# Effect of Total Mixed Ratio (TMR) Supplementation on Milk Nutritive Value and Mineral Status of Female Camels and Their Calves (Camelus dromedarius) Raised under Semi Intensive System during Winter

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**Abstract:** This study was conducted to investigate the nutritional values of female camels' milk and the minerals status, for them and their calves, when fed a total mixed ration (TMR) beside alfalfa hay during winter. Thirty-seven lactating multiparous female camels and their calves were selected at mid-lactation in the Al-Kharj region. Group one was fed only alfalfa hay ad libitum (C) and group two was supplemented with a total mixed ratio (TMR; 4 kg/head/day), primarily containing a mix of barley grain, wheat feed, palm kernel cake, soya hulls, vitamins and minerals. Milk and blood samples were collected in the middle of the winter season and analyzed for minerals using ICP-OES. A significant ($p < 0.05$) higher concentration was observed for protein and inorganic matter in milk from female camels supplemented with TMR in the T group. In addition, Mg, Co, Fe and Zn levels in milk significantly ($p < 0.05$) increased compared with the control group (C). Blood serum concentrations of Ca, P, Mg, Cu, I, Se, Zn and Cd minerals in female camels were significantly ($p < 0.05$) higher in the T group compared to the C group. Blood serum of the calves in the T group was significantly ($p < 0.05$) at higher levels for all minerals than in the control group (C); except iodine. Furthermore, significant correlations were reported between Co and Mn elements with most other minerals under investigation. In conclusion, TMR supplementation in the T group of female camels during lactation in the winter season is highly recommended since it improves the milk composition and mineral profile.

**Keywords:** female camels; milk; minerals; heavy metals; winter; total mixed ration

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## 1. Introduction

The ecosystem in the Middle East and Africa can be primarily classified as arid or semi-arid, with approximately 70% of their lands receiving less than 100 mm of rainfall per year. Traditionally livestock grazing on these lands has been a nomadic system. The inadequate rangeland forage has forced nomadic people to shift to other feed resources and consequently change their production system from nomadic to primarily settled, semi-intensive systems [1]. The main consequence for the feeding behavior of camels in this context is the change from a highly diversified diet (with important variability in nutritive value and grazed ecosystems) to a very monotonous diet (typically alfalfa + more or less barley + more or less concentrate [2].

Camels (*Camelus dromedarius*) are important dairy animals in semi-arid and arid nomadic and other communities as a source of high-quality animal protein, fatty acids, vitamins and minerals contained in milk [3]. Camel production systems are now shifting toward the semi-intensive approach that depends mainly on feed supplements to meet nutrient requirements. Feed supplements consisting of alfalfa hay, Rhodes grass, barley, wheat bran, crop by-products and, rarely, seasonal grazing pasture are the main source of nutrients for camels which do not cover the nutrient requirements including trace minerals, especially during lactation [4]. In camels, features such as low growth rate, seasonal breeding, long gestation period, abortion, low milk production, diseases and the high mortality rate of pre-weaning newborns and dams appear to be the major constraints on the improvement of their productivity and general performance [5]. However, camels are well known for their unique anatomy and physiology, which helps them to be suited for harsh environments, poor feeding and water scarcity. However, the problem with this feature is the unknown nutritional subclinical deficiencies during different seasons, which markedly reduce camel performance and profitability. Many scientific studies have demonstrated alterations in the absorption and metabolism of glucose, protein, lipids and minerals and effects on liver biological function in heat or cold-stressed subjects [6–8].

Seasons are well documented to affect grazing ruminants' health and productivity since there is significant variation in feed availability and nutritive values. Moreover, the animal requirements differ according to seasons, such as summer and winter. Winter is a very stressful season for camels, especially lactating ones, affecting milk yield and composition and so pre-weaned newborn camels' health and growth rate. Dwyer et al. [9] reported the mortality rate of livestock raised under an extensive system as follows: 9% of beef cattle, 15% of sheep, 20% of goat and 30% of camels. The causes of high mortality rate in camels may be caused by poor dam nutrition and late colostrum taking, which impairs immunity transfer and, consequently, neonatal health and growth [10].

Trace and macro minerals are crucial for animal health and productivity, including camels, especially when they become a limiting factor of the diet [11]. They play a pivotal role in many physiological activities, and their deficiency causes various pathological problems and metabolic defects [12]. The levels of nutrients and trace minerals intake are known to affect the reproductive ability of male or female camels [13,14]. The trace minerals such as selenium (Se), copper (Cu), zinc (Zn), manganese (Mn), cobalt (Co), iron (Fe), iodine (I) and molybdenum (Mo) are involved in normal growth and productivity of livestock [15]. Infertility, non-infectious abortion, anemia and metabolic diseases are some of the main clinical signs of deficiencies and abnormalities [16,17]. A few scientific studies have shown evidence of camels' sensitivity to trace and macro mineral disorders as a result of either deficiency or toxicity in the same way as other ruminants [18]). Faye et al. [18,19], and Zong-Ping et al. [20] have reported several incidences of clinical mineral deficiencies in camels being underestimated because signs of subclinical deficiencies may remain undetected for long periods. Regarding toxicity, evidence is even rarer. For example, some cases of selenosis were described [21], as well as fluorosis [22].

Most of these studies in semi-arid and arid areas fail to consider the main factors that affect the mineral and nutritional status of camels, such as seasons, age, breed, sex, physiological status, and management risk factors, especially those linked to the feeding system [23]. Such information is essential to establish a solid background for developing supplementation programs during different seasons to improve camels' reproductive and production efficiency and, consequently, milk and meat quality and quantity. The results indicated a lower concentration of some trace minerals in blood serum and tissue compared with normal levels in camels, significantly varying by breed [24]. Alhidary et al. [25] found that supplementing trace minerals to camels improves the average daily gain, feed efficiency, liver mineral reserve, and immune response. The objective of this study was to investigate the effect of total mixed ratio supplementation to one-humped female camels' calves on milk composition and minerals status during the winter season compared to female camels fed only alfalfa hay raised under semi-intensive systems.

## 2. Materials and Methods

### *2.1. Experimental Site*

This study was performed in the Al-Kharj agricultural region, located southeast of Riyadh province, Saudi Arabia (23°59′ N 47°09′ E–24°22′ N 47°06′ E). The climate in this area is typically arid, hot in the summer and cold in winter, with annual rain precipitation of 132 mm. Winter starts in mid-September to the end of January, the coldest in December. Moreover, the maximum temperature is 18 °C and the lowest is 5 °C.

### *2.2. Samples Collection and Management*

Blood samples were taken with sterilized vacutainer tubes from the jugular vein of 37 multiparous female camels (at mid-lactation; ±2 months) and their calves, raised under a semi-intensive system in Al-Kharj, Riyadh, with a different feeding protocol: Group one (C) twenty female camels fed alfalfa *ad libitium* and group two (T) 17 female camels were fed Total Mix Ration (TMR; 4 kg/head/day) beside the alfalfa hay ad libitum. The chemical composition of the TMR is presented in Table 1. Blood samples were centrifuged (2000 for 10 min) to obtain serum. The serum was treated immediately with 10% trichloroacetic acid (TCA) (1-part serum: 4 parts TCA) and centrifuged (1500× *g* for 10 min). The supernatants were collected and stored at −20 °C until mineral analysis was performed. At the same time, milk samples were collected from each female camel and prepared for composition and mineral analysis.

**Table 1.** Composition and calculated nutrient content of the experimental diet.

| **Ingredients, %** | **Treatments** | |
|---|---|---|
| | **Alfalfa** | **TMR** |
| Barley grain | - | 30.45 |
| Wheat feed | - | 26.00 |
| Wheat Bran | - | 5.00 |
| Palm kernel cake | - | 17.55 |
| Soya Hulls | - | 13.40 |
| Salt | - | 1.00 |
| Limestone | - | 2.50 |
| Molasses | - | 3.00 |
| Acid buffer | - | 1.00 |
| Commercial Premix | - | 0.10 |
| Calculated analysis | | |
| Dry matter, % | 91.3 | 90.8 |
| Crude protein, % | 14.1 | 13.24 |
| Crude fiber, % | 28.7 | 12.72 |
| ME, Mcal/kg | 16.8 | 2.79 |
| Calcium (%) | 378.86 | 617.27 |
| Phosphorous (%) | 1956.6 | 330.58 |
| Iron (µg/g) | 0.185 | 4.5 |
| Copper (µg/g) | 8.58 | 12.84 |
| Zinc (µg/g) | 12.5 | 15.65 |
| Manganese (µg/g) | 2064.6 | 2148.6 |
| Selenium (µg/g) | 1.47 | 17.51 |

Milk samples were immediately pipetted to prevent settling prior to removing the sample. Milk composition (protein %, fat %, lactose % and total solid %) was analyzed after collection using Milko-Scan FT6000 (Foss, Hillerød, Denmark). For trace metals analysis; a 0.5000 ± 0.001 g milk sample was weighed in an acid-washed Teflon™ vessel. Then, 1 mL $HNO_3$ (65% Riedel-de Haen, Hanover, Germany), 1 mL HCl (36% Avonchem, Macclesfield, UK), 1 mL $H_2O_2$ (30% *w*/*v* Avonchem, UK) and 1 mL deionized $H_2O$ (Milli-Q quality) were added to the sample before loading on the digestion units. The samples were digested according to pre-set temperature program recommended by [26]. The digested samples were diluted in a 25 mL volumetric flask using 0.1 normality HCl and mixed very well. Subsamples (5 mL) were taken in sterilized tubes for mineral analysis.

### 2.3. Mineral Analysis

Determinations of major, trace and heavy metals were determined using ICP-OES equipped with a Meinhard Nebulizer type $A^2$. Argon (purity higher than 99.999% supplied by AH group (Dammam, Saudi Arabia) was used to sustain plasma and as a carrier gas. The operating conditions employed for the ICP-OES determination were 1300 W RF power, 15 L $min^{-1}$ plasma flow, 0.2 L $min^{-1}$ auxiliary flow, 0.8 L $min^{-1}$ nebulizer flow, and 1.5 mL $min^{-1}$ sample uptake rate. The axial and radial view was used for metals determination, while two-point background correction and three replicates were used to measure the analytical signal, with the processing mode being the peak area. The emission intensities were obtained for the most sensitive lines free of spectral interference. The calibration standards were prepared by diluting the stock multi-elemental standard solution (1000 mg $L^{-1}$) in 0.5% ($v/v$) nitric acid. The calibration curves for all elements were in the range of 1.0 ng $mL^{-1}$ to 1.0 μg $mL^{-1}$ (1–1000 ppb).

### 2.4. Statistical Analysis

Data were analyzed by using a completely randomized design, through ANOVA (variance analysis), general linear model procedure (Proc GLM) of SAS (v. 9.4, SAS Institute Inc., Cary, NC, USA. The statistical model was $Y = \mu + T_i + \varepsilon_{ij}$, where: Y = minerals concentration in different tissues, blood serum, and milk (P, Mg, Co, Cu, Fe, I, Mn, Se, Cd, Pb); $T_i$ = the effect of the C or T diets; and $\varepsilon_{ij}$ = random error. The variation coefficients ($R^2$ and VC) were considered to determine the models' validity. A correlation was performed to explain the relationship between the minerals in serum, blood and milk of female camels and their calves. Differences among means were compared through LSD (least statistical differences) considering $p < 0.05$.

## 3. Results

### 3.1. Female Camel Nutrition and Milk Composition

Protein content was significantly ($p < 0.05$) higher for female camels' milk in the T group supplemented with TMR (2.71%) than female camels' milk in group C fed only alfalfa hay (2.13%). In addition, the content of inorganic matter was significantly ($p < 0.05$) higher in the female camels' milk fed with TMR and alfalfa hay (0.79%) than in the C group (0.65%) fed only alfalfa. Fat and lactose content did not statistically differ ($p > 0.05$) between female camels' milk in group C (2.29 % and 4.48 %, respectively), and group T (2.49 % and 4.22 %, respectively), as reported in Table 2.

**Table 2.** Camel milk's nutritive value raised under semi-intensive system during winter.

| Nutrients, (%) | Group-C ($n$ = 17) | Group-T ($n$ = 20) | SEM | $p$ Value |
|---|---|---|---|---|
| protein | 2.13 $^{b}$ | 2.71 $^{a}$ | 0.18 | 0.051 |
| Fat | 2.29 | 2.49 | 0.21 | 0.66 |
| Lactose | 4.48 | 4.22 | 0.15 | 0.40 |
| Total solid | 9.45 | 9.81 | 0.44 | 0.70 |
| SNF | 7.07 | 7.39 | 0.29 | 0.58 |
| Inorganic matter | 0.65 $^{b}$ | 0.79 $^{a}$ | 0.02 | 0.04 |

$^{a,b}$ Within a column, means without a common superscript are significantly different. Group-C: fed only alfalfa hay ad libitum during the winter season in a semi-intensive production system. Group-T: fed alfalfa hay ad libitum and 4 kg TMR/head/day during the winter season in a semi-intensive production system. $p$-value: less than 0.05 considered significantly different. SEM: Standard error of means.

### 3.2. Female Camel Nutrition and Minerals Content in Milk

The effects of feeding management on mineral concentrations in the milk and serum of female camels and their calves are shown in Tables 3–5. On average, the rank of the trace minerals levels, from higher to lower, in the milk of the control group were as follows: iodine (46.15 μg/mL), followed by iron (27.77 μg/mL), copper (14.06 μg/mL), selenium (3.90 μg/mL) and zinc (2.05 μg/mL). Other minerals, such as cadmium (0.045 μg/mL), were present at the lowest concentration. Moreover, the highest value for macro minerals was reported for Ca, followed by P, and the lowest was Mg for both groups. The same trend was reported in the treated group with TMR. The content of Mg, Co, Fe, and Zn in female camels' milk (group T) fed TMR, and alfalfa hay in winter was significantly ($p < 0.05$) higher than in female camels' milk (group C) fed only alfalfa hay (Table 3). The serum concentration of macro minerals Ca and P were significantly ($p < 0.05$) higher in the female camel of the T group than in the C group. In contrast, the serum concentration of Mg in female camels in the C group that were fed alfalfa hay was significantly ($p < 0.05$) higher than in female camels in the T group. On the other hand, serum concentrations of trace minerals such as Cu and Zn were significantly ($p < 0.05$) higher in female camels in the T group while the serum concentrations of selenium were significantly ($p < 0.05$) higher in female camels of group C compared to T group. In addition, the serum concentration of the heavy metal, Cd was significantly ($p < 0.05$) higher in the serum of female camel in the C group compared to the T group (Table 4).

A significantly ($p > 0.05$) higher concentration of macro minerals (Ca, P and Mg) was observed in calves' blood serum that suckled from female camels supplemented with TMR. Similarly, the trace minerals (Co, Cu, Fe, Mg, Se and Zn) and heavy metals (Ca and Cd) were significantly ($p < 0.05$) higher in concentration in the serum of calves that suckled from female camels from group T than the blood serum of calves suckling female camels' milk from the control group (Table 5). The two groups observed no significant differences in iodine concentrations between serum female camels and calves (Table 5).

**Table 3.** Effect of concentrate supplementation to female camels beside alfalfa on element concentration of milk during winter.

| Mineral | Group-C ($n$ = 17) | Group-T ($n$ = 20) | SEM | $p$-Value |
|---|---|---|---|---|
| | | Macro minerals, mg/dL | | |
| Calcium | 214.80 | 201.9 | 1.64 | 0.71 |
| Phosphorus | 130.38 | 130.52 | 8.57 | 0.99 |
| Magnesium | 27.84 $^{b}$ | 29.36 $^{a}$ | 2.41 | 0.053 |
| | | Trace minerals, μg/mL | | |
| Cobalt | 0.311 $^{b}$ | 0.536 $^{a}$ | 0.14 | 0.04 |
| Copper | 14.06 | 15.48 | 1.41 | 0.34 |
| Iron | 27.77 $^{b}$ | 32.99 $^{a}$ | 1.52 | 0.03 |
| Iodine | 46.15 | 56.61 | 10.24 | 0.64 |
| Manganese | 1.954 | 2.669 | 0.33 | 0.29 |
| Selenium | 3.909 | 3.706 | 0.34 | 0.78 |
| Zinc | 2.058 $^{b}$ | 2.694 $^{a}$ | 0.41 | 0.054 |
| | | Heavy metals, μg/mL | | |
| Cadmium | 0.045 | 0.051 | 0.01 | 0.57 |
| Lead | 0.580 | 0.555 | 0.16 | 0.95 |

$^{a,b}$ Within a column, means without a common superscript are significantly different. Group-C: fed only alfalfa hay ad libitum during the winter season in a semi-intensive production system. Group-T: fed alfalfa hay ad libitum and 4 kg TMR/head/day during the winter season in a semi-intensive production system. $p$-value: less or equal to 0.05 considered significantly different. SEM: Standard error of means.

**Table 4.** Element concentrations (ug/mL) in the blood serum of female camels raised in a semi-intensive system during winter.

| Mineral | Group-C (*n* = 17) | Group-T (*n* = 20) | SEM | *p* Value |
|---|---|---|---|---|
| | | Macro minerals, μg/mL | | |
| Calcium | 231.3 [b] | 257.1 [a] | 0.083 | 0.03 |
| Phosphorus | 139.77 [b] | 219.87 [a] | 16.88 | 0.01 |
| Magnesium | 35.62 [a] | 30.571 [b] | 1.186 | 0.02 |
| | | Trace minerals, μg/mL | | |
| Cobalt | 0.117 | 0.118 | 0.001 | 0.98 |
| Copper | 1.616 [b] | 2.279 [a] | 0.32 | 0.053 |
| Iron | 0.535 | 0.585 | 0.03 | 0.48 |
| Iodine | 0.053 | 0.092 | 0.002 | 0.16 |
| Manganese | 0.875 | 0.789 | 0.01 | 0.54 |
| Selenium | 1.253 [a] | 0.962 [b] | 0.03 | 0.050 |
| Zinc | 0.127 [b] | 0.159 [a] | 0.01 | 0.052 |
| | | Heavy metals, μg/mL | | |
| Cadmium | 0.024 [a] | 0.023 [b] | 0.0003 | 0.01 |
| Lead | 0.006 | 0.005 | 0.0008 | 0.87 |

[a,b] Within a column, means without a common superscript are significantly different. Group-C: fed only alfalfa hay ad libitum during the winter season in a semi-intensive production system. Group-T: fed alfalfa hay ad libitum and 4 kg TMR/head/day during the winter season in a semi-intensive production system. *p*-value: less or equal to 0.05 is considered to be significantly different. SEM: Standard error of means.

**Table 5.** Elements concentration (ug/mL) in blood serum of calves s raise in a semi-intensive system during winters.

| Mineral | Group-C (*n* = 17) | Group-T (*n* = 20) | SEM | *p*-Value |
|---|---|---|---|---|
| | | Macro minerals, μg/mL | | |
| Calcium | 293.0 [b] | 326.1 [a] | 0.080 | 0.04 |
| Phosphorus | 282.4 [b] | 384.1 [a] | 11.73 | 0.04 |
| Magnesium | 31.90 [b] | 39.82 [a] | 1.964 | 0.03 |
| | | Trace minerals, μg/mL | | |
| Cobalt | 0.01 [b] | 0.02 [a] | 0.004 | 0.04 |
| Copper | 1.46 [b] | 2.82 [a] | 0.41 | 0.052 |
| Iron | 0.55 [b] | 0.76 [a] | 0.04 | 0.01 |
| Iodine | 0.11 | 0.12 | 0.01 | 0.64 |
| Manganese | 0.08 [b] | 0.09 [a] | 0.003 | 0.051 |
| Selenium | 1.08 [b] | 1.38 [a] | 0.07 | 0.02 |
| Zinc | 0.18 [b] | 0.20 [a] | 0.008 | 0.055 |
| | | Heavy metals, μg/mL | | |
| Cadmium | 0.023 [b] | 0.027 [a] | 0.0001 | 0.002 |
| Lead | 0.005 [b] | 0.009 [a] | 0.0003 | 0.06 |

[a,b] Within a column, means without a common superscript are significantly different. Group-C: fed only alfalfa hay ad libitum during the winter season in a semi-intensive production system. Group-T: fed alfalfa hay ad libitum and 4 kg TMR/head/day during the winter season in a semi-intensive production system. *p*-value: less or equal to 0.05 considered significantly different. SEM: Standard error of means.

### *3.3. Correlation between Minerals Concentrations*

Mn and Co concentrations in the blood serum of female camel and milk and calf serum were significantly ($p < 0.05$) correlated with most other minerals under investigation. In the C group, the Mn in the serum of female camels and their calves showed significant ($p < 0.05$) positive correlations with Mn, Cu, Fe, and Zn. On the other hand, Co showed significant ($p < 0.05$) positive correlations with Cu and Se and significant ($p < 0.05$) negative correlations with Mn and Fe within the C group (Table 6). In the T group, Mn in the serum of female camels and their calves showed a significant ($p < 0.05$) positive correlation with Mn, Co, Se and Zn, while it showed a significant ($p < 0.05$) negative correlation with Fe. In addition, the mineral Co showed significant ($p < 0.05$) positive correlations with Mn, Co, Cu, Se, and Zn in group T (Table 6).

**Table 6.** Correlation coefficient of some trace elements for female camels and their calves blood serum.

| Mineral | Mn $^{NB}$ | Cu $^{NB}$ | Fe $^{NB}$ | I $^{NB}$ | Co $^{NB}$ | Se $^{NB}$ | Zn $^{NB}$ |
|---|---|---|---|---|---|---|---|
| Group-C | | | | | | | |
| Mn $^{D}$ | 0.990 ** | 0.946 * | 0.962 * | NC | −0.945 * | NC | 0.901 * |
| Co $^{D}$ | −0.945 * | 0.903 ** | −0.962 * | NC | 0.813 * | 0.914 * | NC |
| Group-T | | | | | | | |
| Mn $^{D}$ | 0.835 * | NC | −0.967 * | NC | 0.989 ** | 0.874 ** | 0.768 * |
| Co $^{D}$ | 0.893 * | 0.946 ** | NC | NC | 0.958 ** | 0.822 * | 0.903 * |

* = $p < 0.05$; ** = $p < 0.01$; NC = No correlation; D = female camels; NB = Newborn.

The correlation coefficients of minerals Mn and Co with minerals in the blood serum and milk of female camel are presented in Table 7. In group C, Mn showed significant ($p < 0.05$) positive correlations with minerals Fe, I, Se and Zn while, Co showed significant ($p < 0.05$) positive correlations with minerals Mn, Fe, I and Co. In addition, the results showed that Mn showed a significant ($p < 0.05$) positive correlation with minerals Mn, Cu, Se and Zn minerals in group T (Table 7).

**Table 7.** Correlation coefficient of some trace elements for female camels' blood serum and milk.

| Mineral | Mn $^{M}$ | Cu $^{M}$ | Fe $^{M}$ | I $^{M}$ | Co $^{M}$ | Se $^{M}$ | Zn $^{M}$ |
|---|---|---|---|---|---|---|---|
| Group-C | | | | | | | |
| Mn $^{D}$ | NC | NC | 0.961 ** | 0.964 * | NC | 0.864 ** | 0.871 * |
| Co $^{D}$ | 0.990 ** | NC | 0.973 ** | 0.961 * | 0.788 * | NC | NC |
| Group-T | | | | | | | |
| Mn $^{D}$ | 0.936 ** | 0.988 * | −0.898 *** | NC | NC | 0.966 *** | 0.875 ** |
| Co $^{D}$ | 0.932 ** | NC | NC | NC | NC | 0.768 * | 0.945 ** |

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; NC = No correlation; D = female camels; M = Milk.

The correlation coefficient of Mn and Co with other minerals in the blood serum of calves and female camel milk is presented in Table 8. Mn showed significant ($p < 0.05$) positive correlations with Fe, I, and Se, while Co was significantly ($p < 0.05$) positively correlated with Fe and negatively with Cu in the C group. In addition, Mn showed significant ($p < 0.05$) positive correlations with Fe, I, Co and Zn, and significant ($p < 0.05$) negative correlation with Se. On the other hand, Co showed significantly ($p < 0.05$) positive correlations with Mn, Fe, I and Zn, and negative ones with Se in the T group (Table 8).

**Table 8.** Correlation coefficient of some trace elements for calves' blood serum and milk.

| Mineral | Mn $^{M}$ | Cu $^{M}$ | Fe $^{M}$ | I $^{M}$ | Co $^{M}$ | Se $^{M}$ | Zn $^{M}$ |
|---|---|---|---|---|---|---|---|
| Group-C | | | | | | | |
| Mn $^{NB}$ | NC | NC | 0.871 * | 0.810 * | NC | 0.756 * | NC |
| Co $^{NB}$ | NC | −0.891 * | 0.903 ** | NC | 0.988 ** | NC | NC |
| Group-T | | | | | | | |
| Mn $^{NB}$ | NC | NC | 0.837 ** | 0.967 * | *0.875 ** | −0.880 * | 0.785 *** |
| Co $^{NB}$ | 0.965 ** | NC | 0.837 ** | 0.938 * | 0.817 * | −0.889 * | 0.856 *** |

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; NC = No correlation; NB = newborn calves; M = Milk.

## 4. Discussion

In Saudi Arabia, there is little information on mineral bioavailability so, the practice of mineral supplementing is little or non-existent; therefore, it is possible that dietary imbalance is associated with mineral deficiencies. For dietary mineral imbalances and their interrelationship, elements were determined in the blood serum and milk of female camels with their calves, during winter. The current study aimed to estimate the micro and macro minerals and heavy metals in the blood serum and milk of female camels and their calves as indicators for determining the effect of supplementing TMR to female camels on their newborns' mineral status during winter. So, for trace minerals to be essential, they must be part of biologically active molecules and affect animal productivity and health [11].

The female camel milk in the current study has low fat, protein, and total solid content compared to Chinese Bactrian camel milk [27] and dromedary milk from Pakistan [28]. Still, it is similar to dromedary milk [29,30] from different Saudi camel breeds [31] and Moroccan camels [32]. In their meta-analysis, Konuspayeva et al. [33] showed higher concentrations of chemical parameters in Bactrian and Asian dromedary compared to dromedary from Arabian Peninsula and Africa. Unlike other dairy products, camel milk's composition and mineral content is mainly influenced by its water content [33]. Additionally, camel milk is influenced by other factors such as feeding conditions, camel breed, stage of lactation, age, and the number of calves [34]. In the present study, the results showed a significant effect of feeding TMR on the protein content of female camels' milk, which could be due to the protein content of the diet. In addition, the content of inorganic matter in the milk of female camels fed TMR was also significantly higher by (14%) compared to the C group. Milk yield was not recorded in the present study, which could explain some results regarding differences in milk composition between groups.

Dietary mineral bioavailability has not been well studied in camels and described in the literature, but it is well documented in other ruminant animals. Micronutrients such as Zn, Fe, Cu, Mn, Co, Mo, and Cr are required in minute amounts for homeostasis and optimal body function, but excessive intake can have negative health consequences [35]. Thus, our expectations regarding mineral metabolism in camels may differ from those of other ruminants because of their digestive process, feeding behavior and other physiological characteristics. In the present study, it was reported that the main mineral content (Ca, P, and Mg) of female camels' milk was higher compared to the milk of Chinese Bactrian camels [27] and the milk of dromedary camels in Saudi Arabia [31,35]. However, the Mg content of female camel milk was lower compared to the data reported for camels in Saudi Arabia [35] and Somali, and Tur-kana camel breeds [36], which were performed in many studies with large variations among them. The zinc concentration in the female camel milk was similar to the value observed by Dell'Orto, Cattaneo, Beretta and Baldi [36] The reason for these large variations could be due to the analytical methods used or factors not considered. In this study, the trace mineral content in female camels' milk was significantly higher than in cow's milk [37]. In contrast to previous studies in other countries, these values differ. The Fe and Cu content (2.98 and 0.14 mg/100 g) were close to the results of three dromedary camels reported by Al-Wabel et al. [38] The Cu content was slightly lower than the value (0.22 mg/100 mL) reported by Raziq et al. [39] for camels from mountainous Baluchistan, Pakistan, but significantly higher than the Fe and Cu content (0.23 and 0.061 mg/100 g) reported by Soliman [40]. The high Fe, Cu, and P contents of camel milk, as well as the fact that camels are fed dry plants, contribute to camel milk being very salty and high in chloride [41]. In the current study, female camels fed TMR had higher concentrations of Co, Fe and Zn in their milk than female camels from the C group. According to the result of this study and previous studies, the overall means differ, which may be due to several different factors, such as different physiological conditions (e.g., stages of lactation), management, feeding, and statistical methodology. The effect of trace elements in the diet on acid-base status is minimal because they are absorbed in such small amounts [42].

The data obtained in this study showed that the minerals Ca, P, Cu, and Zn were in significantly higher concentrations in the serum of female camel-fed TMR than in those fed only alfalfa hay. Interestingly, the serum of calves that suckled from female camel-fed TMR had the highest levels of macro (Ca, P and Mg) and trace mineral (Co, Cu, Fe, Mn, Se and Zn) than that of other calves. On the contrary, Dell'Orto [36] reported that feeding supplements to lactating camels had no effect on calf plasma Ca, P, Mg, Zn and Fe levels. The average plasma phosphorus concentration ranges from 4 to 9 mg/100 mL, depending on the species and age of the animal, and P levels are more influenced by diet than Ca levels [16]. Goff [42] found that serum P levels exceed 2.0 mmol/L and are related to 1,25-dihydroxyvitamin D, which cannot be converted from 25-hydroxyvitamin D and causes milk fever in the cow. Blood Mg levels are not regulated, they reflect dietary Mg intake. It is influenced indirectly by calcium-regulating hormones such as calcitonin and parathyroid hormones. [42].

Toxic heavy metals/metalloids (THMs) such as arsenic, cadmium, lead, and mercury are relatively dense metals/metalloids that are not beneficial to humans or livestock and cause carcinogenicity, organ toxicity, and other negative health effects in small amounts [43]. In addition to industrial, domestic, agricultural, medical, and technological applications of THMs, exposure of food-producing animals (FPAs) and humans to toxic metals may result in massive environmental pollution [44]. Based on these results, female camel milk had the lowest levels of lead and cadmium compared to camel milk in Iran [45]. According to the Food and Agriculture Organization, World Health Organization (WHO), and Codex standard (CXS 193-2007), the determined limit for lead and cadmium is 20 μg/kg and 10 μg/kg, respectively. So, the results of this study showed that lead and cadmium levels were below the recommended levels.

To our knowledge, no study has been conducted on the relationship between the concentration of minerals in the serum and milk of female camels and their calves in dromedary camels except selenium [46]. The mineral correlation test was performed in this study to determine the main relationships between these minerals in serum and milk for female camel and their calves. Manganese and cobalt were found to be strongly correlated with other minerals investigated. Therefore, the correlation analysis and results focused on Mn and Co in the serum and milk of female camels and their calves with other minerals. Manganese is a component of the bone matrix; it is also part of glycoproteins and enzymes [47]. Manganese is required for lipid metabolism and the synthesis of cholesterol, which is required for the synthesis of estrogen, progesterone, and testosterone. Thus, animals with a manganese deficiency have lower reproductive performance [47]. The most common alterations due to magnesium deficiency are loss of appetite, excessive rumen fermentation, decreased milk production and tetany [42]. Cobalt is an essential trace element required for the formation of vitamin B12 (cobalamin) in humans and animals [48]. Cobalt deficiency is only seen in ruminants that consume low levels of copper in their diets, which could lead to a deficiency of this vital vitamin, and cause metabolic disorders, inappetence, weight loss, and reproductive problems [48]. This study found a significant positive correlation between Mn and Co with Cu, Fe, Se, and Zn in calves' blood serum, female camel serum, and milk during the winter in the two groups. Previous studies have shown that Mn reaches the fetus through the placenta, which is related to the amount of Mn in the basal diet [49]. Fortunately, blood Mn concentration is not a good indicator of nutritional status for this trace element. The increase in Mn levels may be due to glucose levels [50]. Essawi and Gouda [51] reported in dromedary camels that newborn weight is not significantly associated with female camel serum levels of the various minerals.

## 5. Conclusions

The nutrient requirement of female camels during lactation in the winter season is higher than to be covered by diet. TMR supplementation improves nutritional milk value, especially protein milk percentage, inorganic matter percentages, and mineral status of female camels' milk compared to female camels fed only alfalfa hay. Moreover, with TMR supplementation, blood serum concentrations of Co, Mn, and Zn of female camels and their calves were increased. Cobalt and Mn were found to have a high correlation with most other studied minerals between female camels, calves and milk. It is highly recommended that female camels must be supplemented with TMR during lactation in the winter season to improve their productivity and mineral status.

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