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Effect of Shelf Life on Physicochemical and Biochemical Parameters of Camel Milk

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ABSTRACT

Background: Animal feed, environmental conditions and the lactation period are the main factors affecting the composition of camel milk.

Methods: In this study, samples from eight (8) camels were collected according to hygiene standards to determine the physico-chemical and biochemical parameters of milk during storage at ambient temperature. pH, titratable acidity, density, total dry matter, ash, fat, protein and vitamin C were determined.

Result: The results of the physico-chemical analyses indicate a pH of 5.98±0.30, a titratable acidity of 17.51±1.35°D and a density of 1.01±0.02 after 24 hours of storage at ambient temperature. At the same time, biochemical analyses show an ash content of 7±0.58 g/l, a fat content of 50.09±5.97 g/l and a protein content of 2.31±0.21%. The total dry matter content of camel milk is 129.27±11.31 g/l. The vitamin C content is 41.89±4.51 mg/l. Monitoring of the pH changes of camel milk during storage at room temperature (22±6°C) showed low acidification of camel milk after 24 storage, confirmed by the statistical study which revealed a non-significant difference in pH ($p>0.41$). While after 24 hours, the differences are significant for pH, dornic acidity and vitamin C content ($p<0.0001$). The remaining ingredients (dry matter, fat, ash) experienced a non-significant progressive decrease ($p>0.05$). A still non-significant decrease in protein content occurred during the first two days of storage. From the second day, the difference became significant ($p<0.001$). The study of density variation showed a slight non-significant increase ($p>0.15$) over time. These results have allowed us to confirm that the analyzed camel milk, has a number of particularities in its chemical and physical composition, which prolongs its shelf life.

Key words: Ambient temperature, Camel milk, Camel, Consumption, Marketing, Nutritional qualities.

INTRODUCTION

Until very recently, camel milk was consumed at the family level and in very limited areas (Srairi *et al.,* 2019). In recent years, however, camel breeding has experienced an undeniable development in several countries around the world. For example, Faye (2020) and Konuspayeva *et al.* (2021) report that, with the exception of goat farming, camel farming outnumbered other herbivorous species.

Camel milk and meat are recognized for their nutritional, therapeutic and dietary interest, justifying their extensive use in food and cosmetics (Yadav *et al.,* 2015, Fguiri *et al.,* 2015, Faraz, 2020). Several experts have suggested the potential effect of camel milk to increase anti-Covid-19 immunity.

Indeed, Khalesi *et al.* (2017); Aqiba *et al.* (2019) and Dong *et al.* (2020) report that camelid immunoglobulins allow the development of therapeutic antibodies as well as protective enzymes, antimicrobials and immunological substances such as lactoferrin. Similarly, Yadav (2015), Kaskous (2017) and Ebaid *et al.* (2023) confirm that camel milk can be used to treat certain diseases and to combat health problems such as gastrointestinal disorders, diabetes, food allergy, psoriasis, hepatitis C and B, autism and tuberculosis. In line with marketing, the collection and conservation of camel milk are steps to control allowing the sale of dairy products in local, regional and even international markets (Faye, 2016).

In Algeria, the real production of camel's milk is poorly known, indeed, camel breeding is concentrated in the steppes and Saharan regions with difficult access. This leads to weak market integration, accentuated by the remoteness

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of production areas. Konuspayeva *et al*. (2021) report that the share of self-consumed milk is likely higher in countries where camel-rearing areas are far away from urban centres.

Furthermore, according to FAO (2021), consumption of camel milk is often limited to certain regions, especially in the Maghreb countries where camel milk is a product of the southern regions. In Algeria, camel herds are located in the south, far from towns with large settlements. In this case, camel milk must be stored for many hours before reaching the consumer. While, for health reasons, many consumers prefer to drink fresh camel milk. The multiplication rate of microbes in milk depends mainly on the initial number of bacteria, the storage temperature and the shelf life Kaskous (2019).

The objective of this study is to determine the physico-chemical characteristics of raw camel milk from an Algerian steppic region (Djelfa wilaya) and to follow changes in some of the physico-chemical properties at room temperature after the milk is transported through the same marketing channels by the sellers.

MATERIALS AND METHODS

Our camel population was located in the steppe region of central Algeria. Climate is defined as arid continental, characterized by both low and variable precipitation. The region is characterized by a more or less long drought and a thin vegetation with gaps between the tufts of vegetation. The semi-sedentary breeding method is based on steppe vegetation without dietary supplements.

Eight camels, aged from 5 to 8 years old with healthy-appearing udders, were manually milked in the morning during the summer period (June 2022). Before milking, the farmer disinfected his hands and the udders of the camels with ethanol (70°). The udders were then well dried. The first sprays were removed and the milk was collected in sterile bottles and transported to the laboratory where it was kept at room temperature to simulate the conditions of the marketing circuit by the sellers. pH was measured alone just after milking and with other physico-chemical parameters after 24 h, 2 days and 3 days after sampling.

The pH was measured using a pH meter electrode (Hanna, pH 211, Romania) at temperatures of 22±2°C. Dornica acid is titrated with sodium hydroxide solution (NaOH N/10) in the presence of 2-3 drops of phenolphthalein dye at 1%. Determination of dry matter content was done by drying in the oven at 100°C for 7 hours; according to Sboui *et al.* (2009). The ash content expressed in grams/litre was determined, according to the same authors, after incineration in a muffle oven set at 505°C. The determination of fat content was carried out by the method (IDF 22B, 1987) and protein-titratable according to Konuspayeva (2007). The vitamin C content was determined by a method recommended by FAO (1995).

For the statistical study, the data obtained was processed by the XLstat 2016 software for the calculations concerning first descriptive analyses. The physico-chemical and biochemical characteristics of milk were studied using a fixed-effect variance analysis model including shelf-life effects. The significance level was set to $P<0.05$.

RESULTS AND DISCUSSION

In our experiment, about 192 data were obtained with 8 samples analyzed after 24 hours, 2 days and 3 days of milking and of which 08 physico-chemical and biochemical parameters were studied.

The pH of the milk samples in this study, evaluated just after milking, ranged from 6.21 to 6.65 with an average of 6.43± 0.15. Several authors found very close pH values for camel milk. Yam *et al.* (2014) and Meribai (2018) and Bouguerra (2021) reported pH values directly after milking ranging from (6.4-6.7), (6.58-6.65) and (6.46-6.77), respectively. However, our results are higher than those reported by Benyagoub and Ayat (2016) who found an average pH of 5.67. In addition, Sboui *et al.* (2009) found that fresh camel milk is more acidic and less dense than cattle (6.6) and human milk (7.01).

The variability observed in the pH results of the different authors may be due to several factors such as geographical location, climate, diet and water availability in addition to other factors such as breed, stage of lactation, age and number of calves (Gorban and Izzeldin, 1997; Al haj and Al Kanhal, 2010).

According to Sharma (2006), pH is an index to measure the actual acidity of the milk and to detect abnormal milk from camels with mastitis. While the relatively high vitamin C content of camel milk is the cause of low pH compared to cow's milk (Saley, 1993).

The slow decrease in pH, observed during the test period, can be explained by the fact that acidity has little influence on pH, the relatively slow decrease. This experimental finding, reported by many authors (Farah *et al.,* 1989; Ramet, 1994; Abu-Tarboush, 1996) is explained by the fact that camel milk has a greater buffer power compared to the milk of other species.

After 24 hours of storage, we recorded a pH value of 5.98±0.30. Statistical analysis did not reveal a significant difference between pH measured immediately after collection and pH measured after 24 hours of storage at room temperature. This result corroborates that of Kaskous (2019) which confirms that after 24 h an ambient temperature the storage of raw milk samples did not have any significant changes in its quality. After 3 days of storage the pH was 4.45±0.30, very close to that of Sodini *et al.* (2002) which who recorded a pH of 4.6 after the same storage period. At 3 days, the pH of our samples was 3.95±0.25. Sodini *et al.* (2002) reported that after 72 h of incubation, the pH of camel milk had not yet reached the final acidification point. (Fguiri *et al.* (2017) reported that lowering the pH during storage is due to lactose fermentation into lactic acid.

This work shows Dornic acidity values, measured 24 hours after milking, of about 17.51±1.35°D. It is comparable to that obtained by Abidi (2001), Mahboub *et al.* (2010), Chethouna (2011) and Siboukeur (2005) in Algeria and Sboui *et al.* (2009) in Tunisia that reveal Dornic D acidity values of 19°D, 21.3±1.44°D, 18°D, 18.2±2.93°D and 17.2°D, respectively.

Other authors have shown titrable acidity values below 17°D, including Ghennam *et al.* (2007), Alloui-Loumbarkia *et al.* (2007) in Algeria and Kamoun (1994) in Tunisia with 15.6°D, 15.12°D and 15.6±1.4°D. In addition, the variation in acidity is also due to variations in animal feed, environmental conditions and lactation (Abu-Tarboush 1996).

It was noted that the acidity of camel milk slowly increased at ambient temperature. Dornic acidity increased from 17.51±1.35°D on the first day to 73.3±3.53°D after 3 days of storage. Ghennam *et al.* (2007), Chethouna (2011), Siboukeur (2005) and Bezzalla and Gouttaya (2013) reported different results after the 7th day of storage, 93.6°D, 92.5°D, 78°D and 98°D, respectively. The increase in milk acidity is attributed to a high concentration of lactic acid formed during lactic fermentation by milk bacteria (developed acidity). This tends to slow down acidification due to the particular tampon of camel milk compared to cow milk (Farah *et al.,* 1989; Ramet, 1994; Abu-Tarboush, 1996).

The density of camel milk recorded in this study was 1.01±0.02 after 1 day. This is very close to those recorded by Mahboob (2010); Siboukeur (2007); Abidi (2001); Kamoun (1995); FAO (1995); with 1.03±0.01, 1.02, 1.02, 1.03 and 1.02, respectively. The latter is strongly related to the frequency of watering (Siboukeur, 2007), sufficient watering leads to an increase in the water content of the milk and a decrease in the total dry matter content, which explains its low density.

The dry matter content of 129.27±11.31 g/l is comparable to that found by Sboui (2009) and Kamoun (1995) in Tunisia and Siboukeur (2007) and Ghennam *et al.* (2007) in Algeria, respectively 119.43 g/l ± 15.34, 116 g/l ± 11.11, 11 g/l ± 10.58 and 129.98g/l ± 4.75.

Kaskous, (2019) and Bengoumi *et al.* (1994), report that the lactation stage has an effect on the solids content of milk; in fact, the solids content in milk increases continuously as the lactation stage progresses. This increase is, according to the same authors, related to the increasingly high fat and protein content of milk.

Analysis of the ash content of camel milk reveals a value of 7±0.578g/l which is not far from the results reported by other authors. It ranges from 7.5 g/l (Sboui 2009) to 7.28 g/l ±0.68 (Siboukeur 2007). According to Yagil (1985), the ash content of camel milk varies widely with dietary intake. As a result, the mineral composition of camel milk depends mainly on the diet and the state of dehydration (Fay, 1997). Attia *et al.* (2000) found that camel milk rich in salted micelles is richer in ash than cow's milk. This variation appears in consecutive amounts of milk produced (Elamin and Wilcox 1992) and in the lactation stage (Farah, 1993).

The average milk fat content in this study is approximately 50.09±5.97 g/l. It is comparable to that reported by Ghennam *et al.* (2007) for the Algerian chamelle (50.50±8.37 g/l). However, it is higher than that described by Siboukeur (2007) in Algeria, Kamoun (1995) and Sboui (2009) in Tunisia, respectively 28±6 g/l, 35±7 g/l and 37.5±8.95 g/l. It is proved that outside of the breed, milking time affects the fat content. In fact, milk processed in the morning is relatively low in fat compared to milk processed during other hours of the day (Kamoun 1994).

Food also plays an important role in the evolution of fat content, the study conducted by Mathieu (1998) showed that when the feed/concentrate ratio in the diet is lower, the amount of volatile fatty acid products increases in the rumen, which has a positive influence on the percentage of fat in camel milk.

In addition, the lactation stage affects the fat content; it increases from the 8th day of lactation during the first months and then goes down to a high level at the end of lactation (El Hatmi *et al.,* 2004).

A low fat content of camel milk compared to other milks and its high content of unsaturated and long-chain fatty acids give it beneficial effects for consumers with cardiovascular problems (Bouguerra, 2021).

Jilo and Tegegne (2016), Singh *et al.* (2017), Rahmeh *et al.* (2019) report that, compared to other ruminants, camel milk fat cells lack agglutinin, making them easily digestible.

According to Hassan *et al.* (2007); Bekele *et al.* (2011), several factors affect the fat content of camel milk such as weather conditions, stage of lactation, diet, presence of water, country and milking method. Indeed, Bekele *et al.* (2011) stated that diet and watering can significantly affect the fat content of camel's milk, as thirsty camels produce milk high in fat.

In addition, Gorban and izzeldin (1997) states that the fat content of camel's milk can also be affected by the type of forage, including the nature of carbohydrates, thus modifying the ratio of volatile fatty acids in milk.

The mean total protein content of the raw milk tested is 2.31±0.21%. It is comparable to that obtained by Abu-Lahia (1994) (2.78±0.12%) and El Amin (1992) (2.81%). Other authors found results above these values, such as Mal *et al.* (2006); Mal *et al.* (2007), Bakheit *et al.* (2008) and Al haj and Al Kanhal, (2010) with 3.73%, 3.89%, 3.4% and 3.1±0.5% respectively.

However, our results remain higher than those published by Kaskous (2019) at 2.28±0.01%; Ellouze and Kamoun (1989) at 2.29%; Raghvendar *et al.* (2004) at 2.30% and Omer and Eltinay (2009) at 2.06%.

In general, the percentage of protein in raw camel milk ranges from 2.1 to 4.9% (Bouguerra, 2021); 2.15 to 4.90% (Konuspayeva *et al.* 2009) or 2.30 to 3.95% (Yadav *et al.,* 2015) or 3 to 3.90% (Jilo *et al.,* 2016).

As with fats, the protein content of our samples appears normal since Bekele *et al.* (2011) have reported that the protein content of camel's milk is not affected when the animal is not deprived of water or food as is the case with our breeding.

Table 1: Physico-chemical analysis of milk.

Storage day	pH	Acidity °D	Density g.cm^{-3}
D0	6.43±0.15^{a}	-	-
D1	5.98±0.30^{ab}	17.51±1.35^{a}	1.01±0.02^{a}
D2	4.45±0.30^{bc}	48.49±3.71^{b}	1.01±0.03^{a}
D3	3.95±0.25^{c}	73.3±3.53^{c}	1.02±0.03^{a}
p	< 0.0001	< 0.0001	0.146

D: Day; P: Significance threshold of difference between means, (a, b, c) in the same column. The values assigned to the same letter do not differ significantly (P>0.05).

Table 2: Biochemical analysis of milk.

Conservation day	Total dry matter (g/l)	Protein (g/l)	Fats (g/l)	Ash (g/l)	Vitamin C (mg/l)
D1	129.27±11.31^{a}	23.1±2.08^{a}	50.09±5.97^{a}	7±0.58^{a}	41.89±4.51^{a}
D2	127.27±8.65^{a}	26.3±3.68^{a}	48.6±4.89^{a}	6.9±0.61^{a}	28.6±4.60^{b}
D3	125.89±8.77^{a}	32.9±3.75^{b}	43.01±4.07^{a}	6.21±1.43^{a}	16.72±3.16^{c}
p	0.62	0.001	0.30	0.28	< 0.0001

D: Day; P: Significance threshold of difference between means, (a, b, c) in the same column. The values assigned to the same letter do not differ significantly (P>0.05).

The stage of lactation leads to a decrease in protein and fat content according to Kamoun (1994), these levels subsequently reach a minimum value coinciding with the peak of lactation and then return to a level comparable to that of departure at the end of lactation. Diet plays an important role in the evolution of protein levels. The protein content varies in the same direction as the energy intake. It depends on the proportion of concentrated food in the ration, its size and its distribution (fineness of the hash, number of meals, food mixture) (Benhedane, 2012).

The vitamin C content of the sample analyzed is 41.89±4.51 mg/l. Farah *et al.* (1992), Siboukeur (2005) and Boudjenah (2012) report similar levels of 37.4 mg/l, 41.4±8.2 mg/l and 45±0.03 mg/l, respectively. The concentration of vitamin C in milk varies with the stage of lactation. Konuspayeva *et al.* (2003) conclude that alfalfa-based diets are more favourable on the concentration of ascorbic acid in plasma and leukocytes than grazing-based diets.

Singh *et al*. (2017); Rahmeh *et al*. (2019) published vitamin C levels between 24-52 mg/kg and reported that camel milk is 3-5 times richer in vitamin C than bovine milk, which is of great nutritional importance.

The variation in vitamin C content is also related to the number of births. Indeed, milk from primipares contains less ascorbic acid than milk from multipares (Konuspayeva *et al.,* 2003). Table 2 shows a decrease in vitamin C content to 16.72±3.16 mg/l after 3 days of milking. This decrease is due to the oxidation of vitamin C by oxygen dissolved in milk and under the effect of light that transforms ascorbic acid into deoxyascorbic acid which remains biologically active but very unstable (Mohamed *et al.,* 2013).

Statistical analysis showed that storage time influenced certain parameters of camel milk. Table 1 and 2 clearly show the significant effect (P<0.001) of storage time on acidity, pH and vitamin C content. The protein content of our samples does not change significantly an ambient temperature until 48 hours and then they changed significantly (P=0.001), on the 3rd day of storage.

The increase in the acidity of milk stored an ambient temperature, is due, according to Kaskous (2019) to the fact that beyond 24 hours of storage, the load of lactic bacteria and the extent of fermentations increase by decreasing, the pH of the milk, the latter then becomes inconsumable. The negative pH evolution observed for our samples is confirmed by the results of Omer and Eltinay (2009) which reported a pH of 6.57 on the day of collection and 5.47 after 3 days vs 6.43 and 4.45 respectively in our study.

The milk fat content of our camels decreased slightly and non-significantly (p=0.30) from 50.09 g/l (24 h) to 48.60 g/l (48 h) to 43.01 g/l (72 h). The same findings were made by Kaskous (2019). In fact, he reported 2.62% at 24 hours and 2.61% at 48 hours. However, Omer and Eltinay (2009) reported a significant increase in mean fat contents with 2.72% at 48 hours and 3.06% at 72 hours.

The results of this study showed that milk quality did not change after a 24-hour storage period at room temperature. However, the milk was acidified after 48 hours. This corroborates the results of Kaskous (2019) which suggests that generally storage at room temperature (24±1.7°C) contributes to the decrease in milk quality and that raw camel milk can be kept at room temperature for 24 hours without noticeable change. Similarly, Millogo (2015) shows that in practice camel milk is generally stored at room temperature for 24 hours in many countries.

CONCLUSION

In Algeria, camel milk consumed, either fresh or preserved, is an invaluable source of food for the inhabitants of the steppes and Saharan areas. This is due to its high nutrient content and its protective. The results of this study focused on the characterization and evaluation of certain physico-chemical parameters of camel milk. Indeed, this milk has important nutritional properties similar to those of cow's milk, necessary for human food. The collected milk is characterized by very high fat content around 50.09±5.97 g/l with a density of 1.01±0.02 g.cm^{-3}. The dry matter of camel milk in this study was 129.27±11.31 g/l and the ash content was 7±0.58 g/l. The total protein content of the raw milk tested was 2.31±0.21%, while a high vitamin C content was found (41.89±4.51 mg/l).

The evolution of the physico-chemical parameters of camel milk kept at room temperature (22±2°C), in particular, the pH and average acidity values seem to be linked to the enzymatic action of the endogenous microorganisms in milk. The pH was very low after 48 hours of storage and the acidity developed around 48.49°D. The decrease in pH and the increase in acidity are accompanied by an increase in total protein content and a non-significant decrease in fat ($p=0.30$) and highly significant vitamin C ($p<0.0001$).

We can conclude that, in fresh form, camel milk is an important nutritional food for consumers. Its shelf life remains longer depending on the temperature. From the perspective and in terms of this study, we can say that raw camel milk is less affected by storage and can be stored for relatively long periods at room temperature, without changing the quality of the milk. Many measures will have to be observed, such as the hygiene of the premises and udder, the use of milking machines, knowing that most breeders milk their camels by hand. This ensures a safe supply of healthy raw milk to the market.

Conflict of interest

All authors declared that there is no conflict of interest.

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