from Tunisia was 0.140 ± 0.002 mg/mL, which is, on average, lower than our results (0.209 ± 0.135 mg/mL). In late-lactation Dromedary camel's milk, Kappeler et al. (1999) found a similar Lf concentration (0.22 mg/mL).

Camel's milk has been renowned for its rich Lf content, compared with cow's milk, since the data of El-Gawad et al. (1996) were published. According to those authors, the Lf concentration in raw camel's milk was higher (2.48 mg/mL) than in cow's milk (0.07 to 0.28 mg/mL, depending on the breed of cow). However, their data were based on HPLC analyses obtained with very few animals. Our results in the Dromedary camel (0.059 to 0.659 mg/mL) also appeared slightly higher but in a lower proportion. In a comparison published by Elagamy (2000), the Lf concentration in cow's milk (0.0767 ± 0.022 mg/mL) was also lower than in Dromedary camel's milk (0.170 ± 0.021 mg/mL). Those results differed slightly from the results of other authors, who showed

that the Lf concentration in cow's milk comprised only between 0.05 and 0.15 mg/mL (Rainard et al., 1982; Xiuyun and Yoshida, 1995), values that are closer to those observed by El-Hatmi et al. (2006) in the Dromedary camel. In the study by Kappeler (1998), the Lf concentration was, on average, 0.220 mg/mL in the camel and 0.140 in the cow.

The Lf content in colostrum is richer than that in mature milk in most species (Kappeler, 1998). El-Hatmi et al. (2006) found a range between 0.74 and 1.67 mg/mL in colostrum of the Dromedary camel from Tunisia, with a significant decrease in Lf concentration after d 8. Those values are comparable to our results (0.58 to 1.42 mg/mL), and we observed a similar change in the first week postpartum. Those values are considerably lower than those published by El-Gawad et al. (1996) of 5.10 mg/mL, on average, in 0- to 2-d camel's milk. Only Mahfouz et al. (1997) found more Lf in milk (1.42 mg/mL) than in colostrum (0.13 mg/mL).

In the Bactrian camel, Zhang et al. (2005) found a Lf concentration in colostrum of between 2.88 and 4.82% of total proteins. In our results it was between 0.32 and 2.43% (mean 1 ± 0.73), which is quite different.

The Lf concentration in camel colostrum (0.586 to 1.422 mg/mL in our results) seemed comparable to that in cow's colostrum: 0.64 to 4.2 mg/mL (El-Gawad et al., 1996). According to different authors cited by El-Hatmi et al. (2006), the Lf concentration in cow's colostrum constituted between 1.0 and 4.0 mg/mL.

IgG Concentration in Milk and Colostrum

The IgG concentration in milk was higher in the winter. The main calving season was between January and March or April. At the beginning of lactation, the milk is known to be richer in IgG even if the colostrum is not taken into account, as in our study. The regular decrease in IgG concentration could probably not be linked only to a dilution effect by increasing milk production in the spring, compared with the winter. First, the dairy yield was low throughout the year, especially for the Bactrian camel. Second, the more favorable seasons were spring and autumn, but the lowest concentrations were found in summer. No seasonal variation of IgG concentration was reported in published papers on camel's milk.

Like Lf, the importance of IgG in camel's milk has been emphasized by many authors to explain the health effects of camel's milk (Sawaya et al., 1984; Elagamy et al., 1992; Farah, 1993; Konuspayeva et al., 2004). The IgG concentration is very high after parturition. In a previous study of the Tunisian camel (El-Hatmi et al., 2006), the IgG concentration at the first milking was between 11.8 and 211.1 mg/mL (mean 100.7 ± 60.4

mg/mL), which is comparable to the 132.5 mg/mL found in the only milk sample obtained at the first milking in our survey. This concentration fell sharply but the level stayed above 4.82 mg/mL at d 7. This trend was similar to those described by El-Hatmi et al. (2006) and Elagamy (1998). Of course, our results were obtained from different animals, in contrast to those in the references mentioned. However, our results are consistent with other data published on camel colostrum (Ungar-Waron et al., 1987). On average, the IgG concentration in camel colostrum seemed to be higher than that in other species (El-Hatmi et al., 2006). In the Bactrian camel, Zhang et al. (2005) mentioned that IgG represented 0.90 to 2.52% of the total proteins from d 1 up to d 7. In our results, the IgG was between 6.6 and 49.1% (mean $19.5 \pm 17.1\%$) of the total protein. The results of Zhang et al. (2005) could be debatable, possibly because of a misreading of the SDS-PAGE owing to the segmentation into H and L chains of IgG.

In the study by Elagamy (2000), the IgG concentration in late-lactation camel's milk was higher than that in our results (2.217 vs. 0.718 mg/mL). In any case, those values appeared higher than the IgG concentration observed in cow's milk: 0.520 ± 0.064 mg/mL (Elagamy, 2000). In the Bactrian camel, the IgG concentration was 0.65 to 1.60% of total protein (Zhang et al., 2005), comparable to our data (0.61 to 2.97%; mean $1.24 \pm 0.53\%$).

Lf and IgG Correlation

To our knowledge, no data showing the correlation between Lf and IgG in camel's milk is available in the literature. The observed correlation in our results was significant, but some milk samples were rich in both LF and IgG. Those rare milk samples allowed us to build a regression line, but with a high error type. Most of those samples were spring milk from the Bactrian breed at Atyrau, close to the Caspian Sea. Omission of those outstanding points led to a lower correlation coefficient (0.34), which is at the limit of the significant level. It is probably more convenient to consider different types of milk with high concentrations of Lf and IgG compared with poor milk (low concentrations of both proteins), as we proposed.

Lf and IgG in Shubat

The fermentation process leads to the degradation of proteins in the milk. In Kazakhstan, traditionally the milk is not heated before the fermentation process. Thus, the observed degradation cannot be attributed to heat denaturation. Elsewhere, the ring-shaped precipitates observed with *shubat* samples were very pale,

which is characteristic of proteolysis, as has been observed in comparison with heat-treated samples (Levieux et al., 2005). In *shubat*, Lf and IgG are probably mainly hydrolyzed into polypeptides with similar antigenic properties as the original protein. This degradation is increased with the age of the *shubat*. Moreover, the technology for *shubat* fermentation is neither controlled nor standardized. Thus, the degree of fermentation is not known (i.e., the importance of the protein hydrolyzing). With the method of Mancini et al. (1965) for SRID, the antibodies, and the standards used in the current study, it was not possible to take in account the content of polypeptides and to differentiate them from the original proteins. The values obtained in some samples from our study could be attributed to "young" *shubat* at the beginning of the protein degradation process. No data on this process are available in the literature.

CONCLUSIONS

Lactoproteins such as Lf and IgG are known as health factors that play an important role for milk consumers. In particular, camel's milk, which is consumed in many countries (such as Kazakhstan) for its medicinal virtues, is renowned for being richer in some lactoproteins compared with cow's milk. In fact, the concentrations of Lf and IgG in camel's milk seem to be only slightly higher than those in other milks. However, this quantitative difference does not explain the highly renowned quality of camel's milk. The quantity of those proteins is probably not the only aspect particular to camel's milk. Other proteins such as lysozyme, lactoperoxidase, and growth factors could be linked to its health effects.

Our results showed that the difference between Bactrian and Dromedary camel's milk was not clear with our observational design, and that the seasonal effect was more important than other variation factors. The seasonal effect is a complex factor that includes a camel's physiological status and feeding. However, these results are a first step toward explaining the observed variability in camel's milk.

ACKNOWLEDGMENTS

The study was supported by the French Ministry of Foreign Affairs (ECONET Programme) and by the French Embassy at Almaty (Kazakhstan). We thank also the Kazakh farmers for their continuing hospitality.

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