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Physiochemical Properties and Nutritional Composition of Camel Milk in Garissa County, Kenya

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ABSTRACT

Camel milk is an important source of food, income, and livelihood for communities in arid and semi-arid regions. It contains essential macronutrients, minerals, vitamins, and bioactive compounds that contribute to human health. Despite Kenya's status as a prominent producer of camel milk, especially in Garissa County, comprehensive data regarding its physicochemical and nutritional composition remain scarce. The present study aimed to determine the physicochemical attributes and nutritional profile of camel milk sourced from Garissa County. Fifteen raw milk samples were collected in May 2024 during the long rainy season from randomly selected, clinically healthy lactating Somali dromedary camels reared under semi-intensive systems on five dairy farms in Garissa County, Kenya, under hygienic conditions (three samples per farm). Physicochemical parameters measured included pH, color, titratable acidity, viscosity, total solids, and moisture. Nutritional components analyzed were fat, protein, lactose, minerals, vitamins, and fatty acids using AOAC methods and gas chromatography–mass spectrometry. The camel milk samples exhibited a mean pH of 6.63 ± 0.10, 0.14 ± 0.03% titratable acidity, 1.86 ± 0.08 mPa·s viscosity, 12.68 ± 0.66% total solids, and 87.20 ± 2.86% moisture. Proximate composition indicated 4.2 ± 0.2% fat, 2.3 ± 0.1% protein, and 5.1 ± 0.2% lactose. Calcium (5293.16 ± 54.49mg/l) was the most abundant mineral. Among vitamins, vitamin C was the most abundant water-soluble vitamin, while vitamin K was the most dominant fat-soluble vitamin. Fatty acid analysis indicated that (55.4%) of the fatty acids were saturated and (44.6%) were unsaturated. Palmitic acid and oleic acid were the most abundant. The results indicated relatively uniform physicochemical and nutritional characteristics of camel milk produced under semi-intensive systems from selected farms in Garissa County, Kenya. The results of this study provided descriptive insight for future studies with larger sample sizes within this county, as well as comparative study across counties and different seasonal conditions.

Keywords: Camel milk, Fatty acid, Nutritional composition, Physicochemical characteristic

INTRODUCTION

Camels are the most prevalent desert livestock animals in arid and semi-arid regions of Africa and Asia, particularly in the Horn of Africa, including Ethiopia, Djibouti, Somalia, and Kenya (Faye, 2020). The single-humped dromedary camel (*Camelus dromedarius*) is exceptionally adapted to hot and arid environments among domesticated animals (Faye, 2020). Current estimates are that there are more than 35 million camels in the world, of which the majority (~97%) are single-humped dromedaries (Camelus dromedarius), and less than 3% are two-humped Bactrian camels (*Camelus bactrianus*; Faye, 2020). Camels are famous for their resilience in desert environments, tolerating heat and limited availability of water (Faye, 2020). Although they need significantly less feed than other livestock due to their highly efficient metabolism and ability to utilize sparse desert vegetation. Camels can produce very high rates of milk, at times even higher than other livestock types in deserts such as cattle, goats, and sheep. In a lactation cycle between 8 and 18 months, a dromedary camel can deliver 1,000 to 2,000 liters of milk (Gebreyohanes and Assen, 2017). The global production of camel milk was reported to be 4.12 million metric tons (MMT) in 2022 (Ait El Alia et al., 2025). Kenya is the largest producer with (1.165 MMT) annually, followed by Somalia (0.958 MMT) and Mali (0.271 MMT; Oselu et al., 2022). The North-Eastern pastoralists in Kenya keep approximately 4.722 million camels, 80 % of the nation's camels (Oselu et al., 2022). Among these communities, such as the Somali, Gabbra, and Rendille, camels play a central role by providing milk, meat, hides, fiber, and transport services (Isako and Kimindu, 2019).

Camel milk is uniquely different from other ruminant milks in terms of nutritional composition and potential health benefits (Faye, 2020). Compared to bovine milk, camel milk contains higher concentrations of vitamin C, lacks β-lactoglobulin (a major allergen in cow milk), and has lower cholesterol levels (El-Agamy et al., 2009). It also contains special bioactive molecules such as immunoglobulins, lactoferrin, lactoperoxidase, and higher concentrations of vitamin

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C than bovine milk (Alhassani, 2024). Moreover, the bioactive molecules in camel milk, particularly immunoglobulins, lactoferrin, and lactoperoxidase, have been reported to exhibit anti-diabetic, anti-allergic, antimicrobial, and immune-modulating effects (Seifu, 2023). The physicochemical characteristics of camel milk vary by geographic region, environmental context, breed, diet, and stage of lactation (Seifu, 2023). Northeastern Kenya is among the globe's biggest producers of camel milk, with Garissa County being among the top production hubs (Oselu et al., 2022). Despite the significance, there is a notable lack of detailed physicochemical and nutritional data on camel milk from Garissa County, Kenya. Addressing this gap is necessary because region-specific composition data can assist processors in setting product standards, support evidence-based nutritional guidance, facilitate product development within the camel milk value chain, and provide baseline values for future studies on factors influencing milk composition. Therefore, this study aimed to characterize the physicochemical properties and nutritional composition of camel milk produced under semi-intensive systems in Garissa County, Kenya.

MATERIALS AND METHODS

Study design and sampling

A cross-sectional descriptive study was conducted to characterize the physicochemical and nutritional composition of camel milk from Garissa County, Kenya. Fifteen samples of raw milk were collected in May 2024 (long-rainy season) from five dairy farms (three samples per farm). Clinically healthy, multiparous Somali dromedary camels (*Camelus dromedarius*) aged 5-12 years and in mid-lactation (3-7 months) were randomly selected. Udders and teats were wiped clean with 70% ethanol before sampling. Camels were reared under semi-intensive systems, grazing freely during the day and housed at night. Camels indicating signs of illness, udder health issues, abnormal lactation stages, or recent drug treatment (within 14 days) were excluded. Milking was performed in the early morning, and approximately 200 mL of milk was collected per camel**.** Samples were aseptically collected, placed on ice (4°C), and transported within 4 hours (Legesse et al., 2017) to the Food Fortification Laboratory, Jomo Kenyatta University of Agriculture and Technology (JKUAT), for analysis.

Physicochemical analysis

Physicochemical parameters were measured by employing the following standardized methods. The pH was measured using a calibrated pH meter (Model AD800, Hanna Instruments, Italy) calibrated with standard buffers pH 4.0, 7.0, and 10.0. Measurements were conducted at a controlled temperature of 25 ± 1°C (Legesse et al., 2017). The color of milk was measured using a Color Flex machine (HunterLab, Reston, VA, USA) with a CIELab system, D65 illuminant, 10° observer angle, and 45/0 measurement geometry. Samples were placed in transparent quartz cuvettes, and color was determined by measuring the light transmitted through the milk (El-Hatmi et al., 2023). The lactic acid content was determined according to the AOAC Official Method 947.05 (AOAC, 2016a) using a titrimetric procedure. Briefly, a known volume of camel milk was titrated with a standardized 0.1 N sodium hydroxide (NaOH) solution until the endpoint was reached, and the lactic acid percentage was calculated based on the volume of NaOH consumed.

The viscosity was measured using an Anton Paar Rheometer (RheolabQC, SN84508188, Anton Paar GmbH, Graz, Austria) with a CC27 concentric cylinder spindle. Before measurement, milk samples were gently homogenized to ensure homogeneity and were carefully put into the measurement cup to avoid air bubble formation. To obtain reliable viscosity values, samples were equilibrated at a controlled temperature of 30 ± 0.1°C for around 10 minutes before analysis. Viscosity measurements were taken at a constant shear rate of 50 s^{-1}, widely employed for low-viscosity dairy fluids. The dynamic viscosity was measured in mPa·s (Alhassani, 2024). Total solid and total moisture content were determined by a drying oven method according to AOAC 925.10 (AOAC, 2016b; AOAC International, Rockville, MD, USA), by placing approximately 5g of milk sample in a weighed crucible and keeping it in a drying oven (Memmert 100-800, Memmert) at 105°C approximately 3 hours or until constant weight was achieved, defined as the point at which repeated cycles of drying, cooling in a desiccator, and reweighing resulted in two consecutive weight measurements differing by less than 0.001 g, indicating complete removal of moisture (Abduku and Eshetu, 2024). Total moisture was determined on the basis of the loss of weight, because water evaporates, which was determined by an analytical balance (Model MS204TS, Mettler Toledo GmbH, Greifensee**,** Switzerland**),** with a precision of ± 0.0001 g. The total solid content was obtained using the weight of the dried sample (Abduku and Eshetu, 2024).

Nutritional composition analysis

Fat content was determined by the Rose–Gottlieb method (AOAC 989.05; AOAC International, Rockville, MD, USA) using approximately 10 g of milk, followed by solvent extraction with concentrated ammonium hydroxide, ethanol, diethyl ether, and petroleum ether in a Mojonnier fat-extraction flask (Gerber Instruments AG, Effretikon,

Switzerland). The extraction solvents were evaporated under vacuum at 60°C utilizing a rotary evaporator to slowly remove the solvents employed in extraction without decomposing the fat. Vacuum evaporation decreases the boiling points of the solvents, allowing them to evaporate at a moderate temperature successfully and leaving behind the crude fraction of fat (Model R-210, Büchi Labortechnik AG, Flawil, Switzerland). After vacuum, the extracted fat was dried at 102 ± 2°C for 30 minutes using a laboratory drying oven (Memmert GmbH and Co. KG, Schwabach, Germany) to eliminate residual moisture and then weighed using an analytical balance (Model MS204TS, Mettler Toledo GmbH, Greifensee, Switzerland; precision ± 0.0001 g; Bakry et al., 2021).

Crude protein content was determined using the Kjeldahl method according to AOAC Official Method 991.20 (AOAC International, Rockville, MD, USA), involving first sample digested with strong sulfuric acid, which converts organic nitrogen into ammonium sulfate. The solution is then made alkaline to release ammonia, which is distilled and collected in boric acid before being quantified by titration with a standard acid to estimate total nitrogen, which is then converted to crude protein using a factor of 6.38 (He et al., 2019).

Lactose content was determined by high-performance liquid chromatography (HPLC; Model LC-20AT, Shimadzu Corporation, Kyoto, Japan) on a carbohydrate analysis column (NH_2, 4.6 × 250 mm, 5 µm) using isocratic elution of acetonitrile water (75:25, v/v; HPLC-grade, Merck KGaA, Darmstadt, Germany) at 1 mL/min and refractive index detection. Quantitation was done using external lactose standards (Khaliq et al., 2024).

Mineral content (zinc, iron, magnesium, calcium, sodium, potassium, and phosphorus) was determined using an atomic absorption spectrophotometer (Model AA-7000, Shimadzu Corporation, Kyoto, Japan) with a graphite furnace. Milk samples were prepared by wet digestion: 5 mL of sample was mixed with 10 mL of concentrated nitric acid (HNO_3) and heated on a hot plate, followed by the addition of 2 mL of perchloric acid ($HClO_4$) until a clear solution was obtained. After cooling, the digest was diluted to 25 mL with deionized water and filtered through Whatman No. 42 filter paper (Cytiva, Buckinghamshire, UK). Mineral concentrations were measured at 213.9 nm for zinc, 248.3 nm for iron, 285.2 nm for magnesium, 422.7 nm for calcium, 589.0 nm for sodium, 766.5 nm for potassium, and 213.6 nm for phosphorus, using element-specific hollow cathode lamps operated at 10 mA. Calibration was performed using standard solutions prepared from certified stock standards (Abduku and Eshetu, 2024).

Vitamins were quantified using High-Performance Liquid Chromatography (HPLC; Model LC-2050C, Shimadzu Corporation, Kyoto, Japan). External standard calibration curves were prepared separately for each vitamin using certified pure standards, and vitamin concentrations were calculated by comparing sample peak areas against these calibration curves. All calibration curves indicated excellent linearity ($R^2 > 0.99$), confirming method validity. Fat soluble vitamins (A, E, K) were separated on a C18 column (4.6 × 250 mm, 5 µm) at 30°C using a gradient mobile phase of acetonitrile and water (0.1% formic acid), and detected at 280 nm with a UV-Vis detector (Faye et al., 2019). Water-soluble vitamins (vitamin C, B_1, B_2, B_3, B_6, B_9, and B_{12}) were separated on an amino column (4.6 × 250 mm, 5 µm) at 30°C using an isocratic mobile phase of water-acetonitrile containing 0.1% acetic acid and detected by fluorescence (excitation 340 nm, emission 450 nm; Faye et al., 2019).

Fatty acid analysis

The lipids were saponified and methylated, and the resulting fatty acid methyl esters (FAMEs) were quantified. The methylation reaction was carried out by combining 2 mL of 0.5 M potassium hydroxide (KOH) in methanol (Sigma-Aldrich, St. Louis, MO, USA) with 2 mL of 12% boron trifluoride (BF_3) in methanol (Sigma-Aldrich, St. Louis, MO, USA) for one hour at 100°C (Freije et al., 2024). The gas chromatograph-mass spectrometer (GC-MS; Agilent 7890B GC with 5977B MSD Detector, Agilent) was utilized to extract and identify the FAMEs. The DB-23 capillary column (30m, 0.25 mm, 0.25 µm) was utilized for this purpose. The parameters of injection included split injection with 1 µL of sample, 1 mL/min of helium carrier gas flow, injection temperature of 270°C, oven temperature program of 50°C for 1 minute, ramp to 240°C at the rate of 10°C per minute, hold at 240°C for 5 minutes, and detection by Mass Spectrometer Detector (Model 5977B MSD, Agilent Technologies Japan, Ltd., Tokyo, Japan). The compounds that were discovered were identified using the NIST 2017 library (Freije et al., 2024). Quantification of FAMEs was achieved using external standard calibration curves prepared from certified FAME standards at known concentrations. Sample peak areas were compared with those of the corresponding standards to calculate the concentrations of individual fatty acids. The results were expressed as the relative percentage of each fatty acid, calculated from its peak area relative to the total peak area of all identified FAMEs.

Statistical analysis

Data analysis was performed using SPSS software, version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were applied to calculate the mean and standard deviation (SD) for each parameter per farm and for the overall samples.

RESULTS

Physicochemical properties

The physicochemical parameters of camel milk from five farms in Garissa County are summarized in Table 1. Descriptive analysis indicated that all measured traits, including pH, color, titratable acidity, viscosity, total solids, and moisture content, indicated close values among the five farms.

Proximate composition

Fat, protein, and lactose contents are presented in Table 2. Descriptive analysis indicated that the levels of fat, protein, and lactose were relatively similar across all farms, with only minor differences observed among samples.

Mineral composition

As presented in Table 3, descriptive analysis indicated that the levels of calcium, sodium, potassium, zinc, iron, magnesium, and phosphorus were relatively similar across farms, with only minor differences observed among samples.

Vitamin composition

Vitamin analysis results are summarized in Table 4. Descriptive analysis indicated that both water-soluble vitamins (C and B-group, including B_1, B_2, B_3, B_6, B_9, B_{12}) and fat-soluble vitamins (A, E, and K) were present, with only minor differences observed among samples across farms.

Fatty acid profile

The fatty acid distribution is presented in Table 5. Descriptive analysis indicated that saturated fatty acids accounted for a slightly higher proportion than unsaturated fatty acids, with only minor differences observed among samples across the farm.

Table 1. Physicochemical properties of camel milk from five farms in Garissa County, Kenya

Parameters	Farm 1 (Mean ± SD)	Farm 2 (Mean ± SD)	Farm 3 (Mean ± SD)	Farm 4 (Mean ± SD)	Farm 5 (Mean ± SD)	Total (Mean ± SD)
pH	6.67 ± 0.05	6.67 ± 0.12	6.70 ± 0.11	6.62 ± 0.06	6.50 ± 0.14	6.63 ± 0.10
Color (L*)	87.64 ± 2.06	88.19 ± 4.56	87.46 ± 2.18	87.31 ± 1.93	88.40 ± 1.53	87.80 ± 2.67
Titratable acidity lactic acid (%)	0.16 ± 0.03	0.14 ± 0.03	0.13 ± 0.03	0.16 ± 0.01	0.13 ± 0.02	0.14 ± 0.02
Viscosity (mPa·s)	1.86 ± 0.08	1.83 ± 0.10	1.85 ± 0.06	1.89 ± 0.09	1.89 ± 0.06	1.86 ± 0.08
Moisture content (%)	85.54 ± 1.16	87.80 ± 3.32	88.06 ± 1.34	88.03 ± 2.70	86.59 ± 4.44	87.20 ± 2.86
Total solid (%)	12.86 ± 0.44	12.16 ± 0.86	13.04 ± 0.77	12.60 ± 0.71	12.78 ± 0.43	12.68 ± 0.66

Note: Values are expressed as mean ± SD per farm (n = 3), with total mean ± SD representing the overall average (N = 15).

Table 2. Proximate composition of camel milk from five farms in Garissa County, Kenya

Parameters	Farm 1 (Mean ± SD)	Farm 2 (Mean ± SD)	Farm 3 (Mean ± SD)	Farm 4 (Mean ± SD)	Farm 5 (Mean ± SD)	Total (Mean ± SD)
Fat content (%)	4.34 ± 0.25	4.08 ± 0.19	4.36 ± 0.05	4.09 ± 0.19	4.17 ± 0.10	4.20 ± 0.17
Protein content (%)	2.40 ± 0.09	2.21 ± 0.18	2.37 ± 0.11	2.30 ± 0.04	2.34 ± 0.20	2.32 ± 0.13
Lactose content (%)	5.17 ± 0.23	5.15 ± 0.22	4.99 ± 0.11	5.00 ± 0.11	5.01 ± 0.18	5.06 ± 0.17

Note: Data are presented as mean ± SD for each farm (n = 3), and the total mean ± SD indicates the combined average for all samples (N = 15)

Table 3. Mineral composition of camel milk from five farms in Garissa County, Kenya

Parameters (mg/l)	Farm 1 (Mean ± SD)	Farm 2 (Mean ± SD)	Farm 3 (Mean ± SD)	Farm 4 (Mean ± SD)	Farm 5 (Mean ± SD)	Total (Mean ± SD)
Zinc (Zn)	3.94 ± 0.32	3.88 ± 0.27	3.89 ± 0.38	3.88 ± 0.27	3.86 ± 0.26	3.89 ± 0.30
Iron (Fe)	4.89 ± 0.15	4.88 ± 0.15	4.97 ± 0.36	4.94 ± 0.25	5.01 ± 0.28	4.93 ± 0.25
Magnesium (Mg)	51.42 ± 1.47	47.33 ± 0.90	48.51 ± 1.55	49.98 ± 1.10	51.38 ± 2.67	49.72 ± 1.65
Calcium (Ca)	5275.33 ± 65.28	5328.91 ± 34.50	5295.48 ± 46.86	5280.32 ± 83.40	5285.79 ± 58.73	5293.16 ± 54.49
Sodium (Na)	427.14 ± 5.09	426.18 ± 5.98	434.07 ± 1.61	423.49 ± 7.45	432.91 ± 1.81	428.75 ± 4.96
Potassium (K)	692.28 ± 3.67	685.64 ± 7.52	674.66 ± 3.41	680.68 ± 20.03	675.07 ± 14.62	681.66 ± 11.80
Phosphorus (P)	97.09 ± 3.86	96.09 ± 2.88	96.54 ± 1.64	97.09 ± 6.29	97.44 ± 2.70	96.85 ± 3.81

Note: Mineral concentrations are expressed as mean ± SD (mg/L) for each farm (n = 3), with total mean ± SD representing the overall average of all samples (N = 15).

Table 4. Vitamin composition of camel milk from five farms in Garissa County, Kenya

Parameters (mg/l)	Farm 1 (Mean ± SD)	Farm 2 (Mean ± SD)	Farm 3 (Mean ± SD)	Farm 4 (Mean ± SD)	Farm 5 (Mean ± SD)	Total (Mean ± SD)
Vitamin B1 (Thiamine)	3.66 ± 0.07	3.65 ± 0.12	3.70 ± 0.15	3.67 ± 0.13	3.73 ± 0.20	3.68 ± 0.14
Vitamin B2 (Riboflavin)	1.00 ± 0.12	1.01 ± 0.10	0.89 ± 0.10	1.00 ± 0.16	0.93 ± 0.09	0.96 ± 0.11
Vitamin B6 (Pyridoxine)	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00	0.02 ± 0.00
Vitamin B3 (Niacin)	3.74 ± 0.21	3.65 ± 0.10	3.66 ± 0.06	3.69 ± 0.08	3.79 ± 0.25	3.70 ± 0.15
Vitamin B9 (Folate)	0.03 ± 0.01	0.03 ± 0.00	0.03 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	0.03 ± 0.01
Vitamin B12 (Cobalamin)	0.23 ± 0.06	0.22 ± 0.03	0.30 ± 0.14	0.27 ± 0.12	0.37 ± 0.08	0.27 ± 0.09
Vitamin C (Ascorbic acid)	188.11 ± 4.30	187.82 ± 1.94	190.70 ± 10.04	183.99 ± 11.16	192.79 ± 0.81	188.68 ± 7.04
Vitamin A (Retinol)	0.67 ± 0.06	0.71 ± 0.09	0.68 ± 0.06	0.66 ± 0.05	0.67 ± 0.04	0.67 ± 0.06
Vitamin E (Tocopherol)	5.81 ± 0.27	6.00 ± 0.15	6.26 ± 0.23	5.96 ± 0.16	5.99 ± 0.16	6.01 ± 0.20
Vitamin K (Phylloquinone)	10.05 ± 0.24	9.93 ± 0.17	9.89 ± 0.03	9.84 ± 0.18	10.24 ± 0.09	9.99 ± 0.16

Note: Vitamin levels are presented as mean ± SD (mg/L) for each farm (n = 3), and the total mean ± SD reflects the average concentration across all samples (N = 15).

Table 5. Fatty acid profile of camel milk from five farms in Garissa County, Kenya

Parameters (%)	Farm 1 (Mean ± SD)	Farm 2 (Mean ± SD)	Farm 3 (Mean ± SD)	Farm 4 (Mean ± SD)	Farm 5 (Mean ± SD)	Total (Mean ± SD
Palmitic acid (C16:0)	25.25 ± 2.12	24.91 ± 3.54	22.36 ± 2.05	24.77 ± 1.52	26.65 ± 2.83	24.78 ± 2.51
Stearic acid (C18:0)	10.95 ± 0.58	11.82 ± 0.73	11.29 ± 0.82	11.16 ± 0.81	11.22 ± 0.17	11.28± 0.66
Myristic acid (C14:0)	10.13 ± 0.32	10.36 ± 0.11	10.03 ± 0.56	10.34 ± 0.43	10.37 ± 0.24	10.24± 0.36
Margaric acid (C17:0)	3.70 ± 0.31	3.66 ± 0.10	3.47 ± 0.28	3.03 ± 0.05	3.57 ± 0.23	3.48 ± 0.21
Pentadecylic acid (C15:0)	3.43 ± 0.39	3.30 ± 0.26	3.26 ± 0.22	3.38 ± 0.28	3.18 ± 0.08	3.31 ± 0.26
Arachidic acid (C20:0)	0.89 ± 0.12	0.87 ± 0.08	0.83 ± 0.06	0.93 ± 0.19	0.88 ± 0.06	0.88 ± 0.11
Capric acid (C10:0)	0.22 ± 0.03	0.18 ± 0.01	0.16 ± 0.09	0.23 ± 0.05	0.26 ± 0.05	0.21 ± 0.05
Lauric acid (C12:0)	0.15 ± 0.04	0.17 ± 0.04	0.20 ± 0.07	0.24 ± 0.04	0.21 ± 0.06	0.19 ± 0.05
Nonadecanoic acid (C19:0)	0.47 ± 0.10	0.45 ± 0.15	0.52 ± 0.16	0.43 ± 0.01	0.43 ± 0.07	0.46 ± 0.11
Tridecanoic acid (C13:0)	0.10 ± 0.01	0.10 ± 0.02	0.10 ± 0.02	0.10 ± 0.03	0.09 ± 0.02	0.09 ± 0.02
Oleic acid (C18:1)	25.31 ± 2.27	27.79 ± 2.20	25.37 ± 1.97	26.46 ± 1.30	27.84 ± 2.37	26.55 ± 2.06
Palmitoleic acid (C16:1)	8.73 ± 0.46	8.56 ± 0.68	8.81 ± 0.18	8.60 ± 0.15	8.95 ± 0.21	8.73 ± 0.39
Linoleic acid (C18:2)	2.58 ± 0.01	2.72 ± 0.12	2.92 ± 0.29	2.63 ± 0.36	2.45 ± 0.16	2.66 ± 0.22
Trans-7-hexadecenoic Acid (C16:1 t7)	1.75 ± 0.20	1.51 ± 0.29	1.56 ± 0.26	1.68 ± 0.17	1.79 ± 0.19	1.65 ± 0.22
Trans-9-dodecenoic acid (C17:1 c10)	1.24 ± 0.10	1.30 ± 0.15	1.32 ± 0.10	1.32 ± 0.15	1.24 ± 0.13	1.28 ± 0.12
Eicosapentaenoic acid (EPA; C20:5 n-3)	0.63 ± 0.03	0.60 ± 0.06	0.71 ± 0.07	0.60 ± 0.12	0.63 ± 0.06	0.63 ± 0.07
Myristoleic acid (C14:1 n-5)	0.16 ± 0.06	0.24 ± 0.05	0.20 ± 0.06	0.24 ± 0.06	0.20 ± 0.01	0.20 ± 0.05
Gondoic acid (C20:1 n-9)	1.67 ± 0.02	1.67 ± 0.03	1.67 ± 0.15	1.71 ± 0.14	1.65 ± 0.04	1.67 ± 0.09

Note: Data are expressed as mean ± SD (% of total fatty acids) for each farm (n = 3), with the total mean ± SD representing all samples combined (N = 15).

DISCUSSION

The physicochemical and nutritional characteristics of camel milk from Garissa County, Kenya, were reported at the farm level, and the descriptive mean values indicated differences between farms. The mean pH (6.63 ± 0.10) was slightly higher than values reported in Ethiopia (6.13 ± 0.11), suggesting a lower acidity that may contribute to extended natural shelf-life by slowing microbial spoilage and delaying coagulation (Legesse et al., 2017). The pale appearance of the milk (L* = 87.8 ± 2.7) corresponded with previous observation in Ethiopia (Seifu, 2023). Titratable acidity (0.14 ± 0.03% lactic acid) was below Moroccan values (0.19%; Alaoui Ismaili et al., 2019), and viscosity (1.86 ± 0.08 mPa·s) was marginally higher than Ethiopian milk (1.78 ± 0.02 mPa·s; Habtegebriel et al., 2020), reflecting desirable consistency for consumer preference. Moisture (87.2 ± 2.9%) and total solids (12.7 ± 0.8%) were within the ranges previously reported in camel milk from the Somali Region of Ethiopia (Legesse et al., 2017), reinforcing the compositional camel milk stability. The differences observed across countries are consistent with those reported in the cited studies, where variation in lactation stage, feeding conditions, and production environment influenced physicochemical traits of camel milk.

Proximate composition demonstrated that Fat averaged (4.20 ± 0.17%), which is higher than the (3.28 ± 0.48) reported in Turkey (Karaman et al., 2022), which may reflect rich forage and mineral availability in Garissa rangelands. Protein averaged (2.3 ± 0.16%), which is lower than the (3.15 ± 0.15%) range described in Ethiopia (Legesse et al., 2017), while Lactose content was (5.1 ± 0.25%), closely matching the (4.81 - 5.02%) recorded in Ethiopia (Seifu, 2023). The observed levels of fat, protein, and lactose contribute to the recognized nutritional value of camel milk and provide baseline composition data that can be used to compare production systems, support quality monitoring, and inform value-addition efforts. The variation in fat and protein compared to Turkey and Ethiopia is consistent with the influence of local forage quality, feed availability, and production system differences described in those studies.

The mineral profile reaffirmed camel milk as an outstanding source of essential micronutrients. Calcium was the most abundant mineral, with a concentration (5293.17 ± 60.1 mg/L), exceeding the mean of 1052 mg/L reported for camel milk across seven regions of Iran (Mostafidi et al., 2016). The higher calcium levels observed in the present study may be attributed to differences in grazing ecology, mineral-rich forage availability, and water quality. The high calcium bioavailability in camel milk is particularly beneficial for bone development in children and maintaining skeletal health in pregnant and lactating women. Zinc and iron averaged 3.9 ± 0.3 mg/l and 4.9 ± 0.3 mg/l, respectively, which were comparable to the 3.99 ± 0.67 mg/l and slightly higher than the 3.77 ± 1.57 mg/l reported in camel milk from China (Yang et al., 2025). Zinc and iron fell within the international ranges for camel milk and are recognized for immunomodulatory and hematological roles, supporting nutritional resilience in arid and semi-arid communities (Yang et al., 2025).

Several other nutritionally important minerals were detected in Garissa camel milk, including Magnesium, sodium, potassium, and phosphorus were all present, supporting essential physiological roles including bone mineralization, electrolyte balance, muscle contraction, and energy metabolism (Mostafidi et al., 2016). Such differences in mineral content between regions have been associated with environmental mineral availability, soil characteristics, and water quality in the reference articles.

For water-soluble vitamins, vitamin C was abundant at 188.7 ± 7.05 mg/L, exceeding the 24-36 mg/l reported in Arabian dromedary camel milk from the United Arab Emirates (Wernery, 2006). The higher vitamin C concentration observed in the present study is likely due to methodological differences and better sample preservation, as vitamin C is highly unstable and rapidly degrades with heat, light exposure, and prolonged storage. The high vitamin C concentration in camel milk reflects camel physiology, where vitamin C supports thermoregulation and oxidative stress defense in hot climates and contributes significantly to daily dietary antioxidant intake. Vitamin B1 (Thiamine) was 3.7 ± 0.1 mg/l, which was markedly higher than the 0.33 - 0.60 mg/l reported in Arabian dromedary camel milk from the United Arab Emirates (Wernery, 2006), highlighting its contribution to energy metabolism. Other B-group vitamins detected included riboflavin (B2), niacin (B3), folate (B9), and cobalamin (B12), supporting energy metabolism, DNA synthesis, red blood cell formation, and neural health (Wernery, 2006). Vitamin B6 was also present, contributing to immune and amino acid metabolism. Among fat-soluble vitamins, vitamin A and vitamin K were found, which are important for immune function, vision, antioxidant activity, bone health, and blood clotting (Wernery, 2006).

The fatty acid profile indicated that palmitic acid (C16:0) was the most prevalent saturated fatty acid at 25.0 ± 2.6%. This was comparable to the 27.9% reported in camel milk from the farming system in Sudan (Mohamed and Mustafa, 2016), supporting energy supply and cell membrane structure.

Oleic acid (C18:1) was the most prevalent unsaturated fatty acid at 27.8 ± 2.7%, which is slightly higher than the 22.44% reported for Sudanese camel milk under farming systems (Mohamed and Mustafa, 2016), contributing to heart health and improved lipid metabolism. In addition, the detection of Long-chain polyunsaturated fatty acids (PUFAs) such as Eicosapentaenoic acid (EPA) averaged 0.6 ± 0.1%, which is considerably higher than the 0.12% reported in camel milk from Sudan under farming and pastoral systems (Mohamed and Mustafa, 2016), particularly in the farming system. Both Oleic acid and Eicosapentaenoic acid (EPA) are recognized for their anti-inflammatory and cardioprotective roles, reinforcing the functional food potential of camel milk (Alhassani, 2024). The fatty acid differences are consistent with previous reports where farming system and diet composition influenced the proportion of major fatty acids in camel milk.

In summary, the present results provide descriptive baseline information for camel milk produced in Garissa County and can support future studies on camel milk composition in Kenya.

CONCLUSION

The present study characterized the physicochemical and nutritional properties of camel milk produced under semi-intensive systems in Garissa County, Kenya. Revealing a consistent composition across farms and alignment with values reported in other camel-producing regions. The results of the present study highlighted the nutritional importance of

camel milk as a reliable food resource for communities in arid and semi-arid environments. The results provide essential baseline data for Kenyan camel milk and can inform nutritional profiling and value-addition initiatives in the dairy sector. However, given the limited number of farms and production systems assessed, further studies covering diverse regions, management practices, and seasonal variations are recommended to better understand the determinants of camel milk variability at a national scale.

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Author's contributions

Yoonis Dayr Mohamed conceived and designed the study, carried out the laboratory experiments, performed the data analysis, and drafted the manuscript. Prof. Rebecca Waihenya provided overall supervision, ensured the study followed its study objectives, and offered constructive feedback during the study process. Dr. Kenneth Ogila guided the methodological framework and assisted in refining the experimental design, while Dr. Raphael W. Lihana critically reviewed the manuscript and provided technical input for improvement. All authors read and approved the final edition of the manuscript.

Competing interests

The author declares no competing interests.

Ethical considerations

The present study was conducted in accordance with ethical study practices. The manuscript has been thoroughly reviewed to ensure originality, integrity, and compliance with standards, including avoidance of plagiarism, data fabrication, or duplicate submission. The authors confirm that no AI tools were used for data generation, analysis, or interpretation, and the study complies with ethical research and publication standards.

Availability of data and materials

All datasets generated and/or analyzed in this study are included in the manuscript. Additional information can be made available by the corresponding author upon reasonable request.

REFERENCES

Abduku H and Eshetu M (2024). Physico-chemical properties and processing characteristics of camel milk as compared with other dairy species: A review. Asian Journal of Dairy and Food Research, 43(1): 1-7. DOI: https://www.doi.org/10.18805/ajdfr.DRF-303

Ait El Alia O, Zine-Eddine Y, Chaji S, Boukrouh S, Boutoial K, and Faye B (2025). Global camel milk industry: A comprehensive overview of production, consumption trends, market evolution, and value chain efficiency. Small Ruminant Research, 243: 107441. DOI: https://www.doi.org/10.1016/j.smallrumres.2025.107441

Alaoui Ismaili M, Saidi B, Zahar M, Hamama A, and Ezzaier R (2019). Composition and microbial quality of raw camel milk produced in Morocco. Journal of the Saudi Society of Agricultural Sciences, 18(1): 17-21. DOI: https://www.doi.org/10.1016/j.jssas.2016.12.001

Alhassani WE (2024). Camel milk: Nutritional composition, therapeutic properties, and benefits for human health. Open Veterinary Journal, 14(12): 3164-3180. DOI: https://www.doi.org/10.5455/OVJ.2024.v14.i12.2

Association of official analytical collaboration (AOAC) (2016a). Official methods of analysis of AOAC international, 20th Edition. AOAC International, USA. Available at: https://aoac.org/official-methods-of-analysis/

Association of official analytical collaboration (AOAC) (2016b). Official methods of analysis of AOAC international, 20th Edition. AOAC International, USA. Available at: https://aoac.org/official-methods-of-analysis/

Bakry IA, Yang L, Farag MA, Korma SA, Khalifa I, Cacciotti I, Ziedan NI, Jin J, Jin Q, Wei W et al. (2021). A comprehensive review of the composition, nutritional value and functional properties of camel milk fat. Foods, 10(9): 2158. DOI: https://www.doi.org/10.3390/foods10092158

El-Agamy EI, Nawar M, Shamsia SM, Awad S, and Haenlein GFW (2009). Are camel milk proteins convenient to the nutrition of cow milk allergic children? Small Ruminant Research, 82(1): 1-6. DOI: https://www.doi.org/10.1016/j.smallrumres.2008.12.016

El-Hatmi H, Oussaief O, Hammadi I, Dbara M, Hammadi M, Khorchani T, and Jrad Z (2023). Relation between color and chemical composition of dromedary camel colostrum. Animals, 13(3): 442. DOI: https://www.doi.org/10.3390/ani13030442

Faye B (2020). How many large camelids in the world? A synthetic analysis of the world camel demographic changes. Pastoralism: Research, Policy and Practice, 10(25): 1-15. DOI: https://www.doi.org/10.1186/s13570-020-00176-z

Faye B, Konuspayeva G, and Bengoumi M (2019). Vitamins of camel milk: A comprehensive review. Journal of Camelid Science, 12: 17-32. Available at: https://hal.science/hal-05174776v1

Freije A, Abdulghafoor R, Abdulhussain H, Khonji A, Albasara J, Hussain H, Dhaif A, Aljar MA, and Perna S (2024). Analysis of the nutritional composition of Bahraini breed camel (*Camelus dromedarius*) milk: fatty acid, mineral, phenolic, and antioxidant content. Arab Journal of Basic and Applied Sciences, 31(1): 604-613. DOI: https://www.doi.org/10.1080/25765299.2024.2426294

Gebreyohanes MG and Assen AM (2017). Adaptation mechanisms of camels (*Camelus dromedarius*) for desert environment: A review. Journal of Veterinary Science and Technology, 8(6): 1000486. DOI: https://www.doi.org/10.4172/2157-7579.1000486

Habtegebriel H, Wawire M, Gaukel V, and Taboada ML (2020). Comparison of the viscosity of camel milk with model milk systems in relation to their atomization properties. Journal of Food Science, 85(10): 3459-3466. DOI: https://www.doi.org/10.1111/1750-3841.15451

He J, Xiao Y, Orgoldol K, Ming L, Yi L, and Ji R (2019). Effects of geographic region on the composition of bactrian camel milk in Mongolia. Animals, 9(11): 8901. DIO: https://www.doi.org/doi:10.3390/ani9110890

Isako T and Kimindu V (2019). Camel milk value chain in Kenya: A review. Journal of Marketing and Consumer Research, 58: 51- 64. DOI: https://doi.org/10.7176/JMCR/58-06

Karaman AD, Yildiz Akgül F, Öğüt S, Seçilmiş Canbay H, and Alvarez V (2022). Gross composition of raw camel's milk produced in Turkey. Food Science and Technology, 42: e59820. DOI: https://www.doi.org/10.1590/fst.59820

Khaliq A, Mishra AK, Niroula A, Baba WN, Shaukat MN, and Rabbani A (2024). An updated comprehensive review of camel milk: Composition, therapeutic properties, and industrial applications. Food Bioscience, 62: 105531. DOI: https://www.doi.org/10.1016/j.fbio.2024.105531

Konuspayeva G, Faye B, and Bengoumi M (2022). Mineral status in camel milk: A critical review. Animal Frontiers, 12(4): 52-60. DOI: https://www.doi.org/10.1093/af/vfac044

Legesse A, Adamu H, Alamirew N, and Feyera T (2017). A comparative study on the physicochemical parameters of milk of camel, cow and goat in Somali Regional State, Ethiopia. Chemical Sciences Journal, 8(4): 1000171. DOI: https://www.doi.org/10.4172/2150-3494.1000171

Mohamed E and Mustafa A (2016). Fatty acids content in milk of dromedary camel (*Camelus dromedarius*) from farming and pastoral systems in Sudan. International Journal of Science and Research, 5(6): 570-573. DOI: https://www.doi.org/10.21275/v5i6.nov164095

Mostafidi M, Moslehishad M, Piravivanak Z, and Pouretedal Z (2016). Evaluation of mineral content and heavy metals of dromedary camel milk in Iran. Food Science and Technology, 36(4): 717-723. https://www.doi.org//10.1590/1678-457X.16116

Oselu S, Ebere R, and Arimi JM (2022). Camels, camel milk, and camel milk product situation in Kenya in Relation to the World. International Journal of Food Science, 2022: 1237423. DOI: https://www.doi.org/10.1155/2022/1237423

Seifu E (2023). Camel milk products: Innovations, limitations and opportunities. Food Production, Processing and Nutrition, 5(1): 15. DOI: https://www.doi.org/10.1186/s43014-023-00130-7

Wernery U (2006). Camel milk: The white gold of the desert. Journal of Camel Practice and Research, 13(1): 15-26. Available at: https://camelsandcamelids.com

Yang Q, Xu L, Zheng W, Baisanbieke D, Zhu L, and Yimamu M (2025). Geographical variation in the mineral profiles of camel milk from Xinjiang: Implications for nutritional value and species identification. Agriculture, 15(20): 2120. DIO: https://www.doi.org//10.3390/agriculture15202120