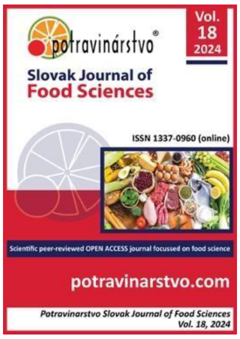

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Regional features of camel milk composition and properties in the Republic of Kazakhstan

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ABSTRACT

Camel milk, renowned for its distinctive nutritional qualities, has captured the interest of scientific researchers due to its potential health benefits. This study aims to compare the biochemical composition of camel milk sourced from two distinct regions of Kazakhstan: Jetisu and Mangystou. Analytical methods were employed to achieve this objective, including gas chromatography for fatty acid analysis, chemical methods for physicochemical parameter determination, and assessment of amino acid, fatty acid, mineral, and vitamin content. In samples from the Jetisu region, protein content ranged from 3.61% to 3.70%, fat from 3.85% to 4.64%, and lactose from 4.80% to 4.85%. In comparison, samples from the Mangystou region exhibited protein content ranging from 3.65% to 3.81%, fat from 4.72% to 5.75%, and lactose from 4.21% to 4.28%. Regarding amino acid composition, Mangystou region samples contained more essential amino acids per 100 g of protein than Jetisu region samples: 41.29 g versus 38.20 g, respectively. Additionally, the Jetisu region sample contained 64.291% saturated fatty acids, while the Mangystou region sample had 62.135%, indicating differences in fatty acid composition based on geographical origin. In terms of mineral composition, camel milk from the Mangystou region exhibited higher calcium and zinc content compared to Jetisu region samples, with calcium and zinc content measured at 124.50 mg/100 g and 490.15 µg/100 g, respectively, for Mangystou samples, and 112.50 mg/100 g and 321.24 µg/100 g, respectively, for Jetisu samples. Overall, the study underscores regional variances in camel milk's biochemical composition, which can impact its nutritional and biological value. These findings provide dairy product producers in Kazakhstan with enhanced opportunities to create healthy, high-quality dairy products.

Keywords: amino acids, camel milk, chemical composition, fatty acids, mineral

INTRODUCTION

Camel breeding has been a longstanding practice in the Republic of Kazakhstan, dating back to ancient times. This livestock farming sector stands out as one of the most lucrative, particularly in desert climates, as it provides the population with milk, meat, wool, and leather.

According to the Bureau of National Statistics **[1]**, Kazakhstan's camel population is currently experiencing a consistent rise, as illustrated in Figure 1.

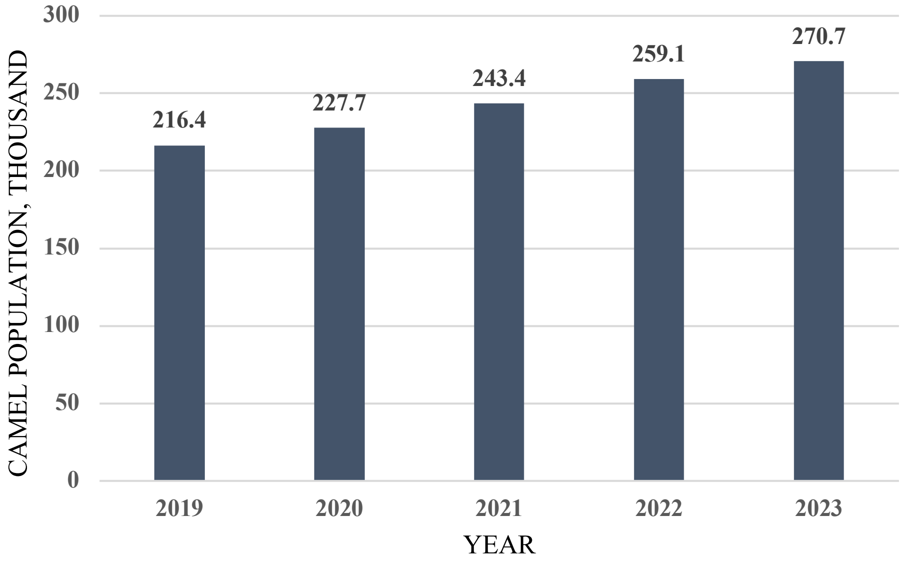

Figure 1 Number of Camels in the Republic of Kazakhstan.

Naturally, Kazakhstan's substantial population of camels (270 thousand heads in 2023) presents an opportunity to utilize camel milk productivity. This entails allocating additional resources from the agro-industrial complex for the dairy industry of the Republic of Kazakhstan. It also underscores the need to process camel milk into high-quality, safe dairy products, expanding and diversifying their range.

Camel milk products such as shubat, saumal, kurt, and balkaimak are integral to Kazakh culture and culinary heritage. These products offer delightful taste and health benefits and carry significant traditional value, reflecting Kazakhstan's rich cultural stories and traditions.

There is a growing interest in camel milk globally, making it increasingly popular in various cuisines and cultures. Producing camel milk-based cheeses, yogurts, and dairy drinks presents a unique approach to diversifying dairy products in the global market.

While the use of camel milk in the global food industry is not yet as extensive as that of milk from other animals, there is a clear trend toward leveraging this product's potential. Camel milk's distinctive nutritional and medicinal properties attract the attention of producers and consumers alike, offering new prospects for innovation in the food industry.

Categorised as an albumin-type product, camel milk resembles female breast milk composition **[2]**. Noteworthy for its optimal protein content and easily digestible fats, camel milk distinguishes itself by the absence of β-lactoglobulin, rendering it suitable for consumption without eliciting allergic reactions **[3]**.

The diminutive size of camel milk fat globules accelerates their hydrolysis, facilitating superior absorption by the human body **[4]**. The quality of camel milk fat surpasses that of fat derived from other types of farm animal milk. Furthermore, the relatively elevated presence of unsaturated fatty acids positions camel milk as a product with notable dietary properties **[5]**.

Camel milk is a valuable source of vitamins essential for ensuring the normal progression of biochemical and physiological processes within the human body. It contains 3-5 times more vitamin C than cow's milk **[4]**.

Furthermore, camel milk is enriched with macro- and microelements crucial for sustaining the body's normal development. A review article by Konuspayeva et al. noted that camel milk is relatively rich in potassium (K), sodium (Na), chloride (Cl), iron (Fe), and zinc (Zn) **[6]**.

Studies indicate that various factors, including geographical area, feeding conditions, season, and stage of lactation influence camel milk's composition. Therefore, understanding the composition of camel milk in different regions of Kazakhstan is crucial for optimising the production and utilisation of this valuable product in the food industry.

This study aims to comprehensively analyse the physicochemical and biochemical indicators that characterise the nutritional and biological value of camel milk in the western and southern regions of Kazakhstan, with a specific focus on the Mangystou and Jetisu regions. These areas have traditionally considered camel milk a key element of their food culture. Analysing these data will enhance our understanding of camel milk's potential to promote the health and well-being of these regions' populations. Additionally, it will help justify practical measures to improve the quality and efficiency of camel milk production and utilisation.

Scientific hypothesis

This study's hypothesis suggests that camel milk produced in the Mangystou and Jetisu regions of western and southern Kazakhstan has unique physicochemical and biochemical characteristics that affect its nutritional and biological value. This hypothesis is based on the assumption that local camel housing conditions, nutritional habits, and climate influence the composition and properties of the milk.

MATERIAL AND METHODOLOGY

Samples

Samples of whole fresh milk from dromedary camels were obtained from farms in the Jetisu region (n = 12) and Mangystou region (n = 12).

The milking of camels took place during two seasons, the summer (July) and winter (December) of 2022, in the early morning. The samples were collected from the milk that was obtained. The camels are under constant veterinary and zootechnical supervision.

The regions from which the camel milk samples were collected have diverse climates (see Figure 2).

The Mangystou region is situated southwest of Kazakhstan. The climate is desert-like and arid, with extremely hot summers. The average temperature in January is -1 °C, rising to +26.4 °C in July. During the summer, temperatures can reach as high as +44 °C. Strong winds and storms are common, with minimal precipitation, with an average annual amount not exceeding 100-150 mm.

The Jetisu region is located in the southeast of Kazakhstan. The climate there is continental, with an average annual precipitation of 600-650 mm. The primary maximum rainfall occurs in April-May, with a secondary maximum in October-November.

Chemicals

All reagents used were of U.S.P. purity or higher. All solvents, including water, were used with the LC/MS label.

Instruments

pH meter: pH-150 MI (Measuring Technologies LLC, Russia).

Gas chromatograph: Shimadzu GC-2010 (Shimadzu Corporation, Japan).

Distiller for steam distillation: Velp Scientifical UDK 129 (Himlaborreaktiv LLC, Italy).

Mass spectrometer: Agilent 7900 (Agilent Technologies, Japan).

High-performance liquid chromatograph: LC-20 Prominence (Shimadzu Corporation, Japan).

Capillary electrophoresis system “KAPEL-205” (Lumex-Marketing LLC, Russia)

Laboratory Methods

The laboratory of Nutritest LLP in Almaty conducted analyses on camel milk samples. The following parameters were assessed: protein content **[7]**, fat content **[8]**, lactose **[9]**, titratable acidity **[10]**, active acidity **[11]**, amino acid composition **[12]**, fatty acid composition **[13]**, vitamins **[14]**, **[15]**, **[16]**, and minerals **[17]**. The vitamin content was determined partially, excluding some vitamin types.

To determine the fatty acid composition, camel milk samples were prepared according to SST 32915-2014: each milk sample was divided into two centrifuge tubes (50 cm^3 each), and then centrifuged at 10,000 rpm for 15 ±1 minutes. After centrifugation, the upper-fat fraction was collected and transferred to a 250 cm^3 glass container. Next, 150 cm^3 of hexane was added to the fat fraction, gently mixed, and homogenized for 3-5 minutes. The hexane layer containing the dissolved fat was separated and transferred to a 250 cm^3 round-bottomed flask. The flask was connected to a rotary evaporator and the solvent was completely distilled off at a temperature of 70 ±2 °C. Methyl ether was added to the resulting fatty fraction, and 1 µl of a solution of fatty acid methyl esters was injected into a Shimadzu GC-2010 Plus gas chromatograph with a flame ionization detector. An Agilent HP-88 capillary column with dimensions of 100 m × 0.250 mm × 0.20 µm was used. The detector was supplied with gas from a gas flow regulator with the following gases: nitrogen, hydrogen, and air; the maximum detector temperature was set to 260 °C. The temperature parameters were as follows: 100 °C for 5 minutes, increased to 210 °C for 8 minutes at a speed of 4 °C/min, and further increased to 240 °C for 25 minutes at a speed of 10 °C/min. The sample flow division was 1/40, and the total analysis time was 48.25 minutes.

The amino acid composition was determined by capillary electrophoresis (CEP), which involves preliminary acid and alkaline (only for tryptophan) hydrolysis to convert amino acids into free forms, obtaining phenylisothiocarbamyl derivatives and their subsequent separation and quantitative determination by capillary electrophoresis. Tryptophan was an exception, as its determination utilized direct detection on Kapel-205 equipment in the UV spectral region at a wavelength of 254 nm, using a quartz capillary with an internal diameter of 50 µm and a total length of 75 cm, with a sample volume of 2.5 cm^3.

Description of the Experiment

Sample preparation: Milk samples are collected from dromedary camels by the sample preparation process at farms in designated regions. This collection process typically involves using specialized containers to minimize potential contamination and maintain the sample's integrity. Subsequently, the milk samples must be transported to the laboratory carefully for further analysis.

Number of samples analyzed: we analyzed 24 samples.

Number of repeated analyses: 3

Number of experiment replication: 3

Design of the experiment: During the initial phase of the experiment, samples of fresh whole camel milk were collected from dromedary camels at farms in the Jetisu region (six samples each from summer and winter) and the Mangystou region (six samples each from summer and winter). Following the milking process, the temperature and pH of the camel milk were promptly measured using an electronic thermometer and a pH meter. Each camel milk sample (approximately 500 ml) was carefully collected into clean, sterilised bottles. The samples were refrigerated at 4 °C (<24 h) and transported for further laboratory analysis.

For the analysis, the physicochemical parameters, amino acid and fatty acid composition, and vitamin and mineral content were taken and investigated at the local accredited laboratory (Nutritest LLP).

In the final stage, we analyzed the obtained results, conducted statistical analysis, and verified the validity of our hypotheses.

Figure 2 Map of Kazakhstan, indicates the locations of sampled Jetisu (Zhetysu) and Mangystau regions.

Statistical Analysis

The results of the experimental studies were processed using mathematical statistics. The experimental data was analysed using the Data Analysis in Microsoft Excel and Statistica. Each experiment was performed with a minimum of three to seven repetitions. The acquired results were subjected to standard processing methods and are presented as average values and standard errors of the mean (± SEM). Statistical results were assessed using the Student's t-test, with differences considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

Camel milk is a historically renowned source of nutrition, offering essential nutrients and possessing adaptive properties that enhance survival in challenging climatic conditions. This study aimed to identify the difference in several parameters of dromedary camel milk during the summer and winter seasons, which helps determine that the local camel housing conditions, nutritional habits, and local climate influence the composition and properties of the milk. The received results are illustrated in Table 1.

Table 1 The physicochemical composition of camel milk in the Jetisu and Mangystou regions during the summer and winter seasons.

Seasons	Protein, %	Fat, %	Lactose, %	Dry matter, %	Titratable acidity, °T	pH
Jetisu region						
summer	3.61 ±0.02	3.85 ±0.03	4.85 ±0.04	13.06 ±0.03	16.50 ±0.5	6.56 ±0.05
winter	3.70 ±0.03	4.64 ±0.05[a]	4.80 ±0.03	13.92 ±0.05[b]	16.30 ±0.3	6.47 ±0.02
Mangystou region						
summer	3.65 ±0.03	4.72 ±0.05	4.21 ±0.05	13.98 ±0.03	17.00 ±0.5[d]	6.30 ±0.05[e]
winter	3.81 ±0.05[a]	5.75 ±0.03[b]	4.28 ±0.03	14.66 ±0.04[c]	16.60 ±0.2	5.86 ±0.03

Note: [a, b, c, d, e] – means significantly differ from other season samples of the indicated region (p <0.05). All values are expressed as the mean of ±SD (Standard Deviation).

The above-presented results revealed the variability in the chemical composition of milk based on the region and time of year. These findings are consistent with previous studies Ishill et al. **[18]** and Dikhanbayeva et al. **[19]** on Kazakh camel milk, but surpass the data from a study on Egyptian dromedary camel milk **[20]**.

The fat and protein content increased from summer to winter. During winter, camel milk from the Mangystou region exhibited a higher protein content (3.81%) compared to the Jetisu region (3.70%). The same scenario was with the protein content, where Mangystou region (3.65%) was higher by 3.68% than Jetisu region (3.61%). The fat content, particularly in winter, was also higher in camel milk from the Mangystou region, reaching a maximum of 5.75%.

The fat content in camel milk from the Mangystou region rose from 4.72% in summer to 5.75% in winter, with protein content increasing from 3.65% to 3.81%. A similar trend was observed in camel milk from the Jetisu region.

In the Jetisu region, the lactose content in camel milk was approximately 4.85% in summer and 4.80% in winter, while in the Mangystou region, it was about 4.21% in summer and 4.28% in winter. Thus, the lactose content of camel milk demonstrates relative stability under different conditions, which may be crucial for understanding its nutritional value and relevance to consumers.

Our study confirms the variability in protein content of camel milk, as noted in the works of other authors. For example, the average protein content in camel milk from the Jetisu region ranged from 3.61% to 3.70% in different seasons, consistent with the findings **[21]**. However, it's worth noting that some studies, such as **[22]**, indicate a wider range of protein content, from 2.04% to 3.05%.

In one line, our study indicates camel milk's relatively low lactose content. Our data shows that the average lactose content ranges from 4.21% to 4.85% in different seasons and regions, comparable to other studies. For instance, **[23]** reported similar lactose content in Egyptian camel milk (4.86 g/100 g), and **[24]** and **[25]** also demonstrated low lactose levels in camel milk. Thus, the consistency of this parameter in camel milk across different geographical regions is confirmed, emphasizing its uniqueness among other types of milk.

A comparative analysis of dry substance content in camel milk during summer and winter in various regions of Kazakhstan revealed an increase in dry substance content in winter compared to summer. In the Jetisu region, the average dry matter content was 13.06% in summer and 13.92% in winter, while in the Mangystou region, these values were 13.98% and 14.66%, respectively. This indicates a more concentrated nature of camel milk in winter, likely due to the increased fat content.

During hot months, camels require more fluid due to high temperatures and intense evaporation. This can lead to milk production with higher water content, reducing the overall solids content.

The analysis of camel milk's chemical composition from different regions and seasons is valuable for understanding the variability in its quality characteristics based on the animals' environmental and living conditions. Our results show that camel milk produced in the Mangystou region generally has higher protein and fat content than milk from the Jetisu region.

Milk protein and fat content variations can be attributed to differences in housing conditions and animal diets across regions. The relatively high-fat content in camel milk from the Mangystou region, particularly in winter, may be due to the physiological characteristics of camels in this region. It is possible that they actively store fat reserves in winter to survive harsh climatic conditions.

Additionally, changes in lactose content between seasons may be associated with variations in the camels' diet and the composition of vegetation in their environment. Importantly, in the current investigation, camel milk samples from the Jetisu region exhibited higher lactose content than those from the Mangystou region. This difference may be attributed to the predominant desert conditions in the Mangystou region, where camels primarily graze on halophytic plants. These plants, consumed by camels in desert environments, fulfil their physiological salt requirements, reducing lactose content in camel milk **[26]**.

In both regions, milk's acidity and pH levels are consistently within the normal range. Samples of camel milk from the Jetisu and Mangystou regions consistently exhibited pH values ranging from 6.36 to 6.56, irrespective of the season. The low pH of camel milk could be attributed to its high Vitamin C content **[2]**. Additionally, milk pH may change depending on the animals' water availability and fodder quality **[27]**.

Titrated acidity (°T) in camel milk samples from these regions ranged from 16.30 to 17.00 °T, consistent with previous findings. These results align with the scientific work Cherifa et al. **[28]**.

According to **[22]**, camel milk's low pH value and high titratable acidity may be associated with its microbial flora, particularly lactic acid bacteria producing lactic acid under milking conditions at ambient temperatures.

The results underscore the significance of considering regional characteristics when analyzing and utilizing camel milk within the food industry. These findings confirm the importance of such considerations and offer potential insights for developing strategies to enhance milk quality through camel feeding and management.

Amino Acid Composition: Proteins, as high-molecular compounds composed of amino acids, play a crucial role in the body's functional activity. Amino acids serve both substrate and regulatory functions in protein biosynthesis, actively participate in energy processes, act as a source of physiologically active amines, and contribute to forming nucleic acids, lipids, and hormones **[29]**.

As highlighted by **[23]**, camel milk is notably rich in essential and non-essential amino acids, except for lysine, glycine, threonine, and valine.

Research indicates that camel milk contains higher levels of methionine, valine, phenylalanine, arginine, and leucine than cow's milk **[30]**.

The amino acid composition of camel milk from the regions above was examined to assess the biological value. The results are detailed in Table 2.

Table 2 Comparative analysis of the amino acid composition of camel milk.

Amino acids, g/100 g	Jetisu region	Mangystou region
Essential amino acids		
Valine	5.46 ±0.04	6.03 ±0.05[a]
Methionine	2.07 ±0.003	3.4 ±0.004[a]
Phenylalanine	4.28 ±0.05	4.64 ±0.05[a]
Isoleucine	4.96 ±0.02[b]	4.53 ±0.03
Leucine	8.17 ±0.06	9.00 ±0.05[a]
Lysine	7.19 ±0.05	7.56 ±0.06[a]
Threonine	4.77 ±0.04	4.67 ±0.04
Tryptophan	1.3 ±0.003	1.46 ±0.003
Nonessential amino acids		
Aspartic acid	7.01 ±0.06[b]	6.01 ±0.06
Glutamic acid	20.25 ±0.09[b]	19.2 ±0.06
Histidine	2.65 ±0.003	2.75 ±0.005
Arginine	4.55 ±0.03	5.08 ±0.04[a]
Serine	4.66 ±0.05[b]	2.82 ±0.02
Glycine	1.65 ±0.002	1.15 ±0.003
Alanine	3.02 ±0.03	3.23 ±0.05
Tyrosine	4.45 ±0.05	4.25 ±0.05
Cysteine	1.56 ±0.003	1.58 ±0.002
Proline	11.95 ±0.05	12.63 ±0.06[a]

Note: [a, b] – means significantly differ from other season samples of the indicated region (p <0.05). All values are expressed as the mean of ±SD (Standard Deviation).

The results of a comparative analysis of the amino acid composition (Table 2) indicate that both samples of camel milk contain all eight essential amino acids. In 100 g of camel milk protein from the Jetisu region, 38.20 g of essential and 61.74 g of non-essential amino acids were detected. Meanwhile, 41.29 g of essential and 58.70 g of non-essential amino acids were found in 100 g of camel milk protein from the Mangystau region.

The largest amounts of essential amino acids in both samples were leucine (8.17-9.00 g/100 g), lysine (7.19-7.56 g/100 g), and valine (5.46-6.03 g/100 g), while the tryptophan content was lower (1.30-1.46 g/100 g). The total amount of essential amino acids is higher in milk from the Mangystou region.

Regarding non-essential amino acids, both camel milk samples contain the largest amounts of aspartic acid (6.01-7.01 g/100 g), glutamic acid (19.20-20.25 g/100 g), and proline (11.95-12.63 g/100 g), while cysteine (1.56-1.58 g/100 g) and glycine (1.15-1.56 g/100 g) are present in smaller quantities. Previous studies on the amino acid composition of camel milk **[23]** also confirm that glutamic acid, proline, and aspartic acid are major components. At the same time, methionine and glycine are present in lesser quantities.

It is noted that camel milk from the Jetisu region has a higher total level of essential amino acids than camel milk from the Mangystou region.

The obtained data on the amino acid composition of camel milk from both regions (Table 2) are consistent with the authors' previous works. Thus, the study revealed similar general characteristics of the biological value of camel milk in both regions, with minor differences in the content of individual amino acids. These results underscore the importance of camel milk as a food product with high biological value, providing essential amino acids to support a healthy diet and supporting the potential for further research in the food industry.

Fatty Acid Composition: Camel milk, renowned for its high nutritional value, is a subject of interest for research in the food industry. The fatty acid composition of camel milk plays a crucial role in its biological value. It can vary depending on several factors, including the animals' location and feeding conditions. This study compared camel milk's fatty acid composition from two Kazakhstan regions: Jetisu and Mangystou.

Table 3 presents the quantitative composition of fatty acids in camel milk from both regions.

Table 3 Comparative Analysis of the Fatty Acid Composition in Camel Milk.

FA name	Fatty acid code	Fatty acid, %	
		Jetisu region	Mangystou region
Saturated FA			
Butyric acid	C4:0	-	-
Caproic acid	C6:0	0.145 ±0.003[a]	0.097 ±0.002
Caprylic acid	C8:0	0.228 ±0.002[a]	0.068 ±0.001
Capric acid	C10:0	0.259 ±0.004[a]	0.101 ±0.003
Lauric acid	C12:0	1.103 ±0.005[a]	0.820 ±0.002
Myristic acid	C14:0	9.484 ±0.006[a]	8.027 ±0.002
Pentadecylic acid	C15:0	1.009 ±0.002	1.678 ±0.004[b]
Palmitic acid	C16:0	32.461 ±0.004[a]	29.321 ±0.005
Margaric acid	C17:0	1.571 ±0.002	1.704 ±0.002[b]
Stearic acid	C18:0	16.540 ±0.005	18.866 ±0.003[b]
Arachidic acid	C20:0	0.452 ±0.002	0.540 ±0.001[b]
Behenic acid	C22:0	0.551 ±0.006[a]	0.494 ±0.003
Lignoceric acid	C24:0	0.488 ±0.002[a]	0.419 ±0.002
Monounsaturated FA			
Myristoleic acid	C14:1	0.484 ±0.003[a]	0.442 ±0.004
Pentadecylic acid	C15:1	0.200 ±0.002	0.380 ±0.005[b]
Palmitoleic acid	C16:1	6.836 ±0.004	6.606 ±0.003
Heptadecanoic acid	C17:1	0.453 ±0.003	0.774 ±0.006[b]
Oleic acid	C18:1 (ω-9)	18.558 ±0.005	23.684 ±0.005[b]
Polyunsaturated FA			
Linolenic acid	C18:2n6t	0.528 ±0.004	1.070 ±0.008[b]
Linoleic acid	C18:2n6c	4.357 ±0.005[a]	2.905 ±0.005
γ -Linolenic acid	C18:3n6	3.223 ±0.002[a]	1.194 ±0.006
Eicosadienoic acid	C20:2	0.422 ±0.005	0.414 ±0.002
Arachidonic acid	C20:4n6	0.313 ±0.002[a]	-
Eicosapentaenoic acid	C20:5n3	0.337 ±0.001	0.366 ±0.004
Saturated FA		64.291 ±0.043	62.135 ±0.032
Monounsaturated FA		26.531 ±0.017	31.886 ±0.023
Polyunsaturated FA		9.18 ±0.019	5.494 ±0.025

Note: [a, b] – means significantly differ from other season samples of the indicated region (p <0.05). All values are expressed as the mean of ±SD (Standard Deviation).

The data obtained revealed a significant disparity in saturated and unsaturated fatty acid concentrations between two distinct regions of Kazakhstan.

In the fat extracted from camel milk samples in the Jetisu region, 23 fatty acids were identified. In comparison, 22 types were discerned in the camel milk sample from the Mangystou region. Generally, the Jetisu region sample exhibited higher levels of saturated and polyunsaturated fatty acids, whereas the Mangystou camel milk sample displayed elevated monounsaturated fatty acids. Predominantly, saturated fatty acids constituted the major proportion in both samples, accounting for 62.135% to 64.291% of the total fatty acids. These data are consistent with the results of the researchers' work Konuspayeva et al. **[31]** and Teng et al. **[32]**.

Specifically, the concentration of saturated fatty acids in the Jetisu region's camel milk sample was 64.291%, while in the Mangystou region, it amounted to 62.135% of the overall fatty acid composition.

In both samples, the predominant saturated fatty acids were myristic (C14:0), palmitic (C16:0), and stearic (C18:0). The obtained data are similar to previous data for Turkish camel milk **[33]**.

The camel milk samples from the Jetisu region exhibited higher concentrations of capron ($C_{6:0}$), caprylic ($C_{8:0}$), caprine ($C_{10:0}$), lauric ($C_{12:0}$), myristic ($C_{14:0}$), palmitic ($C_{16:0}$), lignoceric ($C_{20:0}$), and behenic acids ($C_{22:0}$) compared to the samples from the Mangystou region. Conversely, camel milk samples from the Mangystou region demonstrated elevated levels of arachidic, stearic, margaric, and pentadecanoic acids.

Notably, neither of the samples contained butyric acid ($C_{4:0}$). These data are similar to those from previous scientists Dreiucker and Vetter **[34]**.

The most significant intergroup difference was observed in the concentrations of specific saturated fatty acids. For instance, the palmitic acid content ($C_{16:0}$) in the camel milk sample from the Jetisu region was 3.14% higher than that in the Mangystou region. In contrast, the stearic acid content ($C_{18:0}$) in the Jetisu camel milk sample was 2.33% lower than in the Mangystou region's camel milk sample.

As per Table 2, the mean content of monounsaturated fatty acids in both samples was 26.531% to 31.886%. Notably, camel milk from the Mangystou region stands out for its richness in monounsaturated fatty acids, constituting 31.886% of the total sum of all fatty acids. Oleic acid (C18:1) emerged as the predominant acid, comprising 23.684%.

In contemporary perspectives, considerable emphasis is placed not only on the quantity but also on the chemical composition of fats, with a particular focus on the content of polyunsaturated acids. This attention stems from the fact that the human body cannot synthesize linoleic and linolenic acids, and the biosynthesis of arachidonic acid is limited, categorizing them as essential or irreplaceable.

It is noteworthy that polyunsaturated fatty acids play a crucial role in eliminating excess cholesterol from the body, impeding its deposition on the walls of blood vessels and safeguarding the body against the development of atherosclerosis.

The findings of our study revealed distinct lipid profiles in camel milk between the Mangystou and Jetisu regions, with a notable difference in polyunsaturated fatty acid content. Specifically, the lipids in camel milk from the Mangystou region exhibited a concentration of -5.494%, while in the Jetisu region, the content was 9.18%. Among the Jetisu region's camel milk, the highest concentration of polyunsaturated fatty acids was observed at 9.18%, prominently featuring linoleic (4.36%) and γ-linolenic (3.22%) acids. Additionally, arachidonic acid (0.33%) was identified in camel milk samples from the Jetisu region, aligning with the findings in the prior work of Teng et al. **[32]**.

In conclusion, the analysis of the fatty acid composition of camel milk from both the Jetisu and Mangystou regions indicated the prevalence of specific fatty acids in both samples. $C_{14:0}$, $C_{16:0}$, $C_{18:0}$, $C_{16:1}$, and $C_{18:1n9c}$ were identified as the most abundant fatty acids in both samples. These findings are consistent with Kazakh scientists studying Bactrian camel milk **[35]**.

Mineral Substances: According to a review of publications on camel milk, the overall mineral content, as measured by total ash content, varied between 0.60% and 1.30%, with an average value of 0.80% **[36]**.

Figure 1 illustrates the outcomes of a comparative analysis of mineral content in camel milk samples collected from the Jetisu and Mangystou regions.

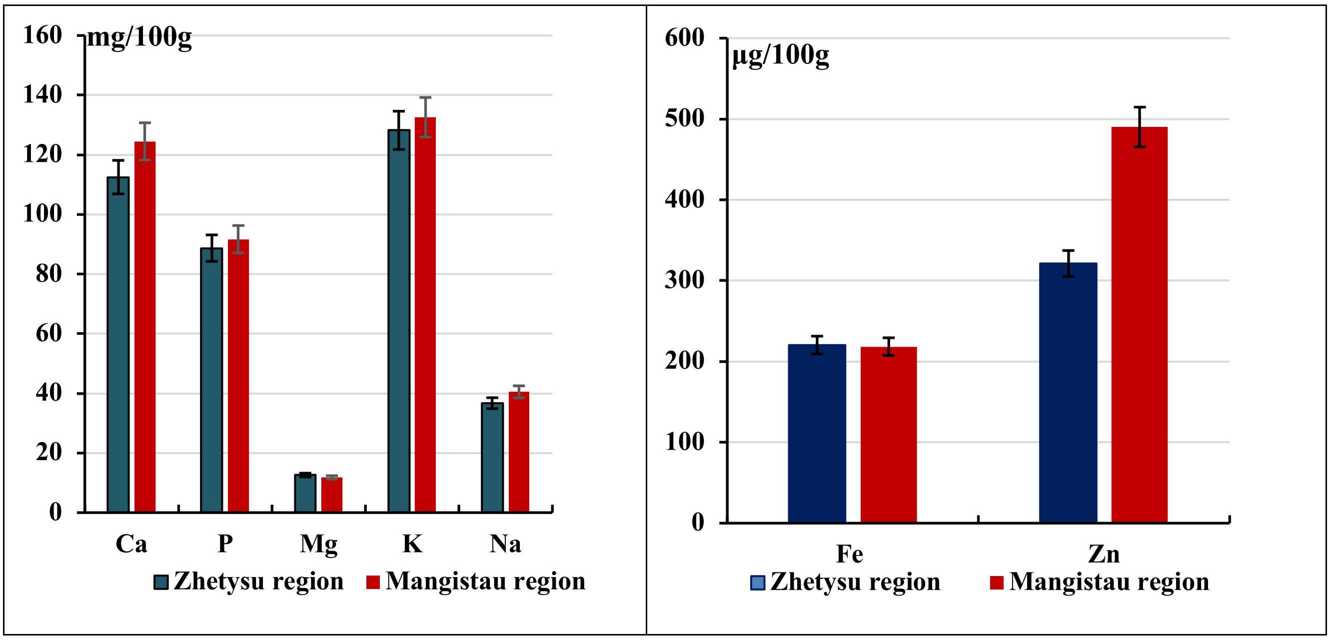

Figure 3 Composition of Macro- (A) and Microelements (B) in Camel Milk.

The results of the analysis of macro- and microelements in camel milk (Figure 3) indicate that, in general, no significant differences were observed between the regions in terms of mineral content, except for calcium (Ca) and zinc (Zn).

The calcium and zinc content in camel milk samples from the Mangystou region was notably higher than those from the Jetisu region. Specifically, the calcium content in the camel milk samples from the Jetisu region was 112.50 mg/100 g, while in the samples from the Mangystou region, it was 124.50 mg/100 g. On average, these values are consistent with the findings of the scholars of Dikhanbayeva et al. **[19]**. Notably, the elevated calcium levels in camel milk from the Mangystou region may be attributed to the conditions in which the camels are kept. According to Mostafidi et al. **[37]**, camels living in desert conditions tend to have higher calcium content in their milk than those in nourishing conditions.

The phosphorus content in milk is influenced by factors such as the animals' feeding diet, breed, and stage of lactation. Our study found no significant differences in phosphorus content between the two samples, with an average phosphorus content of 90.10 mg/100 g, which is practically comparable to the findings of the study Al-Otaibi and el-Demerdash **[38]**.

Magnesium is present in milk in modest quantities and is crucial in maintaining the normal function of the nervous system and heart muscles. It also exhibits a vasodilating effect, stimulates bile secretion, and enhances intestinal motor activity, facilitating the removal of toxins from the body. On average, the magnesium (Mg) content in both camel milk samples was 12.20 mg/100 g. Our results are similar to those reported by researchers The phosphorus content in milk is influenced by factors such as the animals' feeding diet, breed, and stage of lactation. Our study found no significant differences in phosphorus content between the two samples, with an average phosphorus content of 90.10 mg/100 g, which is practically comparable to the findings of the study Al-Otaibi and el-Demerdash **[38]**. Still, they exceed the data presented by author Soliman **[39]**.

The average potassium content in both camel milk samples was 130.40 mg/100 g. These findings align with those of studies The phosphorus content in milk is influenced by factors such as the animals' feeding diet, breed, and stage of lactation. Our study found no significant differences in phosphorus content between the two samples, with an average phosphorus content of 90.10 mg/100 g, which is practically comparable to the findings of study Al-Otaibi and el-Demerdash **[38]** and Dikhanbayeva et al. **[19]**, but are lower than the results reported by the Soliman **[39]**.

The average sodium content in both camel milk samples was 38.60 mg/100 g. Our data show lower sodium levels compared to previous studies by authors Al-Otaibi and el-Demerdash **[38]** and Shamsia **[23]**, but are consistent with the findings of Kazakh scientists Dikhanbayeva et al. **[19]**.

Iron, an essential trace element in milk, is noteworthy for its significance. Khaskheli et al. **[40]** emphasize that camel milk is notably richer in iron than cow's milk. Our study revealed an average iron content of 219 µg/100g in both samples, comparable to the data reported by researcher Soliman **[39]**.

In the Mangystou region, the zinc content in camel milk samples was 490.15 µg/100 g, which is 34.40% higher than in camel milk samples from the Jetisu region. The Mangystou region is an industrial and mining area responsible for 25% of Kazakhstan's oil production (almost 20 million tons). In line with the findings of scientific research by Meldebekova et al. **[41]**, it is plausible that emissions from these industries have influenced the increase in zinc content in camel milk in the Mangystau region.

Vitamins: Vitamins are integral to camel milk, encompassing both water-soluble and fat-soluble varieties **[42]**. Table 4 presents a comparative examination of vitamin content in camel milk samples from the Jetisu and Mangystou regions.

Table 4 Comparative Analysis of the Vitamin Composition of Camel Milk.

Vitamins, mg/100 g	Jetisu region	Mangystou region
A	0.063 ±0.005	0.074 ±0.003
B1	0.077 ±0.002	0.069 ±0.003
C	5.37 ±0.25	6.41 ±0.30^{b}

Note: a, b - means significantly differ from other season samples of the indicated region (*p<0.05*). All values are expressed as the mean of ±SD (Standard Deviation).

According to the results in Table 4, no discernible differences were observed between the regions regarding vitamin A content. Specifically, in camel milk samples from the Jetisu region, vitamin A was found to be 0.063 mg/100 g. In contrast, in samples from the Mangystou region, it measured 0.074 mg/100 g, respectively. Our findings surpass previous studies, such as Konuspayeva et al. **[31]**, who reported vitamin A content in camel milk as 12.60 µg/100 ml, and Haddadin et al. **[42]** where vitamin A content was noted as 201 µg/l. Nevertheless, our data align with the findings of Jordanian scientists **[43]**.

The vitamin B1 content in Jetisu camel milk samples measured 0.077 mg/100g, and in Mangystou samples, it was 0.069 mg/100 g, respectively. These results were lower than Kazakh scientists' findings Dikhanbayeva et al. **[19]** for Kazakh camel milk. Wang et al. **[44]** also noted that the vitamin B1 content in camel milk was lower compared to that in cow's milk.

Regarding vitamin C, Jetisu camel milk samples showed a content of 5.37 mg/100 g, while Mangystou samples registered 6.41 mg/100 g. These findings were lower than those reported by Kazakh scientists Konuspayeva et al. **[45]**, but are consistent with the results presented by the authors of Stahl et al. **[46]**. On average, the vitamin C content in Mangystou camel milk is 16.20 % higher than that in Jetisu camel milk. This disparity is likely attributed to feeding conditions, as animals predominantly acquire vitamins through their diet. Additionally, factors such as age, time of year, lactation period, and the microflora of camel rumen and intestines may contribute to these variations. Notably, the high vitamin C content in Mangystou camel milk is crucial given the predominantly desert conditions in this region, where fruits and vegetables are scarce.

CONCLUSION

Based on the above results, the following conclusions can be drawn:

1. Comparative analysis showed subtle differences in the biochemical composition of camel milk samples obtained from the Jetisu and Mangystou regions;
2. Camel milk samples from the Mangisatu region contained more protein and fat compared to camel milk samples from the Jetisu region their content was 3.65-3.81% and 4.72-5.75%;
3. Regarding amino acid composition, camel milk samples from the Jetisu region had more essential amino acids per 100 g of protein than camel milk samples from the Jetisu region: 41.29 g versus 38.20 g, respectively;
4. A study of fatty acid composition showed that camel milk samples from the Jetisu region contained 64.291% saturated fatty acids, 26.531% monounsaturated fatty acids, and 9.18% polyunsaturated fatty acids, while camel milk samples from the Mangystou region had 62.135% saturated fatty acids, 31.886 % monounsaturated fatty acids, and 5.494% polyunsaturated fatty acids, respectively;
5. Mineral composition, including calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), iron (Fe), and zinc (Zn) content. The results of the analysis showed the following values for the content of mineral elements in 100 g of camel milk: calcium (Ca): 112.50 mg in the Jetisu region and 124.5 mg in the Mangystou region; phosphorus (P): 88.70 mg in Jetisu region and 91.70 mg in Mangystou region; magnesium (Mg): 12.60 mg in Jetisu region and 11.80 mg in Mangystou region; potassium (K): 128.2 mg in Jetisu region and 132.6 mg in Mangystou region; sodium (Na): 36.70 mg in Jetisu region and 40.50 mg in Mangystou region; iron (Fe): 220.32 µg in the Jetisu region and 321.24 µg in the Mangystou region; zinc (Zn): 218.42 mcg in Jetisu region and 490.15 mcg in Mangystou region. Camel milk from the Mangystou region has a higher content of calcium, phosphorus, magnesium, potassium, sodium, iron and zinc compared to samples from the Jetisu region;
6. Analyzing the vitamin composition of camel milk from the above-mentioned regions, we can conclude that camel milk samples from the Mangystau region are a rich source of vitamin C, its content was 6.41 mg/100.

These findings represent a valuable contribution to the limited body of information on camel milk's nutritional and biological value from the western and southern regions of Kazakhstan, particularly the Jetisu and Mangystou regions. Given that camel milk serves as a staple food in these areas, its unique chemical composition and nutritional and biological values can be advantageous. This distinctive profile not only enhances the potential of dairy producers but also provides the opportunity to produce healthy and high-quality dairy products in Kazakhstan.

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