Food Science and Engineering
https://ojs.wiserpub.com/index.php/FSE/

UNIVERSAL WISER PUBLISHER

Research Article

Comparative Minerals and Vitamins Composition of Bactrian (*Camelus bactrianus*) and Dromedary (*Camelus dromedarius*) Meat

Gulzhan Raiymbek[1], Isam Kadim[2], Osman Mahgoub[2], Gaukhar Konuspayeva[1,4], Bernard Faye[3,4*]

[1]Department of Biotechnology, Al-Farabi Kazakh National University, 71 av. Al-Farabi, 050040, Almaty, Kazakhstan
[2]College of Food and Veterinary Sciences, University of Arab Emirates, Al-Ain, United Arab Emirates
[3]Center of International Cooperation on Agriculture Research for Development (CIRAD), Department Environment and Society, UMR SELMET, Campus International de Baillarguet, TA C/112A, 34398, Montpellier, France
[4]Antigen Ltd, Azerbayev str., Abay Village, Karasai District, 040905, Almaty, Kazakhstan
E-mail: bernard.faye@cirad.fr

Received: 7 January 2025; **Revised:** 6 June 2025; **Accepted:** 11 June 2025

Abstract: One humped dromedary (*Camelus dromedarius*) and two humped Bactrian (*Camelus bactrianus*) camels are different species, but with close biology allowing fertile crossbreeding. Several publications have explored the differences in meat composition (amino acids and fat). This study was designed to compare the mineral and vitamin composition of dromedary and Bactrian camel meat. Six muscle samples were collected from nine Bactrians, from Kazakhstan, and ten dromedaries from the Sultanate of Oman. Minerals were determined using an Atomic Absorption Spectrophotometer and the vitamins were investigated by high-performance liquid chromatography. Differences in mineral and vitamin composition were investigated using discriminant analysis. Calcium, potassium, phosphorus, and zinc were the most important discriminating minerals allowing for 71.3% of well-classed animals. A close percentage (74.4%) was observed with the combination of vitamins B1, B12, and C. Dromedary meat contained significantly more calcium, zinc, vitamin B1, and B6 than Bactrian. However, the inter-species difference appeared to be less important than the inter-muscle differences, with a more specific composition of the *Longissimus thoracis*, compared to other muscles, especially its low mineral concentration and relatively higher vitamin E. Bactrian and dromedary camels, despite their relative genetic proximity, live in two different ecosystems, which may explain the differences in their meat composition.

***Keywords*:** food analysis, food composition, camel meat, dromedary, Bactrian camel, minerals, vitamins, multivariate analysis, meat quality

Abbreviations

AAS	Atomic Absorption Spectrophotometer
AHC	Ascending Hierarchical Classification
BF	*Biceps femoris*
DGP	Dual Gradient Pump
FDA	Factorial Discriminant Analysis
HPLC	High-Performance Liquid Chromatography
IS	*Infraspinatus*

DOI: https://doi.org/10.37256/fse.6220256365

LT	*Longissimus thoraces*
PCA	Principal Components Analysis
PTFE	Polytetrafluoroethylene
SM	*Semimembranosus*
ST	*Semitendinosus*
TB	*Triceps brachii*
TCA	Trichloroacetic Acid

1. Introduction

Minerals and vitamins are essential nutrients for humans. Meat and meat products are good sources of minerals such as iron, zinc, selenium, potassium, and phosphorus, as well as vitamins such as cobalamine (B12), niacin (B3), and pyridoxine (B6) and others [1]. Moreover, mineral and vitamin content might be responsible for quality parameters of meat, notably color, tenderness, and oxidation [2].

With an official production of 612,000 tons in 2023 (source: FAOSTAT, 2025), camel meat represented 0.62% of the supplied world red meat only and 2.52% in arid countries from Africa and Asia. However, its production and consumption are growing faster than beef or sheep meat [3] and may reach more than 20% in countries such as Mauritania, Somalia, and Gulf countries [4]. Usually, dressing percentage and slaughtering conditions are similar to that of beef.

Large domestic camelids are represented by two species living in two different environmental conditions: the one-humped dromedary camel (*Camelus dromedarius*) in hot arid countries from Africa, the Middle East, and South Asia, and the two-humped Bactrian camel (*Camelus bactrianus*) in the cold deserts of Central Asia. Both of them are regarded as multipurpose animals, providing milk, meat and wool, but also as pack or riding animals including for sportive activities and other cultural events. If dromedary is a better dairy species than Bactrian, while this last is a better wool producer, both of them are used as meat producers in arid and semi-arid countries of the old world.

If studies on dromedary camel meat [5] and Bactrian camel meat [6] started in the 1990s, few studies have compared the two species [7, 8]. Most of the available publications are focused on meat composition and physical properties, and their variability according to age, breed or gender.

The present study aimed to compare the mineral and vitamin compositions of dromedary and Bactrian meat reared in the Sultanate of Oman and Kazakhstan, respectively, and determine the most discriminating components. Moreover, the comparison to other red meats such as beef, goat or sheep would be discussed, contributing to a better understanding of the nutritive value of camel meat.

2. Material and methods

The experiment was conducted strictly in accordance with the ethics committee guidelines of Co Antigen LTD and based on the order of the Minister of Health of the Republic of Kazakhstan dated November 19, 2009, No. 744.

2.1 *The animals and meat sampling*

Nine Bactrian camels (2-3 years old; five females, four males) and ten dromedary camels (2-3 years old; five females, five males) were used in this study. All the animals were reared in their natural environment under extensive management. The slaughtering of the camels occurred on-farm for Bactrian camels in of Kyzylorda region (Kazakhstan), and at the Bausher Central slaughterhouse in the Sultanate of Oman for dromedary camels. A similar slaughtering procedure, followed by the same researcher, was used in both Kazakhstan and the Sultanate of Oman, including pre-slaughter handling and slaughtering according to accepted welfare rules, then dressing based on the normal commercial slaughter procedures (camels in the crouching position, with the head flexed towards the tail, quick cutting with sharp knife at the base of the neck, skinning and organ extraction after total bleeding. The following muscles were excised on the left side of the carcass, less than 20 minutes after death: *Infraspinatus* (IS), *Triceps brachii* (TB), *Longissimus*

thoraces (LT), *Biceps femoris* (BF), *Semitendinosus* (ST), and *Semimembranosus* (SM). External fat and connective tissues of each muscle were extracted, then the meat was stored in a chiller at 3-4 °C for 48 h. Two parts of the muscles weighing approximately 8 g each were removed from the central part, and then stored at -20 °C. All the sampling was achieved by the same researcher firstly in Kazakhstan, then in Oman within the same month. The meat samples from Kazakhstan were sent to the laboratory of meat analysis at Sultan Qaboos University, Sultanate of Oman, where all the analyses were achieved by an unique technical team. Mineral and vitamin compositions were determined on each sub-sample collected in triplicate. The means were calculated for each muscle, i.e., three determinations for two subsamples, the means of the 6 values were used for further statistical analysis, and applied finally to all muscle samples (six muscles from 19 animals for minerals, and 16 for vitamins). It was expected a limited variability between animals belonging to one species, to ensure a sufficient analytical power in the interspecific difference as it was observed for other elements as amino-acids and fatty acids [7].

2.2 *Minerals and vitamins analysis*

2.2.1 *Micro and macro-elements determination*

Macro- and micro-mineral profiles of camel meat samples were carried out in two phases: digestion and analysis. Standard (1,000 mg L^{-1}) solutions (Sigma-Aldrich; Chemie GmbH. Steinheim Germany and Sherwood: Paddocks, Cambridge, UK) were used to determine Ca, P, Mg, Na, K, and Zn in the muscles. Digestion of freeze-dried meat samples was completed using a microwave system Model Mars 907511 (CEM Cooperation, Mathews, North Carolina, USA) at a maximum temperature of 200 °C in closed Polytetrafluoroethylene (PTFE) vessels. Ten mL of HNO_3 concentrated was added to each digestion vessel and heated to 200 °C over 30 min period. The digest obtained was collected in 100-mL volumetric flasks and made up to volume. Measurements of minerals were carried out on an AAS system (Shimadzu Model AA-6800) equipped with a GFA-EX7 240V CE Graphite Furnace, HVG-1 Hydride Vapor Generator, MVU-1A Mercury Vaporizer and ASC-6100 Auto Sampler (Japan).

Regarding quality control, the calibration curve was constructed using the external standard method. The method underwent validation based on key parameters including specificity, linearity, precision, accuracy, and sensitivity. Linearity assessment involved employing linear regression to process the calibration plot, followed by determination of the linear equation and correlation coefficient. Repeatability and intermediate precision were evaluated through the determination of relative standard deviations. The results indicate that the developed methods exhibited precision within acceptable thresholds.

2.2.2 *Vitamins determination*

The water- and fat-soluble vitamin content of the muscle samples was determined using High-Performance Liquid Chromatography (HPLC). All chemicals and reagents used were of the highest purity available and were purchased from Sigma-Aldrich (Chemie Gm6H Steinheim, Germany). To prepare the samples, 40 g of fresh meat sample was mixed with 20 mL of hot water, blended using a blander (Black & Decker, model SC300, UK) to obtain homogeneous samples, and transferred to sealed 100 mL amber glass. The bottles were placed in a boiling water bath at 100 °C for 30 min. Eight grams of boiled samples were placed into a 50 mL centrifuge tube and 1 g of TCA was added, mixed thoroughly, and centrifuged at 3,000 rpm for 10 min. to separate these two phases. Three mL of 4% TCA was then added to the upper layer (acid extract), mixed, and centrifuged at 3,000 rpm for 10 min. The solid phase was discarded, and the two acid extracts were combined and incubated at -20 °C for 10 min. Acid extracts were centrifuged at 4,000 rpm for 5 min and incubated at -20 °C for 5 min. The fat layer was eliminated using a spatula and the acid extract was centrifuged again. The extract was filtered through a 0.45 µm filter before HPLC injection.

The standard concentration of l-methionine was 200 mg/L, ascorbic acid 600 mg/L, vitamin B6 200 mg/L, vitamin B 200 mg/L, Riboflavin 2 mg/L, and folic acid 2 mg/L were prepared using eluent A, which consisted of potassium dihydrogen phosphate (0.005 M) and 5% v/v acetonitrile (HPLC grade) and adjusted to pH 5.6. Saponification and heating were used to prepare 2 mg/L folic acid and 2 mg/L riboflavin, and both sets of standards were mixed and filtered through a 0.2 µm membrane filter prior to injection into the HPLC column. The standard concentration of water-soluble vitamins, such as Vit C, B6, B12, Riboflavin, and folic was used with the running tested samples and the results showed that the procedure was accurate to recover these vitamins.

For the chromatography analysis, the mobile phases (eluent A) were prepared by mixing potassium dihydrogen phosphate (0.005 M) with 5% v/v acetonitrile in HPLC grade, adjusted to pH 5.6 and degassed using vacuum filtration. Eluent B was prepared by mixing potassium dihydrogen phosphate (0.005 M) with 50% v/v acetonitrile (HPLC grade), adjusted to pH 5.6 and degassed using vacuum filtration. HPLC analysis was carried out using a Dionex UltiMate 3000 HPLC System equipped with a Dual Gradient Pump DGP-3600SD, an Inline-3000TSL Split Loop Auto-sampler, Thermostatted Column Compartment TCC-3000RS, Solvent Rack with Degasser SRD-3600, Thermostatted Column Compartment TCC-3000SD, and controlled with Chromeleon 7, version 7.1. Dionex Acclaim, 120-C18, (3 µm particle size) column (3 × 150 mm).

Similar quality control for minerals was applied to vitamins determination.

2.3 *Statistical analyses*

There were three main objectives for statistical analyses: (i) assessing the differences in mineral and vitamin composition of the six muscles regardless of the species and of the two types of meat (dromedary and Bactrian) regardless of the muscle, (ii) assessing the relationships between mineral and vitamin profiles and the type of muscles (IS, LT, TB, BF, ST, and SM) and camel species (Bactrian and dromedary), and (iii) determining the main discriminant minerals and vitamins distinguishing Bactrian from dromedary. Analysis of Variance (ANOVA) with Fisher's test was used to assess the effects of muscles and species after verification of the homoscedasticity of the data (test of normality Shapiro-Wilk). In case of a lack of normality, the data were normalized by appropriate transformations using the procedure "data normalization" of the software. The normalization procedure used was x-mean/SD (n-1).

For the second objective, Principal Components Analysis (PCA) followed by cluster analysis (Ascending Hierarchical Classification (AHC)) was applied to dataset (i, j) representing 54 Bactrian and 60 dromedary muscle samples (i = 114) and minerals' composition (j = 6). Similar analyses were applied for vitamins, but due to misuse on three carcass samples, 48 Bactrian and 48 dromedary muscle samples only were involved (i = 96), described by their vitamins' composition (j = 8). The two species (Bactrian and dromedary) and the six muscles (IS, TB, LT, ST, SM, and BF) were considered as supplementary variables.

For the third objective linear Factorial Discriminant Analysis (FDA) was used based on a stepwise ascending model, including the Box test (F value) and Kullback test (K value), followed by a validation test consisting of randomly removing a part of the samples (n = 1, 10, 30, and 50) in the dataset according to the methodology described by Huberty [9]. The FDA allows verifying whether the groups (Bactrian/dromedary) are distinct or not, identifies the discriminant parameters of the groups on the basis of their minerals and vitamins' composition, and predicts the group of affectation for all new muscle samples with unknown origin.

The software used for all statistical analyses was XLstat, version 2024 (Addinsoft ©).

3. Results

3.1 *Minerals*

On average, mineral values (mg/100 g) in the 6 muscles were 364.3 ± 42.6 for phosphorus; 774.6 ± 56.0 for potassium; 147.4 ± 6.9 for sodium; 40.3 ± 4.8 for magnesium; 13.9 ± 0.5 for calcium and 5.57 ± 0.34 for zinc. The mineral composition of the muscles was significantly ($P < 0.001$) different between muscles within species (Table 1). The mean difference between species was also significant ($P < 0.001$) for magnesium, calcium, and zinc, and higher in dromedary camel meat, while there was no significant difference for potassium, sodium, and phosphorus. Similar muscle patterns were observed in both species with respect to the mineral content in the different muscles. For instance, in both species, the LT muscle had the lowest levels of phosphorus, potassium, sodium, magnesium, and zinc, while the ST muscle contained the highest concentrations of potassium and sodium. TB muscle was poor in calcium in both species. Dromedary and Bactrian BF muscles were characterized by their richness in phosphorus and zinc, whereas SM muscle was the richest in calcium (Table 1). Only a slight difference was observed for magnesium, where the highest concentration was observed in the dromedary SM and Bactrian BF muscles.

Table 1. Mean values of the different minerals in Bactrian and dromedary camel (in mg/100 g). No SD given for a better reading of the table

Muscles	*P*	Na	K	Mg	Ca	Zn
	Dromedary					
SM	386.7 ± 7.1^{c}	150.4 ± 2.7^{c}	800.2 ± 4.1^{bcd}	45.4 ± 2.5^{c}	14.62 ± 0.25^{d}	5.76 ± 0.06^{c}
ST	387.8 ± 5.0^{c}	156.4 ± 1.3^{d}	803.8 ± 3.2^{d}	43.0 ± 3.4^{bc}	14.07 ± 0.06^{c}	5.73 ± 0.03^{c}
BF	393.3 ± 3.1^{d}	150.0 ± 2.8^{c}	796.1 ± 5.1^{b}	45.0 ± 2.3^{c}	13.85 ± 0.15^{b}	5.78 ± 0.06^{c}
IS	370.9 ± 3.8^{b}	149.80 ± 3.9^{c}	796.6 ± 6.5^{bc}	36.7 ± 1.5^{a}	13.79 ± 0.16^{b}	5.74 ± 0.04^{c}
TB	370.5 ± 11.9^{b}	145.0 ± 2.6^{b}	801 ± 4.9^{cd}	41.8 ± 1.6^{b}	13.36 ± 0.13^{a}	5.55 ± 0.17^{b}
LT	271.6 ± 4.0^{a}	135.2 ± 1.7^{a}	652.1 ± 8.4^{a}	34.8 ± 1.3^{a}	14.47 ± 0.18^{d}	5.21 ± 0.41^{a}
Mean D SD	363.5 ± 42.8^{A}	775.0 ± 55.8^{A}	147.8 ± 7.11^{A}	41.2 ± 4.7^{B}	14.03 ± 0.5^{B}	5.6 ± 0.3^{B}
	Bactrian					
SM	388.0 ± 1.8^{c}	149.8 ± 1.8^{c}	801.9 ± 12.0^{b}	42.78 ± 1.9^{b}	14.38 ± 0.24^{c}	5.62 ± 0.04^{b}
ST	390.2 ± 4.3^{cd}	154.6 ± 3.1^{d}	802.9 ± 2.38^{b}	43.00 ± 1.6^{b}	13.99 ± 0.03^{b}	5.69 ± 0.06^{b}
BF	392.6 ± 2.2^{d}	149.9 ± 3.6^{cd}	792.7 ± 16.4^{b}	43.56 ± 2.3^{b}	13.50 ± 0.22^{a}	5.71 ± 0.04^{b}
IS	372.9 ± 3.5^{b}	148.2 ± 1.6^{c}	795.9 ± 3.6^{b}	34.22 ± 1.8^{a}	13.39 ± 0.22^{a}	5.70 ± 0.03^{b}
TB	374.9 ± 2.4^{b}	145.3 ± 2.3^{a}	801.5 ± 4.9^{b}	39.33 ± 1.3^{a}	13.31 ± 0.22^{a}	5.58c ± 0.04^{a}
LT	272.4 ± 2.6^{a}	134.8 ± 2.2^{b}	650.3 ± 3.8^{a}	33.11 ± 1.6^{a}	14.30 ± 0.20^{c}	4.66 ± 0.20^{a}
Mean B SD	365.2 ± 42.6^{A}	774.2 ± 56.8^{A}	147.1 ± 6.7^{A}	39.3 ± 4.6^{A}	13.81 ± 0.5^{A}	5.49 ± 0.4^{A}

$^{a, b, c, d}$ Means in a column within species with common superscripts do not differ significantly at $P < 0.05$
$^{A, B}$ Means in the lines "Mean D and B" between species with common superscripts do not differ at $P < 0.05$

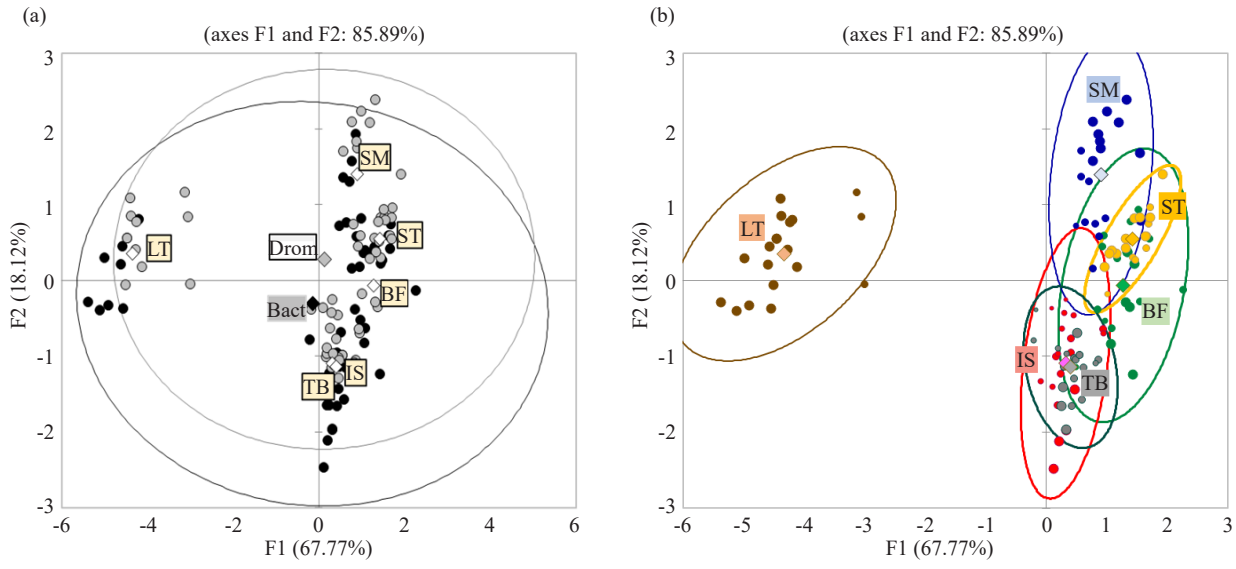

Figure 1. (a) Repartition of the 54 Bactrian meat samples (●) and 60 dromedary samples (○) on the factorial plan (F1 × F2) explaining 85.9% of the variance. The centroids of the 6 muscles (◇) and of the 2 species are projected on the plan; (b) Distribution of the 114 muscle samples according to the different muscles (represented by different colors and their ellipse of inertia) on the main factorial plan

Principal Component Analysis (PCA) showed that differences between muscles were more important than differences between species. Indeed, the variable "muscle" contributed mainly to the first factor (67.8% of the total

variance). This may be explained by the opposite trend of LT muscle to all other muscles regardless of the species, and the variables "species" were correlated to the second factor (18.1% of the total variance), the variable "Bactrian" appearing in opposite to the variable "dromedary" along this second factor (Figure 1).

The correlation circle showed a clear opposition between calcium, highly correlated with the second factor (r = 0.820), and all other minerals, mainly correlated with the first factor (Figure 2 and Table 2). All correlations between the minerals were highly significant (P < 0.001), except for calcium, which was significantly negatively correlated with potassium, phosphorus, and zinc. Therefore, the difference between Bactrian and the dromedary seems to be mainly linked to calcium concentrations in their muscles.

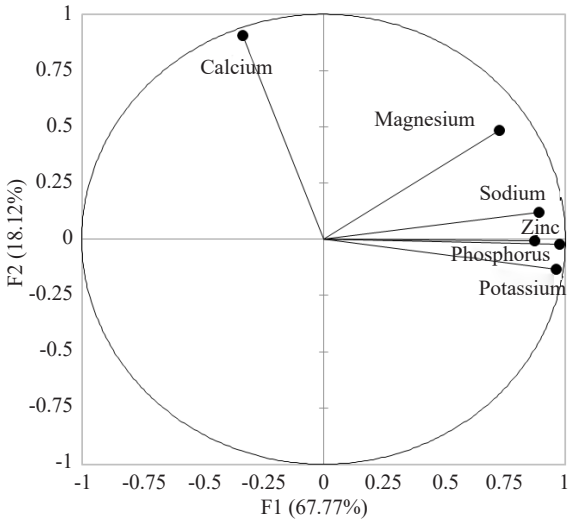

Figure 2. Correlation circle of the active variables (minerals) with the two main factors (F1 × F2) of the Principal Components analysis

Table 2. Correlations between the different variables (minerals, species, muscles) to the main factors of the PCA. The highest correlations are in bold

Variables	Factors of PCA				
	F1	F2	F3	F4	F5
Variance percentage (%)	67.77	18.12	6.56	4.56	2.49
Loading score (%)	83.78	11.59	2.53	1.46	0.59
Phosphorus	0.949	0.001	0.000	0.001	0.033
Potassium	0.922	0.017	0.001	0.001	0.046
Sodium	0.791	0.014	0.022	0.138	0.034
Magnesium	0.528	0.235	0.218	0.011	0.007
Calcium	0.112	0.820	0.056	0.000	0.011
Zinc	0.764	0.000	0.096	0.122	0.018
IS	0.053	0.613	0.329	0.003	0.002
TB	0.086	0.688	0.168	0.031	0.015
LT	0.992	0.007	0.000	0.000	0.002
ST	0.774	0.114	0.004	0.086	0.022
SM	0.281	0.668	0.007	0.001	0.042
BF	0.830	0.002	0.108	0.026	0.015
Dromedary	0.142	0.643	0.016	0.133	0.052
Bactrian	0.142	0.643	0.016	0.133	0.052

This was confirmed by discriminant analysis. The discriminant minerals distinguishing Bactrian and dromedary muscles were in the following order according to their *F* values: Ca, Zn, phosphorus, and potassium (Table 3). The introduction of magnesium and sodium into the ascending stepwise model did not improve the discriminant order. Both Box and Kullback tests revealed a highly significant ($P < 0.0001$) difference in muscle mineral composition between the two species. The four discriminant minerals (calcium, zinc, phosphorus, and potassium) allowed us to obtain an optimal discriminating power with 74% of well-classed (79.6% of the Bactrians were well-classified *vs* 68.3% of the dromedary meat samples).

Table 3. Synthesis of the significant interspecies discriminating minerals, *F* values (Box test), *p* values and discriminating power (ascending stepwise model)

Number	Minerals	*F*	Pr > *F*	Wilks lambda	Pr < Lambda
1	Ca	5.989	0.016	0.949	0.016
2	Ca/Zn	8.676	0.004	0.880	0.001
3	P/Cz/Zn	8.862	0.004	0.815	< 0.0001
4	P/K/Ca/Zn	8.543	0.004	0.756	< 0.0001

Using validation tests on 10 randomly selected samples, the percentage of well-classed camels for these four minerals was 71.3% (75.93% for Bactrian and 66.67% for dromedary) testifying to the good stability of the discriminant model.

The minerals discriminating the 6 muscles (all at $P < 0.0001$) were in the order phosphorus, potassium, calcium, magnesium and sodium with 93.3 % of well classed, confirming the highest differences between muscles than between species.

3.2 *Vitamins*

On average, the concentrations of vitamin B1 (thiamine) in meat samples were 85 ± 8 µg/100 g; vitamin B12 (cyanocobalamin) 4.58 ± 0.29 µg/100 g; vitamin B6 (pyridoxine) 654 ± 46 µg/100 g; vitamin B5 (pantothenic) 850 ± 27 µg/100 g; vitamin B2 (riboflavin) 225 ± 17 µg/100 g; vitamin A (retinol) 10.3 ± 0.49; vitamin E (tocopherol) 875 ± 42 µg/100 g and vitamin C (ascorbic acid) 0.328 ± 0.201 µg/100 g. Dromedary meat contained significantly ($P < 0.05$) higher levels of vitamins B1 and B6, Bactrian camel meat contained more vitamin C ($P < 0.001$), but there was no significant difference for the other vitamins. Within species, there were significant differences between muscles, except for vitamin B6 in the dromedary and vitamins B12 and B2 in Bactrian (Table 4). In both species, IS muscle contained more vitamins B2 and C, TB muscle contained more vitamin B5, and LT muscle had higher concentrations of vitamins A and E. In both species, the vitamin E levels were low in the ST muscle. Moreover, the maximum concentration of vitamin B12 was recorded in the dromedary ST muscle, and vitamin B6 in the dromedary TB muscle.

Table 4. Mean values of the different vitamins in Bactrian and dromedary camel (in µg/100 g). No SD given

Muscles	Vit B1	Vit B12	Vit B6	Vit B5	Vit B2	Vit A	Vit E	Vit C
	Dromedary							
SM	91 ± 7^{bc}	4.58 ± 0.22^{abc}	652 ± 20^{a}	839 ± 12^{a}	227 ± 16^{ab}	10.0 ± 0.38^{ab}	863 ± 6^{b}	0.37 ± 0.23^{b}
ST	91 ± 4^{bc}	4.77 ± 0.17^{c}	657 ± 20^{a}	842 ± 18^{ab}	221 ± 4^{ab}	9.9 ± 0.16^{a}	820 ± 9^{a}	0.31 ± 0.09^{b}
BF	85 ± 4^{a}	4.4 ± 0.17^{a}	660 ± 27^{a}	835 ± 24^{a}	218 ± 8^{ab}	9.97 ± 0.01^{ab}	867 ± 7^{b}	0.20 ± 0.15^{ab}
IS	93 ± 3^{c}	4.66 ± 0.24^{bc}	659 ± 22^{a}	866 ± 27^{b}	231 ± 20^{b}	10.36 ± 0.18^{c}	878 ± 55^{b}	0.33 ± 0.13^{b}
TB	84 ± 5^{a}	4.74 ± 0.12^{bc}	699 ± 134^{a}	872 ± 36^{b}	211 ± 6^{a}	10.21 ± 0.17^{bc}	923 ± 48^{c}	0.13 ± 0.03^{a}
LT	86 ± 6^{ab}	4.55 ± 0.29^{ab}	657 ± 22^{a}	858 ± 20^{ab}	228 ± 23^{b}	11.21 ± 0.17^{d}	925 ± 9^{c}	0.28 ± 0.16^{b}
Mean D SD	88 ± 6^{B}	4.62 ± 0.24^{A}	664 ± 46^{B}	852 ± 28^{A}	223 ± 17^{A}	10.29 ± 0.47^{A}	879 ± 48^{A}	0.27 ± 0.17^{A}
	Bactrian							
SM	84 ± 3^{b}	4.48 ± 0.12^{a}	643 ± 19^{ab}	828 ± 28^{a}	230 ± 18^{a}	10.14 ± 0.05^{bc}	864 ± 14^{b}	0.29 ± 0.21^{a}
ST	81 ± 2^{ab}	4.47 ± 0.20^{a}	655 ± 11^{b}	856 ± 22^{c}	221 ± 9^{a}	9.93 ± 0.13^{ab}	825 ± 11^{a}	0.39 ± 0.21^{a}
BF	83 ± 5^{ab}	4.48 ± 0.19^{a}	634 ± 13^{a}	835 ± 24^{a}	228 ± 25^{a}	9.84 ± 0.15^{a}	869 ± 16^{b}	0.50 ± 0.12^{a}
IS	83 ± 6^{b}	4.46 ± 0.15^{a}	648 ± 20^{ab}	857 ± 18^{bc}	232 ± 22^{a}	10.46 ± 0.88^{d}	855 ± 13^{b}	0.50 ± 0.25^{a}
TB	83 ± 3^{ab}	4.75 ± 0.68^{a}	633 ± 14^{ab}	867 ± 19^{bc}	227 ± 14^{a}	10.28 ± 0.08^{c}	884 ± 26^{b}	0.24 ± 0.18^{a}
LT	75 ± 16^{a}	4.57 ± 0.11^{a}	653 ± 23^{ab}	843 ± 15^{ab}	222 ± 7^{a}	11.28 ± 0.27^{e}	927 ± 9^{c}	0.38 ± 0.14^{a}
Mean B SD	82 ± 8^{A}	4.54 ± 0.33^{A}	644 ± 19^{A}	848 ± 26^{A}	227 ± 18^{A}	10.32 ± 0.51^{A}	871 ± 35^{A}	0.38 ± 0.21^{B}

[a, b, c, d] Means in a column within species with common superscripts do not differ significantly at $P < 0.05$
[A, B] Means in the lines "Mean D and B" between species with common superscripts do not differ at $P < 0.05$

The main factorial plan (F1, F2) issued from the PCA (Figure 3) was explained by the differences between the muscles, the centroids of the species being projected close to the center of gravity. The main factor of the analysis (25.5% of the total variance) was determined by the difference between the vitamin compositions of LT on one hand to ST, BF and SM on another hand (Figure 3a, b and c). The variable "species" was significantly correlated to the third factor (r = 0.412) and secondary to the second factor (r = 0.301) while the variable ''muscle" was diversely correlated among the three first factors (Table 5).

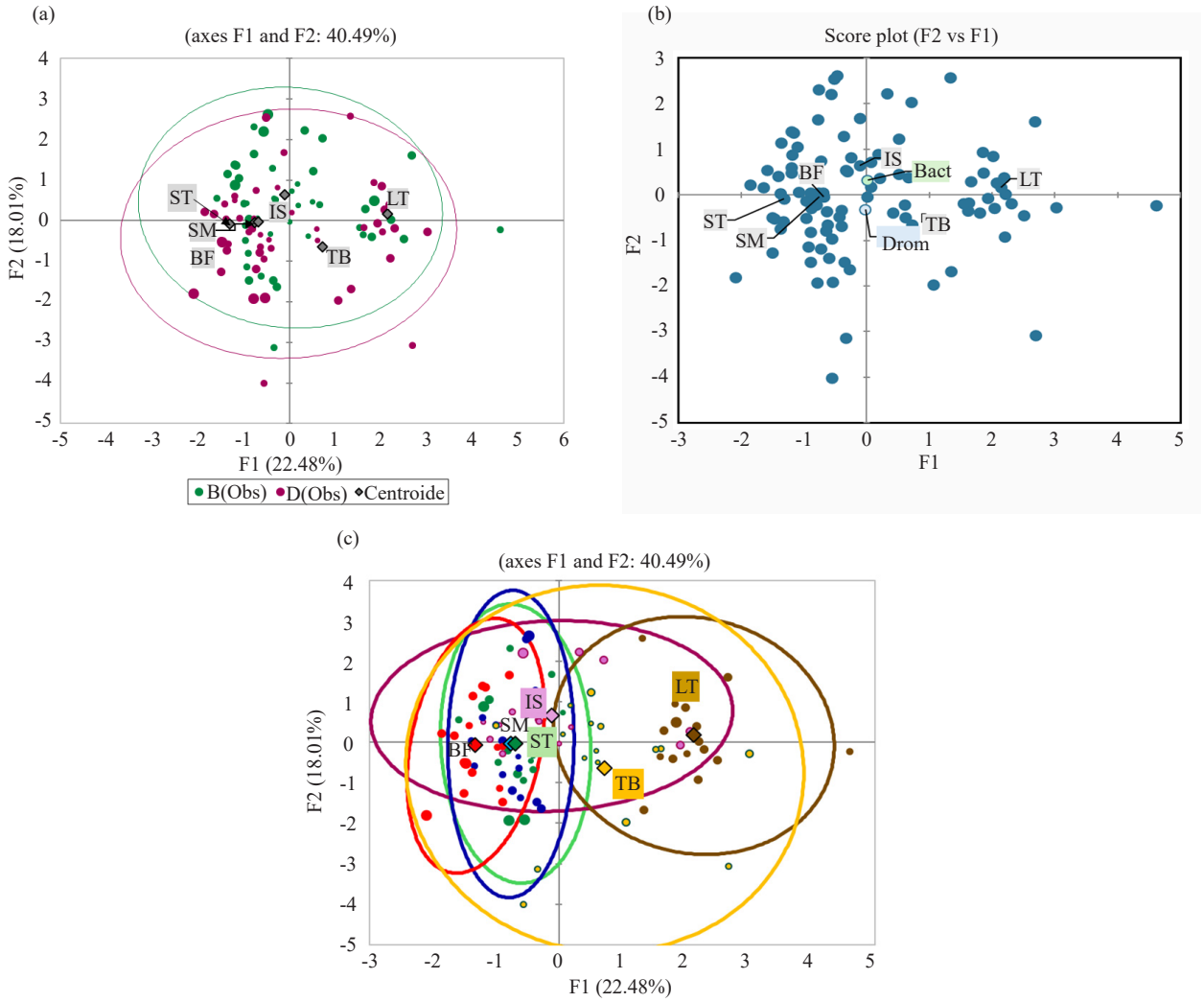

Figure 3. (a) Repartition of the 48 Bactrian meat samples (●) and the 48 dromedary samples (○) on the factorial plan (F1 × F2) explaining 42.6% of the variance. The centroids of the 6 muscles (◇) and of the 2 species are projected on the plan. (b) Score plot of the 96 muscle samples according to the type of muscles and to species. (c) Repartition of the 96 muscle samples according to the different muscles (represented by different colors and their ellipse of inertia) on the main factorial plan

Table 5. Correlations (Cos^2) between the different variables (vitamins, species, muscles) to the main factors of the PCA. The highest correlations are in bold

	Factors of the PCA				
	F1	F2	F3	F4	F5
Variance percentage (%)	22.48	18.01	12.86	12.05	11.31
Loading score (%)	28.23	20.24	12.21	11.07	10.07
Vitamin B1	0.226	0.001	0.379	0.000	0.057
Vitamin B12	0.000	0.238	0.333	0.021	0.038
Vitamin B6	0.017	0.239	0.019	0.058	0.631
Vitamin B5	0.108	0.232	0.263	0.171	0.016

Table 5. (cont.)

	Factors of the PCA				
	F1	F2	F3	F4	F5
Vitamin B2	0.025	0.164	0.003	0.585	0.151
Vitamin A	0.613	0.017	0.015	0.060	0.000
Vitamin E	0.803	0.005	0.003	0.007	0.003
Species-D	0.001	0.301	0.412	0.025	0.103
Species-B	0.001	0.301	0.412	0.025	0.103
Muscle-LT	0.833	0.005	0.001	0.062	0.001
Muscle-IS	0.016	0.556	0.203	0.002	0.157
Muscle-TB	0.255	0.203	0.203	0.058	0.000
Muscle-ST	0.773	0.003	0.000	0.095	0.004
Muscle-SM	0.660	0.002	0.060	0.101	0.000
Muscle-BF	0.373	0.001	0.396	0.010	0.024

The interpretation of the main factorial plan (F1, F2) based on the correlation circle (Figure 4) showed that the LT muscle was close to vitamins A and E, whereas vitamins B6 and B12 were opposite to the other vitamins of group B (B1, B2, B5) and C on the second factor, with unclear correlations to muscles.

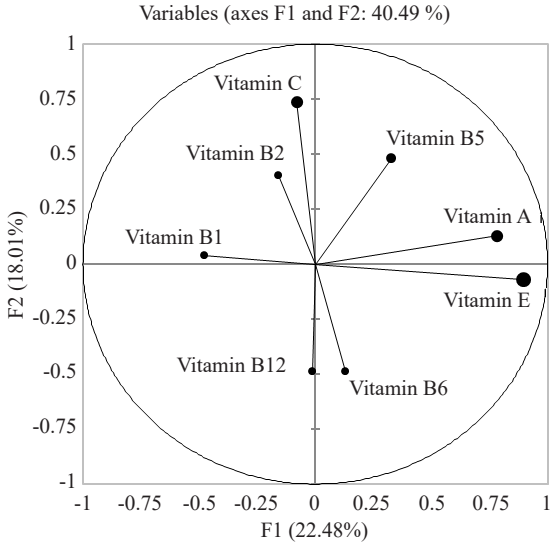

Figure 4. Correlation circle of the active variables (vitamins) with the two main factors (F1 × F2) of the Principal Components analysis explaining 40.5% of the total variance

On the factorial plan (F2 × F3) expressing the opposition between the two species, the centroids "Bact" (Bactrian) and "Drom" (dromedary) are related to vitamin C and vitamin B1, respectively, but are relatively close to the center of

gravity. Thus, the differences in vitamin composition of the meat from the two species appeared slight.

By ascending stepwise analysis, three vitamins were retained in the discriminant model: vitamin B1 (thiamine), B12 (cobalamine), and C (ascorbic acid). The main inter-species discriminating contribution was thiamine ($P < 0.0001$), with the contributions of the other two vitamins (B12 and C) being slightly significant ($P < 0.05$). Further introduction of other vitamins in the model did not improve the discriminant power to differentiate Bactrian from dromedary muscles (Table 6). Both Box and Kullback tests showed highly significant ($P < 0.0001$) differences for these three vitamins between the two species. Generally, Bactrian meat contained more vit. C, whereas dromedary meat is rich in thiamine and cobalamine. The percentage of well-classed camels for these three vitamins was 74.4%, with different distribution within species (68.2% for Bactrian and 80.9% for dromedary). Using validation tests on ten randomly selected samples, the discriminating power was stable, and the percentage of well-classed species was the same.

Table 6. Synthesis of the significant interspecies discriminating vitamins, *F* values (Box test), *p* values and discriminating power (ascending stepwise model)

Number	Variables	*F*	Pr > *F*	Lambda wilks	Pr < Lambda
1	Vit. B1	13.183	< 0.0001	0.864	< 0.0001
2	Vit. B1/Vit. C	9.325	0.003	0.777	< 0.0001
3	Vit. B1/Vit. B12/Vit. C	5.191	0.025	0.731	< 0.0001

Regarding the muscles, the following vitamins were discriminant: in the order, vitamin A ($P < 0.0001$), vitamin E ($P < 0.0001$), vitamin B5 ($P < 0.001$) and vitamin C ($P < 0.05$) leading to a percentage of well-classed muscle sample of 82.3%.

4. Discussion

4.1 *Minerals*

Comparison of mineral levels in camel meat from the current study with those of other studies is difficult. This is mainly due to differences in the muscles used, different methods of analyses, or expression of units (on fresh or dried weight basis). Some values appear to be highly questionable [10]. Various factors have been studied, including age [11-13], sex [14], processing [11-16], season [17], and breed [12] (Table 7). To our knowledge, only one study [18] referred to the mineral and vitamin composition of Bactrian camel meat, while Ebadi [14] compared the meat composition of dromedary with F1 crossbreeds (*Camelus dromedarius* × *Camelus bactrianus*) and found no significant breed effect on mineral composition, but a high effect of cutting regions. In all cases, the main source of variation seemed to be the muscle type rather than the species.

There is little published information on the comparison between individual muscles within species and between species of camels. Si et al. [18] analyzed three muscles from Bactrian carcasses: *Longissimus thoracis*, *Semitendinosus* and *Psoas major*. Except for zinc, there was no significant effect of muscle type on the composition of these muscles (Table 8).

Contrary to our results for the dromedary muscles, Ibrahim et al. [11] did not report differences between camel muscles (Table 8). However, the quantity of minerals was comparable, that is, the relative abundances of potassium and phosphorus in the different muscles. Except for lower potassium concentrations in the dromedary, the LT muscle was not exceptionally higher than other muscles, contrary to our observations (Table 8). Calcium is essential for the excitability of muscles, whereas phosphorus is an important element in generating ATP and creatine phosphate, and both are important high-energy compounds. Magnesium is required by enzymatic reactions involving the storage of energy in ATP, and zinc is also a part of enzymes involved in energy metabolism, and their quantity in different muscles could reflect the differences in their energetic activities [26]. The high dynamic function of the muscle, except *Longissimus*

thoracis which is linked to the rachis, could explain the particularity of this muscle regarding its mineral composition, these minerals playing different roles in the contractile activities.

Table 7. Mineral concentrations in camel meat according to some references from literature (mg/100 g fresh weight)

Mineral	Ca	K	Mg	Na	*P*	Zn	References
Rump	-	-	-	-	-	-	Badiei et al. [19]
Intercostal	8.5	515	29.5	300.5	-	74.0	
Scapula	10.0	670	51.0	225.0	-	58.0	
Sirloin	10.2	446	28.0	188.5	-	66.0	
Flank	8.4	811	49.5	223.0	-	69.5	Rashed [20]
Front knuckle	8.4	630	37.0	299.5	-	73.5	
Front limb	9.8	548	42.5	312.5	-	85.5	
Chuck	11.5	249	17.4	73.5	-	3.7	
Rib-eye	8.1	231	16.3	67.1	-	3.7	Dawood and Alkanhal [21]
Leg	10.3	251	17.1	69.7	-	3.9	
Leg + loin	4.9	228	17.7	47.9	-	3.2	Elgasim and Alkanhal [5]
Shoulder	5.1	357	20.6	69.1	196	3.5	
Thigh	5.4	361	21.0	70.4	199	3.1	
Ribs	4.7	324	18.5	84.1	181	3.9	El-Faer et al. [22]
Neck	5.6	338	18.5	87.3	181	4.8	
Dromedary meat	5.9	193	12.9	45.3	105	-	Kadim et al. [23]
Dromedary meat	4.9	228	17.7	47.9	-	3.2	Elgasim and Alkanhal [5]
Dromedary meat*	27	1,008	56.7	252	549	15	Mahmud et al. [24]
Dromedary meat	6.5	195	13.5	44.9	113	3.5	Mohammed et al. [25]
Dromedary meat	24.4	298	19.3	107	155	-	Abdel-Raheem et al. [13]
Dromedary meat*	63.3	1212	72	327	683	15.7	Sahraoui et al. [12]
Dromedary	14.0	148	41.2	775	363	5.6	Present study
Bactrian	13.8	147	39.8	774	365	5.5	

*On 100 g dry-weight meat

Table 8. Mineral composition of different muscles in Dromedary and Bactrian according to some references

	Muscles							
	SM		ST		BF		LT	
	Dromedary							
Mineral	Ref1	Ref2	Ref1	Ref2	Ref1	Ref2	Ref1	Ref2
P	386.7	389	387.8	355	393.3	393	271.6	352
Na	150.4	141	156.4	139	150.0	141	135.2	149
K	800.2	778	803.8	751	796.1	759	652.1	797
Mg	45.4	35.6	43.8	34.9	45.0	35.9	34.8	37.1
Ca	14.62	14.4	14.07	14.1	13.85	13.6	14.47	13.3
Zn	5.76	5.49	5.73	4.98	5.78	5.58	5.21	5.11
	Bactrian							
			Ref1	Ref3			Ref1	Ref3
P	-	-	390.2	204.4	-	-	272.4	204.5
Na	-	-	154.6	55.6	-	-	134.8	52.7
K	-	-	802.9	368.4	-	-	650.3	358.25
Mg	-	-	43.00	22.98	-	-	33.11	22.33
Ca	-	-	13.99	4.59	-	-	14.30	2.73
Zn	-	-	5.69	3.69	-	-	4.66	3.03

Ref1: present study; Ref2: Ibrahim et al. [11]; Ref3: Si et al. [18]

According to Mohammed et al. [25], there were significant differences in the mineral composition of camel, beef, mutton, and chicken meat, with relatively less calcium, potassium, phosphorus, sodium, and zinc in the dromedary camel compared to other species. Magnesium was slightly higher in camel meat than in chicken meat, although it was lower than that in beef or mutton meat. However, such comparisons must be performed with caution. In other comparative studies, Muhammad et al. [10] reported higher values for all minerals in camel meat than in beef meat, in contrast to the study by Elgasim and Alkanhal [5], who found a reverse trend, except for sodium.

4.2 *Vitamins*

Published literature on camel meat vitamin profiles is scarce, especially for Bactrian camels [27, 28]. Therefore, the comparison of our results with the findings of published literature is limited, particularly because of the different muscles used.

There were no significant differences due to camel age, except for thiamine (vit. B1) [11]. Similar to the findings of the present study, Ibrahim et al. [11] reported small differences in vitamin content between carcass muscles (Table 9).

Table 9. Vitamin composition of different muscles and mixed meat in dromedary camel according to some references

	Muscles									
	SM		ST		BF		LT		Meat	
	Dromedary									
Vitamins	Ref1	Ref2	Ref1	Ref2	Ref1	Ref2	Ref1	Ref2	Ref1	Ref3
B1	91	90	91	80	85	90	86	110	88	89
B6	652	610	657	610	660	620	657	590	664	450
B5	839	720	842	760	835	770	858	780	852	-
B12	4.58	4.68	4.77	4.77	4.4	4.69	4.55	4.64	4.62	6.5
B2	227	260	221	220	218	260	228	230	223	-
A	10	10.1	9.9	11.2	9.97	9.99	11.21	10.5	10.3	4.0
E	863	860	820	920	867	830	925	850	879	860

Ref1: present study; Ref2: Ibrahim et al. [11]; Ref3: Muhammad et al. [10]

An interspecies comparison by Muhammad et al. [10] showed significant differences in vitamin content between camel, beef, mutton, and chicken meat. Camel meat was poor in vitamin A, but rich in all other vitamins compared to other species. For instance, regarding vitamin B12, the value in camel meat was 650 µg/100 g *vs* 3.2 µg/100 g in beef, 2.9 µg/100 g in mutton and 3 µg/100 g in chicken meat, i.e., a ratio of 1 : 200 to 300. In a review by Kadim et al. [27], comparisons were carried out with other species according to data published by Purchas et al. [29] on beef and lamb, confirming the highest values of all vitamins in dromedary meat, especially vitamin B12, with a ratio (approximately three times higher) appearing more probable than in the study by Muhammad et al. [10].

Vitamins play important roles in muscle function. For example, thiamine (vitamin B1) is a cofactor in the conversion of carbohydrates to energy, and riboflavin (vitamin B2) is also a cofactor in the mitochondrial respiratory chain, helping in the release of energy from foods. Pyridoxine (vitamin B6) is used as a cofactor for enzymatic reactions in protein and amino acid metabolism; Vitamin B12 contributes to fat and carbohydrate metabolism, as well as to the synthesis of proteins; pantothenic acid (vitamin B5) is a component of coenzyme A in the Krebs cycle [26]. It is well known that selenium is acting in synergy with vitamin E in the body. Moreover, the particular richness of LT in selenium was already observed in lamb supplemented in selenium [30]. A similar mechanism could occur in camel, explaining the higher concentration in vitamin E in this muscle in relation to its low dynamic function.

4.3 *Comparisons between species of large camelids*

The main differences between dromedaries and Bactrians may be linked to their genetic differences. However, this might also be due to the composition of their diet; the nutritive value of desert plants in Oman is different from that in the Kazakh steppe.

To the best of our knowledge, the effect of diet on the mineral and/or vitamin composition of meat has never been investigated in large camelids. In cattle calf meat, a slightly significant difference in potassium and magnesium content was observed with increasing concentrations of these two minerals when calves were supplemented with silage [31]. In foal meat, the type of finishing diet before slaughtering can modify the mineral composition, especially potassium and phosphorus, and to a lesser extent, calcium [32]. In beef cattle, the type of diet has a small but significant effect on certain minerals, a negligible effect on water-soluble vitamins (B complex), and a large effect on vitamins A and E [33]. Notably, vitamin E levels are significantly higher in beef

cattle on pasture than in those receiving a mixed diet [34]. However, in the current study, despite the different floristic composition of rangelands, all animals were fed natural grasses and sampled during the same season of the year.

Regarding potential genetic effects, most of the studies were focused on the heritability of the vitamin A concentration in organs or serum, but not in the meat [35]. But globally, the heritability appeared very low, for example for trace elements [36]. Few studies investigated potential breed effects, for example on magnesium [37] or vitamins A and E in beef meat [38]. To our knowledge, no data on the camel was available, except one reference regarding selenium in *Longissimus dorsi* muscle [39]. However, the analyses were achieved in camels arriving at slaughterhouses and coming from different places. Thus, it was difficult to state if the breed differences were linked to genetic or to specific selenium status of the feeds. Due to the lack of common environmental conditions in our study, it is also difficult to specify what is the parameter (genetic *vs* diet) having the higher effect.

The percentage of well-classified large camelids after discriminant analysis both for minerals and vitamins was approximately 72-75% which was low compared to the values recorded for fatty acids (100%) and amino acids (93.1%) in the same muscle samples [7, 29, 40]. Contrary to these investigations, the variability in mineral and vitamin composition between muscles was more important than interspecies differences. Surprisingly, the percentage of well-classed animals in the present study was like the percentage (75.4%) observed in the discriminating analysis of milk composition [41]. Bactrians and dromedaries are two different species, but their crossbreeds are fertile, testifying to their genetic proximity. In this respect, the literature indicates that diet has a greater influence on muscle fat composition than on mineral and vitamin components. Moreover, except for liposoluble vitamins, the diet had a marginal effect on most minerals and water-soluble vitamins, which may be because the slight differences observed in our study are largely dependent on genetic factors.

5. Conclusions

Bactrian and dromedary camels, despite their relative genetic proximity, live in two different ecosystems, which may explain the differences in their meat composition as it has been observed formerly for protein and fat composition. The present comparative study regarding minerals and vitamins allowed for the discrimination of these two species to a reasonable extent. Phosphorus, potassium, calcium, zinc, thiamine, pyridoxine, and vitamin E were sufficient to recognize the origin of camel meat with 75% certainty. Owing to the lack of studies on camel meat mineral and vitamin components, further investigations using convenient analytical procedures could be useful to substantiate the findings of the present values, especially by investigating the differences in meat composition in a similar environment which could be possible in Kazakhstan where the two species are reared sometimes in the same farms. However, according to our investigations, camel meat is a good source of vitamins and minerals for consumers compared to other red meats, contributing to their dietetic and nutritive value for the consumers of arid and semi-arid countries.

Acknowledgement

The present work was carried out within the framework of a PhD study supported by Al-Farabi Kazakh National University and Kazakh National Agrarian University (Kazakhstan) in collaboration with Sultan Qaboos University, Oman Sultanate. The study was financed by the Ministry of Agriculture of the Republic of Kazakhstan in the frame of project BR22886598.

Credit authorship contribution statement

Gulzhan Raiymbek: Writing the material and methods chapter, review and editing, sampling, data collection, and laboratory analysis. Isam Kadim: Supervision, conceptualization, review and editing, and laboratory and field support. Osman Maghoub: Laboratory and Field Support, Review and Editing. Gaukhar Konuspayeva: logistic support in

Kazakhstan, review and editing, bibliography support. Bernard Faye: Statistical analysis, writing the first draft, and submission for publication.

Compliance with ethical standards

Human and animal rights and informed consent: This study was conducted in the regular process of meat production at slaughterhouses in Oman and Kazakhstan, respecting the welfare rules of national regulations. Muscle samples were obtained from carcasses of dead animals. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee in both Kazakhstan and Oman. The manuscript does not contain any clinical studies or patient data.

The Local ethical Committee of the Kazakh National University was established on the basis of the ethical Committee of the Faculty of Medicine and Public Health in 2020 and was registered with the U.S. Office for Human Research (IRB00010790 Al-Farabi Kazakh National University IRB #1).

See https://farabi.university/science/lec?lang=en&active_tab_order=3.

Source of funding

This research did not receive any specific grants from funding agencies, except for the scholarship of the PhD and the support of Ministry of Agriculture in Kazakhstan for the logistic and publication.

Consent to publish

The manuscript entitled, "Comparative minerals and vitamins composition of Bactrian (*Camelus bactrianus*) and dromedary (*Camelus dromedarius*) meat" is prepared following the Guide for Authors available on the journal's website and it has not been published elsewhere in part or in its entirety. All authors attest to the validity of its content and agree with its submission.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

References

[1] Geay Y, Bauchart D, Hocquette JF, Culioli J. Effect of nutritional factors on biochemical, structural, and metabolic characteristics of muscles in ruminants, consequences on dietetic value and sensorial qualities of meat. *Reproduction Nutrition Development*. 2001; 41(1): 1-26. Available from: https://doi.org/10.1051/rnd:2001108.

[2] Osorio MT, Zumalacárregui JM, Bermejo B, Lozano A, Figueira AC, Mateo J. Effect of ewe's milk versus milk-replacer rearing on mineral composition of suckling lamb meat and liver. *Small Ruminant Research*. 2007; 68(3): 296-302. Available from: https://doi.org/10.1016/j.smallrumres.2005.11.010.

[3] Faye B, Abdelhadi O, Raiymbek G, Kadim I, Hocquette JF. La production de viande de chameau: état des connaissances, situation actuelle et perspectives [The production of camel meat: State of knowledge, current situation and prospects]. *INRA Productions Animales*. 2013; 26(3): 289-300. Available from: https://doi.org/10.20870/productions-animales.2013.26.3.3158.
[4] Faye B. Camel meat in the world. In: Kadim I, Maghoub O, Faye B, Farouk M. (eds.) *Camel Meat and Meat Products.* Oxfordshire, UK: CAB International Publisher; 2013. p.7-16.
[5] Elgasim EA, Alkanhal MA. Proximate composition, amino acids and inorganic mineral content of Arabian Camel meat: Comparative study. *Food Chemistry*. 1992; 45(1): 1-4. Available from: https://doi.org/10.1016/0308-8146(92)90002-J.
[6] Urbisinov ZhK. *Pishchevaya i Biologicheskaya Tsennost' Traditsionnykh Mestnykh Molochnykh i Myasnykh Produktov [Food and Biological Value Traditional Local Milk and Meat Products]*. Doctoral Dissertation. Alma-Ata, Kazakhstan; 1992. p.172.
[7] Raiymbek G, Kadim I, Konuspayeva G, Mahgoub O, Serikbayeva A, Faye B. Discriminant amino-acid components of Bactrian (*Camelus bactrianus*) and Dromedary (*Camelus dromedarius*) meat. *Journal of Food Composition and Analysis*. 2015; 41: 194-200. Available from: https://doi.org/10.1016/j.jfca.2015.02.006.
[8] Faye B, Konuspayeva G. The encounter between Bactrian and Dromedary camels in Central Asia. In: Knoll EM, Burger P. (eds.) *Camels in Asia and North-Africa: Interdisciplinary Perspectives on Their Past and Present Significance*. Wien, Austria: Austrian Academy of Sciences Press; 2012. p.27-33.
[9] Huberty CJ. *Applied Discriminant Analysis*. New York: Wiley-Interscience Publication; 1994.
[10] Muhammad BF, Mahmud AB, Mustapha A. Effect of processing method on composition and consumer acceptability of camel (*Camelus dromedarius*) meat and beef. *Nigerian Journal of Animal Production*. 2011; 38(1): 135-144. Available from: https://doi.org/10.51791/njap.v38i1.696.
[11] Ibrahim GA, Nour IA, Al-Maqbali R, Kadim IT. Effect of age on concentrations of nutrients in four muscles of the Sudanese dromedary (*Camelus dromedaries*) camel. *Journal of Applied Animal Research*. 2017; 45(1): 577-584. Available from: https://doi.org/10.1080/09712119.2016.1232266.
[12] Sahraoui N, Moula N, Boujenah S, Hornick JL. Main mineral contents in camel meat in Algeria. *Journal of Livestock and Veterinary Medicine in Tropical Countries*. 2018; 71(4): 163-166. Available from: https://doi.org/10.19182/remvt.31672.
[13] Abdel-Raheem H, Ahmed H, Abd-Allah S, Abdel-Rasoul M. Nutritive value of the dromedary camel meat. *SVU-International Journal of Veterinary Sciences*. 2019; 2(1): 68-74. Available from: https://doi.org/10.21608/svu.2019.9670.1006.
[14] Ebadi Z. The comparison of carcass characteristics and chemical composition of dromedary and crossbred (*C. dromedarius and C. bactrianus*) camel meat during two growth periods. *Small Ruminant Research*. 2015; 128: 41-49. Available from: https://doi.org/10.1016/j.smallrumres.2015.03.005.
[15] Kadim IT, Al-Ani MR, Al-Maqbaly RS, Mansour MH, Mahgoub O, Johnson EH. Proximate, amino acid, fatty acid and mineral composition of raw and cooked camel (*Camelus dromedarius*) meat. *British Food Journal*. 2011; 113(4): 482-493. Available from: https://doi.org/10.1108/00070701111123961.
[16] Mohammad BF, Abubakar FM. Chemical composition of raw and cooked camel (*Camelus dromedarius*) meat cuts. *Savannah Journal of Agriculture*. 2011; 6(2): 32-36.
[17] Arabi OH, Elmawlla SF, Abdelhai E, Moneim A. Macro minerals profiles in camel's meat. *International Journal of Current Research and Review*. 2014; 6(5): 19-24.
[18] Si R, Na Q, Wu D, Wu X, Ming L, Ji R. Effects of age and muscle type on the chemical composition and quality characteristics of Bactrian camel (*Camelus bactrianus*) meat. *Foods*. 2022; 11(7): 1021. Available from: https://doi.org/10.3390/foods11071021.
[19] Badiei K, Mostaghni K, Pourjafar M, Parchami A. Serum and tissue trace elements in Iranian camels (*Camelus dromedarius*). *Comparative Clinical Pathology*. 2006; 15: 58-61. Available from: https://doi.org/10.1007/s00580-006-0610-x.
[20] Rashed MN. Trace elements in camel tissues from a semi-arid region. *The Environmentalist*. 2002; 22: 111-118.
[21] Dawood A, Alkanhal MA. Nutrient composition of Najdi-Camel meat. *Meat Science*. 1995; 39(1): 71-78. Available from: https://doi.org/10.1016/0309-1740(95)80008-5.
[22] El-Faer MZ, Rawdah TN, Attar KM, Dawson MV. Mineral and proximate composition of the meat of the one-humped camel (*Camelus dromedarius*). *Food Chemistry*. 1991; 42(2): 139-143. Available from: https://doi.org/10.1016/0308-8146(91)90029-N.
[23] Kadim IT, Mahgoub O, Al-Marzooqi W, Khalaf SK, Mansour MH, Al-Sinani SSH, et al. Effects of electrical

stimulation on histochemical muscle fiber staining, quality, and composition of camel and cattle Longissimus thoracis muscles. *Journal of Food Science*. 2009; 74(1): S44-S52. Available from: https://doi.org/10.1111/j.1750-3841.2008.00992.x.

[24] Mahmud T, Rehman R, Anwar J, Ali S, Abbas A, Salman M. Minerals and nutritional composition of camel (*Camelus dromedarius*) meat in Pakistan. *Journal of the Chemical Society of Pakistan*. 2011; 33(6): 835-838.

[25] Mohammed HHH, Jin G, Ma M, Khalifa I, Shukat R, Elkhedir AE, et al. Comparative characterization of proximate nutritional compositions, microbial quality and safety of camel meat in relation to mutton, beef, and chicken. *LWT*. 2020; 118: 108714. Available from: https://doi.org/10.1016/j.lwt.2019.108714.

[26] Huskisson E, Maggini S, Ruf M. The role of vitamins and minerals in energy metabolism and well-being. *Journal of International Medical Research*. 2007; 35(3): 277-289. Available from: https://doi.org/10.1177/147323000703500301.

[27] Kadim IT, Al-Amri IS, Alkindi AY, Haq QM. Nutritional values and health benefits of dromedary camel meat. *Animal Frontiers*. 2022; 12(4): 61-70. Available from: https://doi.org/10.1093/af/vfac051.

[28] Raiymbek G, Kadim I, Al-Amri Issa S, Alkindi Abdulaziz Y, Faye B, Khalf SK, et al. Concentrations of nutrients in six muscles of Bactrian (*Camelus bactrianus*) camels. *Journal of Camel Practice and Researc*h. 2018; 25(1): 109-121. Available from: https://doi.org/10.5958/2277-8934.2018.00016.4.

[29] Purchas RW, Wilkinson BH, Carruthers F, Jackson F. A comparison of the nutrient content of uncooked and cooked lean from New Zealand beef and lamb. *Journal of Food Composition and Analysis*. 2014; 35(2): 75-82. Available from: https://doi.org/10.1016/j.jfca.2014.04.008.

[30] Blanco M, Lobón S, Bertolín JR, Joy M. Effect of the maternal feeding on the carotenoid and tocopherol content of suckling lamb tissues. *Archives in Animal Nutrition*. 2019; 73(6): 472-484. Available from: https://doi.org/10.1080/1745039X.2019.1655354.

[31] Dimov K, Kalev R, Penchev P. Effect of finishing diet with excluded silage on amino-acid, fatty-acid and mineral composition of meat (*m longisimus dorsi*) in calves. *Bulgarian Journal of Agricultural Sciences*. 2012; 18(2): 288-295.

[32] Franco D, Lorenzo JM. Effect of muscle and intensity of finishing diet on meat quality of foals slaughtered at 15 months. *Meat Science*. 2014; 96(1): 327-334. Available from: https://doi.org/10.1016/j.meatsci.2013.07.018.

[33] Webb EC. Manipulating beef quality through feeding. *South African Journal of Food Science and Nutrition*. 2006; 7(1): 1-24.

[34] Gatellier P, Mercier Y, Renerre M. Effect of diet finishing mode (pasture or mixed diet) on antioxidant status of Charolais bovine meat. *Meat Science*. 2004; 67(3): 385-394. Available from: https://doi.org/10.1016/j.meatsci.2003.11.009.

[35] Kato Y, Ito M, Hirooka H. Genetic parameters of serum vitamin A and total cholesterol concentrations and the genetic relationships with carcass traits in an F_1 cross between Japanese Black sires and Holstein dams. *Journal of Animal Science*. 2011; 89(4): 951-958. Available from: https://doi.org/10.2527/jas.2010-2872.

[36] Tizioto PC, Taylor JF, Decker JE, Gromboni CF, Mudadu MA, Schnabel RD, et al. Detection of quantitative trait loci for mineral content of Nelore longissimus dorsi muscle. *Genetics Selection Evolution*. 2015; 47: 1-9. Available from: https://doi.org/10.1186/s12711-014-0083-3.

[37] Valaitienė V, Klementavičiūtė J, Stanytė G. The influence of cattle breed on nutritional value and mineral content of meat. *Veterinarija ir Zootechnika*. 2016; 73(95): 133-137.

[38] Solarczyk P, Gołębiewski M, Slósarz J, Łukasiewicz M, Przysucha T, Puppel K. Effect of breed on the level of the nutritional and health-promoting quality of semimembranosus muscle in purebred and crossbred bulls. *Animals*. 2020; 10(10): 1822. Available from: https://doi.org/10.3390/ani10101822.

[39] Sahraoui N, Boudjenah S, Dotreppe O, Brahim Errahmani M, Babelhadj B, Guetarni D, et al. Effect of breed, age and sex on selenium content of dromedary camel Longissimus dorsi muscle. *Journal of Camelid Science*. 2013; 6: 63-71.

[40] Raiymbek G, Faye B, Kadim IT, Serikbaeva A, Konuspayeva G. Comparative fatty acids composition and cholesterol content in Bactrian (*Camelus bactrianus*) and dromedary camel (*Camelus dromedarius*) meat. *Tropical Animal Health and Production.* 2019; 51: 2025-2035. Available from: https://doi.org/10.1007/s11250-019-01894-2.

[41] Faye B, Konuspayeva G, Messad S, Loiseau G. Discriminant milk components of Bactrian camel (*Camelus bactrianus*), dromedary (*Camelus dromedarius*) and hybrids. *Dairy Science & Technology*. 2008; 88: 607-617. Available from: https://doi.org/10.1051/dst:2008008.