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Interplay of Management Practices and Physiological Factors Influences Camel Milk Characteristics in Tamanghasset, Southern Algeria

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ABSTRACT

Background: In the Saharan ecosystems where the harsh environmental conditions persist, camels (*Camelus dromedarius*) with stand these conditions through their distinctive physiological adaptation and produce milk more than other animals over extended lactation period. The present study was designed to evaluate the effect of breeding system, milked she-camel population and the hygienic status of the udder on the physicochemical and microbiological proprieties of camel milk.

Methods: 30 samples of camel milk were gathered during May and June 2024 in Tamanghasset (south Algeria), the samples originated from camels belonging to two populations and managed under two systems. After sanitary milking precautions, milk was subjected to california mastitis test (CMT), physicochemical and microbiological analysis.

Result: The results of pH, acidity, conductivity, fat, solids non-fat (SNF), total solids, density, proteins, lactose, salt, freezing point and reviable aerobic mesophilic microflora (RAMF) analysis were 6.17±0.27, 17.4±3.05° D, 5.78±0.86 mS/cm, 2.15±0.94%, 9.03±0.47%, 11.18±1.09%, 31.80±1.72, 3.28±0.18%, 4.94±0.21%, 0.69±0.05%, -0.57±0.03°C and 3.15±1.03 UFC/ml respectively. Further analysis based on the T-test and Mann-Whitney exhibit a significant effect ($p<0.05$) of breeding system on pH, acidity, conductivity and salt level; while only the bacterial load was significantly affected by camel population type, whereas the udder health status seems impact on the pH parameter. Complementing these findings, Principal component analysis (PCA) highlights an overall significant effect of udder health on milk composition and a moderate to slight influence of breeding system and camel population.

Key words: Camel milk, Management practices, Physicochemical properties, Physiological factors.

INTRODUCTION

In Algerian semi-arid and arid ecosystems, where the hostile climatic conditions and scarcity of food availability persist, only camels (*Camelus dromedarius*) have the ability, among other farm species, to produce a high amount of milk for a long period (Ansari *et al.,* 2024), in addition to its great nutritional value and health-promoting properties (Yadav *et al.,* 2015; Boudalia *et al.,* 2023; Raj and Rani 2024), camel milk is considered as a vital source for rural dwellers to face food security concerns (Abdelazez *et al.* 2024), which draw extensively the attention of researchers in the last years (Mohamed and Czyz, 2020). Given its nutritional and economic importance, camel milk characteristics have been reported to vary under numerous factors related to animal characteristics (breed, age, parity, stage of lactation, season of calving, physiological stage, reproductive status (estrus, gestation and the animal's health), nutritional and watering provisions (feed variety, feeding practices, water availability and accessibility), environmental conditions (season, climatic conditions, heat stress) and management practices and conditions like milking frequency, method of milking (hand or machine) and presence or absence of the calf (Musaad *et al.,* 2013; Seifu 2023; Abduku and Eshetu 2024). Despite the Algerian camel population that estimated in 2021 at 417 167 heads (MADR 2021), a few official data are available about the real production because of the complexity of the field and the inaccessible nomadic populations across the steppes and Saharan regions (Harek *et al.,* 2022; Lankri *et al.,* 2024). Therefore, this study aims to promote this neglected vital source and spot the light on the physicochemical characteristics of camel milk in Tamanghasset, south Algeria and see to what extent it is affected by management practices and physiologicalfactors.

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MATERIALS AND METHODS

Study area and sampling

The study was conducted in Tamanrasset, southern Algeria (1943 km from Algiers, 1320 m altitude), characterized by arid climate with 136 mm rainfall and temperatures of 36°C during the sampling's season (Chelghoum and Belhamri 2011). The region hosts 85180 camels including 50445 she-camels (MADR, 2021). Thirty (30) milk samples were collected (May-June 2024) from local markets (intensive system, n=22) and peri-urban farms (semi-extensive system, n=8), representing Targui (n=13) and Sahraoui (n=17) populations at different lactation stages. Following hand disinfection with 70% alcohol, milk was collected directly into autoclaved glass bottles and transported to "sciences and environment" laboratory at the university of Tamanghasset within one hour using cooling boxes**.**

Samples diagnostic

Quality assessment covered hygienic, physicochemical, microbiological and compositional analyses. Hygienic status was evaluated using california mastitis test (CMT) following the method of Seligsohn *et al.* (2021), where 3-4 mL RAIDEX reagent (RAIDEX GmbH solution, Germany) was mixed with equal raw camel milk volume in CMT paddle, with horizontal circular shaking determining viscosity graded from 1 to 5 using Scandinavian scoring system (1=liquid; 5=gel formation). Furthermore, physicochemical parameters included pH and conductivity measured using digital meters (EUTECH ION 2700 for laboratory measurements and EXTECH EC 500 (Taiwan) for field measurements) and titratable acidity (TA) following Aggad *et al.* (2009) method: 10 mL milk mixed to 3 drops of phenolphthalein (1%) titrated with 0.1 N NaOH until persistent pink color, calculated as TA (°D) = NaOH volume (mL) $\times$ 10. In addition, microbiological analysis consisted of RAMF enumeration using plate count agar medium following SP-SDS methodology (Thomas *et al.* 2015), with serial dilutions in peptone water incubated for 24 h at 30°C. The milk composition analysis (total solids, fat, protein, lactose, density, salt and freezing point) was performed using an ultrasonic Milkotester (Master Eco 308, Bulgaria), although camel-specific calibration was unavailable, the analyzer provided enabled reliable analysis focusing on relative compositional differences between sample groups rather than absolute quantification. Despite the potential inaccuracies in absolute values, the bias from the calibration affects all samples uniformly safeguards the reliability of statistical relationships. This methodological consistency with prior studies showed a significance correlation, albeit modest, between estimated and reference methods in camel milk (Konuspayeva *et al.,* 2023). All analytical measurements were conducted in triplicate on the thirty freshly collected raw camel milk samples to ensure measurement reliability.

Statistical analysis

Statistical analysis was carried out using R software (version 2023.06.01). Bacterial load was expressed as $\log_{10}$ values. T-test was used to compare means and examine the effect of farming system, camel population and hygienic conditions on raw milk composition. Non-parametric tests (Mann-Whitney U Test and Kruskal-Wallis Test) were utilized for the non-normally distributed parameters, as well as for evaluating the effects of lactation stage and transportation on milk characteristics. The interaction of all parameters was assessed using Principal Component Analysis (PCA). A significance level of 5% (p-value $\leq$0.05) was used as the threshold for interpreting results.

RESULTS AND DISCUSSION

The results of physicochemical and microbiological analysis are summarized in Table 1.

Camel milk properties, composition and management effects

pH and titratable acidity

The pH ranged 5.53-6.72 (mean 6.17±0.27), more acidic than other Algerian regions: Oued Souf 6.34±0.11, Adrar 6.50±0.18 (Hadef *et al.,* 2021; Boudalia *et al.,* 2023), Morocco 6.51±0.08 (Bouhaddaoui *et al.* 2019) and Dubai 6.81±0.01 (Chand and Singh 2019), highlighting geographical effects. Breeding system significantly affected pH (p=0.01, α=0.05); semi-extensive systems produced more acidic milk (5.95±0.24) versus intensive systems (6.25±0.24), consistent with Mekkaoui *et al.* (2022). Sahraoui camels produced slightly more alkaline milk (pH 6.24±0.24) than Targui camels (pH 6.08±0.29) without significant difference. Mastitis did not affect pH values, corroborating Hadef *et al.* (2020). Average titratable acidity was 17.4°±3.05D, consistent with other Algerian studies (Hadef *et al.* 2018, 2021) and Morocco (Bouhaddaoui *et al.* 2019).

Conductivity and freezing point

Conductivity values fluctuated between 4.65-8.23 mS/cm (average 5.78±0.86 mS/cm), paralleling Boudalia *et al.* (2023) findings in Algeria (5.96 mS/cm) and Saudi Arabia 4.54±0.51 (Mohammed *et al.* 2022). The hygienic status showed no significant effect on conductivity, harmonizing with Hadef *et al.* (2020), though management system showed highly significant effect (p=0.00007, α=0.05). Freezing point of samples ranged from -0.63° to -0.50°C, relatively higher than outcomes reported by Boudalia *et al.* (2023) in Algeria and Elobied *et al.* (2015) in Sudan. Konuspayeva *et al.* (2023) declared freezing point sensitivity to ionic balance, attributing it to breed effect, physiological status and management system.

Density and total solids

Average density was 1.032±0.001 g/cm^3, identical to South East Algerian Sahara 1.032±0.002 g/cm^3 (Hadef *et al.* 2018) and Ethiopian camel milk 1.028 (Omer and Dol Ateye 2022). No significant effects of management system, physiological status or breed were observed, aligning with Mekkaoui *et al.* (2022). Total solids analysis revealed content ranging 9.00-13.30% (average

Table 1: Physicochemical and microbiological analysis of raw camel milk samples collected from local cattle's market peri-urban farms in Tamanghasset region.

Group	All samples			Dromedary population type		Breeding system		CMT case	
				Targui	Sahraoui	Intensive	Semi- extensive	Positive	Negative
Number of samples	30			13	17	22	8	3	27
	Min	Max	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
pH[a]	5.53	6.72	6.17±0.27	6.08±0.29	6.24±0.24	6.25±0.24	5.95±0.24	6.53±0.2	6.13±0.25
pH[b]	5.77	6.69	6.39±0.2	6.35±0.23	6.42±0.19	6.44±0.2	6.26±0.14	6.57±0.13	6.37±0.2
Titrable acidity (D°)	12.67	26.00	17.4±3.05	17.71±3.77	17.15±2.45	16.06±1.68	21.08±2.97	15.56±0.51	17.60±3.15
Conductivitya (mS/cm)	04.65	8.23	5.78±0.86	5.83±1.1	05.74±0.67	5.38±0.44	6.88±0.8	5.57±0.24	5.80±0.91
conductivityb (mS/cm)	04.66	8.03	5.72±0.83	5.76±1.02	05.68±0.69	5.35±0.43	6.72±0.87	5.74±0.29	5.71±0.87
Log CFU/ml	01.48	5.50	3.15±1.03	2.78±0.86	03.44±1.07	3.31±1.11	2.70±0.56	2.89±0.56	3.18±1.07
FAT %	0.70	3.87	2.15±0.94	2.15±1.09	02.14±0.84	2.14±0.9	2.15±1.1	2.28±0.36	2.13±0.98
SNF %	8.03	9.93	9.03±0.47	9.06±0.51	09.00±0.44	9.13±0.43	8.77±0.49	8.76±0.72	9.06±0.44
Total solids %	9.00	13.30	11.18±1.09	11.22±1.33	11.15±0.91	11.28±0.96	10.92±1.43	11.05±0.42	11.20±1.15
Density	27.93	35.13	31.80±1.72	31.93±1.8	31.70±1.7	32.15±1.68	30.83±1.52	30.81±2.87	31.91±1.59
Proteins %	2.90	3.60	3.28±0.18	3.29±0.2	03.27±0.17	3.31±0.16	3.19±0.19	3.18±0.28	3.29±0.17
Lactose %	4.50	5.35	4.94±0.21	4.94±0.25	04.94±0.19	4.99±0.19	4.81±0.22	4.89±0.34	4.95±0.2
Salt %	0.60	0.80	0.69±0.05	0.68±0.7	0.69±0.04	0.70±0.04	0.66±0.05	0.67±0.07	0.69±0.05
Freezing point (°C)	-0.63	-0.50	-0.57±0.03	-0.57±0.04	-0.57±0.03	-0.57±0.03	-0.55±0.04	-0.55±0.05	-0.57±0.03

Abbreviations:

- CMT: California mastitis test; SNF: Solids non-fat.
- a: pH or Conductivity measurement on site.
- b: pH or Conductivity measurement in laboratory after samples transport.

11.18±1.09%), fluctuating within the reported interval 8-15% (Atigui *et al.* 2023). Results aligned with Ethiopian studies (Shegaw *et al.* 2020) and nearby Ghardaïa-Algeria research (Hanou *et al.* 2016). No significant effects were observed among studied factors, suggesting seasonal and geographical location effects (Shuiep *et al.* 2008; Elbashir and Elhassan 2018).

Fat content

Samples presented large fat content variation, fluctuating between 0.70-3.87% (average 2.15±0.94%). Results aligned with Chethouna *et al.* (2022) in Ouargla, Algeria (2.84±0.7%) and Tunisia 19.3±7.6% (Atigui *et al.* 2023). The three studied factors showed no significant effect on fat composition, contrasting nearby southeastern Algeria studies revealing mastitis infection significance. Results remained constant within management systems, supported by Mekkaoui *et al.* (2022), though Chergui *et al.* (2024) suggested higher fat content under intensive versus semi-intensive systems.

Protein, lactose and salt content

Protein content ranged 2.90-3.60% (average 3.28±0.18%), previously reported in southeastern and south-central Algeria by Hadef *et al.* (2018, 2021): 3.37±0.18% and 32.76±0.48% respectively. Results were described in African and Asian countries, including Tunisia 31.9±6.0% (Atigui *et al.* 2023) and Sudan 3.49±0.06% (Mustafa *et al.* 2021). Milk protein was independent of subclinical mastitis effect, opposing Hadef *et al.* (2020) findings. Lactose content fluctuated between 4.50-5.35% (average 4.94±0.21%), higher than Hadef *et al.* (2020) and Mekkaoui *et al.* (2022) results. Similar results were found in Morocco 4.98±0.71% and Sudan 4.73±0.09% (Bouhaddaoui *et al.* 2019; Mustafa *et al.* 2021). Management system and breed showed no impact on lactose content, supported by Mekkaoui *et al.* (2022).

Average salt content was 0.69±0.05%, reflecting Hadef *et al.* (2021) outcomes in Adrar, Algeria and Atigui *et al.* (2023) in Tunisia. Results were lower than southeastern

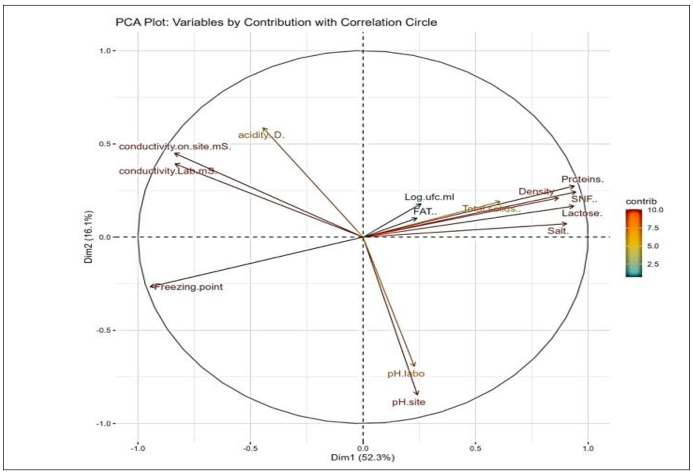

Fig 1: Correlation circle of physicochemical variables contributing to principal components.

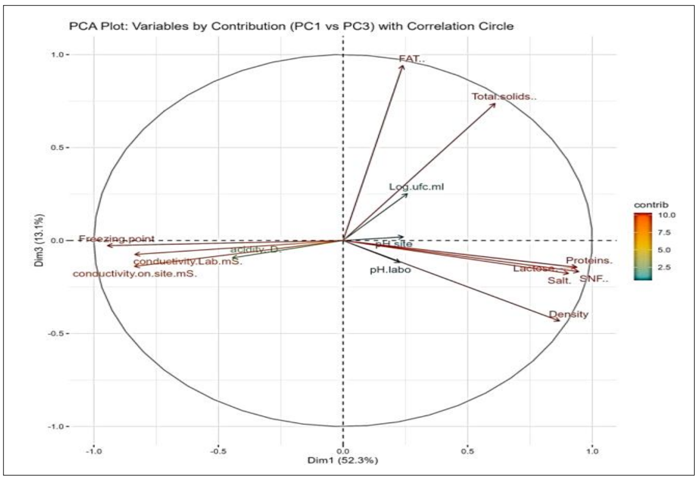

Fig 2: Variables by contribution (PC1 vs PC3) with correlation circle.

Algeria reports (Hadef *et al.* 2018, 2020). Mineral content wasn't affected by population or udder hygienic status, aligning with Hadef *et al.* (2020).

Lactation stage effects on physicochemical characteristics revealed no significant impact except for pH, which decreased significantly with lactation progression, confirmed by Aljumaa *et al.* (2012) in Saudi Arabia. However, Hadef *et al.* (2018) and Kraimia *et al.* (2024) found no direct lactation stage effect on pH. Transportation showed pH increased significantly after transport (mean less than one hour), explained by carbonic acid dissociation accelerated by heat and agitation leading to CO_2 off-gas before microflora acidification begins (Ma and Barbano 2003; McSweeney and Fox 2009).

Bacteriological analysis

Bacterial enumeration on plate count agar medium ranged from 1.48 to 5.50 log_{10} UFC/ml with an average of 3.15±1.03 log_{10} UFC/ml, relatively lower than the value declared by (Boudalia *et al.,* 2023) and (Kadri *et al.,* 2021) in Algeria and Morocco, respectively, which could be related to milking practices and time lag between the sampling and the bacterial culture. The statistical analysis revealed no significant effect of the three factors on camel milk bacterial counts.

Principal component analysis

The first three principal components had eigenvalues greater than 10 and together explained 81.5% of the total variance (PC1: 52.3%, PC2: 16.1%, PC3: 13.1%).

The first PC (Fig 1) was defined by a high contribution of SNF (12.22%), Proteins (12.03%), Lactose (11.98%), Salt (11.18%), Density (10.30%), Conductivity (~9.55%) and negatively the freezing point (12.21%) representing the compositional richness. The second PC was mainly influenced by a negative correlation between acidity (15.23%), conductivity (8.97%) and strongly pH; which represent the milk's freshness and ionic balance, which reflect signs of the potential microbial activity, for that we could considered PC2 as a proxy for milk quality and shelf-life. The third PC (Fig 2) was figured by fat, SNF and density as positive contributors, alongside a strong negative relationship with acidity highlighting the structural richness and buffering characteristics of camel milk.

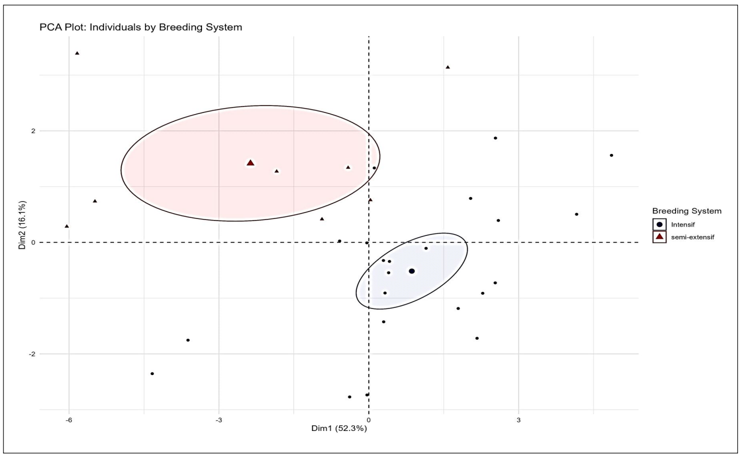

Fig 3: PCA plot of camel milk samples colored by breeding system (intensive vs. semi-extensive).

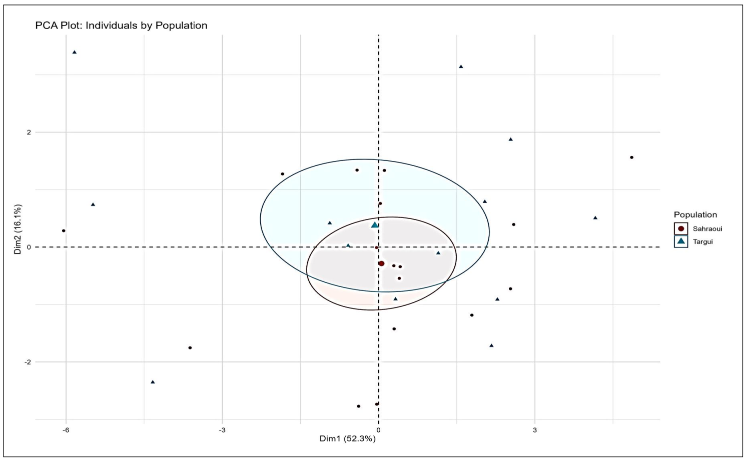

Fig 4: PCA plot of camel milk samples colored by population (Sahraoui vs. Targui).

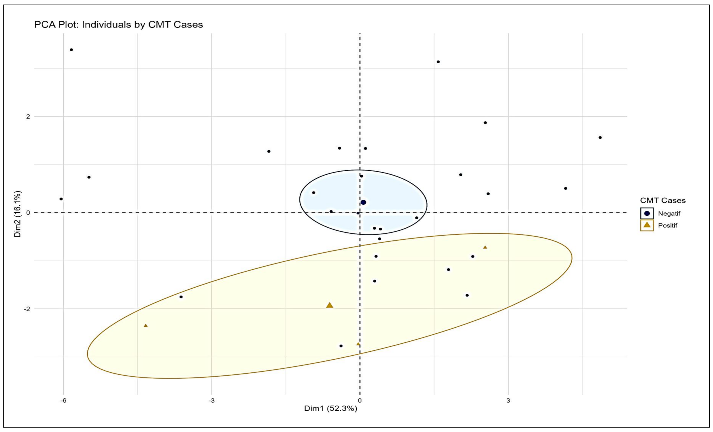

Fig 5: PCA plot of camel milk samples colored by CMT status (Healthy vs. Infected).

The PCA biplot in the figures (Fig 3), shows a moderate influence of management system (intensive vs semi-extensive) on milk composition possibly due to diet; the slight clustering exhibited in (Fig 4) demonstrate that breed variation (Targui vs Sahraoui) could have a minor impact on camel milk composition; furthermore, the Hygienic Status represented by CMT displays a clear separation in (Fig 5) reflecting a significant effect on both nutritional quality and ionic balance.

CONCLUSION

Beyond the importance of dromedary's milk as nutritious food in pastoralist regions and its use for medical revenues proven by several researchers, the present study emphasizes the importance of milking and handling practices on physicochemical and microbiological quality of camel milk, as well as the degree of correlation between physicochemical parameters which appears to be moderately affected by the management system and the population of the milked she-camel compared to the influence of mastitis. Yet, further investigation is needed, including feeding type, watering, milking practice and routine, age and parity number effect, to assesses and promote the technological aspect of camel's milk.

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Disclaimers

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish or preparation of the manuscript.

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