

COMPARATIVE STUDY OF THE PHYSICOCHEMICAL PROPERTIES OF CISTERNAL, ALVEOLAR, AND RESIDUAL MILK OF DROMEDARY CAMELS FROM SOUTH KAZAKHSTAN REGION

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Annotation. Understanding the physicochemical characteristics of cisternal, alveolar, and residual milk is essential for optimizing milking management, improving milk quality evaluation, and monitoring udder health in agricultural animals. This knowledge contributes to more efficient milk production and better utilization of dairy resources. In Kazakhstan, the use of machine milking for camels is still insufficiently developed. Therefore, studying the physicochemical characteristics of these types of milk of dromedary Camels has great importance for improving milking practices, evaluating milk quality, and ensuring better utilization of camel dairy resources.

The present study investigated the composition of cisternal (C), alveolar (A) and residual (R) milk of one humped n -14 camels (*Camelus dromedarius*) in 150±15 days after calving from South Kazakhstan. The camels were injected with Atosiban (CAS 90779-69-4) at a dose of 10 µg/kg of body weight and 4 ml of oxytocin (RK-LS-5№022381) per animal, after which the camels were milked by hand. The data on individual milk yield were recorded immediately after milking, then which milk samples were then collected and analyzed for composition in containers with cooling agents. Cisternal, alveolar and residual milk volumes and compositions as protein, dry matter, solid non-fat, fat, density and pH, somatic cells were evaluated within 1-3 hours after milking. On average, the proportion of cisternal milk was 2.77%, alveolar was 91.18% and residual milk 6.05% of total milk yield in dromedary Camels. The fat contents (%) of C, A and R for dromedary camels were 1,94; 4,15 and 5,96 respectively while the pH was between 6.1 and 6.2 for all types of milk. The protein (%) of C, A, R in dromedary camels was 3,15; 3,11 and 3,05 respectively.

Key words: Camel milk, Cisternal milk, Alveolar milk, Residual milk, fat, protein.

Introduction. Camel farming in Kazakhstan has been developing steadily in recent years. According to national statistics, there are 246,375 camels across all types of farms [1], this population growing regularly for the last 20 years [2,3]. The majority of the camel population - about 82% is concentrated in the Mangystau, Atyrau, Kyzylorda, and Turkistan regions, which are traditionally known for camel breeding [Figure 1]. More than 200 specialized camel farms are engaged in milk production. Official reports indicate that by January 1, 2020, the number of

pedigree camels reached 16.8 thousand heads, consisting of 6.7 thousand Kazakh Bactrians and 10.1 thousand Arvana camels. Importantly, the production of camel milk has shown positive dynamics: by the end of the last reporting year, it increased by 9.9%. These data highlight both the growing economic potential of camel farming and the rising importance of camel milk as a valuable product in Kazakhstan’s dairy sector in response to the growing demand for products such as *shubat* and powdered camel milk.

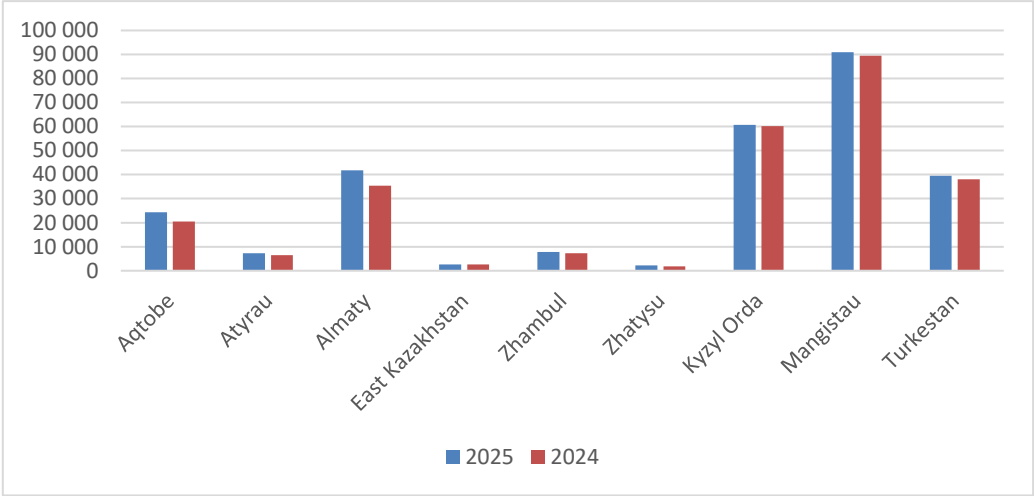


Figure 1 – Population of Camels in Kazakhstan by main regions

However, despite Kazakhstan’s large camel population and growing interest in camel dairy products, the actual production volumes remain very low compared to cow milk. While cow milk output exceeds 3.5 million tons annually, camel milk contributes only an estimated 15–18 thousand tons, with officially registered *shubat* production accounting for about 3,000 tons. This indicates limited productivity in the camel dairy sector [Table 1].

Table 1 – Production of animal food

Species (product)	Estimated production (latest year)	Unit / year	Source / note
Cow (raw milk, all categories)	3,500,000	tons (2024, raw cow milk)	Official reporting / industry summaries: cow milk production 3.5 million t in 2024. (DairyNews)
Camel (raw milk, estimate)	15,000 – 18,000	tons/year (estimate, recent years)	National estimates and press reports give ~15k–18k t/yr (raw camel milk); official statistics for raw camel milk are limited and fragmentary — many sources report volumes for processed <i>shubat</i> instead. (PMC)
Camel — <i>shubat</i> (fermented camel milk, processed)	3,000	tons (2023–2024, processed <i>shubat</i>)	Processed <i>shubat</i> (industrial/registered production) reported 3,003 t (recent year report). This is processed product, not total raw camel milk. (qazinform.com)

One of the reasons is the underdevelopment of the camel dairy sector is the low use of mechanized milking technologies: most camel herds are still milked by hand, which constrains both efficiency and milk quality although the first implementation worldwide of machine milking in camel was achieved at Soviet time [4].

Addressing this technological gap is essential to unlock the full potential of camel farming in Kazakhstan, this highlights the need for further investment in infrastructure, selective breeding programs, and modern milking technologies. One important constraint in camel milking, especially

with hand milking, is the insufficient extraction of the milk in the udder. In all dairy animals, the milk in the udder is shared in 3 parts: cisternal (milk in the cistern of the udder), alveolar (milk into the mammary acinis) and residual (milk extracted by overpressure at the end of milking). The relative proportions of cisternal, alveolar and residual milk depend on species, stage of lactation, and milking interval. For example, in sheep after 12 h of milk accumulation, only about 38–47% of the total yield was stored in the cistern, while after 24 h the cisternal fraction increased to The partitioning of milk into cisternal and alveolar fractions, as well as the concept of residual milk, has significant implications for both dairy management and animal health. Understanding these compartments is crucial because the efficiency of milk removal directly affects total yield, milk composition, and the susceptibility of the udder to disorders such as mastitis [16]. Despite this importance, studies in this area remain relatively scarce, especially in developing dairy systems and in non-bovine species.

In dairy cattle, much of the foundational work on cisternal versus alveolar milk dynamics was conducted in Europe and New Zealand [17]. These studies demonstrated that the alveolar compartment fills more rapidly than the cisternal, and that fat content is consistently higher in alveolar milk compared to cisternal fractions. In sheep, research carried out in the United States [18] confirmed similar patterns, with a significant increase in cisternal storage as the milking interval lengthens. Goats have also been studied, mainly in Mediterranean countries such as Spain, Italy, and Greece, where cisternal storage capacity was found to be relatively larger than in sheep, which has practical consequences for machine milking efficiency [19, 20].

By contrast, there are few published studies on camels, although camel dairy production is expanding in Central Asia, the Middle East, and Africa. The unique mammary anatomy of camels suggests differences in alveolar–cisternal partitioning compared to ruminants like cows or sheep, yet systematic experimental data are largely missing [21]. Similarly, studies on buffaloes are limited, with most research originating from South Asia, particularly India and Pakistan [22]. For equines, such as mares, some investigations have reported a relatively small cisternal storage fraction, but the body of literature remains fragmented and geographically restricted [23].

Residual milk represents another critical but underexplored component. High residual volumes not only reduce effective milk yield but also create a microenvironment favorable for bacterial growth, potentially increasing mastitis risk [16]. Improving let-down efficiency and milking practices is therefore essential, particularly in regions where hand-milking still dominates and oxytocin stimulation is not routinely managed.

Overall, while research on cisternal and alveolar milk partitioning has advanced our understanding in dairy cows, sheep, and goats, there is a clear geographical gap in the literature. Very little work has been conducted in Central Asia, Africa, or Latin America, and non-bovine dairy species such as camels, buffaloes, horses, and yaks remain underrepresented. Expanding research in these regions and species is vital for optimizing dairy production, ensuring milk quality, and safeguarding udder health. Thus, the objective of the present paper was to assess the volume and composition of cisternal, alveolar, and residual milk fractions to support the modernization of milking practices and enhance camel dairy productivity. Such distribution of the milk in camel udder was never investigated in Arvana dromedary breed. Thus, the objective of the present paper was to assess the volume and composition of cisternal, alveolar, and residual milk fractions to support the modernization of milking practices and enhance camel dairy productivity

Material and research methods. For the experiment, 14 one-humped camels (*Camelus dromedarius*), Aravan breed (approximately body weight 500 ± 50 kg; 5–13 years old; parities 1 to 7), were used at 150 ± 15 days after calving in private farms from South Kazakhstan ($43^{\circ}45'54''$ N, $69^{\circ}10'53''$ E). The camels were injected with Atosiban (CAS 90779-69-4), a beta-blocking molecule of the oxytocin, at a dose of $10 \mu\text{g/kg}$ of body weight to extract the residual milk only (which can be extracted passively), then injected with 4 ml of oxytocin (RK-LS-5№022381) to extract the alveolar milk. At the end of this step, hand stimulation was achieved to extract the residual part of the milk [Figure 2].

Morphometric measurements of the udder (length from front to back) and teats (length of

left front teats) were taken before milking. The parameters as pH, protein, DM, SNF, fat and density were determined with Lactan and somatic cells in Somatos Mini (OOO VPK Sibagropribor).

Results and discussion. The length of the left front teat varied from 2.0 to 3.0 cm, while the udder length (front to back) ranged from 23 to 30 cm. In most cases, the front part of the udder was smaller than the back part, although equal or larger proportions were also occasionally observed.

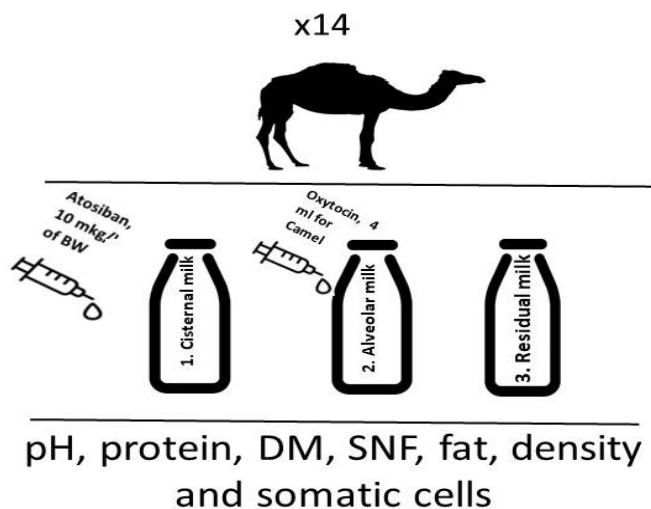


Figure 2 – Main design of experiment

These findings indicate variability in udder conformation among dromedaries, which is an important factor for improving milking practices and potential machine-milking adaptation [5].

Distribution of the milk fractions. The highest proportion of milk in Arvana dromedary camel was alveolar milk (91.18 ± 4.39 %) followed by residual milk (6.05 ± 4.77 %). The alveolar milk, the easiest part to milk was 2.77 ± 1.59 % only. The alveolar milk fraction appeared lower than in dromedary camel from Saudi Arabia [5] which was around 9%, but comparable to the results obtained in Maghrebi camels from Tunisia [6] with mean value of 3.44%.

Composition of the milk fractions. The fat content of dromedary milk fractions (cisternal, alveolar, and residual) showed clear variation. Cisternal milk exhibited the lowest fat concentration, ranging from 0.65% to 3.54%, with an average of 1.94 ± 0.81 %. Alveolar milk contained intermediate values, between 2.27% and 6.03%, averaging 4.15 ± 1.08 %. Residual milk consistently demonstrated the highest fat levels, varying from 4.04% to 8.15%, with a mean of 5.96 ± 1.11 % (Figure 3). These results confirm that the majority of milk fat is retained in the alveolar and residual compartments. Therefore, efficient stimulation and complete milk let-down are essential to maximize fat yield and ensure accurate evaluation of dromedary milk composition [7].

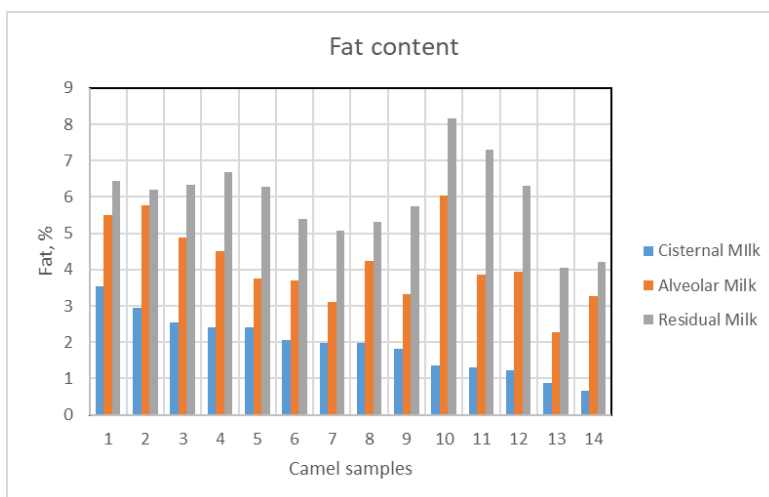


Figure 3 – Difference of fat content of C, A, R milk of Arvana dromedary camels (The samples were ordered according to the ascending fat content in cisternal milk)

The analysis of protein content in dromedary milk fractions (cisternal, alveolar, and residual) revealed relatively stable values across all compartments. Cisternal milk protein ranged from 2.76% to 3.72%, with an overall mean of approximately 3.14%. Alveolar milk showed similar levels, varying between 2.81% and 3.38%, with a mean of about 3.12%. Residual milk protein content was also consistent, ranging from 2.75% to 3.34%, averaging 3.08% (Figure 4). Unlike fat distribution, which is highly variable between fractions, the protein concentration demonstrated minimal differences across compartments. This indicates that protein in dromedary milk is more evenly distributed among cisternal, alveolar, and residual fractions, suggesting that incomplete milk let-down is less critical for protein yield compared to fat recovery.

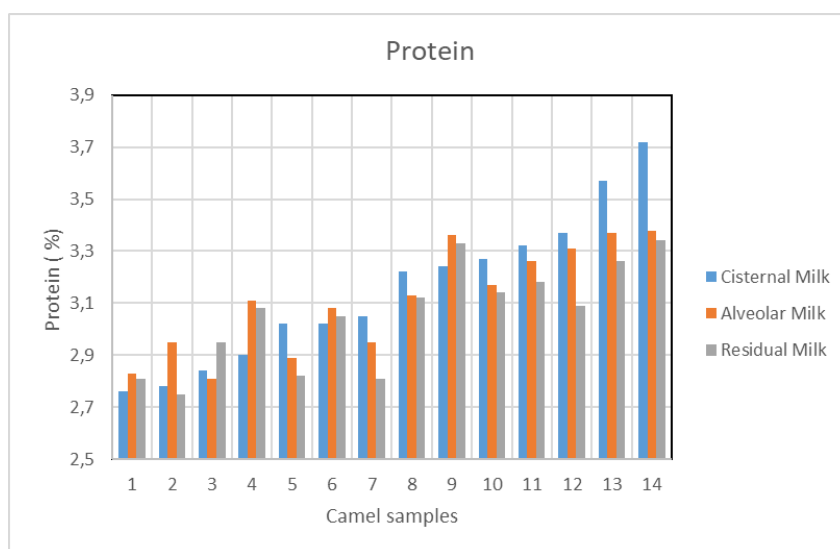


Figure 4 – Difference of protein content of C, A, R milk of Arvana dromedary camels (The samples were ordered according to the ascending fat content in cisternal milk)

Regarding the pH, an overall stability appeared across samples. The pH was remarkably consistent, remaining between 6.1 and 6.2 in all fractions, indicating normal milk acidity. Dry matter (DM) values ranged from 8.63% to 19.84%, with higher concentrations generally observed in residual milk compared to cisternal and alveolar fractions due to the highest proportion of fat. Similarly, solids-not-fat (SNF) varied between 7.51% and 10.41%, showing moderate stability across compartments. Milk density ranged from 1022.9 to 1036.7 kg/m³, with slightly higher values in cisternal milk, reflecting its lower fat content, while residual milk tended to show higher densities due to higher fat concentration. Somatic cell counts (SCC) were generally low, mostly $\leq 268 \times 10^3/\text{mL}$, although a few samples reached values above $300 \times 10^3/\text{mL}$. These results suggest that, apart from expected variation in solids and density linked to fat content, dromedary milk fractions are relatively homogeneous in their pH, SNF, and SCC, confirming their good hygienic quality and physiological stability.

Comparison with literature. The comparative evaluation of cisternal and alveolar milk fractions among different dairy species revealed pronounced interspecies variations in both fat and protein contents. In cows, the proportion of fat was consistently higher in the alveolar fraction than in the cisternal fraction across different studies [9,10]. This observation is in line with previous reports suggesting that milk fat globules are predominantly secreted and stored in the alveolar compartment, while cisternal milk is more diluted due to its proximity to the teat cistern. Similarly, buffalo milk exhibited significantly higher fat and protein levels in the alveolar fraction [11], further supporting the role of alveolar milk as the main reservoir of nutritive components. Small ruminants, including dairy ewes of the Manchega breed and Najdi sheep, demonstrated a comparable trend,

with alveolar milk enriched in both fat and protein [12,13]. These findings highlight the universal physiological mechanism of milk storage and composition in ruminants, though the magnitude of differences appears species-specific. For example, Najdi sheep showed a particularly pronounced increase in fat concentration from cisternal to alveolar fractions, indicating strong partitioning of energy-rich components into alveolar milk. Camels showed moderate differences between cisternal and alveolar fractions, with both fat and protein being only slightly elevated in alveolar milk [14]. Interestingly, in dromedary camel, the fat content in alveolar milk was higher than in cisternal milk, while protein differences were minimal. This suggests that, unlike in cows or buffalo, camel milk exhibits a more homogeneous distribution of proteins between cisternal and alveolar compartments. Such characteristics may be linked to species-specific mammary gland anatomy and milk ejection physiology, where camels demonstrate slower milk let-down and a higher dependency on oxytocin release during milking [15]. Taken together, these results confirm that alveolar milk generally represents the nutritionally richer fraction across domestic dairy species, particularly in terms of fat content. However, the magnitude of compositional differences is strongly dependent on species and breed.

Conclusion. From a practical perspective, these findings underline the importance of complete alveolar milk extraction in order to obtain representative milk samples for nutritional evaluation and to ensure accurate estimation of milk yield and quality, especially in camels where incomplete milking may lead to underestimation of fat content.

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СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ ФИЗИКО-ХИМИЧЕСКИХ СВОЙСТВ ЦИСТЕРНАЛЬНОГО, АЛЬВЕОЛЯРНОГО И ОСТАТОЧНОГО МОЛОКА ОДНОГОРБЫХ ВЕРБЛЮДОВ ЮЖНОГО КАЗАХСТАНА

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Аннотация. Изучение физико-химических характеристик цистернального, альвеолярного и остаточного молока имеет важное значение для оптимизации управления доением, улучшения оценки качества молока и контроля здоровья вымени у сельскохозяйственных животных. Эти знания способствуют повышению эффективности производства молока и рациональному использованию молочных ресурсов. В Казахстане машинное доение верблюдов остаётся недостаточно развитым. Поэтому исследование физико-химических характеристик указанных фракций молока у одnogорбых верблюдов имеет большое значение для совершенствования практики доения, оценки качества молока и более рационального использования верблюжьего молока.

В данной работе изучен состав цистернального (С), альвеолярного (А) и остаточного (R) молока у 14 одnogорбых верблюдов (*Camelus dromedarius*) на 150 ± 15-й день после отёла в Южном Казахстане. Животным вводили Атозибан (CAS 90779-69-4) в дозе 10 мкг/кг живой массы и 4 мл окситоцина (RK-LS-5№022381), после чего доили вручную. Данные об индивидуальном удое фиксировались сразу после доения, а пробы молока собирались в контейнеры с охлаждающими элементами для последующего анализа. Объём и состав цистернального, альвеолярного и остаточного молока (белок, сухое вещество, обезжиренный остаток, жир, плотность, pH, соматические клетки) определялись в интервале 1–3 часов после доения. В среднем доля цистернального молока составила 2,77%, альвеолярного — 91,18%, остаточного — 6,05% от общего удоя. Содержание жира (%) в С, А и R составило соответственно 1,94; 4,15 и 5,96, при этом pH находился в диапазоне 6,1–6,2 для всех типов молока. Содержание белка (%) в С, А и R составило 3,15; 3,11 и 3,05 соответственно.

Ключевые слова: Верблюжье молоко, цистернальное молоко, альвеолярное молоко, остаточное молоко, жир, белок.

ОНТУСТІК ҚАЗАҚСТАН ӨНІРІНДЕГІ ЖАЛҒЫЗ ӨРКЕШТІ ТҮЙЕЛЕРДІҢ ЦИСТЕРНАЛЫҚ, АЛЬВЕОЛЯРЛЫҚ ЖӘНЕ ҚАЛДЫҚ СҮТІНІҢ ФИЗИКА-ХИМИЯЛЫҚ ҚАСИЕТТЕРІНІҢ САЛЫСТЫРМАЛЫ ЗЕРТТЕУІ

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Аңдатпа. Цистерналық, альвеолярлық және қалдық сүттің физика-химиялық қасиеттерін зерттеу сауу үдерісін оңтайландыру, сүт сапасын бағалау және малдың желін саулығын бақылау маңызды. Мұндай мәліметтер сүт өндірісінің тиімділігін арттырып, сүт ресурстарын ұтымды пайдалануға ықпал етеді. Қазақстанда түйелерді машинамен сауу әлі жеткілікті дамымаған. Сондықтан бір өркешті түйелердің сүт фракцияларының физика-химиялық қасиеттерін зерттеу сауу тәжірибесін жетілдіруге, сүт сапасын бағалауға және түйе сүтін тиімді пайдалануға зор маңызға ие.

Бұл зерттеуде 14 бір өркешті түйенің (*Camelus dromedarius*) төлдегеннен кейінгі 150 ± 15 күнінде алынған цистерналық (С), альвеолярлық (А) және қалдық (R) сүттің құрамы талданды. Жануарларға Атозибан (CAS 90779-69-4) 10 мкг/кг тірі салмақ дозасында және 4 мл окситоцин (RK-LS-5№022381) енгізіліп, кейін қолмен сауылды. Жеке сауын көрсеткіштері сауудан кейін бірден тіркеліп, алынған үлгілер салқындатқыш элементтері бар контейнерлерге жиналып, талдау үшін зетхананаға жіберілді. Цистерналық, альвеолярлық және қалдық сүттің көлемі мен құрамы (ақуыз, құрғақ зат, майсыз құрғақ қалдық, май, тығыздық, рН, соматикалық жасушалар) сауудан кейін 1–3 сағат ішінде анықталды. Орта есеппен цистерналық сүттің үлесі 2,77%, альвеолярлық - 91,18%, ал қалдық сүт - 6,05% болды. Май мөлшері (%) С, А және R-де тиісінше 1,94; 4,15 және 5,96 құрады, ал рН барлық түрлерінде 6,1–6,2 аралығында болды. Ақуыз мөлшері (%) С, А және R-де сәйкесінше 3,15; 3,11 және 3,05 болды.

Тірек сөздер: Түйе сүті, цистерналық сүт, альвеолярлық сүт, қалдық сүт, май, ақуыз