Journal of King Saud University – Science (2015) 27, 168–175

King Saud University
Journal of King Saud University – Science
www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

Comparative milk and serum cholesterol content in dairy cow and camel

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Received 31 May 2014; accepted 18 November 2014
Available online 26 November 2014

KEYWORDS

Milk;
Serum;
Camel;
Cow;
Cholesterol;
Fat

Abstract In order to compare cholesterol contents in cow and camel milk in similar farming conditions, milk and blood of seven cows and seven camels maintained at normal diet at the middle of lactation were sampled at morning and evening, then after two weeks of keeping them at low protein diet. The cholesterol content in camel milk (5.64 ± 3.18 mg/100 g, SD) was not significantly lower than in cow milk (8.51 ± 9.07 mg/100 g, SD). Fat contents in cow milk were higher. Cholesterol/fat ratios were similar in the two species (camel: 225 ± 125 mg/100 g fat; cow: 211 ± 142 mg/100 g fat). The serum cholesterol concentration was significantly higher in cow (227.8 ± 60.5 mg/100 ml) than in camel (106.4 ± 28.9 mg/100 ml). There was a significant difference between morning and evening milking in milk fat compositions and concentrations in cholesterol. Fat levels increased in cow after two-week low energy-protein diet.

1. Introduction

Cholesterol is a sterol commonly present in milk and meat products intended for human consumers. As the nutritionists claimed, for a long time, a relationship exists between high blood cholesterol concentration and heart failure (Hofvendahl, 1971), and many medical advices push to reduce the cholesterol intake, even if the effect of cholesterol on health is not completely clarified (Parodi, 2009; Alabdulkarim et al., 2012).

Camel meat is known for its low cholesterol content (Kadim et al., 2008) making it a commercial argument by the promotion of the healthy image of this product on the meat market. Although everyone agrees on the low cholesterol level of camel meat compared to other species, yet the situation is controversial for camel milk. Many workers argue that camel milk contains less cholesterol than cow milk (Kamal and Salama, 2009; Raziq et al., 2008) while others reported the

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Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksus.2014.11.003
1018-3647

reverse (Gorban and Izzeldin, 1999; Konuspayeva et al., 2008). Elsewhere, the camel milk consumption is increasing compared with the consumption of cow milk, under the growing interest of consumers for "non-cattle milk" (Faye and Konuspayeva, 2012). The objective of the present paper was, thus, to compare the cholesterol contents in camel and cow milk produced under similar farming conditions and to assess the impact of low protein diet on the cholesterol concentration in milk and serum.

2. Materials and methods

2.1. Animals and milking

For the experiment, 7 Holstein cows (5–9 years old, average weight 420 kg) and 7 she-camels (6–12 years old, average weight 650 kg), belonging to the Conservation and Genetic Improvement Center, Kharj (Saudi Arabia), were used. The experimental camels were composed of different phenotypes (Waddah, Majaheem and Homor) but belonging to the same genotype (Abdallah and Faye, 2012; Almathen et al., 2012) and were at approximately the middle stage of lactation. Cows were in the late lactation stage, after the peak of production. On an average, just before the experiment, the camel produced 6.6 liters/day and the cow 15.4 liters/day.

Table 1 Chemical composition of the commercial concentrate given to cows and camels.

Components	Values
Crude protein (%)	18.00
Crude fat (%)	3.00
Crude fiber (%)	6.00
Ash (%)	6.5
Salt (%)	0.70
Calcium (%)	1.00
Phosphorus (%)	0.60
Vitamin A (IU g^{-1})	20.0
Vitamin D (IU g^{-1})	3.0
Vitamin E (IU g^{-1})	15.0
Energy (ME kcal kg^{-1})	2780

In the Center, the cows and the camels were milked twice a day by a milking machine (cow: Gascogne Melotte Lectron 612©; vacuum level 45 Kpa, 60 pulses/min, pulsation rate 50/50; camel: Boumatic©, vacuum level 50 Kpa, 60 pulses/min, pulsation ratio 60/40; in different milking parlors) at 7:00 and 16:00.

2.2. Diet

At the center, cows were given a daily ration of 15 kg of Rhodes grass hay (*Chloris gayana*), and 7.5 kg commercial concentrates (18% crude proteins, Table 1), while camels were provided 12 kg alfalfa (*Medicago sativa*) and 3 kg commercial concentrates each day (nutritive values in Table 2). All animals received in addition salt licks (100 g/day/animal) enriched in minerals and vitamins. Experimental animals were given low energy diet (concentrate decreased 50%, i.e., 1.5 kg for camel and 3.5 kg for cow) for 21 days after the collection of the first milk/blood samples. There were no refusals both for cows and camels. The quantity of milk expected according to the energy level with normal diet was 6.3 kg/day for camel and 9.9 kg/day for cow. With low-energy diet, these values were 5.3 and 7.2 kg/day respectively for camel and cow. The values based on the protein level of the diet were 9.8 and 18.3 kg/day with normal diet (camel and cow respectively) and 7.5 and 12.3 kg/day with low diet (camel and cow respectively) (Table 2).

2.3. Experimental design

The experiment included two steps for sampling:

- Milk and blood samples of each cow and camel were at the morning and afternoon milking at day 1. All animals received their normal diet described below. As it was the current diet, there was no need for an adaptation period.
- Milk and blood sampling of the same cows and camels at day 21 after two weeks of distribution of low-energetic diet is described below.

Finally, 56 milk samples and 56 blood samples were analyzed (28 cow samples and 28 camel samples for milk or blood).

Table 2 Intake, dry matter (DM), energy (Milk forage Unit/, MFU/kg DM), protein value (PDIN, Digestible Protein in Intestine), minerals (Ca, P) and milk production expected by energy and protein in dairy cow and camel according to the distributed diet.

Components	Intake (kg/animal) (*low diet*)	DM (%)	Energy (MFU (kg DM^{-1})	PDIN (kg DM^{-1})	Ca (%)	P (%)	Milk (Energy)	Milk protein
Camel								
Alfalfa	12	70	0.85	126	15	3.5		
Concentrate	3 (*1.5*)	93	1.2	145	10	6.0		
Cow								
Rhodes grass hay	15	90	0.6	75	6	3.5		
Concentrate	7.5 (*3.5*)	93	1.2	145	10	6.0		
Normal diet								
Total camel	15		10.5	1465	154	46	6.3	9.8
Total cow	22.5		16.2	2029	151	89	9.9	18.3
Low-energy diet								
Total camel	13.5		8.8	1262	140	38	5.3	7.5
Total cow	18.5		12.0	1487	113	67	7.2	12.3

2.4. Sampling procedure and laboratory analyses

Milk and blood were collected at milking time. Milk sample of each animal was directly taken in individual milking cans and blood was collected from the mammary vein just after milking with a vacutainer. The milk samples were immediately frozen at −80 °C until analyzed at the IDAC laboratory (Saudi Arabia) for cholesterol (AOAC-994.10 method, 2010) and fat (AOAC-989.05 method, 1996) contents.

The blood samples were centrifuged (5000 rpm; 30 min) to separate serum in small tubes. Total cholesterol was determined directly by a Biochemist analyzer KENZA Max (Biochemis TRY, BIOLABO©, Maizy, France) by using a Biolabo kit (n°LP80106) based on the CHOD-PAP method, as described by Daecon and Dawson (1979) and Tietz (1995).

2.5. Statistical analysis

The objectives of the statistical analyses were (i) to assess the differences in the cholesterol values between camel and cow milk and serum, then within species between morning and evening milking and between diets; (ii) to determine the correlations between the parameters: cholesterol in milk and cholesterol in serum, cholesterol in milk/serum and fat.

To achieve the first objective, a one-way analysis of variance (ANOVA) was used based on the comparison with the Fisher test (LSD) for assessing the effect of species (camel/cow), time of milking (morning/afternoon), type of diet (normal/low) and the interactions. For the second objective, the correlation of Pearson was applied and calculated for the whole samples (camel and cow), then for each species. For statistical analysis, the software XLStat version 2013-5-03 (Addinsoft©) was used.

3. Results

3.1. Mean values

The average cholesterol contents in camel milk were lower (5.64 ± 3.18 mg/100 g, SD) than in cow milk (8.51 ± 9.07 mg/100 g, SD) but the difference was not significant (Table 3). The variability of cholesterol content was higher in cow milk (coefficient of variation, CV 107) than in camel milk (CV 55). Fat content in camel milk (2.69 ± 0.98 g/100 g) was significantly lower ($P < 0.001$) compared to cow milk (4.52 ± 3.36 g/100 g). Camel (225 ± 125 mg/100 g fat) and cow (211 ± 142.4 mg/100 g fat) milk maintained almost similar cholesterol/fat ratios.

In serum, cholesterol was almost 2 times higher in cow (227.8 ± 60.5 mg/100 ml) than in camel (106.4 ± 28.9 mg/100 ml) ($P < 0.001$).

3.2. Effect of milking time and diet

Cholesterol content was significantly lower ($P < 0.05$) in the morning milking than in the afternoon milking in cow milk (5.04 ± 4.41 and 12.64 ± 11.0 mg/100 g, respectively) contrary to camel milk where no significant difference ($P = 0.164$) was observed (4.97 ± 2.84 and 6.31 ± 3.45 mg/100 g respectively) (Table 3). In spite of higher mean values observed on cholesterol content after one week distribution of low diet (Fig. 1), the differences were not significant both in camel (4.71 ± 3.73 vs. 6.57 ± 4.09 mg/100 g with normal and low diet respectively) and in cow milk (6.77 ± 6.38 vs. 10.91 ± 11.0 mg/100 g). The ratio cholesterol/fat in milk did not change significantly whatever the milking time or the type of diet (Fig. 2). The fat content in milk was higher with low diet in cow compared to normal diet (5.93 ± 3.88 g/100 g vs. 3.10 ± 2.02 g/100 g respectively), while no change was observed in camel (2.70 ± 1.25 vs. 2.69 ± 0.66 g/100 g, respectively). The milk production was decreased by 19% in camel after low diet distribution and by 30% in cow.

Table 3 F values, degree of freedom (dof) and probability (P values) for the different variation factors of cholesterol in milk (milkchol) and serum (serumchol), milk fat (fatmilk) and milk cholesterol/fat ratio (Chol/fat) in camel and cow.

Species	Parameter	F value	Dof	P value
Camel vs. cow				
Species	Milkchol	3.109	55	0.084
	Serumchol	91.772	55	**< 0.0001**
	Fatmilk	7.603	55	**< 0.01**
	Chol/fat	0.145	55	0.705
Milking time (AM vs. PM)				
Camel	Milkchol	1.252	27	0.273
	Serumchol	0.077	27	0.784
	Fatmilk	8.27	27	**< 0.01**
	Chol/fat	0.038	27	0.846
Cow	Milkchol	5.790	27	**< 0.05**
	Serumchol	0.075	27	0.787
	Fatmilk	25.52	27	**< 0.001**
	Chol/fat	1.866	27	0.184
Diet (high vs. low energy diet)				
Camel	Milkchol	2.532	27	0.124
	Serumchol	1.598	27	0.217
	Fatmilk	0.000	27	0.989
	Chol/fat	1.054	27	0.314
Cow	Milkchol	1.492	27	0.233
	Serumchol	3.204	27	0.085
	Fatmilk	5.864	27	**< 0.05**
	Chol/fat	0.664	27	0.194

Bold values represented the significant probit.

Contrary to milk, there was no difference in serum cholesterol between morning and afternoon sampling (166 ± 81.5 mg/100 ml vs. 168 ± 74.1 mg/100 ml) both in camel and cow (Table 3).

At reverse, the diet had a significant effect ($P < 0.05$): the decrease of concentrates by 50% in the diet contributed to the increase of cholesterol in the serum (154 ± 77.6 mg/100 ml vs. 180 ± 75.8 mg/100 ml in normal and low diet respectively). However, in spite of the same trend, this difference did not appear significant within each species.

3.3. Relationships between cholesterol and fat in milk and serum

There was no significant correlation between cholesterol in milk and in serum in both species (Fig. 3). At reverse a positive significant correlation was observed between cholesterol and fat in milk ($r = 0.636$; $P < 0.001$) (Fig. 4) and between fat in milk and cholesterol in serum ($r = 0.344$; $P < 0.01$).The

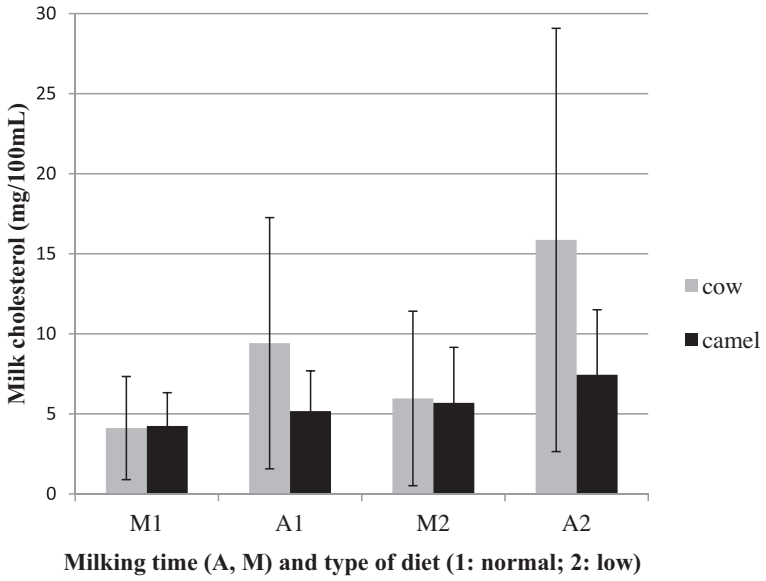

Figure 1 Changes in cholesterol content (mean and SD) in camel and cow milk at different milking times and types of diet (M1: morning with normal diet; A1: afternoon with normal diet; M2 morning with low diet; A2: afternoon with low diet).

cholesterol level in camel and cow appeared quite different with globally a lower quantity in camel compared to cow.

4. Discussion

4.1. Cholesterol in milk

The cholesterol content in cow milk is widely documented in Western countries for a long time (Paniangvait et al., 1995). In a review report published by Piironen et al. (2002) regarding food consumed in Finland, the cholesterol contents varied between 5.6–6.4 mg/100 g in semi-fat cow milk (1.5% fat) to 11.2 mg/100 g in full fat (3%) cow milk. A range of 5–8 mg/100 g was generally given for milk with 1.5–2% fat in the food composition tables (Piironen et al., 2002). Higher values were reported in zebu (10.2 ± 9.7 mg/100 ml) from Pakistan (Talpur et al., 2006). Higher values were generally reported in goat and sheep milk, between 8.1 and 22.7 mg/100 ml (Strzalkowska et al., 2006; Mayer and Fiechter, 2012). Compared to these values, the cholesterol content appeared low in our study both in cattle and in camel, but reported to the fat content of the milk, the difference was less marked. According to the distributed diet, enriched or not with linseed oil, the content of cholesterol in fat varied from 232 to 373 mg/100 g fat in cow milk (Reklewska et al., 2002).

In their comparative study, Gorban and Izzeldin (1999) reported total cholesterol in camel colostrum of 27.6 mg/100 ml and 31.3 mg/100 ml in mature milk. The concentration in cow milk was 25.6 mg/100 ml in mature cow milk. Elsewhere, the proportion of total cholesterol to total lipid was

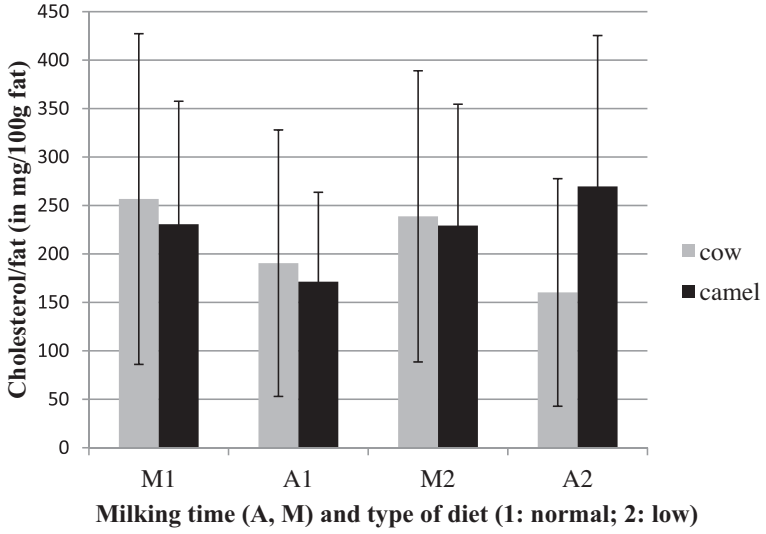

Figure 2 Changes in the cholesterol/fat ratio (mean and SD) in camel and cow milk at different milking times and types of diet (M1: morning with normal diet; A1: afternoon with normal diet; M2 morning with low diet; A2: afternoon with low diet).

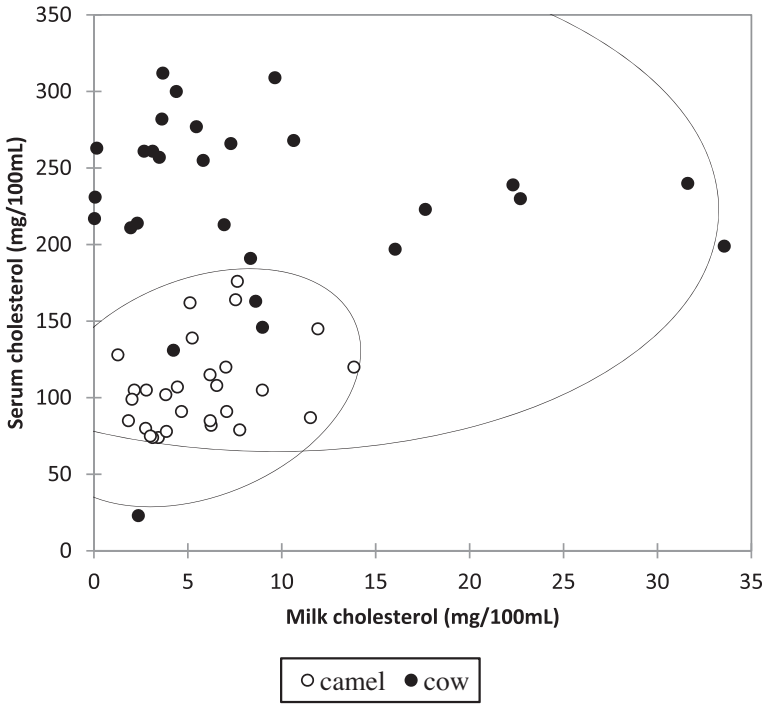

Figure 3 Relationships between milk and serum cholesterol levels in camel and cow.

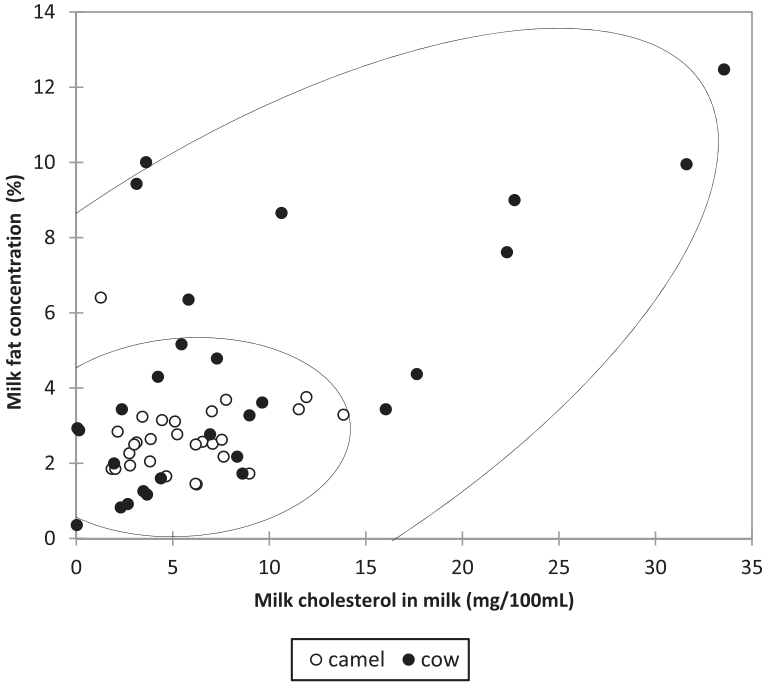

Figure 4 Relationships between milk cholesterol and fat contents in camel and cow.

reported to 0.93% in camel milk compared to 0.69% in cow milk (Gorban and Izzeldin, 1999). For Kamal and Salama (2009), the cholesterol concentration in camel milk decreased with the advancement of the lactation as well as in cow milk (Strzalkowska et al., 2010). In camel, it was stated that cholesterol concentration was higher in the colostrum (contrary to that reported by Gorban and Izzeldin, 1999) with a value of 44.5 mg/100 ml at day 1 post-partum and 18.9 mg/100 ml at day 30 post-partum (Kamal and Salama, 2009). In dromedary and Bactrian camels from Kazakhstan, the mean value of cholesterol in milk was reported as 37.1 mg/100 ml (Konuspayeva et al., 2008), but the animals had a high level of fat in milk (5.9%). The calculated ratio cholesterol/fat was higher than in our study (628 mg/100 g fat on average).

Clearly, the level of cholesterol in the milk being closely dependent on the quantity of fat matter, it is not possible to affirm that camel milk is less or more rich in cholesterol than cow milk. The ratio cholesterol/fat was quite comparable between the two species. The apparent low level in cholesterol in our study in camel could be linked to the low level in fat concentration in our milk. It was already stated that a high variability in fat concentration was observed in camel throughout the world with a range of 0.28–6.40 g/100 g (Konuspayeva et al., 2009). The higher values were reported in Central Asia (mainly on Bactrian camel) and the lower in the Middle East. Finally, the results reported in the literature regarding the comparison between camel and cow, should be taken into consideration for the variability in fat content in the milk.

The difference observed in our study between morning and evening milking was already described in dairy cows (Lakic et al., 2011). In all the cases, the fat content was higher in evening milking than in morning. In consequence, the cholesterol content was also increased, while the ratio cholesterol/fat being similar whatever the time of milking. The milk excretion was generally higher at the morning milking, because of the longer interval, than in evening contributing to the dilution of the fat content (Chladek et al., 2011). However, in camel, a higher milk production with an 8 h interval compared to 12 h has been reported. (Ayadi et al., 2008). When the interval between milking increased, the pressure in the udder also increased and affected the permeability in the udder, contributing to the change in milk composition, especially fat (Stelwagen, 2001; Lakic et al., 2011).

The source of fat in the diet could have an effect on cholesterol status of farm animals, especially by modulating its content in milk (Reklewska et al., 2002). Usually, mixed ration including silage contributed to increase cholesterol in dairy cows compared to traditional diet based on natural grassland (Barlowska et al., 2011). However, the most significant effect expected by modification of the diet would be on the serum cholesterol. At our knowledge, no data were available regarding the effect of different types of diet on camel cholesterol milk. The increase of fat concentration in cow milk after two weeks of low diet distribution was not observed in camel. It is known that camel is less sensitive to a small shortage of food and that she can maintain both the milk production and composition after fasting contrary to cow which decreases drastically its milk production (Yagil and Etzion, 1980).

The relatively low level of fat content in camel milk in our results could be linked to the lactation stage. Our camels were at the peak of lactation at the sampling time contrary to cows which were already at the decreasing step of their lactation curve. In camel, it corresponds to the lower concentration of fat, due to the dilution effect (Firkins and Eastridge, 1992; Musaad et al., 2013). Elsewhere, the peak of lactation corresponded also to the hot season. In cow, a depressive effect of external temperature on fat content in milk with significantly lower cholesterol in summer milk compared to winter milk both in quantity and in proportion of fat has been reported. (Strzalkowska et al., 2011).

4.2. Cholesterol in serum

The values in cow serum in our study were on an average comparable to those reported in the literature: 196.3–212 mg/100 ml (Hansen et al., 2014), 175.9–235 mg/100 ml (Engle et al., 2001) or 192.2–229.3 mg/100 ml (Hutchinson et al., 2012), while lower values were observed by Chladek et al., 2004): 104.5 to 177.5 mg/100 ml, or by Guedon et al., 1999): 101 ± 3 mg/100 ml. In camel, the references were scarce. In Djibouti, Faye and Mulato (1991) reported low values in camel compared to cattle in extensive systems: 19.5 mg/100 ml on average with range of 9–52 mg/100 ml. Those values were closed to those reported in India on young camel, 24.8–30.3 mg/100 ml (Nagpal et al., 2011), and in Iran in adult camels, 27.8–31.7 mg/100ml according to the season (Tajik et al., 2013), but lower than those reported in Iran by Omidi et al. (2014): from 63.8 to 77.1 mg/100 ml according to the lactation stage. Contrary to cholesterol in milk which seemed to be decreasing with the lactation stage, there was a significant increase in serum total cholesterol concentration with advance in lactation in camel serum (Omidi et al., 2014), but this trend was not observed by Amer et al. (1999). In all the cases, the cholesterol concentration in serum appeared quite lower in camel compared to cow.

The modulation of serum cholesterol by different types of diet was widely investigated in cow. The use of different sources of starch (Mikula et al., 2011), fat (Hutchinson et al., 2012; Bianchi et al., 2014) or minerals (Engle et al., 2001; Hansen et al., 2014) has been tested in dairy cow and sheep with significant effect. In camel, the effect of diet was experimented in some cases. In a trial achieved in India, with the addition of groundnut haulms and cluster bean straw, the camels showed significantly different levels of serum cholesterol (from 35.3 to 48.7 mg/100 ml) according to the ratio between these two elements, the highest cholesterol level being observed with a ratio 75:25 (groundnut/bean), i.e., with the diet richer in crude protein and ether extract (Gupta et al., 2012). Globally the level of cholesterol in serum is linked to the dairy yield, at least in dairy cows (Fayet et al., 1986). The diet contributing to increase in the milk production (for example supplementation with high energy-protein) is generally linked to the increase of glycaemia, and glucose is one of the main precursors for cholesterol synthesis in the small intestine or liver (Iqbal et al., 2012).

5. Conclusion

The cholesterol in milk depending on the fat content, and the probable low cholesterol content in camel milk are not a characteristic of the species. In high-fat camel milk, cholesterol is present in similar quantity than cow's milk. However, the cholesterol concentration in serum is quite lower than in cow, suggesting a difference in the lipid metabolism between the two species. The variability all along the lactation and in different feeding contexts, especially by exploring the changes in milk composition in different farming systems (pastoral or intensive) should be investigated to confirm or invalidate the true interest of camel milk regarding its cholesterol content.

Acknowledgements

The present study was undertaken within the FAO camel project UTF/SAU/044/SAU. Authors thank FAO and Ministry of Agriculture, Saudi Arabia, for allowing the conduct of the experiment. Special thanks to Dr Fuad Alzuraiq, General

Manager, Conservation and Genetic Improvement Center; and to Dr Abdallah Oihabi, FAO Program Coordinator, for their support.

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