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Meat and milk Camel quality in livestock extensive system

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ABBREVIATIONS

ASR	Sulfite-reducing Clostridium
Bcpl	Bromo- Cresol Purple Lactose
FC	Fecal Coliform
FS	Fecal streptococces
GLP	Good Laboratory Practicies
MPN	Most Propable nember
PCA	Plate Count Agar
SD	Standard Revision
SFB	Selenite F Broth
TAMAT	Total Aerobic Mesophile Flora
TC	Total Coliform
TS	Total Streptococcues
TSI	Tryptone Salt Water

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Abstract

In regions with challenging climates for animal management and production, camels stand out as a practical source of meat. Adapted to endure extreme conditions, they thrive where other domestic animals struggle.

In this study, we collected a total of 12 raw camel milk samples and 3 camel meat samples from mixed milking sources in two regions: Tamanrasset in southern Algeria and Bou Saâda in the southwestern part of the Hodna region (north of the Sahara). These samples were analyzed for their physicochemical and bacteriological properties.

Our research highlights the challenges encountered in obtaining cooperation from camel breeders. Factors such as pastoral conditions, nomadic lifestyles, remote pastures, and the absence of a reliable identification and traceability system greatly complicated the process. Moreover, our analysis of the physicochemical and microbiological properties indicates that both raw camel milk and meat meet the required standards, demonstrating satisfactory quality.

These findings deepen our understanding of camel-derived products and promote their safe and sustainable use in Algerian agriculture and beyond. Furthermore, conservation programs aimed at camel breeds could enhance biodiversity and support sustainable ecosystems in regions vulnerable to climate change. Providing livestock training courses to smallholders offers them opportunities for fair income and better working conditions, which could significantly contribute to social equity and local economic development.

Keywords:

Sustainable camel livestock; Milk quality; Meat quality; Breeders cooperation; Extensive system.

Résumé

Dans les régions aux climats difficiles pour la gestion et la production animale, l'élevage camelin se distingue comme une source pratique de lait cru et de viande. Adaptés pour endurer des conditions extrêmes, les chameaux prospèrent là où les bovins, ovins et caprins rencontrent des difficultés.

Dans cette étude, nous avons collecté un total de 12 échantillons de lait de chamelle cru et 3 échantillons de la viande de chamelle provenant de sources de traite mixtes dans deux régions : Tamanrasset, au sud de l'Algérie, et Bou Saâda, dans la partie sud-ouest de la région de Hodna (au nord du Sahara), ainsi que 3 échantillons de viande en provenance de la région de Bou Saâda. Ces échantillons ont été analysés pour leurs propriétés physico-chimiques et bactériologiques.

Notre étude a surlignée les défis rencontrés pour obtenir la coopération des éleveurs du camelin. Des facteurs tels que les conditions pastorales, les modes de vie nomades, les pâturages éloignés et l'absence d'un système fiable d'identification et de traçabilité ont grandement compliqué la collecte des échantillons. De plus, notre analyse des propriétés physico-chimiques et microbiologiques indique que tant le lait de chamelle cru que la viande, répondent aux normes requises, démontrant une qualité satisfaisante.

Ces résultats approfondissent notre compréhension des produits dérivés du chameau et encouragent leur utilisation sûre et durable. De même, les programmes de conservation visant l'élevage camelin pourraient améliorer la biodiversité et soutenir des écosystèmes durables dans les régions vulnérables aux changements climatiques. Offrir des cours de formation en bonnes pratiques d'élevage aux petits exploitants leur offre des opportunités de meilleures conditions de travail et de revenus plus équitables, ce qui pourrait contribuer significativement à l'équité sociale et au développement économique national.

Mots clés :

Élevage camelin durable ; Qualité du lait cru ; Qualité de la viande ; Coopération des éleveurs ; Système extensif.

الملخص

في المناطق ذات الظروف المناخية الصعبة لإدارة وإنتاج الحيوانات، تبرز الإبل كمصدر عملي للحوم. تتكيف هذه الحيوانات مع الظروف القاسية، مما يجعلها تزدهر حيث تعاني الحيوانات المستأنسة الأخرى.

في هذه الدراسة، جمعنا مجموعة من 12 عينات من حليب الإبل و3 عينات من لحم الإبل من مصادر متنوعة في منطقتين: تامنراست في جنوب الجزائر وبو سعادة في الجزء الجنوبي الغربي من منطقة الهضاب الشرقية (شمال الصحراء). تم تحليل هذه العينات لتقييم خصائصها الفيزيكوكيميائية والبكتيريولوجية

تسلط دراستنا الضوء على التحديات التي واجهناها في الحصول على التعاون من مربي الإبل، مثل الظروف الرعوية وأساليب الحياة الرحلية والمراعي النائية والنقص في نظام التعريف والتتبع الموثوق به، مما أدى إلى تعقيد كبير في العملية. كما أن تحليلاتنا للخصائص الفيزيكوكيميائية والميكروبيولوجية أظهرت أن حليب الإبل ولحمه يتوافقان مع المعايير المطلوبة، مما يدل على جودتهما المرضية.

تعزز هذه النتائج فهمنا لمنتجات الإبل وتعزز استخدامها الآمن والمستدام في الزراعة الجزائرية وخارجها. كما يمكن أن تساهم برامج الحفاظ على سلالات الإبل في تعزيز التنوع البيولوجي ودعم النظم البيئية المستدامة في المناطق الضعيفة المعرضة لتغير المناخ. وتوفير دورات تدريبية في تربية الماشية للمربين الصغار يمنحهم فرصاً للحصول على دخل عادل وظروف عمل أفضل، مما يسهم بشكل كبير في التوازن الاجتماعي والتنمية الاقتصادية المحلية.

الكلمات المفتاحية:

تربية الإبل المستدامة؛ جودة الحليب؛ جودة اللحم؛ تعاون المربين؛ نظام مرعي واسع.

Content

1. Introduction

In regions where the harsh climate poses challenges for animal management and production, the camel emerges as a viable meat source. Adapted to endure extreme conditions, camels thrive in environments where other domestic animals struggle to survive. This exceptional resilience stems from a combination of anatomical and physiological features. Remarkably, camels can go for several months without drinking water. In exceedingly hot conditions, they may only drink once every eight to ten days, enduring dehydration that can lead to a loss of up to 30% of their body weight (Al-Owaimer et al., 2014).

The drylands of Sub-Saharan Africa are characterized by limited rainfall, environmental aridity, climate fluctuations, and limited suitability for crop cultivation, both ecologically and economically. Consequently, these conditions provide opportunities for livestock rearing, as animals demonstrate better adaptation to the harsh environment compared to other natural resource-based activities. Pastoralism has emerged as the most viable livelihood option in the drylands of the Horn of Africa (Kena, 2022).

In comparison to other animals, camels possess distinctive characteristics and resilience suited to endure our challenging climatic conditions. Given that much of our country comprises desert and semi-desert regions, camels exhibit exceptional tolerance to high temperatures, low temperatures, and temporary water scarcity (Zhumabay et al., 2023).

Because of their distinct physiological traits, single-humped camels have emerged as symbols of resilience in confronting harsh conditions within arid and semi-arid regions. These camels serve multiple functions within domestic settings, being utilized for milk and meat production, transportation, ecotourism, and draft labor. Additionally, they offer hides, wool, hair, bones, and blood, and are engaged in racing activities. Camels hold diverse social and cultural roles within pastoral societies (Seifu, 2023). Given their distinctive physiology and considering the current effects of climate change on ecosystems, camels are positioned as highly suitable candidates for production (Chergui et al., 2024)**.**

In the world, around 40 million camels are used to produce more than three million tons of milk and more than 600.000 tons of meat annually (Koc et al., 2023). Camel meat boasts a rich nutritional profile, comprising approximately 76–78% moisture, 19% protein, 2.9–3% fat, and 1.2% ash. The nutrient composition of the meat can vary depending on factors such as age, sex, weight, and cut. Notably, camel meat is recognized for its leanness,

containing lower fat content compared to meat from other livestock like cattle and sheep. Furthermore, it contains less cholesterol and relatively higher levels of polyunsaturated fatty acids. Given the rising demand for healthy protein sources, these nutritional attributes have contributed to an increased consumption of camel-based products. However, despite this trend, there has been limited attention paid to the quality of camel meat and its correlation with the structural characteristics of camel muscle tissue (Al-Owaimer et al., 2014)**.**

Camel meat is promoted as a key dietary resource to meet the nutritional requirements of people in regions such as Arabia, Africa, and certain parts of Asia, especially in hot climates (Hamed Hammad Mohammed et al., 2020). Camels can offer an affordable and premium meat source, abundant in minerals and distinguished by its elevated protein yield, reduced fat and cholesterol levels, lower saturated fatty acid content, and increased monounsaturated fatty acid content (Belguith et al., 2024)**.**

Recently, the camelina breed has garnered considerable interest among scientists and breeders due to its ability to produce substantial quantities of milk for extended periods (Zhumabay et al., 2023)**.** Compared to milk from other species, camel milk offers superior nutritional content and therapeutic benefits (Seifu, 2023)**.**

Camel milk has garnered increasing interest and preference owing to its remarkable nutritional composition. Enriched with essential amino acids like proteins, glutamic acid, and lysine, camel milk provides vital elements essential for human dietary requirements (Yao et al., 2023). Camel milk serves as a primary dietary staple for millions residing in arid and semi-arid regions. Typically consumed raw or after spontaneous souring (Benmeziane – Derradji, 2021)**.**

Given the limited research on camel livestock in Algeria, this study aimed to address this gap by evaluating the physicochemical and microbiological properties of raw camel milk and meat from extensive farming systems. The specific objectives included analyzing the nutrient composition, quality, and safety of camel milk and meat. This comprehensive assessment is essential for improving the understanding of camel-derived products and promoting their safe and sustainable use in Algerian agriculture and beyond.

2. Materials and methods

2.1. Study area

The study was conducted over an extensive area of 37,962 km², encompassing two distinct regions in Algeria. The first region is the Tamanrasset area, situated in the southern part of the country, with coordinates 22° 47′ 13″ N and 5° 31′ 38″ E. The second region is Bou Saâda, located in the southwest of the Hodna region within the Hauts Plateaux, with coordinates 35° 13′ 09″ N and 4° 10′ 54″ E (Figure 1).

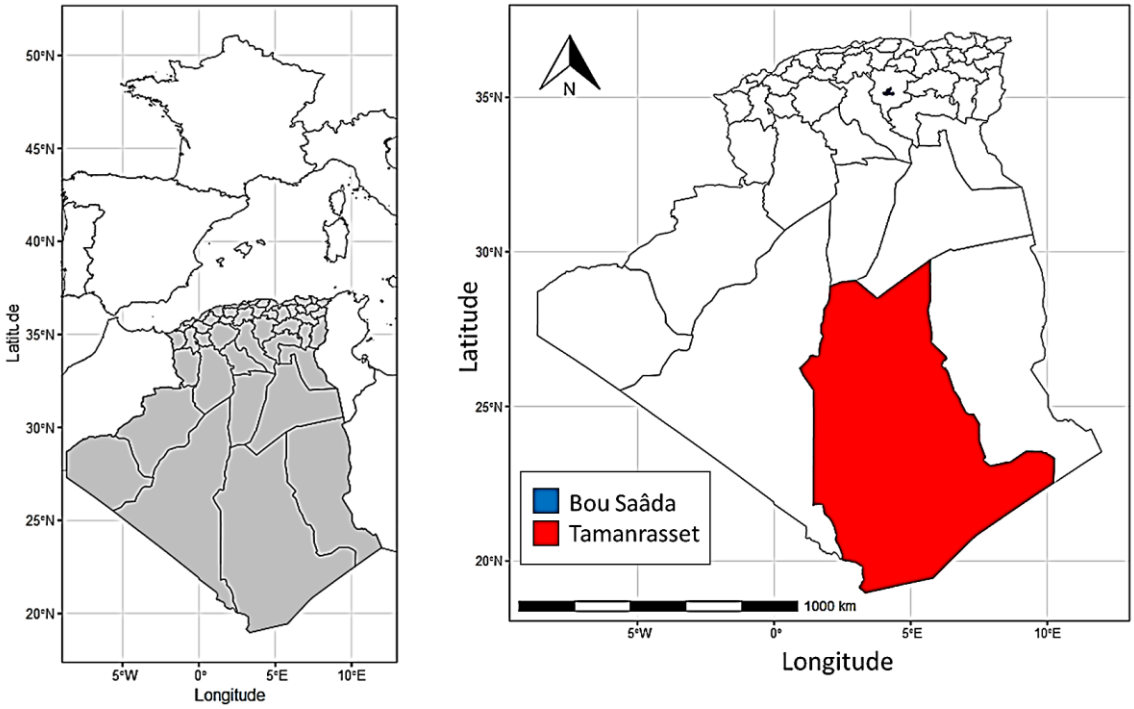

Figure 1: Map showing the study region of Tamanrasset and Bou Saâda, southeast Algeria. Map created using the Free and Open Source QGIS.

2.2. Samples collection

A total of 200 ml to 1 L of camel milk was collected from each herd, comprising nomadic and semi-nomadic livestock groups. The milk was collected in sterile glass bottles and immediately placed in a cooler. A portable car refrigerator was used to transport the milk from the breeders' locations to the residence of our guide, where it was frozen. Meat samples were collected directly from butchers.

The samples were then transported to the university laboratory at Université 8 Mai 1945 in Guelma, northeast Algeria, covering distances of 1530 km from Tamanrasset and 460 km from Bou Saâda, either by plane or bus. Camel milk was obtained by hand milking camels grazing in open-air fields, following udder washing. All bottles used for milk collection

were previously sterilized by autoclaving at 121 °C under 1 bar of pressure for 15 minutes. Adhering to aseptic procedures and Good Laboratory Practices (GLP), the vials were filled from a container of mixed milk, with hands disinfected before the process. No preservatives were added to the milk to accurately reflect field conditions.

This meticulous approach ensured the integrity and quality of the samples for subsequent physicochemical and microbiological analysis.

2.3. Bacteriological analysis

- ***Preparation of culture media***

Three samples of meat were ground and homogenized, and then 25 g of each sample were aseptically weighed and added to 225 ml of TSE (tryptone salt water) for the enrichment and resuscitation of germs which is the dilution 10^{-1}. Following thorough mixing, serial decimal dilutions were performed. Twelve samples of milk were added to 225 ml of TSE also for the enrichment and resuscitation of germs which is the dilution 10^{-1}. Following thorough mixing, serial decimal dilutions were performed. The various dilutions (10^{-1} to 10^{-3}) were inoculated in duplicate onto culture media and incubated at specific temperatures appropriate for the target microorganisms to be quantified.

- ***Culture media used***

Based on the employed techniques and the specific strains to be identified, the following culture media were utilized:

- ***Plate Count Agar PCA***

It is a non-selective, differential medium designed to support the growth of mesophilic aerobic bacteria by providing essential nutrients and a suitable environment for colony formation. PCA contains peptone, beef or yeast extract, agar, and sometimes a fermentable carbohydrate such as glucose.

- ***Meat Liver Glucose Agar***

Used for the enumeration of sulfite-reducing Clostridium spores because:
Glucose and peptone (as energy sources) promote the development of anaerobic bacteria.
Starch facilitates the germination of spores.
Anaerobic bacteria reduce sulfite to sulfide, which, in the presence of iron, leads to the blackening of colonies due to the formation of iron sulfide

- ***Mannitol Salt Agar***

Allows the enumeration of pathogenic staphylococci:

- The elevated concentration of sodium chloride suppresses the growth of most bacteria except staphylococci.

- Mannitol fermentation, indicated by the yellowing of the pH indicator phenol red, aids in diagnostic identification.

- Confirmatory testing for pathogenic staphylococci should include coagulase tests, and potentially deoxyribonuclease and phosphatase assays.

- ***Selenite F Broth SFB***

It is the medium used for the selective enrichment of *Salmonella* spp from both clinical and food samples. It is a buffered Lactose Peptone Broth to which Sodium Biselenite is added as the selective agent:

- The selenite content ensures the inhibition of microorganisms other than *Salmonella*, particularly coliforms and enterococci.

- Disodium phosphate helps maintain the pH and reduces the toxicity of selenite, thereby enhancing the recovery capacity of the medium.

- ***Rothe Broth***

It is used for the confirmation in the detection and enumeration of fecal streptococci in drinking water, wastewater, frozen products, and other foodstuffs using the most probable number (MPN) method.

The confirmation of fecal streptococces by: Eva Litsky

- ***Bromo-Cresol Purple Lactose (Bcpl)***

Bromo-Cresol Purple Lactose is utilized for identifying coliforms in water and food, as well as determining lactose-fermenting bacteria. Typically paired with Durham tubes to indicate gas production.

Lactose fermentation leads to acidification, turning the pH indicator (Bromo-Cresol purple) yellow, accompanied by gas accumulation in Durham tubes.

E. coli and coliforms, being lactose fermenters, generate gas and change the purple color to yellow.

The confirmation of fecal coliforms by: Schubert.

- ***Pseudosel Agar or Pseudomonas Cetrimide Agar***

Cetrimide agar is a selective medium used for isolating and presumptively identifying *Pseudomonas aeruginosa*.

Cetrimide, a quaternary ammonium compound, inhibits many bacteria, making the agar highly selective for *Pseudomonas aeruginosa*, especially when incubated at 42 °C.

- ***MRS agar***

Man, Rogosa and Sharpe, it is used to detect and enumerate *Lactobacillus* in dairy products, other food products, and animal feed**.**

- ***Sabouraud Chloramphenicol***

Sabouraud agar is a general-purpose medium used to grow and isolate a wide variety of yeasts and molds. The addition of chloramphenicol inhibits the growth of both Gram-positive and Gram-negative bacteria.

The microbiological analyses conducted in this Master's work were performed according to the protocols published in the Official Journal of the Algerian Republic (JORA, 1998, 2017).

- **Enumeration of total coliforms and fecal coliforms**

  - ***Inoculation***

To enumerate total and fecal coliforms, we use the Most Probable Number (MPN) technique.

Prepare a series of 9 tubes containing BCPL medium in a rack, and then put:

10 ml from the stock sample in 3 tubes.

1 ml from the stock sample in 3 tubes.

0.1 ml from the stock in 3 tubes.

Enumerate fecal coliform based on the positive reactions from the presumptive test subculture into a tube containing Schubert medium (confirmation test).

After incubation, we use Kovacs reagent.

- ***Incubation***

For total coliforms, the plates are incubated at 37 °C for 24 to 48 hours.

For fecal coliforms, the plates are incubated at 44 °C for 24 hours.

- ***lecture***

Total coliforms: turbidity, color change, increases in volume of the Durham tube.

Fecal coliforms: turbidity, increase in volume of the Durham tube, red ring.

- **Enumeration of fecal *streptococci***

  - ***Inoculation***

To enumerate total and fecal *streptococci*, we use the Most Probable Number (NPP) technique (the same as total and fecal coliform).

We use roth medium.

Enumerate fecal streptococci based on the positive reactions from the presumptive test subculture into a tube containing Eva litsky medium (confirmation test).

  - ***Incubation***

For total streptococci, the plates are incubated at 37 °C for 24 to 48 hours.

For fecal streptococci, the plates are incubated at 44 °C for 24 to 48 hours.

  - ***Lecture***

Total streptococci: turbidity, color change, increases in volume of the Durham tube.

Fecal streptococci: turbidity, increase in the volume of the Durham tube, white or purple ring.

- **Enumeration of Total Aerobic Mesophilic Flora (TAMF)**

  - ***Inoculation***

From decimal dilutions add 1 ml of the dilution to an empty petri dish then put Plate Count Agar (PCA) medium.

Distribute the inoculum in the shape of an "8" to ensure thorough mixing with the agar.

  - ***Incubation***

Incubate the plates at 30 °C for 72 hours, taking readings every 24 hours (at 24, 48, and 72 hours).

  - ***Lecture***

It is done by counting the colonies on each petri dish.

- ***Enumeration of psychrophilic bacteria***

- ***Inoculation***

Psychrophilic organisms are extremophiles capable of living and reproducing at low temperatures.

Same method as Total Aerobic Mesophilic Flora (TAMF)

- ***Incubation***

Incubate the plates at -5°C for 10 days.

- ***Lecture***

It is done by counting the colonies on each petri dish.

- **Enumeration of presumptive pathogenic *staphylococci***

- ***Inoculation***

From decimal dilution 0.2 ml are inoculated on a solid medium (Chapman agar) by surface spreading.

- ***Incubation***

The plates are incubated at 37 °C for 48 hours.

- ***Lecture***

Staphylococcus aureus appears as small, smooth, slightly raised colonies with regular edges, and they are either yellow (due to mannitol fermentation).

To confirm the presence of *Staphylococcus aureus* colonies, perform rapid biochemical tests (catalase and coagulase).

Conduct the coagulase test only on catalase-positive colonies, and record the number of colonies that are positive for both catalase and coagulase.

- **Detection of *Salmonella***

- ***Inoculation and incubation***

- **Pre-enrichment Step:** Incubate the inoculated Buffered Peptone Water solution for 16-20 hours at 37 °C.

- **Enrichment Step:** From the pre-enrichment, perform an enrichment using double-concentrated SFB broth. Incubate for 18-24 hours at 37 °C.

- **Isolation Step:** Only isolate from the flasks that show a brick-red color change on Hektoen agar. Incubate at 37 °C for 18-24 hours.

Note: During this step, also perform a secondary enrichment by adding 10 ml of SFB broth to a tube and incubate for 18-24 hours at 37 °C.

- ***Lecture***

Typical colonies (strong suspicion of *Salmonella*): colonies with regular edges, transparent (green on Hektoen) with or without a black center (H2S positive).

Subculturing on TSI (Triple Sugar Iron): This allows the detection of lactose, glucose, and sucrose fermentation, as well as gas and H2S (hydrogen sulfide) production.

- **Enumeration of sulfite-reducing Clostridium (ASR)**

- ***Inoculation***

The prepared dilutions are introduced into a water bath at 80°C for 10 minutes (favorable conditions).

A cold-water thermal shock (unfavorable conditions) is then applied to destroy the vegetative form and spore activity. Subsequently, 15 ml of meat liver glucose agar is introduced through deep inoculation, with 0.2 ml of iron alum and 0.5 ml of sodium sulfite.

- ***Incubation***

The tubes are incubated at 46 °C for 48 hours.

- ***Lecture***

Sulfite-reducing Clostridia appear as large black colonies with a diameter greater than 0.5 mm.

- **Enumeration of lactobacillus**

Inoculation

From decimal dilution Transfer 0.2 ml and added to a petri dish containing MRS agar, then spread it evenly.

- ***Incubation***

The plates are incubated at 37 °C for 48 hours.

- ***Lecture***

White colonies are observed after performing Gram coloration and examining them under the microscope. If the colonies are identified as purple bacilli, we will proceed with the API 20E test for confirmation.

- **Enumeration of *pseudomonas***

  - ***Inoculation***

From decimal dilution 0.2 ml inoculated on a solid medium (citrimid agar) by surface spreading.

  - ***Incubation***

The plates are incubated at 37 °C for 48 hours.

  - ***Lecture***

It is done by counting the green colonies on each petri dish.

- ***Enumeration of yeasts and molds***

  - ***Inoculation***

From decimal dilutions add 1 ml of the dilution to an empty petri dish then put Plate sabouraud chloramphenicol agar.

Distribute the inoculum in the shape of an "8" to ensure thorough mixing with the agar.

  - ***Incubation***

The plates are incubated at 25 °C for 5 days

  - ***Lecture***

Yeasts

Colonies are generally smooth, shiny, and white or cream-colored, medium-sized.

Molds

Colonies are often fluffy or powdery, with variable colors (white, green, black, etc.), with visible filamentous structures.

2.4. Physiochemical analysis

2.4.1. Physicochemical milk properties

For the physicochemical analysis of milk, various parameters were assessed using specialized equipment and standardized methods. The pH was measured with a pH meter (Adwa, AD1000), while the acidity (expressed in °D) was determined following the procedure outlined by Boudalia et al. (2023). Several other properties, including density (mg/cm³), electrical conductivity (µS/cm), freezing point (°C), fat content (%), protein

content (%), lactose content (%), mineral content, vitamin content (%), and the rate of added water (%), were measured using a Lactoscan milk analyzer (Milkotronic Ltd., Nova Zagora, Bulgaria). This analyzer was specifically calibrated for camel milk in accordance with the manufacturer's instructions, ensuring precise and accurate measurements for these components.

2.4.2. Physicochemical meat properties

- ***pH***

A 5 g sample of meat was weighed and mixed with 20 ml of distilled water (1:4, v/v). The mixture was then homogenized for 20 minutes at medium speed. The pH was measured using a glass electrode pH meter (AD1000, Adwa, Szeged, Alsó-Kikötő sor, Hungary).

- ***Total Dry Matter***

The total dry matter content was determined by oven-drying 5 g of minced meat at 105 °C for 12 hours, following the test standard NM ISO 5534-2001. After drying, the crucibles were cooled in a desiccator for 45 minutes. The dry matter was then weighed and compared to the initial mass to determine the amount of evaporated water. The percentage of dry matter (DM) in the sample was calculated using the following expression:

$$\% (DM) = (\text{mass (DM)} / \text{mass (sample)}) \times 100$$

$$\% (H_2O) = 100 - \% (MS)$$

- ***Water Holding Capacity***

The water holding capacity of the muscle was assessed following the method described by Goutefongea (1963). In this procedure, 5 g of muscle tissue was placed in a grooved 45 ml centrifuge tube, and 7.5 ml of water was added. The muscle was then ground directly in the centrifuge tube using a mortar. The prepared samples were centrifuged at 6500 rpm for 20 minutes in a centrifuge, which was cooled by water circulation to maintain a stable temperature.

After centrifugation, the supernatant liquid was carefully removed, and the centrifuge tubes containing the pellets were allowed to drain for 10 minutes to ensure complete removal of any remaining liquid. The weight of the samples was measured before and after the procedure to determine the water holding capacity. This measurement was calculated based on the weight loss or gain, which corresponded to the amount of water retained or lost by

the muscle tissue. The results were expressed as a percentage, providing an indication of the muscle's ability to retain water during processing.

Color measurements

Color is a multifaceted visual experience that can be measured using three basic parameters: luminance or brightness, chrominance or hue, and saturation. The hue is defined by the color's wavelength, luminance by the percentage of light an object reflects, and saturation by the color's purity. To objectively measure color, colorimetry is employed. The L*a*b* color space, also known as CIELAB, is one of the most commonly used systems for this purpose across various fields. This color space is three-dimensional, with L* indicating luminance, a* representing the red-green axis, and b* signifying the yellow-blue axis. (Robertson, 1977).

Konica Minolta CR-410 colorimeter with a D65 illuminant (Konica Minolta, Tokyo, Japan) was used to measure color, following the method approved by AACC 14-22.01. (AACC, 2010). Meat samples were placed in the patty material accessory, after which their color was measured. The results are presented using the color space system. (Robertson, 1977) for L* (lightness; 0 = black, 100 = white), a* (red-green; +a = red, -a = green), and b* (yellow-blue; +b = yellow, -b = blue). The colorimeter was calibrated prior to measurement using a standard white tile with values of (L* = 98.45, a* = -0.10, and b* = -0.13).

According to Güler et al. (2021), the values for the whiteness index (WI), hue angle (h°), and saturation (C) were calculated using the following formulas:

$$WI=100-\sqrt{(100-L)^2+a^2+b^2}$$

$$h^{\circ} = \arctan\left(\frac{a}{b}\right)$$

$$C = \sqrt{a^2 + b^2}$$

Figure 2 : Konica Minolta Colorimeter Model CR-410 (Université 8 Mai 1945, Guelma)

2.5. Data Analysis

The results are presented as means ± standard deviation (SD). A comprehensive descriptive analysis of the data was conducted using Minitab software, version 16 (Minitab Ltd., United Kingdom). The significance level was considered set at $p < 0.05$.

2. Results and discussion

2.1. *Camels'* characteristics

Figure 3 show different livestock included in this study. Breeders/herders of these animals are nomads, which are extremely difficult to meet. Moreover, convincing participants to actively engage in the study poses significant challenges. Additionally, collecting samples and ensuring that logistics are handled under optimal conditions is difficult. We faced similar issues in our previous study conducted in the Wilaya of Oued Souf (Boudalia et al., 2023). As reported in other regions, the nomad refers to people who move cyclically or periodically with an ephemeral habitat (tent), while the transhumant implies a seasonal movement of people and their herd for grazing (Amsidder et al., 2021).

In this extensive system, there is no livestock identification or traceability system in place. However, in certain regions, traditional camel identification is conducted using familial symbols ("الوشم" in Arabic), which are engraved with red iron brands on visible body locations such as the neck, cheek, or thigh (Bedda et al., 2019; Caja et al., 2016). As far as our knowledge extends, camel identification is strictly regulated only in the Emirate of Abu Dhabi, where radio-frequency identification microchips or transponders are employed (ADFCA, 2010).

Camel breeders have observed that milk yield is notably low in extensive systems. Our own research in the Oued Souf region (Boudalia et al., 2023), supports this finding, as do the results reported by Hadef et al. (2020), who found an average milk yield of 4.32 ± 0.14 L/day from healthy camels in southeast Algeria. Additionally, Adamou and Boudjenah (2012) noted that Sahrawi camel breeds, under semi-intensive farming conditions in the same region, produce approximately 2.48 L/day of milk.

Figure 3: Extensive camel livestock. Photographs were captured on a traditional farm located in Tamanrasset area, situated in the southern part of the country, depicting the extensive breeding practices conducted there.

2.2. *Milk properties*

2.2.1. Physicochemical properties

In this study, camel milk exhibited an average pH of 5.43, which is lower than the pH values reported in other studies: 6.34 ± 0.11 by Boudalia et al. (2023) and 6.63 ± 0.22 by Khaldi et al. (2022). This lower pH indicates that the milk is more acidic, which is probably due to poor forage quality and a higher microbial load caused by higher temperatures. Furthermore, these results are in concordance with those reported in the locality of Bir Naam (South-East Algeria) (Hadef et al., 2018; Hadef et al., 2020), in Bechar, El Al-Bayadh and Naama (Algeria) (Merzouk et al., 2013), and in southern Morocco (Alaoui Ismaili et al., 2019; Bouhaddaoui et al., 2019).

The average fat content in our study was found to be 6.01 ± 4.45%, indicating significant variability. This is notably higher than the values reported by other researchers. For instance, Boudalia et al. (2023), reported fat content ranging from 3.53% to 3.68% (35.3 to 36.8 g/L) with a low coefficient of variation (CV) of 1.6%. Similarly, Khaldi et al. (2022) observed a fat content of 5.95 ± 0.39%. Furthermore, Seifu (2023) reported a fat content values of 32 g/l (3.2%) milk. The higher variability and greater average fat content in our study highlight potential differences in sample sources, methods of analysis, or regional variations in milk composition.

The average protein content recorded in our study was 2.975%, which aligns closely with the values reported by Boudalia et al. (2023), who found a protein content of 2.8 ± 0.02% (28 ± 0.2 g/L). Similarly, Seifu (2023) reported a protein content of 31 g/L in milk. Other studies have shown some variation in protein content: Merzouk et al. (2013) reported 29.20 ± 4.55 g/L in Algerian camel milk, while Alaoui Ismaili et al. (2019) found 25.5 ± 2.70 g/L in Moroccan camel milk. These findings indicate a generally stable protein concentration in camel milk, with minor regional differences.

The lactose content recorded in our study was 62.65 ± 29.45 g/l, which is higher than the values reported by Boudalia et al. (2023), at 42.20 ± 0.02 g/l, and by Hadef et al. (2018) in southeast Algeria at 40.5 ± 2.5 g/l. Concerning mineral levels, our study reported a concentration of 8.65 ± 0.35 g/l, which is higher compared to the literature values of 69 ± 18 g/l reported by (Alloui-Lombarkia et al., 2007).

The average conductivity values recorded in our study were 8.11 ± 0.285 mS/cm. To our knowledge, the conductivity of camel milk is poorly documented. However, our findings are

consistent with those reported in India (6.08 mS/cm) and Algeria (6.84 ± 0.14 mS/cm) by (Hadef et al., 2020; Yoganandi et al., 2014). Additionally, our freezing point results were similar to those described by Yoganandi et al. (2014) for raw camel milk collected from the Anand and Kheda districts in India (-0.518 ± 0.001 °C).

The variation in the proximate composition of raw camel milk samples can be attributed to factors such as season, water access, breeding area, production system, lactation stage, health status, season, method of analysis, milking interval, breed, lactation stage, climatic conditions and feeding practices (Boudalia et al., 2023; Seifu, 2023).

Table 1: Physicochemical characteristics of the analyzed camel milk samples (N = 12)

	Mean	SD	Min	Max
pH	6.01	4.45	1.56	6.01
Titratable acidity (° Dornic)	18.758	0.829	18	20
Density (mg/cm^3)	1028.6	0.22	1028.4	1028.9
Conductivity (mS/cm)	8.11	0.285	8.115	8.4
Freezing point (°C)	-0.27675	0.13046	-0.369	-0.1845
Fat (%)	6.01	4.45	1.56	10.46
Protein (%)	2.975	0.395	2.58	3.37
Lactose (%)	6.265	2.945	3.32	9.21
Mineral content and vitamins (%)	0.865	0.355	0.51	1.22
Added water rate (%)	7	0.74	5.76	7.69

SD: Standard Deviation.

2.2.2. Microbiological analysis

The descriptive characteristics of the enumerated flora are summarized in Table 2. The *total aerobic mesophilic flora* (TAMF) is a reliable indicator of the hygienic quality of raw milk (Ghazi and Niar, 2011). The enumeration of this flora in the raw milk samples revealed an average microbial load that indicates a satisfactory quality of raw camel milk, meeting the required standard of 3 × 10^5 CFU/ml (JORA, 1998). Additionally, our data show lower microbial loads compared to those reported by Boudalia et al. (2023) and Merzouk et al. (2013) in three different Saharan regions (Bechar, El-Bayadh, Naama, and Oued Souf) here the microbial load was higher, exceeding 2.2 × 10^5 UFC/ml. Moreover, our results are similar

to those reported by Alaoui Ismaili et al. (2019) who observed TAMF rates ranging from 5.6 × 10^3 to 1.8 × 10^9 CFU/ml in camel milk collected in Morocco.

Coliforms generally indicate fecal contamination, and their numbers are usually proportional to the degree of pollution caused by fecal matter (Aggad et al., 2010). The results from samples were lower than those reported by Khaldi et al. (2022), which recorded an average of (5.16 ± 1.49 log CFU/ml), and also data recorded by Boudalia et al. (2023) in Oued Souf region. This lower value reflects a satisfactory quality of raw camel milk, adhering to the required standards of (3 × 10^{-5} CFU/ml) (JORA, 1998) .

Sulfite-reducing clostridia (ASR) were scarcely present in the analyzed samples, with low concentrations (<50 CFU/ml). The absence of *Salmonella* in all camel milk samples is a crucial indicator of its microbiological safety. It suggests that the milk is free from a common pathogen known to cause serious foodborne illnesses, highlighting the effectiveness of good hygiene practices during milk collection and handling. In the same way, the absence of *Staphylococcus aureus* in all samples except one, they indicate a satisfactory quality of raw camel milk according to the required standards, which are 10^{-3} CFU/ml (JORA, 1998). This finding is consistent with results from other studies Khaldi et al. (2022), but relatively different in comparison with the data reported by Boudalia et al. (2023) in Oued Souf region, ho recorded for, two positive cases for Salmonella (22.22% of total samples), and those recorded by (El-Ziney and Al-Turki, 2007), which reported 8 positive cases out of 33 raw camel milk samples (24%) collected in the Quassim region (Saudi Arabia).

Table 2: Descriptive characteristics of studied flora and milk standards (UFC/ml) (N = 12 raw camel milk)

Flora (UFC/ml)	Mean ± SD	Standard (CFU/ml)
TMAF (× 10^3)	49 ± 108	10^5
T. Col (× 10^3)	6.81 ± 6.96	10^3
F. Col (× 10^3)	6.81 ± 6.96	10^3
SF (germe/100 ml)	4.75 ± 6.34	/
Lactobacilles (ufc/ml)	Absence	/
Staphylococcus	1 positive case	Absence
Sulphite reducing *Clostridium*	5.83 ± 6.68	50 UFC/ml
Salmonella	Absence	Absence

TMAF: Total Mesophilic Aerobic Flora; T. Col.: total Coliforms; F. Col.: fecal Coliforms; fecal streptococces; SD: Standard Deviation

2.3. Meat properties

2.3.1. Physicochemical properties

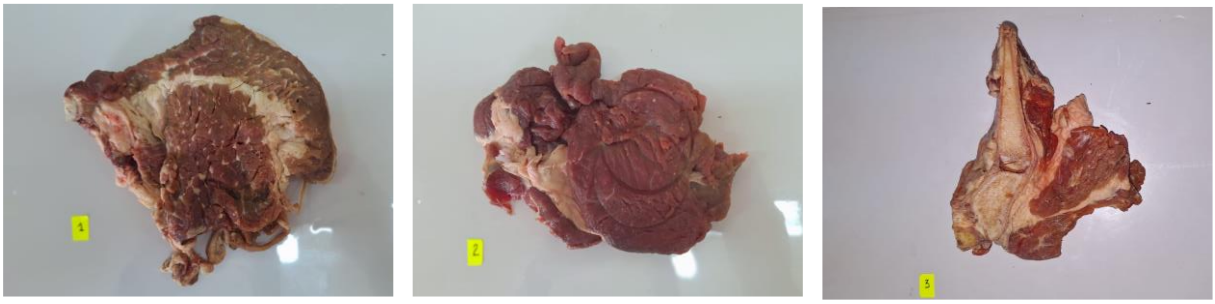

Figure 4: Camel meat samples analyzed for colors.

In our study, the pH values of camel meat samples were 6.18, 6.037, and 6.1, respectively. These values are consistent with those reported by Abdelhadi et al. (2017), who found pH values of 6.10 in male camels and 6.18 in female camels. The pH of meat is a critical factor as it significantly impacts various physicochemical and quality properties, including water-holding capacity, tenderness, and juiciness (Hamed Hammad Mohammed et al., 2020)**.** A higher pH value is often associated with better water-holding capacity, which helps in retaining moisture and improving the overall tenderness and juiciness of the meat. Furthermore, the high muscle pH observed in our results may be attributed to low stored muscle glycogen. Camel muscles possess unique properties compared to bovine muscles, which can result in higher pH values (Abdelhadi et al., 2017).

Our results for the dry matter content in camel meat were significantly higher than expected. Specifically, samples S1 and S3 had dry matter contents of 93%, while sample S2 had a dry matter content of 95%. These values are markedly aberrant when compared to the data reported in the literature. For instance, Abdelhadi et al. (2017), reported dry matter contents of 22.9 ± 0.27% for males and 24.2 ± 0.11% for females.

Concerning color, we reported slight variations in the color measurements of the three camel meat samples: (sample 1: L* = 45.29, a* = 12.29, b* = 45.29, sample 2: L* = 36.08, a* = 18.41, b* = 36.08). These values are higher to those reported by Hamed Hammad Mohammed et al. (2020), who found L* = 41.69 ± 0.24, a* = 21.67 ± 0.18, and b* = 17.10 ± 0.22. Similarly, they are also higher than data reported in another study: L* = 24.5 ± 0.53, a* = 15.1 ± 1.05, and b* = 5.6 ± 0.45 (Abdelhadi et al., 2017). The high redness (a*) and yellowness (b*) in fresh camel meat may be due to the high levels of heme pigment and myoglobin content found in fresh camel meat Hamed Hammad Mohammed et al. (2020)**.**

Table 3: Physicochemical characteristics of the analyzed camel milk samples (N = 3)

	S1	S2	S3
Dry material (%)	93	95	93
H_2O (%)	7	5	7
Water Holding Capacity (%)	8	8	8
pH	6.18	6 037	6.1
L*	45.29	36.08	41.89
a*	12.29	18.41	14.27
b*	11.27	6.56	8.09
WI	42.81	32.99	39.62
h°	1.09	2.80	1.76
C	16.68	19.54	16.4

S: sample.

2.3.2. Microbiological analysis

In our study, the enumeration of Total Aerobic Mesophilic Flora (TAMF) in camel meat samples indicated its absence in samples 1 and 3, while it was present in sample 2. This suggests satisfactory quality of the camel meat. Furthermore, fecal coliforms and Pseudomonas bacteria were completely absent in all camel meat samples, indicating no fecal contamination. These findings are well below the established norms of 10^2 and 10^5 ufc/g, respectively, demonstrating good microbiological quality. From literature, study has shown the prevalence of *Listeria monocytogenes* in camel meat in Riyadh, Saudi Arabia, with some strains exhibiting antibiotic resistance (Yehia et al., 2020). The microbial quality of camel meat and edible offal, including liver, kidneys, lungs, and rumen, has been investigated, revealing the presence of various microorganisms (Tang et al., 2020). Studies have also explored the impact of different compounds, such as tannic acid, date seed extract, catechin, and green tea extract, on lipid oxidation, microbial load, and overall quality of camel meat products (Maqsood et al., 2016) (Maqsood et al., 2015). In other studies, essential oils and vacuum packaging have been studied for their effects on spoilage microorganisms in marinated camel meat, showing changes in the population of lactic acid bacteria under different conditions (Osaili et al., 2021).

Table 4: Descriptive characteristics of studied flora and meat standards (UFC/ml) (N = 3 meat samples)

Flora (UFC/ml)	**Mean ± SD**	**Standard (CFU/ml)**
TMAF	< 15	10^5
T. Col (× 10^2)	20 ± 22	10^3
F. Col	00	10^3
SF (germe/100 ml)	4.75 ± 6.34	/
Lactobacilles (ufc/ml)	Absence	/
Staphylococcus	1 positive case	Absence
Sulphite reducing *Clostridium*	10 ± 10	50 UFC/ml
Yest and molds(ufc/g) (× 10^2)	5.33 ± 4.04	Absence
Psychrophylic bacteria(ufc/g) 10^2	24 ± 16	/
Pseudomonas(ufc/g)	00	/

TMAF: Total Mesophilic Aerobic Flora; T. Col.: total Coliforms; F. Col.: fecal Coliforms; sf: fecal streptococces; SD: Standard Deviation

3.Conclusion

In this study, we assessed the physicochemical and microbiological properties of raw camel milk and meat obtained from extensive farming systems in two regions: Tamanrasset in the southern part of Algeria, and Bou Saâda in the southwest of the Hodna region (north of the Sahara).

One of the challenges encountered in our study was the collection of samples, primarily due to difficulties in obtaining cooperation from camel breeders. The pastoral conditions, nomadic lifestyle, remote pastures, and extensive mobility without a reliable identification and traceability system made the process very complex.

Our findings regarding the physicochemical and microbiological properties indicate satisfactory quality of both raw camel milk and meat, meeting the required standards. These results can contribute to understanding camel-derived products and promote their safe and sustainable utilization in Algerian agriculture and beyond.

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