Mineral status in camel milk: a critical review

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Implications

- Minerals in camel milk are presented among elements contributing to its reputation for health benefit to consumers
- Both major and trace minerals are not in exceptional quantity compared to other species except cations (K, Na, Cl) and probably iron and zinc.
- There is a lack of data regarding the effect of diet composition on mineral concentration of camel milk.

Key words: anions, camel, cations, milk components, trace elements

Introduction

The potential and expected therapeutic effect of a regular camel milk (**CM**) consumption on different diseases is a strong commercial argument usually justifying the high price of the product on market compared to cow milk (Konuspayeva et al., 2021). Making confusion between "health effect" and "medicinal virtues", many scientists are looking for the bioactive components potentially explaining the beneficial impact of CM consumption on human health. Generally speaking, many review papers on "medicinal properties" of CM (for example, Abdelgader and Al-Haider, 2016; Hassen, 2020) emphasize the richness of this milk in some components as minerals and vitamins. Whether or not the mineral composition of CM is unique comparing to other domestic species is unknown. Yet, except for vitamin C, niacin (vitamin B3) and vitamin D, the concentrations of other vitamins are not so high or even can be in lower quantity than cow milk (Faye et al., 2019). The question of the mineral composition is obviously important to support the idea that CM is also exceptional in this matter. Thus, the objective of the present review was to provide up-to-date data on the mineral composition of CM based on available references.

Methodology

The number of references regarding mineral concentrations in CM is relatively limited compared to data available on cow or small ruminants' milk. Moreover, a certain confusion occurred due to the variable analytical techniques that could change with the progress in sensitivity and accuracy of laboratory equipment for the last years, and with the units used by the authors for presenting their results. The most popular equipment to determine the minerals in milk is atomic absorption spectrophotometry or inductively coupled argon plasma-atomic emission spectrometer (**ICP-AES**). For some elements as iodine or molybdenum, colorimetric methods are preferred, but chromatographic methods have been also proposed. For selenium, fluorimetry was used formerly, and different types of spectrometry are used nowadays. For a better understanding, the present review displays the results, element by element and as far as it will be possible, an effort was done to convert all published data into similar units to make comparison easier. However, an important risk of contamination (especially with trace elements) could occur during sampling collection and preparation procedure with a potential high impact on the results. Such contaminations could explain sometimes high reported values, well above most of the available references.

Major Minerals in CM

The main minerals in milk are calcium, phosphorus, magnesium, sodium, potassium, and chlorides. These minerals are generally electrically charged, and it is possible to distinguish the cations (positively charged as Ca^{++}, Mg^{++}, Na^+, K^+) from the anions (Cl^-, PO_4^{3-}). Some elements (Ca^{++}, Mg^{++}, PO_4^{3-}) are associated with milk proteins, contributing notably to form casein micelles (colloidal particles) involved in cheese processing. Some minerals are diffusible (Na^+, K^+, Cl^-) and contribute for example to the salty taste, especially when the camels are grazing halophytes. Although their global quantity in CM rarely overpasses 1 g/L, they can provide an important part of the requirements for the baby camel and for the consumers. In a previous meta-analysis compiling 121 references on CM composition (Konuspayeva, 2020), the mean value of total minerals in CM was 0.81 ± 0.19 g/L (0.58–2.48 g/L).

Calcium

The values of total calcium in CM are comprised between 0.3 and 2.57 g/L (Faye and Bengoumi, 2018). A part of this variability could be attributed to water repletion status. Indeed, camels are known for their ability to space out watering, and the dehydration status can influence milk calcium concentration (Yagil and Etzion, 1980). In a comparative study involving different camel species living in the same environment (Faye et al., 2008), calcium content in Bactrian CM appeared significantly higher (1.30 ± 0.29 g/L) than in dromedary milk (1.16 ± 0.27 g/L) while crossbreed Bactrian*dromedary presented intermediary value (1.23 ± 0.27 g/L). In China, Jirimutu et al., (2010) reported similar calcium concentrations in milk from wild Bactrian (*Camelus b. ferus*) and from Bactrian (*Camelus bactrianus*): 1.43 ± 0.05 g/L vs. 1.23 ± 0.08 to 1.83 ± 0.19 g/L according to different farms.

Some other variation factors were investigated as the camel breeds (Mehaia et al., 1995; Al-Haj et al., 2022), the degree of intensification in farming systems (Alwan and Zwaik, 2014) with contradictory results. The physiological stage is also linked to a variation of calcium content in milk. For some authors, calcium is increasing at the end of lactation (Mal et al., 2007), but the colostrum collected at parturition contained more calcium than that of 10 d postpartum milk: 1.75 ± 0.16 g/L vs. 1.21 ± 0.17 g/L (El-Khasmi et al., 2001). However, in a monitoring of minerals in Arvana camel (dromedary) throughout the lactation (Konuspayeva et al., 2010), the maximum value of milk calcium was observed at early lactation (1.43 g/L), and the minimum at the lactation peak (0.70 g/L). Monthly variation was also reported in Jordan dromedaries (Haddadin et al., 2008), probably linked to lactation stage of the dairy camels as their reproduction cycle is seasonal: indeed, the beginning of lactation occurring in winter, the highest concentration was observed in January while the peak of lactation occurring in summer, the lowest was observed in August (Figure 1).

There are few data regarding the impact of heat treatment on calcium content in CM. Recently, Al-Haj et al., (2022) found significant differences in calcium content between heat-treated and raw CM samples. Moreover, heat treatment decreasing the concentration of ionic calcium, it induces an inhibition of rennet coagulation (Metwalli and Hailu, 2020). However, the same calcium level was observed in pasteurized CM at 72 °C for 5 min compared to raw milk. Contrary to cow milk, calcium in CM seems more stable after heat treatment at 80 °C for 60 min (Felfoul et al., 2016). The addition of calcium during rennet coagulation of CM was not necessary to improve curd, whatever source – calcium phosphate or calcium chloride – as there was no impact on the coagulation yield.

Compared to milk from other species, results were not always coherent. Globally, CM is containing comparable calcium concentration (0.70 ± 0.09) than in cow (0.66 ± 0.04), goat (0.75 ± 0.07), and sheep milk (0.82 ± 0.01 g/L) (Al-Wabel, 2008). However, in Egypt, if calcium content in CM (1.20 ± 0.07) is like in cow milk (1.11 ± 0.04), goat (1.30 ± 0.02), and buffalo milk (1.63 ± 0.05 g/L) contained significantly more (Soliman, 2005). On the other hand, in old references, lower calcium values were found in CM (0.40–0.94 g/L) than in goat milk (1.33 g/L). Quite questionable higher calcium content in goat milk compared to CM was reported also recently: 12.82 vs. 1.16 g/L.

So, even if CM is regarded as an important source of calcium, the amount in this mineral is not exceptional compared to other milk origin.

Phosphorus

The total quantity of phosphorus in CM is lower than calcium. Literature data give a range of 0.34 to 1.00g/L (Faye and Bengoumi, 2018). A narrow range was revealed in older references 0.86–1.39 g/L. Variation factors as farming system were also investigated by different authors, and reverse to calcium, it was found significant higher phosphorus concentration in milk from intensive farm than in Bedouin system.

Regarding the effect of lactation stage, Mal et al., (2007) found similar pattern than for calcium, i.e., lower concentration in early lactation (0.42 ± 0.05) than in late (0.47 ± 00.5 g/L) and El-Khasmi et al., (2001) reported higher content in colostrum at parturition (1.1 ± 0.014 g/L), than 10th day postpartum (0.82 ± 0.10 g/L). In the study of Konuspayeva et al., (2010), the changes throughout the lactation were parallel to calcium, the maximum value (1.16 g/L) being observed at early lactation and minimal (0.57 g/L) at the peak of lactation. Consequently, the ratio Ca/P was relatively constant and correlation between P and Ca values, highly significant (Konuspayeva et al., 2008).

Heat treatment of raw CM for processing seems to have no impact on phosphorus content (Metwalli and Hailu, 2020).

As for calcium, phosphorus is in higher concentration in Bactrian milk (1.08 ± 0.18) than in dromedary milk (0.91 ± 0.19 g/L) with significant seasonal variation, values in summer being significantly lower than in spring and winter (Konuspayeva et al., 2008). In dromedary milk and in another climatic context (Haddadin et al., 2008), the lowest value in phosphorus was observed in August (0.61 g/L), and the highest in December (0.99 g/L) (Figure 1). The phosphorus content in milk is the main discriminating component allowing to distinguish Bactrian milk from dromedary milk (Faye et al., 2008). Such difference could be attributed to the higher fat content in Bactrian milk, notably in phospholipids. The ratio Ca/P, at least in camels (Bactrian and dromedary) from Kazakhstan where the 2 species are cohabiting, appears the lower among all other specific milk (Figure 2).

In comparative studies, phosphorus content in CM appears generally lower than in cow, goat, and buffalo milk: 0.81 ± 0.031 vs. respectively 0.95 ± 0.072, 1.10 ± 0.016, and 1.11 ± 0.026 g/L (Soliman, 2005). The lower phosphorus values in CM compared to goat were confirmed later: 0.87 vs. 1.31 g/L. In a recent comparative study (Khaldi et al., 2022), phosphorus recorded in Gharbi sheep milk was 1.45 ± 0.19 vs. 1.18 ± 0.24 in goat and 0.58 ± 0.18 in Maghrebi CM. Thus, as for calcium, the concentration of phosphorus in CM is not exceptional.
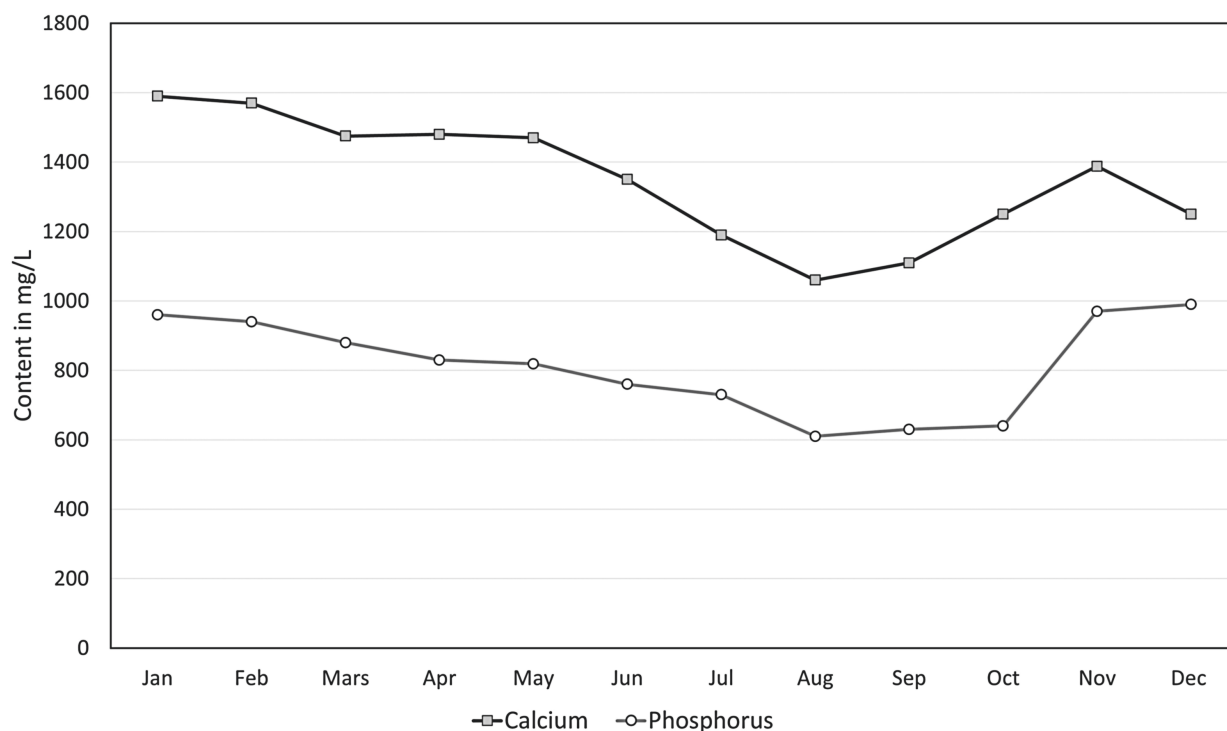
Figure 1. Monthly changes of calcium and phosphorus concentration in CM from Jordan (calculated from Haddadin et al., 2008).

Magnesium

Magnesium concentrations in CM varied between 45 and 200 mg/L. For example, 130 ± 11 to 116 ± 16 mg/L in different Saudi camel breeds (Mehaia et al., 1995), 73 ± 3.2 to 110 ± 5.7 mg/L according to different farming systems (Alwan and Zwaik, 2014) or 90 ± 8.6 mg/L in Jordan with a monthly range of 77–98 (Haddadin et al., 2008).

As for the other cations, magnesium concentration is higher in colostrum (236 ± 31) than in milk: 112 ± 22 mg/L (El-Khasmi et al., 2001). However, in Kenya, slightly lower values in early lactation were reported compared to late lactation: 118.2 ± 2.2 vs. 135.8 ± 3.1 mg/L (Oselu et al., 2022). In Chinese Bactrian camel, a range of 58.5–96.7 mg/L was reported (Chen et al., 2020). In their comparative data regarding wild and domestic Bactrian camels, Jirimutu et al., (2010) found more magnesium in the first: 111.3 ± 2.6 vs. 63 ± 1 to 92.5 ± 2 mg/L in different camel farms.

Compared to other species, magnesium appears in lower quantity. For example, 67 ± 14 in camel vs. 295.6 ± 7.9 in buffalo, 134.2 ± 2.4 in cow, and 138.7 ± 1.1 mg/L in goat milk (Soliman, 2005). However, in recent results, Chen et al., (2020) did not find statistical differences between magnesium content in camel (79.6 ± 33.2), goat (92.5 ± 12.0), cow (83.2 ± 10.3), buffalo (58.5 ± 11.3), and yak milk (96.7 ± 12.3 mg/L), contrary to Felfoul et al., (2016): 83 ± 0.0 vs. 120 ± 1.0 mg/L in camel and cow respectively. Globally, with a range of 97–146 mg/L, cow milk contains more magnesium than camel milk.

Sodium

Contrary to cations, the concentrations in anions appear more important in CM. The range of sodium in CM is 220–690 mg/L (Faye and Bengoumi, 2018), but values up to 902 ± 92 mg/L were cited (Bengoumi et al., 1998). For Al-Haj and Al-Kanhal (2010), mean sodium value in CM was 590 ± 160 mg/L. The variation factors are obviously the same than for cations: sodium content is higher in late lactation compared to early lactation: 815.9 ± 20.8 vs. 682 ± 12 mg/L (Mal et al., 2007). Similar figure was reported by Oselu et al., (2022), but not by Alwan and Zwaik (2014) where the physiological changes were not significant. With an average of 575 ± 118 mg/L all over the year, a marked monthly variability was observed (Haddadin et al., 2008) with higher values in summer (Figure 3).

In their comparison between farming systems, Alwan and Zwaik (2014) found higher sodium concentrations in desert milk than from intensive farm. Such difference could be explained by the abundance of halophytes plants in desert while the diet in intensive farms is mainly composed of irrigated fodders. Besides, CM produced in desert is more often salty.

Compared to other species, CM contains more sodium: twice more in Bactrian milk compared to cow or goat milk (Wang et al., 2011). Similar pattern was reported recently (Chen et al., 2020): 428 ± 79 mg/L for CM vs. 292 ± 50 (cow), 253 ± 55 (goat), 276 ± 66 (buffalo), and 345 ± 59 (yak). Similar ranking was observed by Al-Wabel (2008), including sheep milk. Although CM contained more sodium than other species, the differences were less marked in the observations of Soliman (2005): 578.4 ± 12.2
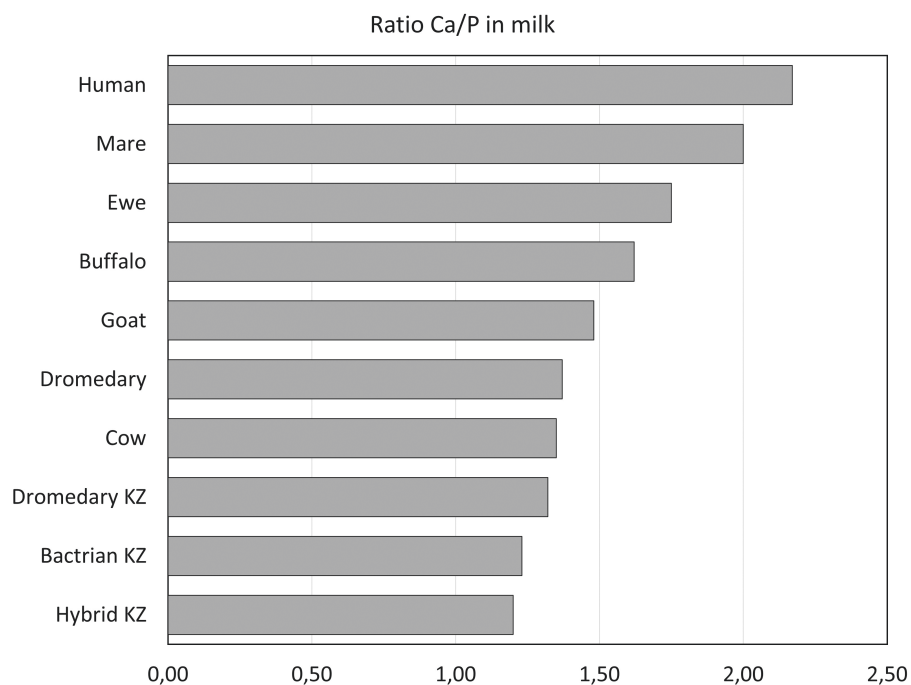
Figure 2. Ratio Ca/P in milk from different species including different camel species from Kazakhstan (KZ) and other dromedaries (estimated from literature data).
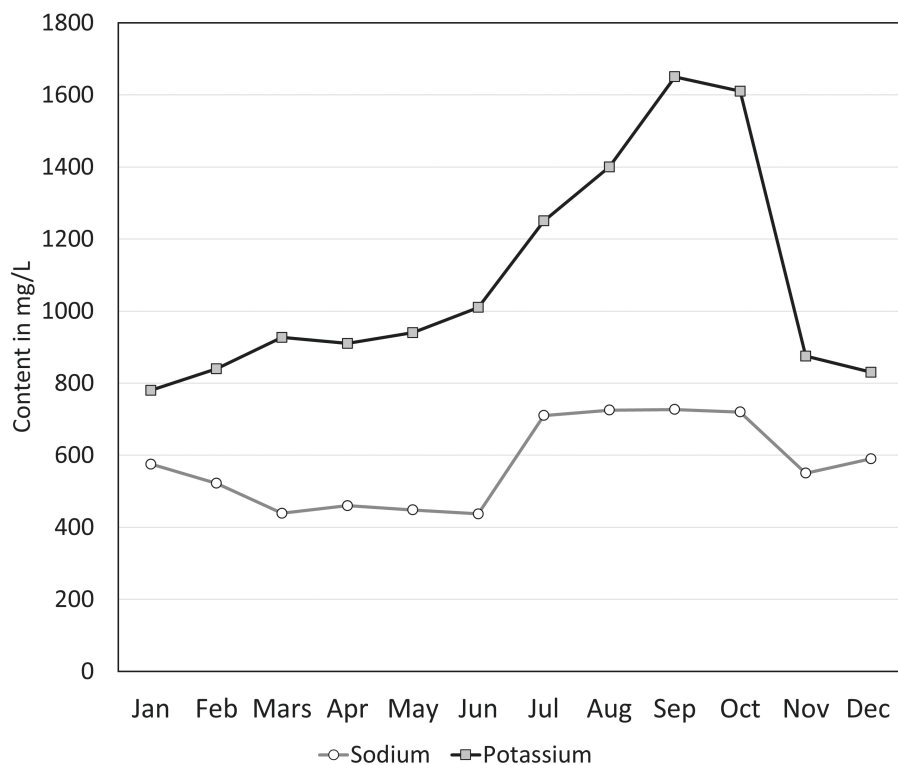

Figure 3. Monthly changes of sodium and potassium concentration in CM from Jordan (calculated from Haddadin et al., 2008).

in CM vs. 516.6 ± 6.6 in buffalo, 496.7 ± 7.0 in cow, 503.4 ± 7.7 in goat, and 160.3 ± 3.0 mg/L only in human milk.

Potassium

Potassium content in CM is generally high, the values being comprised between 520 and 1800 mg/L (Faye and Bengoumi, 2018), but concentrations above 2000 mg/L are cited (Bengoumi et al., 1998; Mal et al., 2007). If no sex difference was reported, important variations throughout lactation or season are mentioned (Mal et al., 2007) with higher values at late lactation. Exactly same increasing (40%) was reported in Kenya from early to late lactation (Oselu et al., 2022), whatever the farming system (Alwan and Zwaik, 2014).

Accordingly, higher level of potassium was observed from July to October (Figure 3), i.e., when most of the lactating camels are in late lactation. Milk potassium at the end of summer is 2 times higher than in winter passing from 780 to 1,650 mg/L (Haddadin et al., 2008). Contrary to most of the minerals, potassium in camel colostrum was little bit less than in mature milk: 1,654 ± 371 vs. 1,703 ± 344 mg/L respectively (Gorban and Izzeldin, 1997).

Controversial data has been found between other species. For example, for Chen et al. (2020), potassium level in Bactrian CM (930 ± 99) is lower than in goat (1,377 ± 325), cow (1242 ± 279), and yak milk (1,363 ± 200 mg/L). Only buffalo milk (698 ± 194 mg/L) presented lower values. Yet, in another reference (Jirimutu et al., 2010), Bactrian CM contained high level of potassium, between 1,640 ± 17.2 and 1958.4 ± 29.9 mg/L according to different farms. At reverse, but with questionable very low values (Al-Wabel, 2008), CM had comparable values to that of sheep milk and significantly higher than cow and goat milk. In Egypt, Soliman (2005) found slightly significant difference between potassium level on camel (1563.2 ± 28.5), cow (1470.2 ± 15.5), buffalo (1671.8 ± 31.6), and goat (2014.5 ± 19.0 mg/L).

Chloride

There are few data regarding chloride in CM. Reported values range around 2,000–2,800 mg/L, but lower values were reported sometimes. After dehydration (Figure 4), chloride content in milk increased by almost 100% as well as potassium while sodium increased by 80% (Yagil et al., 1980).

Due to the sensitivity of the electrolytes during the cycles of dehydration/rehydration, a seasonal variation was observed with lower values in summer (periods of intensive drinking) than in winter.

The comparison between animal species is difficult because the high variability in camel linked to its hydration status. The feeding behaviour of camel in desert, looking for halophyte plants is the main explanation for the higher concentrations in milk chloride compared to cow or buffalo milk (Al-Haj and Al-Kanhal, 2010).

Trace Elements in CM

It is generally stated that CM contains also high quantities of trace elements, especially iron and zinc. But such statement is often based on a limited number of publications. Trace elements are necessary in low quantity in the diet and in case of excess, milk is one of the excretion ways to eliminate the "surplus". Globally, regarding investigation of trace elements in milk, data are scattered, and rarely focus on mineral change according to different variation factors as diet composition, physiological stage, or health status. Moreover, the analytical procedures were not homogenous between references and could explain some of the gaps in the published values. Therefore, it is not easy to state the biological standards, and a high variability in available data is observed.

Copper

Copper content in CM ranges from 30 to 800 µg/100 mL (Faye and Bengoumi, 2018) but more extreme values are mentioned in the literature. For example, in Morocco, 1,130 ± 490 µg/100 mL (Bengoumi et al., 1998) while very low values were found in Kazakhstan: 5–7 µg/100 mL (Diacono et al., 2008). In Bactrian camel, a mean value of 470 µg/100 mL was reported.

There are few data regarding the effect of copper supplementation on the CM mineral status. On camels receiving trace element supplementation, Dell'Orto et al. (2000), did not observe significant change in the milk copper content between supplemented (37 µg/100 mL) and nonsupplemented camels (40 µg/100 mL).

Regarding the comparative studies, an extreme confusion is occurring. According to old references (for example Abdelrahim, 1987), copper in CM is comparable to that of goat milk while in India, no difference was found with cow, goat, and sheep milk. In their review, Faye and Bengoumi, 2018 stated that CM contained 12 times more copper than cow milk (490 µg vs. 13 µg/100 mL) and Soliman (2005) found more copper in CM (61 ± 2.3 µg/100 mL) than in cow (17 ± 1.6), buffalo (40 ± 2.5), and goat milk (40 ± 1.0 µg/100 mL). Higher quantity of copper in CM was also found by Al-Wabel (2008) compared to small ruminants (161 µg/100 mL vs. 57 in goat and 62 in sheep) while cow milk was richer (180 µg/100 mL). In the recent study of Chen et al. in 2020 on Bactrian camel, the hierarchy between species was as follows: yak (522 ± 115), camel (248 ± 55), buffalo (209 ± 93), milk (208 ± 98), and the lowest, cow milk (165 ± 58 µg/100 mL). For other authors, however, CM is the poorest regarding copper content.

Zinc

Zinc content in milk is highly variable according to authors 30–1,200 µg/100 mL. Thus, the reference values are not clear, and probably the results reported in the literature are depending on the analytical procedures and potential contamination, dust being rich in zinc. A range of 170–530 µg/100 mL was recently published. In CM samples from different regions of Kazakhstan, a mean of 470 µg/100 mL was found, with significant regional variation, and wide range between camel farms from 150 to 7,400 µg/100 mL. Zinc content changed also according to lactation stage with a significant trend to decrease throughout the lactation (from 440 to 390 µg/100 mL), and according to the farming systems, the milk collected in extensive system being richer (580 ± 52) than in intensive farms (420 ± 21 µg/100 mL) (Alwan and Zwaik, 2014). However, there were no clear seasonal patterns (Haddadin et al., 2008).

The effect of zinc supplementation in diet of camel was experimented by Dell'Orto et al., (2000): with a Zn supplement of 7,000 ppm, zinc concentration in milk increased from 252 to 316 µg/100 mL. In Kazakhstan (Meldebekova et al., 2008), zinc concentration seemed in higher quantity in fermented milk (1180 µg/100 mL) compared to raw milk from the same
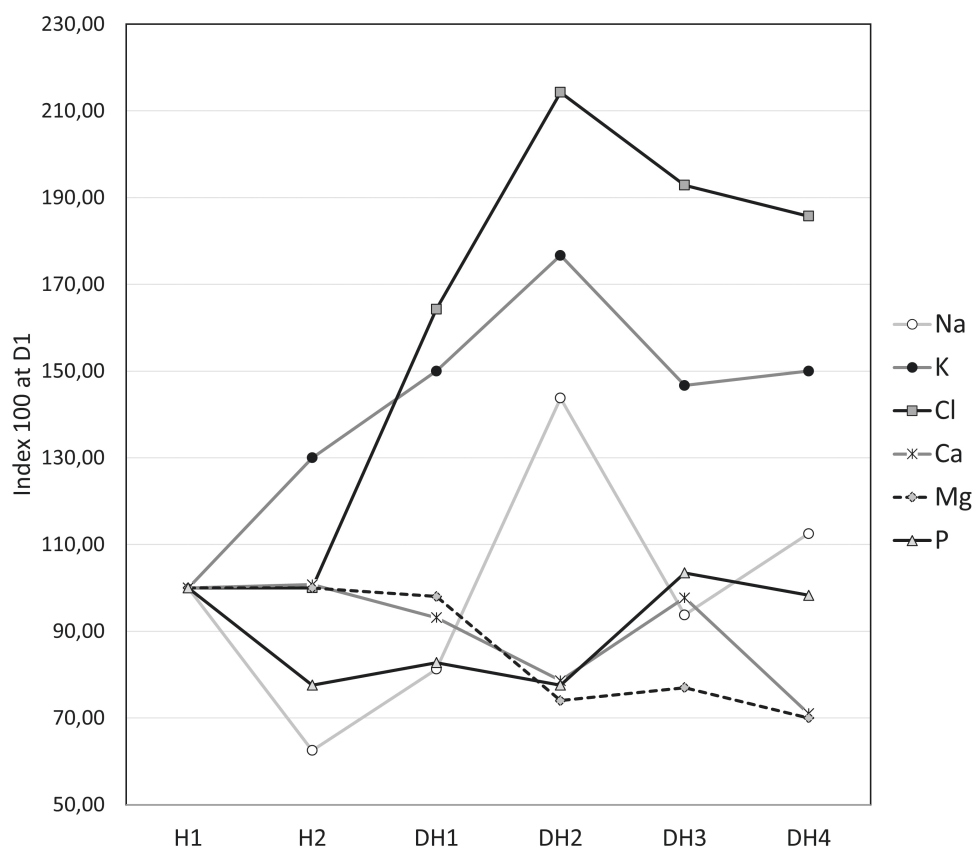
Figure 4. Relative changes in main minerals in CM after 2 periods of hydration (H1, H2) and 4 periods of 10 d dehydration followed by 2 h rehydration (DH1–DH4) during summer (calculated from Yagil and Etzion, 1980).

sample (370 µg/100 mL). Similar observations were done regarding zinc in camel yoghourt compared to raw milk: 250 vs. 482 µg/100 mL on average (Elhardallou and El-Naggar, 2016). Copper concentration (as zinc and iron) increased by a factor 5 during ultrafiltration process (Mehaia, 1996). Contrary to copper also, zinc in camel colostrum is in higher concentration (180 ± 148) than in mature milk (49 ± 18 µg/100 mL) (Gorban and Izzeldin., 1997).

In most of the comparative studies and unlike copper, zinc seems to be in higher concentration than in other species. Long time ago, Sawaya et al. (1984) had already stated that CM contained more zinc than cow milk: 440 vs. 390 µg/100 mL respectively. Such difference was confirmed later, on Bactrian camel (Diacono et al., 2008; Jirimutu et al., 2010; Wang et al., 2011). However, for Abdelrahim (1987), zinc content in CM (230 ± 60) was lower than in goat milk (550 ± 20 µg/100 mL). For Soliman (2005), zinc concentration in CM was 510 ± 15 vs. 380 ± 10 (cow), 240 ± 8 (buffalo), 320 ± 30 µg/100 mL (goat). Almost similar findings were reported recently by Chen et al. (2020). In the reference of Abba et al., (2021), zinc in CM was 625 ± 30 µg/100 mL, i.e., almost 2 times the values of other species. Although most authors emphasized the relative richness of CM in zinc, some references did not confirm such results (Al-Wabel, 2008).

Iron

Iron is one of the most important trace elements for the young mammals as their requirements are high before weaning, and milk of the mother is the only source of iron. Like for other elements, data regarding iron content in CM are highly variable between references with contradictory observations regarding the comparison with milk from other species (Faye and Bengoumi, 2018). For example, between the data of Elhardallou and El-Naggar (2016) and that of Elamin and Wilcox (1992), the gap is in a ratio of around 1/700: 0.49 and 341 mg/100 mL respectively. In the old reference of Sawaya et al. (1984), even lower value was reported: 0.26 mg/100 mL. Generally speaking, the lack of standardization in analytical methods could contribute to a certain low reliability of published results.

Most of the recent references, however, gave values around 10–20 mg/100 mL: in Bactrian camel, 14.8 ± 5.3 (Meldebekova et al., 2008), 20.2 ± 12.4 mg/100 mL (Konuspayeva et al., 2008). In comparison to dromedary milk, Bactrian CM presented higher iron concentration leading to consider iron as a potential discriminant element to identify the specific origin of the milk (Faye et al., 2008): 21.1 ± 16.3 for Bactrian vs. 19.3 ± 10.6 mg/100 mL for dromedary. There is a lack of regional variability (Rashed, 1998) and of the effect of iron supplementation (Dell'Orto et al., 2000). Colostrum contains more

iron than mature milk: 19 ± 2 vs. 13 ± 6 mg/100 mL (Gorban and Izzeldin, 1997) but with stable quantity throughout the year (Haddadin, 2008).

As usual, the ranking between species is not constant. For some authors, CM contains more iron than other milk (Gorban and Izzeldin, 1997; Soliman, 2005). In few references, goat milk contained more iron than CM. In Bactrian camel, CM contained 5 times more iron than in cow and 8 times than in goat milk (Wang et al., 2011). However, Chen et al. (2020) found less iron in CM (12.9 ± 7.3) than cow (14.5 ± 5.2) and yak milk (25.4 ± 6 µg/100 mL), but more than goat (10.8 ± 3.8) and buffalo milk (10.1 ± 2.4 mg/100 mL). For Al-Wabel (2008), CM was the poorest milk compared to all other domestic ruminants.

Thus, like for other minerals, the assertion that CM is particularly rich in iron and recommended for anaemic people must be put into perspective. This richness is depending on the environmental context and the interspecies comparisons are often based on milk samples coming from different regions.

Manganese

Manganese is less commonly determined in CM, probably because it is not a convenient indicator of its intake. Moreover, data from the literature are not very coherent, varying from around 5–6 µg/100 mL (Haddadin, 2008) to 780 µg/100 mL (Rashed, 1998). Camel colostrum contained more manganese (10.7 ± 1.6) than mature milk (8.3 ± 1.6 µg/100 mL) (Gorban and Izzeldin, 1997).

The between-species comparisons are incoherent: no significant difference (Soliman et al., 2005; Al-Wabel, 2008), more manganese in CM (19.3) than in cow (1.6) and human milk (4.2 µg/100 mL) (Gorban and Izzeldin, 1997). In the comparative study of Chen et al (2020), manganese content in CM (18.8 ± 10.6) was comparable to that of cow (18.7 ± 12.5), buffalo (16.9 ± 4.9), and goat milk (15.6 ± 3.1 µg/100 mL). Only yak milk had significant higher value (25.6 ± 6.1 µg/100 mL).

Thus, the richness of CM in manganese as stated by some review publications is not confirmed.

Selenium

Few references are available on selenium content in CM, but the same remark could be done on the high variability in the available data. In their experiments on selenium metabolism in lactating camels receiving different levels of supplementation, Faye and Seboussi (2009) found values in a range of 39.5 to 482.6 ng/mL with an average of 86.4 ± 39.1 ng/mL in nonsupplemented camels vs. 167.1 ± 97.3 ng/mL in supplemented ones. However, lower values (mean = 13.9 ± 2.4 ng/mL) were reported by Al-Awadi and Srikunar (2001). The maternal transfer of selenium in camel was regarded as very efficient as the mean value in colostrum was 302 ± 94.60 in baby camels issued from supplemented dams vs. 108.2 ± 43.9 ng/mL in nonsupplemented group (Faye and Seboussi, 2009). When Se supplementation is under organic form, higher content was observed in colostrum compared to camel supplemented with

inorganic selenium (Faye et al., 2014). Camel colostrum contained higher selenium concentration (46.2 ± 26.8), then decreased gradually down to 12.0 ± 3.0 ng/mL at d90 postpartum (Faye et al., 2014).

At our knowledge, there was no reference regarding comparison between species, except in Chen et al., (2020) where selenium in CM appeared significantly lower (29.4 ± 18.0 ng/mL) than in cow milk (37.2 ± 14.2) and similar to goat (28.1 ± 10.4) and buffalo milk (32.4 ± 11.0), but higher than yak milk (14.0 ± 5.3 ng/mL). However, camel appears very sensitive to selenium supplementation (Faye and Seboussi, 2009).

Other trace-elements

Few data are available on other trace elements in CM and most of the time, only values are reported without clear description of the context (physiological stage, mineral supplementation in the diet…).

Regarding **molybdenum**, CM concentration is around 650–700 ng/mL. Few references are available also on other specific milk, making difficult the comparisons.

Nickel was determined in CM in China (Chen et al., 2020) and Nigeria giving comparable values, 131 ± 148 and 220 ± 10 ng/mL respectively that is higher than in other species (between 32 and 82 ng/mL).

Sulfur was determined in Bactrian camel (range 283–402 ng/mL) and wild Bactrian CM (396 ± 8 ng/ml) in China (Jirimutu et al. 2010).

The other trace elements in milk determined by Chen et al., (2020) were **aluminium** (0.45 ± 0.29 ng/mL), **chromium** (13.6 ± 5.3 ng/mL), **tin** (50.6 ± 29.0 ng/mL), and **strontium** (3050 ± 850 ng/mL). Compared to other species, CM contained particularly more strontium. In the reference of Elhardallou and El-Naggar (2016), mean value for chromium was higher (193 ng/mL) but not strontium (151 ng/mL).

Lead, cadmium, and arsenic were also determined in CM (Chen et al., 2020), but they are more contaminants than biological elements.

Conclusion

Despite statement of many review papers regarding CM virtues, the mineral composition is not fundamentally different from cow milk. The main characteristics of the mineral composition of CM is its relative richness in K, Na, and Cl and probably iron and zinc. However, due to the lack of studies regarding the effect of some factors, notably the level of minerals in diet, it is difficult to specify a camel reference or usual values. Moreover, the variability in analytical procedures and the lack of accuracy in the methodology used by several authors, resulting in highly contradictory results, lead to regard some published data as highly questionable. An important effort should be done by the scientific community to establish a clear status of the mineral composition of CM potentially explaining some of the attributed health effect.

Conflict of interest statement. None declared.

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