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COMPOSITION AND HEAT STABILITY OF MOROCCAN CAMEL MILK

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ABSTRACT

Fifty samples of camel's milk were collected from local breed and analysed for their composition, heat stability and microbial counts. Average milk composition was (in w/v) : 10.8% for total solids, 2.7% for fat, 3.3% for protein, 4.1% for lactose, 0.83% for ash and 0.24% for chloride. Mean nitrogen content, in mg/100 ml was 510, 344, 80 and for total nitrogen, casein nitrogen, non protein nitrogen and whey protein nitrogen, respectively. The pH value, titratable acidity and specific gravity were 6.61, 0.17% and 1.032 respectively. The heat stability of camel milk was relatively lower at high temperature treatments. Heat coagulation time (HCT) in the range 100 - 130°C was too short (< 2 min). In these conditions, camel milk heat preservation can be done only by pasteurisation. Average microbial counts (cfu/ml) in raw milk were 2.17×10^5 for aerobic total count, 2.30×10^4 for psychrotrophic bacteria and 1.64×10^4 for total coliforms. After LTLT pasteurisation, counts of aerobic total and psychrotrophic bacteria were significantly ($p<0.05$) reduced and coliforms were not detected.

Key words: Camel's milk, chemical composition, heat stability, microbial counts, pasteurisation

Camel's milk is an important food and a source of income for breeders in arid and semi arid zones. In Morocco, the camel milk is consumed fresh or soured in a traditional way (*Frik*, *sligh* and *mtaâm*) (Kouniba & Sghiri, 2000). Data concerning chemical composition of camel milk and its heat processing, such as pasteurisation and sterilisation as preservation means, are very limited in Morocco. This work was carried out to study the physico-chemical characteristics and heat stability of camel milk produced in the south of Morocco.

Materials and Methods

Milk samples

Fifty samples of raw camel milk were collected in the city of Laâyoune, southern Morocco. Each milk sample represented a pooled sample from individual milks of 4 herds of 10 females each. Herds were conducted according to the semi-intensive system. They went to the pasture during the day and they received barley in the evening (2 kg/animals). Females were milked manually twice a day in the morning and evening. Samples collected were immediately cooled and transferred to the laboratory.

Chemical analysis

Camel milk samples were analysed for pH, titratable acidity, specific gravity, total solids, fat, ash, nitrogen composition (total nitrogen, non-casein nitrogen, non-protein nitrogen and whey protein nitrogen), lactose and chlorides. All these analyses were done in duplicate. The pH was measured with an electronic pH-meter type PHN 130T. Titratable acidity, total solids, fat and ash were determined according to procedures outlined in AOAC (1990). The specific gravity was determined by a thermostatically controlled Quevenne lactometer at 15°C. Lactose content was determined by polarimetry (AOAC, 1990). Chloride titration was done by precipitation using the Charpentier-Vohlard method (Osborne & Voogt, 1978).

Nitrogen was determined by the standard Kjeldahl method (AOAC, 1990). Milk samples were fractionated for total nitrogen (TN) and non casein nitrogen (NCN) by the method of Rowland (1938). Non protein nitrogen (NPN) content was determined according to the method reported by Cerbulis and Farrel (1975). Nitrogen fractions were calculated using the following formula : Protein nitrogen (PN) = TN -

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NPN, casein nitrogen (CN) = TN - NCN and whey protein nitrogen (WPN) = NCN - NPN.

Nitrogen to protein conversion factor of 6.38 was used for calculation of protein contents and various fractions of milk samples.

Determination of milk heat stability

The pH of milk samples was adjusted to various values in the range 6.3 - 6.9 by adding 0.1 M NaOH or 0.1 M HCl. Heat coagulation time (HCT) was determined in a thermostatically controlled oil bath at 85, 95, 100, 110, 120 and 130°C according to the method of Davies and White (1966).

Assessment of efficiency of heat treatment

Pasteurisation of 3 litres of raw camel milk was tested using water bath at 63°C for 30 min (LTLT milk). Then, milk samples were cooled to 7°C in an ice water bath and aseptically transferred to screw-capped sterilised flasks.

Total aerobic (TA), total coliforms (TC) and psychrotrophic bacteria (PB) were estimated before and after pasteurisation. All microbiological tests were performed in accordance with the standard methods for examination of dairy products (Richardson, 1985). Aerobic total count (ATC) was carried out on plate count agar (PCA, oxiod) incubated at 37°C for 72 h; total coliforms on desoxycholate citrate agar (DCL, oxiod) incubated at 37°C for 48 h and psychrotrophic bacteria on plate count agar (PCA, oxiod) incubated at 4°C for 48 h.

Results and Discussion

Chemical composition

The chemical composition of camel milk samples is presented in table 1. The pH fluctuated from 6.25 to 6.70 with a mean of 6.61 ± 0.03. These values are in agreement with those reported by Shalash (1980, 1983) and Farah and Bachmann (1987). However, the average value is lower than pH of 6.80 reported for Libyan camel's milk (Gnan *et al*, 1991), and higher than 6.39 and 6.50 reported by Farag and Kebary (1992) and Mohamed (1990), respectively.

The titratable acidity mean value was 0.177 ± 0.006 % with an amplitude of variation of 0.175 to 0.230%. This value was comparable to that given by Kamoun (1990), i.e. 0.17%, and was higher than the value reported by El Amin and Wilcox (1992), i.e. 0.15%. Differences between theses values could be explained by differences in hygienic conditions in which camel milk was produced, collected an handled.

Table 1. Chemical composition of camel milk produced in South Morocco (in w/v).

Component	Range	Mean (n=50)	SD*
pH value	6.25 - 6.70	6.61	0.03
Titratable acidity (% lactic acid)	0.18 - 0.23	0.177	0.01
Specific gravity (15°C)	1.027 - 1.036	1.032	0.040
Total solids (%)	10.00 - 13.57	10.80	0.14
Fat (%)	1.85 - 3.47	2.65	0.10
Crude protein (Nx6.38) (%)	2.66 - 3.83	3.25	0.08
Ash (%)	0.72 - 0.88	0.83	0.01
Lactose (%)	3.25 - 4.39	4.05	0.08
Chlorides (as % NaCl)	0.12 - 0.27	0.24	0.01

* Standard deviation

The specific gravity varied from 1.027 to 1.036 with an average value of 1.032. It was similar to that reported by Shalash (1983), higher than that obtained by Farah (1993), and lower than that reported by Farag and Kebary (1992). This difference appeared to be related to the many factors including feeding and season (Yagil and Etzion, 1980a).

The mean total solid content was 10.80 ± 0.14%. These results were close to those found by El Amin and Wilcox (1992) i.e. 10.94%, but lower than as reported by Hafez and Hamzawi (1991), i.e. 11.95%, Farag and Kebary (1992), i.e. 12.36% and Mukasa-Mugerwa (1981), i.e. 13.36%. This variation could be due to the breed, stage of lactation, feeding conditions and hydration status. According to Jardali (1988), the frequency of watering has an impact on the content of total solids. Bengoumi *et al* (1994) reported in the South of Morocco an average content in total solids of 7%. This low value was related to the breed, stage of lactation, feeding conditions, hydration status and physiological specificities of the dromedary camel where dehydration led to a milk dilution (Mathé, 2002a,b; Hashi, 1984; Yagil and Etzion, 1980b).

The fat content of camel milk samples analysed varied from 1.85 to 3.47% with an average value of 2.7%. This value was lower than those reported by several authors, i.e. 3.6% (Hafez and Hamzawi, 1991); 4.6% (Mohamed, 1990), 4.33% (Mukasa-Mugerwa, 1981) and a range of 2.4% to 5.6% (Jardali,1988 and Hashi,1984). The ratio of fat content to total solids in camel's milk is 24.6%. This was found to be in accordance with the range was reported by Shalash (1983).

The protein content varied from 2.66% to 3.83% which was well in the range of 2.0 to 4.2% recorded by Larsson-Raznikiewicz (1990). The was similar

to that of Libyan camel's milk, i.e. 3.3% (Gnan and Sheriha, 1986), but lower than those of Ethiopian camel's milk, i.e. 4.5% (Knoess, 1977) and of camel milk from Sudan, i.e. 3.6% (El-Amin, 1979). However it was higher than those of Somali and Saudi Arabian camel's milk, i.e. 3.0% (Mohamed, 1990; Sawaya *et al,* 1984), and Indian camel's milk, i.e. 2.7% (Desai *et al,* 1982).

Mean values for ash and chloride contents were 0.83 ± 0.01% and 0.24 ± 0.01%, respectively. The average ash content was in agreement with those reported by Gnan and Sheriha (1986), Hassan *et al* (1987) and by El Amin and Wilcox (1992), but these values were lower to those found for Ethiopian's camel milk, i.e. 0.90% (Knoess, 1977), and higher than those reported for Indian's and Somali camel milk, i.e. 0.60% (Desai *et al,* 1982; Mohamed, 1990). The ash content of camel milk could be greatly affected by the stage of lactation and drought conditions (Yagil and Etzion, 1980a) and by the genetic and environmental factors (El-Amin and Wilcox, 1992).

Lactose content ranged from 3.25 to 4.39% with a mean value 4.05 ± 0.08%. These values were reported to be in the range, i.e. 2.8 to 5.8% by Hashi (1984). The mean value was in agreement with those reported by Shalash (1980), Hassan *et al* (1987) and El-Amin and Wilcox (1992), but was lower to those found by Dzhu-Maglov (1976), Webb *et al* (1974), Hafez and Hamzawi (1991) and Mehaia (1993), and higher than those observed by Atherton and Newlander (1977). This situation constitutes one of specificities of this milk (Webb *et al*, 1974; Sawaya *et al*, 1984), and is explained essentially by the impact of the availability of drinking water. In fact, lactose content can reach 5% when water is abundant, and it tends toward 2.9% in case of dehydration (Yagil and Etzion, 1980a,b).

Nitrogen distribution (mg N/100 ml) in camel's milk is given in table 2. The average total nitrogen content was 510 ± 13.01 mg/100 ml. It was close to that found by Farag and Kebary (1992), i.e. 500 mg/100 ml and higher than those found by Mehaia and Al-Kanhal (1992), i.e. 485 mg/100 ml, and Hassan *et al* (1987), i.e. 390 mg/100 ml. The mean NPN content was 79.93 ± 2.04 mg/100 ml which corresponds to 15.68% of the TN. This result is in agreement with the published data for Egyptian camel milk by Farag and Kebary (1992), i.e. 15.9%. However, it is relatively higher than those reported for camel milk in Kenya by Farah and Ruegg (1989), i.e. 6.7%, and in Saudi Arabia by Mehaia and Al-Kanhal (1992), i.e. 10.1% and Mehaia (1994), i.e. 9.8%. Our data were higher than those for cow's milk (Abu-Lehia, 1987; Mehaia and Alkanhal, 1989; 1992). Walstra and Jenness (1984) reported NPN content in cow's milk in the range of 25 - 35 mg/100 g of milk.

Casein is the principal protein component of milk and cheese. Average amount of casein nitrogen in camel milk was 344.51 ± 8.79 mg/100 ml which represents about 80% PN.

The percentage of TN of milk as casein is called the casein number (Waite, 1961), and it characterises the suitability of milk for cheese production. The average casein number of camel milk was 67.5%, varying from 60.9 to 72% for individual samples. This value is in agreement with those reported for Saudi Arabia camels by Mehaia *et al* (1995), i.e. 65.7%, while it is lower than that of camel milk in Kenya , i.e. 76% (Farah and Ruegg, 1989) and slightly higher than that reported for Egyptian camels, i.e. 64% (Taha and Kielwein, 1989; Farag and Kebary, 1992). Camel milk would be least suited for cheese manufacturing than cow's milk which contains high casein levels with an average value of 77.9% with individual variation from 64.3 to 83.7% (Cerbulis and Farrell, 1975).

Table 2. Nitrogen distribution in camel's milk produced in South Morocco (w/v).

Nitrogen fractions	Range	Mean (n = 50)	SD
Total nitrogen	417.00 - 601.00	510.00	13.01
Non protein nitrogen	65.91 - 94.20	79.93	2.04
Protein nitrogen	351.09 - 506.80	430.07	10.30
Casein nitrogen	301.30 - 366.00	344.51	8.79
Non casein nitrogen	115.70 - 235.00	165.49	8.02
Whey protein nitrogen	49.79 - 142.80	85.56	2.17

The average WPN corresponds to 16.8% of the total camel milk nitrogen which is close to that reported for Kenyan camel milk, i.e. 17.2% (Farah and Ruegg, 1989), but lower than those of Egyptian camel milk, i.e. 22.6% (Taha and Kielwein, 1989) and Saudi Arabian's camel's milk, i.e. 28.5% (Mehaia and Alkanhal, 1989), 24.3% (Mehaia *et al,* 1995). The average WPN corresponds to 19.9% of the camel milk protein nitrogen. This ratio is in the range, i.e.17 to 23% reported by Farah (1993).

Heat stability

The heat stability of milk can be defined as the time required to induce coagulation at a given temperature. The average HCT obtained on the camel's milk at different values of pH (6.3, 6.5, 6.7, and 6.9) and at different temperatures (85, 95, 100, 110, 120 and 130°C) are represented in the table 3.

The HCT increased progressively with increasing pH at all tested temperatures. The shape of the HCT/pH curve at low temperature (85 and 95°C) was significantly different from those at high temperature (100, 110, 120 and 130°C). The milk heated at a superior or equal temperature of 100°C was unstable to all pH (HCT<180 seconds). These results are in agreement with those reported by Farah and Atkins (1992) who concluded that dromedary milk is unstable at 120 and 130°C for pH of 6.3 to 7.1. It should be noted that cow's milk presents a HCT/pH of different shape (Fox, 1982; O'Connell and Fox, 2000). The milk of type A presents a maximum heat stability at the pH 6.7 and a minimum at the pH 6.9, while the milk of B type presents a HCT that increases according to the pH.

Table 3. Average heat coagulation time of camel's milk (in sec).

pH	Temperature (°C)					
	85	95	100	110	120	130
6.3	499	134	60	68	62	53
6.5	608	174	76	85	80	79
6.7	838	246	88	99	90	93
6.9	1110	314	154	115	99	104

Otherwise, the pH had a significant influence on the heat stability of camel's milk with a tendency to increase for the elevated pH. Therefore, the original pH of milk is determinant on the heat stability level.

According to these results, camel's milk cannot resist to sterilisation as for goat's milk (Fox and Hoynes, 1976; Zadow *et al*, 1983). Explanations of these heat stability differences between cow's milk, on one hand, and the milk of dromedary or goat, on the other hand, lies in the physico-chemical differences. In fact heat-induced interactions between caseins and whey proteins, particularly k-casein and b-lactoglobulin which play an important role in the stability of milk (Surel and Famelart, 2003). According to Ramet (1993), camel milk contains little k-casein (5% of total casein) and the evidence for the presence of b-lactoglobulin in camel milk is conflicting (Farah, 1986).

Assessment of the efficiency of the thermal treatment

It is necessary to know if this physico-chemical stability of camel's milk at the time of the pasteurisation will be accompanied with a thermally acceptable bactericidal efficiency. Data on table 4 show the microbial counts for camel milk before and after LTLT pasteurisation. These counts for raw camel milk were, in general, lower in comparison to raw milk of other species. Barbour *et al* (1984) explained these low counts by the stronger antimicrobial activity of camel's milk as compared to that of other domestic ruminants.

The ATC found in this study ($2.17x10^5$ c.f.u./ml) are lower than those reported for Moroccan's camel milk ($6.2x10^7$ c.f.u./ml) by Benkerroum *et al* (2003), but in agreement with those reported for Saudi camel's milk (i.e., $2.6x10^5$ c.f.u./ml in average) by Al Mohizea *et al* (1996). This variation depends on hygienic conditions in which camel's milk was produced, collected and handled (Al-Mohizea, 1986).

After LTLT pasteurisation, the microbial counts were remarkably reduced in milk samples. The mean of ATC was as low as $3.68x10^3$ c.f.u./ml for LTLT treated milk. Psychrotrophic bacteria appeared in relatively low counts in the pasteurised milk ($9.44x10^1$ c.f.u./ml). Coliform organisms were undetectable (<1 cfu/ml) in LTLT treated milk. This is expected for laboratory-pasteurised milk, prepared from raw milk with good microbiological quality. In addition, the absence of coliform organisms in the pasteurised milk comes from the fact that generally, this type of microorganisms doesn't survive after pasteurisation.

Conclusion

The chemical composition of camel's milk showed variations and also differences in the literature values. These differences might be due to the great variation in the diet of the camel under different circumstances, stage of lactation, breed, daily milk production.

Its heat stability was variable according to the temperature and the pH. It was unsteady at

Table 4. Microbial counts of camel's milk before and after pasteurisation LTLT (in cfu/ml).

Germs N° Trials	total Aerobic		total Coliform organisms		Psychrotrophic organisms	
	Raw milk	LTLT	Raw milk	LTLT	Raw milk	LTLT
1	$9,00.10^4$	$1,53.10^3$	$3,00.10^3$	<1	$6,00.10^3$	$2,26.10^1$
2	$3,00.10^5$	$5,10.10^3$	$1,40.10^4$	<1	$3,20.10^4$	$1,21.10^2$
3	$2,60.10^5$	$4,42.10^3$	$3,20.10^4$	<1	$3,10.10^4$	$1,17.10^2$
Mean	**$2,17.10^5$(a)**	**$3,68.10^3$(b)**	**$1,64.10^4$(a)**	**<1(b)**	**$2,30.10^4$(a)**	**$9,44.10^1$(b)**

Means on the same column that are followed of different letters differed significantly ($p < 0.05$)

LTLT : Low Temperature Long Time pasteurisation

the superior or equal pH at 6.6 (pH of fresh milk) and at the lower or equal temperature to 95°C, the camel milk was thermally steady. It suggests that this milk could be pasteurised. The efficiency of the pasteurisation is acceptable. Low temperature pasteurisation leads to good milk taste that is very important for camel milk consumers.

Further studies on the stability of pasteurised camel milk at +4°C and also the effect of pasteurisation on the therapeutic properties of camel milk will allow a large scale of the use of this milk.

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