ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2025): 4.97
IJAFS 2026; 8(1): 228-233
www.agriculturaljournals.com
Received: 02-12-2025
Accepted: 07-01-2026

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Preliminary studies on "Physicochemical and antioxidant properties of camel and goat milk in Libya"

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DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i1d.1144

Abstract
Prelimnary studies were carried out to assess the various physicochemical and bioactive properties of camel and goat milk collected from different organized farms in Libya. The milk samples collected were subjected to various physicochemical and antioxidant studies namely pH, total acidity, specific gravity, fat, protein, lactose, total solids, moisture content, total phenolics, total flavonoids, and Vitamin C. The goat milk recorded a mean pH value of 6.5, acidity of 0.4% and specific gravity of 1.03 while camel milk showed a mean value of 6.8, 0.2% and 1.027 respectively. With regard to the chemical composition, goat milk recorded a mean fat percentage of 4.5, protein 3.8%, lactose 5%, total solids12.25%, and moisture content of 87.75% while camel milk revealed a fat percent of 2.6, protein 4%, lactose 4.68%, total solids 8.69% and moisture content of 91.31%. Thus camel milk recorded a lower fat content when compared to the goat milk. With regard to bioactive compounds namely total phenolics, total flavonoids and vitamin C content, goat milk showed a value of 244.8 mg/L, 94.8 mg/L and 30 mg/L respectively while camel milk revealed 282.4 mg/L, 153.4 mg/L, and 50 mg/L respectively. The DPPH radical scavenging activity was found to be similar in both the milk, with camel milk showing inhibition of 73% while goat milk revealing more or less similar value of 72%. Thus, the present findings demonstrated that camel milk is superior to goat milk and the superiority of camel milk has been primarily attributed to its higher levels of specific antioxidant vitamins and minerals.

Keywords: Camel milk, goat milk, antioxidant activity, phenolics, flavonoids, DPPH

1. Introduction
Milk is defined as a complex colloidal suspension having proteins, fats, lactose and various vitamins and minerals. It is often considered as one of nature's most complete foods and serves as a vital nutritional source for humans, through all stages of life i.e. from infancy to senility. Besides human breast milk which is divinely provided, miraculous substance, crucial for infant health, immunity, and development, milk from other mammals namely cow, buffalo, goat, camel etc plays a significant role in the dietary landscape. Its versatility is a key feature, as it can be consumed fresh or used in various culinary chores, inspiring a wide range of culinary creations. Packed with an array of essential vitamins and minerals, it is instrumental in promoting various health benefits throughout life. The nutrient profile of milk is genuinely remarkable. It is not only a high-quality source of protein, which supports muscle growth and repair, but also rich in essential vitamins and minerals like calcium, which is crucial for bone health, vitamin B12, which plays a significant role in the production of red blood. Thus milk and its products namely cheese, yogurt, cream, butter, ghee, curd etc are recognized as rich sources of essential nutrients providing a balanced matrix of components with high biological and functional value (Jauhiainen, 2007) [15]. Beyond its basic nutritional role, milk harbors a spectrum of bioactive molecules that confer multifaceted health benefits, including immunomodulatory and antioxidative effects (Harizi *et al.,* 2024) [14].
While cow milk dominates global production, there is growing scientific interest in alternative milks, particularly goat and camel milk, due to their distinctive compositional and

functional attributes (Salhi *et al.,* 2025) [22]. These milks exhibit unique chemical profiles that influence digestibility, mineral bioavailability, and the presence of bioactive compounds (Bilal *et al*., 2024) [9].

Among the bioactive constituents, phenolic compounds and flavonoids are notable secondary metabolites endowed with potent antioxidant activity. These molecules play a pivotal role in mitigating oxidative stress and enhancing the functional properties of goat and camel milk, thereby contributing to improved health outcomes (Almasri *et al.,* 2024; Taj *et al*., 2017) [5, 27].

Consequently, the present study aimed to comprehensively evaluate local Libyan camel and goat milk by quantifying antioxidant-related constituents, including total phenolic content, total flavonoid content, vitamin C, and overall antioxidant capacity, assessed via the DPPH. radical scavenging assay. This investigation provides insights into the nutraceutical potential of these underexplored milks, supporting their value in functional nutrition.

2. Materials and Methods

2.1 Sample Collection

2.1.1 Goat Milk

Fresh goat milk samples were collected from various organized farms in Libya (Omar Al-Mukhtar, Lwsita, and Al-Haniya in the northern part of Al-Jabal Al-Akhdar). The goats belonging to the age group of three years were chosen for the present study. They were maintained on semi intensive system in which they were partially fed in shelters (concentrate feed once a day) and partially allowed for grazing (3-5 hours daily) on naturally growing pastures namely Pistacia lentiscus and Stipa species.

2.1.2 Camel Milk

Fresh camel milk samples were obtained from various semi-arid areas south of Al-Jabal Al-Akhdar, Libya namely Al-Mukhaili, Al-Aziyat, and Al-Jisha. The camels which were in their third lactation period and grazed on Acacia (Sidr), Artemisia (Al-Ramth), and other local vegetation during June 2025 were chosen for the present work.

2.2 Sample Extraction

Milk samples were extracted according to the method described by Alyaqoubi *et al*. (2014) [6] using an extraction solution composed of 95% ethanol and 1N HCl. Fifty milliliters of the extraction solution was added to 5 mL of milk in a brown glass bottle, followed by shaking for 1 hour at 30°C and 300 rpm. The mixture was then centrifuged at 7800 rpm for 15 minutes at 5°C. The supernatant was collected and stored at −20°C until further analysis.

2.3 Physicochemical Analysis

Physicochemical analyses were performed on goat and camel milk samples to determine pH, titratable acidity, specific gravity, fat content, protein content, and lactose concentration, by following the standard methods namely fat content -Gerber volumetric method (AOAC, 2000) [8]; Protein content -Kjeldahl method (AOAC, 1991) [7]; Lactose Content -Lane and Eynon titrimetric method (Lane & Eynon, 1923; Nielsen, 2017) [17, 20]; pH - using a calibrated pH meter at 25°C; Titratable Acidity- by titration with 0.1N NaOH using phenolphthalein as an indicator and expressed as% lactic acid (Konuspayeva, 2009) [16]; specific Gravity- using a lactometer at 20°C;Total solids determined by drying milk at 103°C ± 2°C for 3 hours; moisture calculated by subtracting total solids from 100%.; Total Phenolic Content- Folin-Ciocalteu method (Singleton & Rossi, 1965) [24]; Total Flavonoid Content- measured by colorimetric assay (Yoo *et al.,* 2008) [30], and Vitamin C by Voronina *et al*. (2023) [28].

Determination of Antioxidant Activity (DPPH Assay)

The antioxidant activity of milk extracts was evaluated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH•) radical scavenging assay, following the method of Brand-Williams *et al*. (1995) with slight modifications. Briefly, 100 µL of milk extract was mixed with 3.9 mL of 0.1 mM DPPH• solution in methanol. The mixture was incubated in the dark at room temperature for 30 minutes. Absorbance was measured at 517 nm using a UV-Vis spectrophotometer. The percentage of DPPH• radical scavenging activity was calculated using the formula:

DPPH scavenging%= A control-A sampleA control

where *A*control is the absorbance of the control (DPPH solution without sample) and *A*sample is the absorbance of the sample.

2.4 Statistical Analysis

All the research work were conducted in triplicate, and the results were expressed as mean ± standard deviation (SD). Data were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test to determine significant differences among groups ($p < 0.05$). Statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Graphical representations were prepared using GraphPad Prism version 9.0.

3. Results and Discussion

3.1 Chemical Composition

The physicochemical composition of camel and goat milk is shown in Table 1. With regard to the physical properties namely pH, acidity and specific gravity, goat milk recorded a value of 6.5, 0.4% and 1.03 respectively while camel milk showed a value of 6.8, 0.2% and 1.027 respectively. Regarding chemical composition, goat milk recorded a fat percentage of 4.5, protein 3.8%, lactose 5%, total solids12.25%, and moisture content of 87.75% while camel milk revealed a fat percent of 2.6, protein 4%, lactose 4.68%, total solids 8.69% and moisture content of 91.31%.

Table 1: Physical composition of camel and goat milk

Property	Goat Milk	Camel Milk
pH	6.5	6.8
Acidity (%)	0.4	0.2
Specific Gravity	1.030	1.027
Fat (%)	4.5	2.6
Protein (%)	3.8	4.0
Lactose (%)	5.00	4.68
Total Solids (%)	12.25	8.69
Moisture (%)	87.75	91.31

Camel milk exhibited a higher pH value (6.8) and lower titratable acidity (0.2%) compared to goat milk (pH 6.5; acidity 0.4%). The typical pH range for fresh milk is usually between 6.5 and 6.8 (Soliman, 2005) [25]. The higher pH observed in camel milk indicates its naturally lower acidity, which aligns with previous studies reporting that camel milk tends to be less acidic than goat and cow milk (Farah, 1993)

[11]. In contrast, the titratable acidity of goat milk exceeded the normal average range of 0.18-0.25% lactic acid, potentially reflecting the onset of acid development due to microbial activity or the collection of samples from animals in the later stages of lactation. Recent research also confirmed that goat milk typically exhibits lower pH values compared to camel milk (Salhi *et al.,* 2025) [22]. Goat milk showed a higher specific gravity (1.030) than camel milk (1.027), which is primarily influenced by the content of non-fat solids (SNF) and fat. These findings are consistent with the natural range for both milk types, as the specific gravity of camel milk generally ranges from 1.026 to 1.031 (Al-Haj, 2010) [3]. Fat content in goat milk (4.5%) was considerably higher than that of camel milk (2.6%). This observation is in agreement with studies indicating that camel milk often contains lower fat levels than goat milk, with averages ranging from 2.0-5.5% in camel milk and 3.5-5.0% in goat milk (Soliman, 2005) [25]. Notably, the smaller fat globules in camel milk contribute to its higher digestibility (Soliman, 2005) [25]. Recent studies also reported that camel milk contains lower amounts of short-chain fatty acids compared to goat milk (Liu, 2024) [18].

Camel milk exhibited slightly higher protein content (4.0%) than goat milk (3.8%), which falls within the normal range for both species (3.0-4.5%) (Konuspayeva, 2009) [16]. Literature indicates that protein content in camel milk may be equivalent or higher than in goat milk, with camel milk proteins differing in composition by lacking beta-lactoglobulin, a protein that can cause allergies in some individuals, making it a suitable alternative (Agamy, 2006) [1]. Camel milk also revealed higher lactose content (5.00%) compared to goat milk (4.68%), consistent with reports that lactose in camel milk can reach up to 5.8%, which is higher than the average in goat milk (Konuspayeva, 2009) [16]. Lactose is the primary component contributing to milk sweetness and serves as an important energy source.

Total solids were substantially higher in goat milk (12.25%) compared to camel milk (8.69%), primarily due to the elevated fat content in goat milk samples. Conversely, camel milk exhibited higher moisture content (91.31%), resulting in lower total solids. The relatively low total solids in camel milk (approximately 11.9%) may be influenced by environmental conditions, such as high ambient temperatures or water scarcity, or by the stage of lactation. Camels are known to produce milk with high water content to maintain fluid balance under arid conditions (Farah, 1993) [11], whereas goat milk is typically more concentrated (Alhassani, 2024) [4].

3.2 Total Phenolic Content

The total phenolic content (TPC) of camel and goat milk is shown in Table 2 and Figure 1. Camel milk exhibited a TPC of 282.4 mg GAE/L, which is considerably higher than most comparative studies conducted in Morocco (Dakhla, Fès-Meknès, Errachidia), where TPC values ranged between 33.0 and 37.85 mg/L (Bouhaddaoui *et al*., 2019) [10]. In Pakistan, camel milk TPC was reported as 59.86 mg/L (Abid *et al*., 2022), while in Kenya, Leparmarai *et al*. (2021) reported a value of 18.50 mg/L. A study in Bahrain reported camel milk TPC of 20.24 mg/L. Although these previously reported values are lower than those observed in Libyan camel milk, such variation may be attributed to multiple factors, including animal age, lactation stage, diet, environmental conditions, and the native vegetation of the respective regions (Bouhaddaoui *et al*., 2019) [10]. Goat milk exhibited a lower TPC (244.8 mg GAE/L) compared to camel milk. Nonetheless, Libyan goat milk contained higher phenolic content than goat milk reported in Morocco, which was 39.2 mg/L (Bouhaddaoui *et al*., 2019) [10]. Higher values have been reported in other studies, such as 56.99 mg/mL (equivalent to 569.9 mg/L) in Mal *et al*. (2018) [19]. Phenolic content also varies according to goat breed: Alyaqoubi *et al.* (2014) [6] reported that the Jamapain breed exhibited TPC values ranging from 403.33 to 544.08 mg/100 mL, while Sik *et al*. (2023) found 490.72 mg/100 mL in the Saanen breed. In Pakistan, TPC in goat milk was reported as 72.75 mg/L.

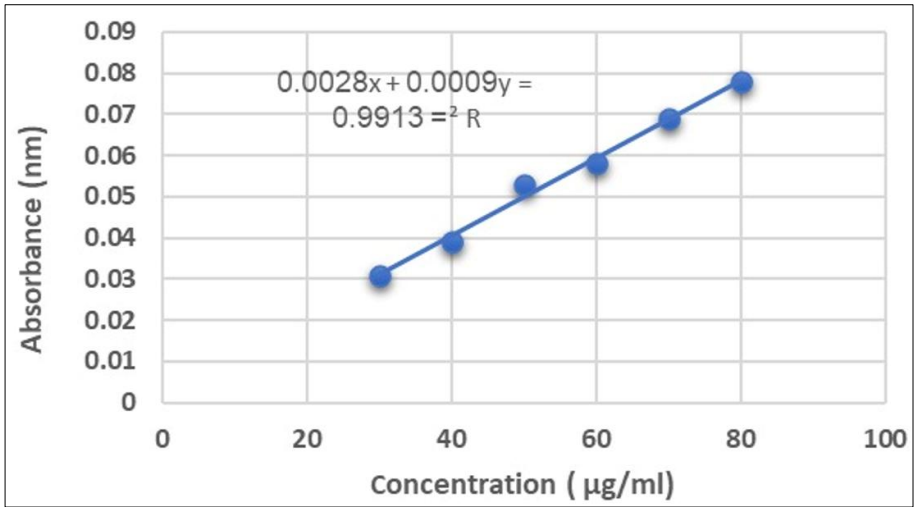

Fig 1: The standard curve for the determination of total phenolic contents

3.3 Total Flavonoid Content

The total flavonoid content (TFC) of camel and goat milk is presented in Table 2 and Figure 2. Camel milk exhibited a TFC of 153.4 mg QE/L, which is considerably higher than previously reported values for *Camelus dromedarius* milk in Bahrain, where TFC was 31.74 mg catechin/L (Freije, 2024) [12]. In Morocco, TFC in camel milk from three different regions ranged from 30.15 to 30.7 mg QE/L (Bouhaddaoui *et al*., 2019) [10]. In goat milk, TFC was 64.8 mg QE/L, exceeding comparative studies in Morocco, which reported

31.30 mg/L (Bouhaddaoui *et al*., 2019) [10]. In contrast, a study in Bahrain reported extremely high values of 89.86 mg quercetin/g (equivalent to 11,569 mg/L), likely reflecting a concentrated diet rich in flavonoid-containing plants.

On comparison, camel milk consistently exhibited higher phenolic and flavonoid concentrations than goat milk. The present findings were in agreement with that of previous studies which revealed that camel milk generally contains higher levels of antioxidant compounds. Alagamy (2009) reported elevated phenolic and flavonoid levels in camel milk, conferring greater antioxidative capacity and resistance to oxidative stress. Moreover, Al Dubaib (2018) [2] noted that the natural desert diet of camels, rich in medicinal herbs, enhances the phenolic content of their milk. Although goat milk contains appreciable amounts of phenolic compounds, variations in feed type and seasonal conditions significantly affect flavonoid concentrations (Park, 2020) [21]. Yadav (2016) [29] also confirmed that, while phenolic levels in goat milk may be relatively lower than in camel milk, they remain sufficient to provide noticeable antioxidant activity.

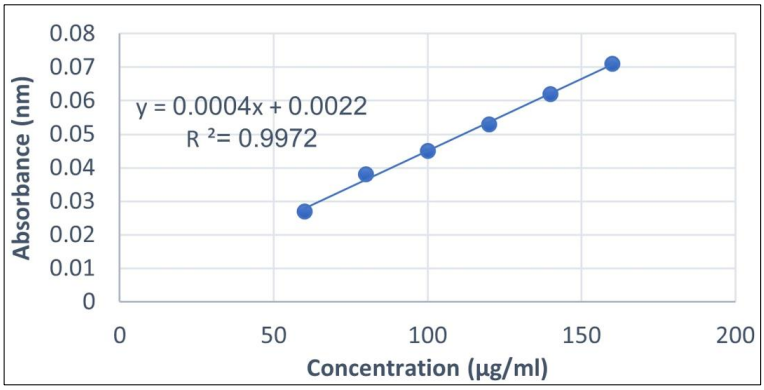

Fig 2: The standard curve for the determination of total flavonoid

3.4 Vitamin C Content

The vitamin C content in camel milk was 50 mg/L. For comparison, previous studies reported 4.6 mg/100 mL (Freije, 2024) [12], and in three regions of Morocco, vitamin C levels in camel milk ranged from 23 to 30.3 mg/L (Bouhaddaoui *et al*., 2019) [10]. Swelem (2021) noted that camel milk contains three to five times higher vitamin C concentrations than cow milk. In goat milk, vitamin C content was 30 mg/L, whereas in Moroccan goat milk, it was 10.7 mg/L (Bouhaddaoui *et al*., 2019) [10]. Seasonal variations also affect vitamin C levels; Voronina *et al* (2023) [28] reported a decline from April to October.

3.5 DPPH Radical Scavenging Activity

The results of the DPPH• radical scavenging assay are presented in Table 2 and Figure 3. Camel milk showed 73% inhibition of DPPH• radicals, in agreement with a Tunisian study reporting 70-80% inhibition, compared to 40-50% in cow milk (Harizi *et al*., 2024) [14]. The high antioxidant activity in camel milk may be attributed to the presence of sulfur-containing amino acids, which efficiently donate electrons or hydrogen atoms to neutralize DPPH• radicals. Goat milk exhibited 72% DPPH• radical inhibition, exceeding the activity reported for Gaddi goats in India (17.85%) (Mal *et al*., 2018) [19]. Alyaqoubi *et al*. (2014) [6] reported that radical scavenging decreases with advanced lactation stages, with inhibition rates of 60-70% in early stages and 59.24% in later stages. Antioxidant activity also varies by breed, ranging from 53% to 67%, with the Jamnapani breed showing the highest inhibition (67%). Lakram *et al.* (2019) reported an inhibition rate of 61.57%.

Despite the higher concentration of antioxidant compounds (phenolics, flavonoids, Vitamin C) in camel milk, the antioxidant effect (DPPH inhibition) was very similar between the two types of milk (73% vs. 72%). This suggests that the antioxidant activity is not solely dependent on the quantified compounds but may also be influenced by the synergistic effect of other compounds present in both milks, such as specific peptides or other bioactive molecules, which warrants further detailed study.

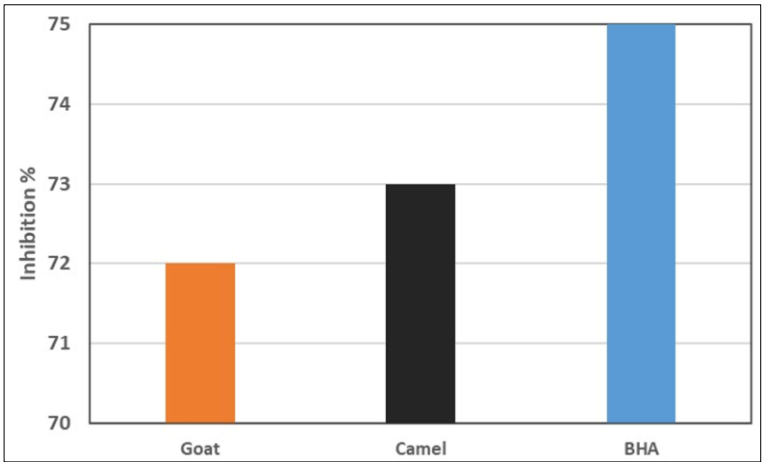

Fig 3: The inhibition rates of goat and camel milk - DPPH• free radicals compared to BHA

Table 2: Total phenolic and flavonoid contents, vitamin C concentration, and antioxidant activity assessed by the DPPH• radical scavenging assay

DPPH• (% inhibition)	Vit C (mg\l)	Flavonoids (mg\l)	Phenols (mg\l)	Sample
72	30	94.8	244.8	Goat milk
73	50	153.4	282.4	Camel milk

4. Conclusion

The present study demonstrated that camel milk is superior to goat milk and the superiority of camel milk has been primarily attributed to its higher levels of specific antioxidant vitamins and minerals. Goat milk is characterized by higher fat and total solids contents, while camel milk contains slightly higher protein and lactose levels. These differences reflect the biological adaptation of each species to its environment. Although this is the first and preliminary report carried out to evaluate the antioxidant properties of local camel and goat milk in Libya, the present findings revealed that both the milk possess numerous bioactive compounds with antioxidant activity. However, camel milk contained higher levels of these compounds, the overall antioxidant effect was comparable between camel and goat milk. This highlights their importance in promoting human health by reducing oxidative stress and its adverse effects. Several factors which influence the antioxidant properties namely breed, age, grazing pastures and other environmental factors make it challenging to compare the findings with previous studies. Keeping in view of the above, further studies are recommended to allow understanding new aspects and different facets of reality.

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