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Physicochemical Properties of Raw Milk from Cow, Goat, Ewe, She-Camel, and Mare from Northwest Libyan region

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الخصائص الفيزيائية والكيميائية للحليب الخام من الأبقار والماعز والنعاج والإبل والأفراس من منطقة شمال غرب ليبيا

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Abstract:
The compositional characteristics of milk vary substantially among animal species, influencing its nutritional value, processing behavior, and industrial utilization. This study aimed to detect and compare the physicochemical properties of fresh raw milk from cows, camels, goats, sheep, and mares using the Lactostar analyzer. Milk samples were collected from and analyzed for fat, protein, lactose, solids-not-fat (SNF), density, and pH. Results revealed notable variations in milk composition among species. Sheep milk exhibited the highest levels of fat (5.06%), protein (3.92%), and SNF (10.42%), reflecting its superior total solids content and suitability for cheese production. Goat milk showed intermediate composition with high digestibility potential, while cow milk presented balanced proportions of major constituents ideal for fluid consumption. Mare milk had low fat (2.08%) and protein (4.87%) but high lactose (7.1%), she-camel milk, however, was characterized by fat (3.84%) and lactose (5.28%) but relatively higher protein (3.66%) compared to cow milk, indicating its functional and nutritional uniqueness. pH values ranged between 6.43 and 6.83, showing no significant differences among species. The study demonstrates that Lactostar technology provides a rapid and reliable means of assessing milk quality across species. Understanding such interspecies compositional diversity is essential for product standardization, dairy process optimization, and the development of species-specific value-added dairy products.

Keywords: Milk composition, Raw milk, Mare, Camel, physicochemical properties, Lactostar.

الملخص:
تختلف الخصائص التركيبية للحليب اختلافًا كبيرًا بين أنواع الحيوانات، مما يؤثر على قيمته الغذائية، وطرق معالجته، واستخداماته الصناعية. هدفت هذه الدراسة إلى الكشف عن الخصائص الفيزيائية والكيميائية للحليب الخام الطازج من الأبقار والإبل والماعز والأغنام والأفراس ومقارنتها باستخدام جهاز تحليل لاكتوستار. جُمعت عينات الحليب وحُللت لمعرفة نسبة الدهون والبروتين واللاكتوز والمواد الصلبة غير الدهنية والكثافة ودرجة الحموضة. كشفت النتائج عن اختلافات ملحوظة في تركيب الحليب بين الأنواع. أظهر حليب الأغنام أعلى مستويات الدهون (5.06%) والبروتين (3.92%) والمواد الصلبة غير الدهنية (10.42%)، مما يعكس محتواه العالي من المواد الصلبة الكلية وملاءمته لإنتاج الجبن. أظهر

حليب الماعز تركيبًا متوسطًا مما يجعل قابليته للهضم عالية، بينما قدم حليب الأبقار نسبًا متوازنة من المكونات الرئيسية، مما يجعله مثاليًا للاستهلاك السائل. يتميز حليب الفرس بانخفاض نسبة الدهون (2.08%) والبروتين (4.87%) وارتفاع نسبة اللاكتوز (7.1%)، بينما يتميز حليب الإبل بارتفاع نسبة الدهون (3.84%) واللاكتوز (5.28%)، ولكنه يحتوي على نسبة بروتين أعلى نسبيًا (3.66%) مقارنةً بحليب البقر، مما يدل على خصائصه الوظيفية والغذائية الفريدة. تراوحت قيم الرقم الهيدروجيني بين 6.43 و6.83، دون وجود فروق جوهرية بين الأنواع. تُظهر هذه الدراسة أن تقنية لاكتوستار توفر وسيلة سريعة وموثوقة لتقييم جودة الحليب بين مختلف الأنواع. يُعد فهم هذا التنوع التركيبي بين الأنواع أمرًا أساسيًا لتوحيد معايير المنتجات، وتحسين عمليات إنتاج الألبان، وتطوير منتجات ألبان ذات قيمة مضافة خاصة بكل نوع.

الكلمات المفتاحية: تركيب الحليب، الحليب الخام، الفرس، الإبل، الخصائص الفيزيائية والكيميائية، لاكتوستار.

Introduction:

Milk is widely known as a highly nutritious food for human in the entire people lifespan, from infants to elders, as provides essential nutrients such as fat, protein, carbohydrates (lactose), vitamins and minerals [1]. However, the cow's milk dominates the global dairy market, the milk from other species, such as goats, ewes, she-camels, and mares, is vital in many regions and increasingly valued for its distinct nutritional and therapeutic properties [2]. In Libya, it has been noticed that increasing consumer demand of she-camel and goat milk which is sold as raw milk. Moreover, mare milk has been thought beneficial for treatment of some serious diseases thus it has been usually used as a folk medicine [3]. Comparative analysis of milk from different species has gained growing scientific and commercial interest due to the distinct nutritional and functional attributes of each type [4,5]. Understanding these differences is vital for ensuring product quality, authenticity, and suitability for specific dairy applications [6].

The compositional and physicochemical characteristics of milk have been extensively studied across different animal species due to their influence on nutritional value, processing suitability, and consumer acceptance. Cow milk remains the most widely consumed type globally, characterized by a relatively balanced composition of fat, protein, and lactose, making it the standard reference for milk quality assessment [7]. However, goats, ewes, she-camel, and mares' milk have attracted increasing attention for their unique nutritional and functional properties, especially in arid and semi-arid regions where they serve as major sources of dietary protein [8].

Recent advancements in analytical instrumentation have enabled rapid, accurate, and non-destructive assessment of milk quality. The Lactostar analyzer, which employs infrared spectroscopy and conductivity-based detection principles, allows simultaneous determination of multiple milk components with high precision and reproducibility (Devise Lactostar 3510 Manual, Funke Gerber, 2020) [9]. Its efficiency and reliability make it an ideal tool for evaluating the physicochemical quality of raw milk from diverse species [10].

As milk compositional characteristic is influenced by geographical, the present study aims to detect and compare the physicochemical properties of fresh raw milk obtained from cows, goats, ewes, she-camels, and mares in northwest region of Libya using the Lactostar analyzer. By quantifying major compositional parameters such as fat, protein, lactose, and solids-not-fat (SNF), this research seeks to elucidate interspecies variations and their implications for milk quality assessment and potential industrial utilization. The findings are expected to contribute to a deeper understanding of species-specific milk characteristics, thereby supporting efforts toward quality control, product development, and valorization of non-bovine milk in the dairy sector.

Materials and Methods:

Sample collection:

Fresh raw milk samples were collected from five animal species cows, ewes, goats, mares, and she-camel from local farms in the northern west region of Libya during February to May 2025. Approximately 500 mL of milk was collected from 10 animals per species with exceptional to ewes and mares (100 mL from 7 and 4 animals respectively) in sterile containers, immediately chilled at 4 °C, and transported to the food hygiene laboratory at Faculty of Veterinary Medicine, University of Tripoli for analysis.

Sample Preparation:

Before analysis, milk samples were gently homogenized to ensure uniform distribution of fat and other solids. Samples were allowed to equilibrate to room temperature before testing. The organoleptic evaluation then was determined through a sensory assessment of their appearance, smell, and texture.

Instrumental Analysis Using Lactostar:

Physicochemical properties of the milk samples were determined using a Lactostar Milk Analyzer (Funke Gerber, Berlin, Germany). The instrument was calibrated according to the manufacturer's instructions prior to measurement. Parameters analyzed included: Fat content (%), Protein content (%), Lactose content (%), Solids-not-fat (SNF, %), and Freezing point (°C). Each sample was analyzed in

triplicate to ensure measurement reliability. The Lactostar uses mid-infrared spectroscopy and conductivity-based detection principles to quantify milk components simultaneously and with high accuracy.

pH and Titratable acidity Determination:

The pH of each milk sample was measured using a calibrated digital pH meter (Knick pH-meter 766 Calimatic, Germany) at 25 °C. The pH meter was standardized using buffer solutions of pH 4.0 and 7.0 before each set of readings according to the manufacturer's instructions. Briefly, the milk sample was gently mixed then 20 mL of the sample was poured into a clean beaker before pH electrode was submerged the sample. After stabilized pH reading display, final pH and temperature were recorded. Titratable acidity was determined by direct titrimetric method as follows:

The total acidity of milk samples was titrated and neutralised by using a 0.1N Sodium Hydroxide (NaOH) solution and a 1% Phenolphthalein as an indicator according to AOAC method No.947.05 [11]. **The acidity was expressed as % of lactic acid in the sample according to calculation formula below:**

$$\text{Lactic Acid \%} = \frac{mL\ of\ NaOH\ used X\ normality\ of\ NaOH\ X\ 0.9}{Volume\ of\ the\ sample} \text{ X } 100$$

Results and Discussion:

Physicochemical Composition of Milk from Different Species:

The mean physicochemical parameters of raw milk samples from cows, camels, goats, sheep, and mares are summarized in Tables 1 – 5 and Graph 1. Significant interspecies variations were observed in all measured components, including fat, protein, lactose, solids-not-fat (SNF), and pH. These differences can be attributed to species-specific genetic, physiological, and nutritional factors. In fact, unlike cow, camel, ewe, and goat milk, mare milk is considered as special milk. Thus, it is characterized by rarely availability and only on demand and mostly used for local flock medical use. Therefore, in this study we faced difficulties to obtain samples for analyse.

Table (1): Results of Test Parameters of Raw Camel's Milk

No	PH Value	Degree of Acidity	Milk Fat%	Protein%	Lactose%	Solids not Fat%	Minerals%	Freezing Point Mc
1	6.47	0.18	4.8	4.06	5.86	10.79	1.22	-0.61
2	6.47	0.14	5.18	4.32	6.23	11.47	1.11	-0.66
3	6.5	0.18	4.55	4.08	5.91	10.87	1.19	-0.62
4	6.43	0.16	3.75	3.15	4.5	8.45	1	-0.48
5	6.47	0.13	2.46	3.05	4.4	8.11	1.3	-0.48
6	6.38	0.2	3.46	3.54	5.34	7.83	1.1	-0.52
7	6.3	0.15	3.5	3.73	5.16	7.91	1.1	-0.59
8	6.38	0.16	3.1	3.6	5.2	9.5	1.18	-0.55
9	6.45	0.17	2.8	3.33	4.7	8.7	1.28	-0.53
10	6.45	0.17	4.75	3.7	5.5	10	1.08	-0.6
Average Value	6.43	0.16	3.84	3.66	5.28	9.36	1.16	-0.56

Table (2): Results of Test Parameters of Raw Cow's Milk

No	PH Value	Degree of Acidity	Milk Fat%	Protein%	Lactose%	Solids not Fat%	Minerals%	Freezing Point Mc
1	6.76	0.18	2.12	3.31	4.84	8.86	0.83	-0.51
2	6.7	0.2	2.17	3.59	5.24	9.6	0.8	-0.55
3	6.77	0.21	2.05	3.32	4.85	9.88	0.85	-0.51
4	6.14	0.38	2.13	3.69	5.4	9.9	0.93	-0.56
5	6.05	0.4	2.85	3.71	5.39	9.9	0.85	-0.56
6	6.56	0.2	2.04	3.52	5.16	9.44	0.86	-0.53
7	6.65	0.2	3.32	3.64	5.29	9.71	0.89	-0.55
8	6.59	0.23	2.38	3.73	5.46	10	0.91	-0.57
9	6.55	0.24	3.37	3.91	5.68	10.42	0.76	-0.59
10	6.75	0.19	2.91	3.46	5.04	9.24	0.91	-0.53
Average Value	6.55	0.24	2.53	3.59	5.24	9.7	0.86	-0.55

Table (3): Results of Test Parameters of Raw Ewe's Milk

No	PH Value	Degree of Acidity	Milk Fat%	Protein%	Lactose%	Solids not Fat%	Minerals%	Freezing Point Mc
1	6.65	0.21	5.14	3.75	5.37	9.92	0.99	-0.55
2	6.63	0.16	5.17	3.78	5.42	10.01	1.01	-0.56
3	6.63	0.21	4.9	3.45	5.03	9.35	1	-0.57
4	6.57	0.14	1.75	3.49	5.1	9.33	0.95	-0.54
5	6.55	0.18	2.82	3.65	5.3	9.73	1.14	-0.56
6	6.38	0.4	4.9	3.39	4.79	8.9	0.67	-0.56
7	6.33	0.43	10.72	5.9	8.45	15.71	0.69	-0.97
Average Value	6.53	0.25	5.06	3.92	5.64	10.42	0.92	-0.62

Table (4): Results of Test Parameters of Raw Goat's Milk

No	PH Value	Degree of Acidity	Milk Fat%	Protein%	Lactose%	Solids not Fat%	Minerals%	Freezing Point Mc
1	6.7	0.18	2.47	3.38	4.94	9.05	0.97	-0.51
2	6.71	0.18	2.54	3.37	4.93	9.03	0.97	-0.51
3	6.7	0.18	2.86	3.48	5.07	9.3	0.99	-0.52
4	6.64	0.2	4.02	3.85	5.57	10.24	0.89	-0.58
5	6.67	0.19	2.9	3.49	5.09	9.33	1.01	-0.53
6	6.68	0.18	3	3.26	4.68	8.64	1.02	-0.52
7	6.65	0.18	2.5	3.31	4.76	9.28	1.01	-0.53
8	6.68	0.18	2.81	3.48	5.08	8.77	1.01	-0.53
9	6.62	0.23	3.59	3.8	5.52	10.14	0.94	-0.57
10	6.62	0.16	3.48	3.15	4.5	8.32	0.87	-0.52
Average Value	6.67	0.19	3.02	3.46	5.01	9.21	0.97	-0.53

Table (5): Results of Test Parameters of Raw Mare's Milk

No	PH Value	Degree of Acidity	Milk Fat%	Protein%	Lactose%	Solids not Fat%	Minerals%	Freezing Point Mc
1	6.55	0.19	4.03	6.54	9.48	14.83	0.83	-0.84
2	6.51	0.2	0.43	5.49	8.1	14.78	0.85	-0.83
3	7.12	0.05	2.96	3.95	5.69	10.48	0.34	-0.63
4	7.13	0.05	0.9	3.48	5.13	9.36	0.36	-0.52
Average Value	6.83	0.12	2.08	4.87	7.1	12.36	0.6	-0.71

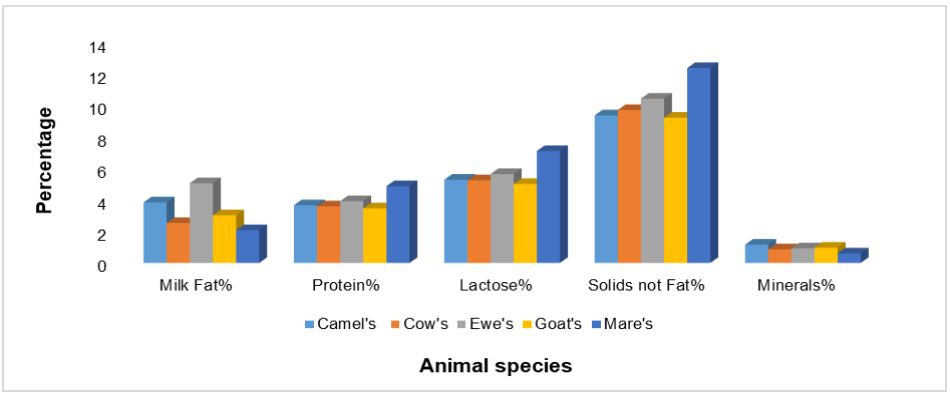

Figure (1): Representation of Average Values for Camel, Cow, Sheep, Goat, and Mare's Milk

Fat and Protein Content:

The results of raw camel's milk samples show significant variation in fat percentage among the samples Table 1, which ranges from 2.46 % to 5.18 %, (average 3.84). Up to our knowledge, there is no official Libyan standard regarding fat percent in raw camel's milk, it has been documented in literature that fat content in camel's milk ranges from 2 % to 6.10% [12], which corresponding with our results. Different factors like lactation stage, time of milking, season, and genetic differences play a major role in the variation of fat concentrations in camel milk [13]. Similar factors might also affect the fat percentage in this study as we notice that camels feed high nutritional forages were revealed higher fat contents comparing to grazing camels. As other chemical compositions of milk samples were not significantly varied among the samples. Thus, the most reasonable factor that affects fat percentage is feeding and watering frequency (availability of water). Dehydrated lactating camels (grazing camel) increases the water content in milk which is important for their young calves. Increasing water content leading to reduction of fat content in camel milk [14]. This is important for protein and lactose levels which may be reduced due to fermentation. in our study protein levels of camel's milk are consistent, averaging 3.66%, which is slightly higher than the average for cow's milk. Similar observation has been reported in literature [13,15,16].

Fat percentage is ranged from 2.04% to 3.37%, legal requirement for fat percentage of raw cow's milk has been stated in Libyan Standard No. 355 requires at least 3.0% fat. Typical cow milk fat ranges from 3.2–4.0% [17]. In this study, the results show that fat percentage was lower than legal requirement in the most tested samples within an average at (2.53%) many factors may affect fat content in cow's milk such as cow breed, animal health, environment, management practices, lactation stage and diet [18]. Excluding milk adulteration, the outcomes of low-fat percentage may be due to lactation stage as some of the samples were collected at last stage of lactation period. In addition, to poor management system as some cows were feeding with poor forages.

Physiochemical analysis of sheep milk samples has shown that there is a large discrepancy in fat content Table 3. Samples 1, 2, 3, and 6 range from 4.9% to 5.17%, which is typical rich sheep's milk. Sample 7 is chemically distinct from the rest of the group. It has extremely high values across the board: fat (10.72%), protein (5.90%), and lactose (8.45%). However, Samples 4 and 5 are surprisingly low in fat (1.75% and 2.82%). This suggests these specific ewes may have been milked out completely (stripping), were on a poor diet, or the milk was diluted (though the freezing points of -0.54 and -0.56 suggest no added water). The freezing point is -0.97 ˚C, which is much lower than the others, confirming a very high concentration of solids. This sample is likely colostrum or milk from a very late stage of lactation. The high acidity (0.43) and lower pH (6.33) also support this. This single sample heavily skews the average values upward.

Globally, goat milk is considered the third most common consumption after cow and buffalo milk. This makes it important food for people particularly in developing word and poor agriculture areas [19] Furthermore, goat milk is considered as a complete and highly nutritional food [20]. Sample 4 in Table 4 has the highest fat (4.02%), highest protein (3.85%), and highest SNF (10.24%). Correspondingly, it has the lowest freezing point (-0.58), indicating the highest concentration of dissolved solids. On the other hand, sample 10 has the lowest protein (3.15%), lactose (4.50%), and SNF (8.32%). While its fat content (3.48%) is around average, the lack of other solids suggests this may be from a late-stage lactation animal or a specific individual with lower constituent output.

These results show that mares' milk has extreme fat variability (ranging from 0.43% to 4.03%) may because horses have a small udder capacity; the foal often drinks the high-fat foremilk, leaving the milker with the thinner, low-fat hindmilk (as seen in sample 2). In literature, it has been reported that mare's milk has a low fat, naturally about 1-2%, much less than cow or human milk, and affected by diet and lactation stage, often decrease by lactation progresses [21].

Lactose and Solids-Not-Fat (SNF):

Camel milk lactose levels are also consistent, averaging 5.28%, which contributes to the slightly sweet taste often associated with camel's milk beside that, minerals (Ash) contribute to a distinct flavor of camel's milk, in our study, mineral content is very stable across all examined samples, hovering closely around the average of 1.16%. which is slightly higher compared to a study that reported 0.79-0.81% [22]. In this study, solids not fat (SNF) ranged from 7.83% to 11.47%, similar results have been reported elsewhere [23]. The results show that the SNF percentage correlates strongly with the protein and lactose content. The sample that had the highest lactose and protein, also had the highest SNF (11.47%). Conversely, sample that shown lowest SNF (7.83%) alongside lower in lactose. Total solids (e.g. dissolved lactose and salts) are important factor that lower the freezing point of milk (typically between -0.512 and -0.550 °C) the average freezing point among the samples was -0.55 and ranged between -0.48 and -0.66 which is consistent with the mineral and lactose content observed in the samples [24].

Other chemical constituents of cows' milk including lactose (ranged from 4.48% to 5.68%), and SNF (ranged from 8.86% to10.42%). However, some samples revealed higher than normal of dissolved solids, these compositions are within the normal level of raw cow's milk [18]. It also has noticed that the sample has coldest freezing point (-0.59˚ C) is consistent with a high concentration of dissolved solids and the sample represents the thinnest composition, with the lowest fat (2.12%), protein (3.31%), lactose (4.84%), and SNF (8.86%) has the highest freezing points (-0.51˚ C). The freezing points of all samples are clustered between -0.51 ˚C and -0.59 ˚C. This consistency across all samples (regardless of pH or fat content) suggests that the milk is of normal quality. The samples are compositionally uniform and show no evidence of major compositional changes.

In general, the results suggest that ewe's milk is rich in total solids [25]. The SNF for samples (1-6) ranges from roughly 8.9% to 10.0%, which is higher than cow and camel milk. This confirms sheep milk is naturally denser in proteins and sugar [25].

Lactose dominance Mare's milk in this dataset has lactose content (average 7.10%). This aligns with the general knowledge that mare's milk is sweet taste. Equine milk is rich in its lactose content, and in Asia mare milk used to produce fermented dairy product known as koumiss [26]. Mineral content mare's milk samples have low average mineral content (average 0.60%) This contributes to the SNF being primarily driven by lactose and protein rather than ash/minerals [27]. Freezing point of mare samples is corresponding with TS contents as the freezing point ranges widely. The "rich" samples (1 and 2) have a very low freezing point (-0.84) due to the high concentration of lactose and protein, while the "thin" samples (3 and 4) are closer to -0.52 ˚C to -0.63˚C [28]. The highest SNF content was observed in mare milk (12.55%), followed by sheep, cow, goat, and camel milk. This trend reflects the higher concentration of solids, minerals, and proteins in mare milk, which contributes to its superior nutritive and technological value [29]. The relatively low SNF in camel milk suggests a higher moisture content and dilution effect due to the animal's adaptive physiology [4].

pH and Titratable acidity:

Degree of acidity and pH are important parameters regarding freshness and keeping quality of raw fresh milk. The pH values for all species ranged from 6.43 to 6.83. in our study the pH values of camel milk are tightly clustered between 6.30 and 6.50 (Average 6.43). This is typical for fresh camel milk, which generally has a higher pH than cow's milk (less acidic). The degree of acidity is low, indicating that the milk samples are fresh and have not undergone significant fermentation or bacterial spoilage or decomposition. Acidity and pH of sheep milk samples can categorize the samples into two "acidity groups": First, low acidity (samples 1-5): freshness is high as the acidity is 0.14–0.21, pH is 6.55–6.65. Second, high acidity (samples 6-7) where the acidity jumps to 0.40–0.43. While sample 7 is likely colostrum, sample 6 (0.40 acidity, 6.38 pH) may indicate mastitis, udder infection, or simply advanced fermentation/age compared to the other samples. The goat's milk result dataset Table 4 shows the highest consistency in pH values and range is only 0.19 (6.62 to 6.71). Combined with low and uniform acidity (0.16–0.23), this indicates excellent handling hygiene, uniform freshness, and likely a homogeneous herd diet.

Comparison with Previous Studies:

The trends observed in this study are consistent with numerous earlier reports. [30,31] noted similar interspecies variations, with sheep milk having the higher total solids, followed by cow, goat, and camel milk. While mare milk has the highest lactose content. The observed lactose and pH values also align with findings by [4,10], confirming that camel milk has a unique physicochemical profile characterized by lower fat and lactose levels. The substantial differences observed across species align with established research, reaffirming that milk composition is species-dependent and influenced by reproductive strategy, metabolic pathways, and dietary behavior. Sheep milk's elevated fat and protein content enhances its suitability for cheese production, while mare milk's high lactose content supports its use in fermented beverage industries.

Slight variations in absolute values among studies may be attributed to differences in animal breed, stage of lactation, diet, and environmental factors. Nevertheless, the consistency of interspecies ranking across studies supports the reliability of the Lactostar analyzer for comparative milk quality evaluation. The application of the Lactostar analyzer enabled efficient and precise multi-parameter analysis, confirming its suitability for both research and dairy industry quality monitoring. These findings highlight the importance of species-specific milk characterization in optimizing processing techniques and developing diversified dairy products catering to different nutritional and functional needs.

The comparison between all tested of raw milk from different species is presented in the Figure 1. which shows that mare's milk samples stand out as the unique outlier in this dataset It has the highest pH (most alkaline), the lowest fat, but the highest protein and lactose content which results in the highest SNF and density. Camel's milk samples are the mineral powerhouse and contain moderate fat and protein levels. Ewe's milk samples are the richest in total fats and standard macronutrients (excluding

the unusually high protein/lactose spikes in the mare samples). Goat's milk samples are the most consistent in pH and freshness, with moderate composition. Cow's milk ranks in the middle for most parameters but has the lowest mineral content. Similar findings have been reported in literature, mare milk is richest milk among tested animals [32]. Camel's milk high in some mineral and has salty taste and low in fat comparing to bovine milk [33]. Ewe's milk is higher in fat than goat and cow milk [34]. Mear milk high in lactose and protein [35].

Conclusion:

This study successfully evaluated and compared the physicochemical properties of fresh raw milk from cows, camels, goats, sheep and mares using the Lactostar analyzer. The results revealed significant interspecies variations in major compositional parameters such as fat, protein, lactose, SNF, while pH values remained relatively consistent across all species.

Among the five milk types analyzed, sheep milk exhibited the highest fat, protein, and SNF contents, confirming its richness in total solids and superior suitability for manufacturing cheese and fermented dairy products. Goat milk presented intermediate levels of fat and protein with favorable digestibility characteristics, whereas cow milk displayed balanced compositional attributes ideal for fluid milk consumption. She-camel milk, on the other hand, was characterized by lower fat and lactose but relatively higher protein content, supporting its growing reputation for nutritional and therapeutic benefits, particularly among lactose-intolerant consumers. Mare milk has the highest lactose concentration, like human milk contributing to its sweet taste.

The use of the Lactostar analyzer proved efficient and reliable for rapid multi-parameter milk quality assessment, demonstrating its value as a practical analytical tool for both research laboratories and industrial quality control. These results contribute to a broader understanding of species-specific milk properties and highlight the potential for diversifying dairy production beyond bovine milk.

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