Original Article

Comparative analysis of nutritional quality and microbial contamination in camel milk

Evaluating safety and public health risks between camel milk obtained from street vendors and farms in Saudi Arabia

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ABSTRACT

الأهداف: تقييم الجودة الغذائية والتلوث الميكروبي لحليب الإبل الخام الذي تم الحصول علية من الباعة المتجولين ومقارنته بالحليب الذي تم جمعة من المزارع، مع التركيز بشكل خاص على الكائنات المسببة للأمراض.

المنهجية: تم جمع عشرين عينة بشكل منهجي من الباعة المتجولين والمزارع بين يوليو 2022 وفبراير 2023 وتم تحليلها في مركز الملك فهد للبحوث الطبية وكلية الصيدلة بجامعة الملك عبد العزيز في جدة. استخدم التحليل الميكروبي تقنيات متعددة تشمل اختبارات العد الميكروبي لتقدير عدد الخلايا البكتيرية الموجودة (CFU)، وعزل المستعمرات الميكروبية من عينات الحليب. استخدمت طرق متقدمة لتحديد الميكروبات، بما في ذلك معدات VITEK–MS وتقنية MALDI–TOF. تم تحليل التركيب الكيميائي من خلال اختبارات الامتصاص المناعي المرتبط بالإنزيم (ELISAs).

النتائج: كشفت النتائج عن اختلافات كبيرة في الأحمال الميكروبية، حيث أظهر الحليب الذي تم الحصول علية من البائعين المتجولين أعداداً ميكروبية أعلى بكثير، بما في ذلك الأنواع المسببة للأمراض مثل المكورات العنقودية الذهبية والإشريكية القولونية. أشارت النتائج إلى أن حليب الإبل من البائعين المتجولين يحتوي على مستوى أعلى من التلوث الميكروبي، مما يشير إلى المخاطر الصحية المحتملة المرتبطة بشرائه واستهلاكه من هذه المصادر.

الخلاصة: تسلط هذه الدراسة الضوء على الحاجة الملحة لتطبيق ممارسات سلامة غذائية صارمة في مراحل التعامل مع حليب الإبل وبيعه وتوزيعه للحد من المخاطر الميكروبية إلى مستويات آمنة، وبالتالي تقليل المخاطر الصحية المحتملة.

Objectives: To evaluate the nutritional quality and microbial contamination of raw camel milk sourced from street vendors and compare it with milk obtained from farms, with a particular emphasis on pathogenic organisms.

Methods: Twenty samples were systematically collected from street vendors and farms between July 2022 and February 2023 and analyzed at King Fahad Medical Research Centre and the Pharmacy College, King Abdulaziz University, Jeddah, Saudi Arabia. The microbial analysis employed culture-dependent techniques for colony-forming unit analysis and isolation of microbial colonies from milk samples. Microbial identification utilized advanced methods, including VITEK-MS equipment and the MALDI-TOF technique. The chemical composition was analysed through enzyme-linked immunosorbent assays.

Results: The findings revealed significant differences in microbial loads, with milk sourced from street vendors exhibiting considerably higher microbial counts than farm-sourced milk, including pathogenic species like *Staphylococcus aureus* and *Escherichia coli*. The results indicated that camel milk from street vendors possessed a higher level of microbial contamination, suggesting potential health risks associated with its purchase and consumption from these sources.

Conclusion: This study highlights the urgent need for stringent food safety practices in handling, selling, and distributing camel milk to reduce microbial risks to safe levels, thereby mitigating potential health hazards.

Keywords: camel milk, microbial contamination, food safety, public health, pathogenic bacteria

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Camels, particularly the one-humped Camelus dromedarius and the 2-humped Camelus bactrianus, have been integral to communities in arid regions such as the Middle East and the Arabian Peninsula, serving diverse roles for generations.[1] Camel milk, known for its unique taste and nutritional profile, varies in composition based on factors such as diet and hydration.[2,3] With a global camel population exceeding 35 million, camel milk not only provides sustenance but also offers nutritional advantages over bovine milk, being closer in composition to human milk.[4-6]

Historically, camels have contributed to human civilization for over 3,000 years, with their milk being a vital part of diets in various cultures.[7] According to the The Food and Agriculture Organization (FAO) in 2019, the economic and cultural significance of camel milk is recognized globally, with the majority of production occurring in African and Asian countries.[6] Beyond its traditional uses, camel milk is praised for its health benefits, including its digestibility, promotion of bone formation promotion in infants, and protective effects against pathogens due to its rich composition of vitamins, minerals, and protective proteins.[8,9]

Despite these benefits, the consumption of raw camel milk carries health risks, primarily due to potential contamination with pathogenic microorganisms, leading to foodborne diseases.[8,10] In Saudi Arabia, the preference for raw camel milk, despite the availability of pasteurized options, underscores the need for comprehensive studies on its microbial load and safety.[11] This study aims to fill this research gap by evaluating the microbial and nutritional qualities of raw camel milk from various sources.

This research addresses a crucial gap in food safety, focusing on the potential health risks associated with the consumption of raw camel milk. Despite its documented nutritional and health benefits, the safety of raw camel milk, especially when obtained from unregulated sources such as street vendors, remains a significant concern. This study takes a comprehensive approach by evaluating microbial loads, with a particular emphasis on pathogenic microorganisms, and assessing the chemical properties of camel milk from different sources.

The primary objective of this study is to carry out an exhaustive evaluation of the microbial load in raw camel milk obtained from street vendors and farms, with a focus on identifying the presence of pathogenic microorganisms. The study is designed to achieve the following objectives: i) investigate the presence of pathogenic bacteria, including *Salmonella*, *Escherichia coli* (*E. coli*), and *Staphylococcus*; ii) assess the chemical properties of raw camel milk, such as potential of hydrogen (pH), acidity, calcium, iron, lactoferrin, and vitamins C and D; and iii) compare raw camel milk sourced from street vendors versus farms, in terms of both microbial and chemical composition.

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Methods. This study systematically evaluated the quality, safety, and nutritional attributes of camel milk from street vendors and farms in Jeddah, Saudi Arabia (SA). It included pilot studies, detailed sample collection, handling procedures, and rigorous laboratory analyses, covering chemical, microbiological, and nutritional assessments for a comprehensive evaluation. The research ethics committee at King Abdulaziz University, Jeddah, Saudi Arabia, approved this study (approval No.: HA-02-J-008).

The research utilized chemicals and media from reputable suppliers: i) Peptone water from Emda International Trading Est. Riyadh-SA; ii) brain-heart infusion (BHI) broth and L-ascorbic acid from King Fahad Medical Research Centre, Riyadh, Saudi Arabia; iii) sample containers and plastic plates from Alshafee Medical Supply, Jeddah, Saudi Arabia; and iv) culture media from Saudi Prepared Media Laboratory Co. Ltd. Riyadh, Saudi Arabia

This study employed a comparative approach to assess camel milk quality, collecting 20 samples equally from street vendors and local farms around Jeddah, Saudi Arabia. To ensure representativeness and minimize selection bias, the samples were randomly selected, all obtained from dromedary camels between July 2022 and February 2023 (**Figure 1**). Analyses were carried out at King Fahad Medical Research Centre and the Pharmacy College at King Abdulaziz University, Jeddah, Saudi Arabia.

Inclusion criteria specified camel milk samples solely from Jeddah, from both street vendors and farms. Farm samples were collected using autoclaved bottles at King Fahad Medical Research Centre, while street vendors' samples were collected in non-sterilized containers to reflect typical storage conditions. Exclusion criteria ensured geographical and methodological consistency by excluding samples from outside Jeddah and non-sterilized farm samples. This approach maintained sample integrity, focusing on the microbial load and nutritional values of camel milk.

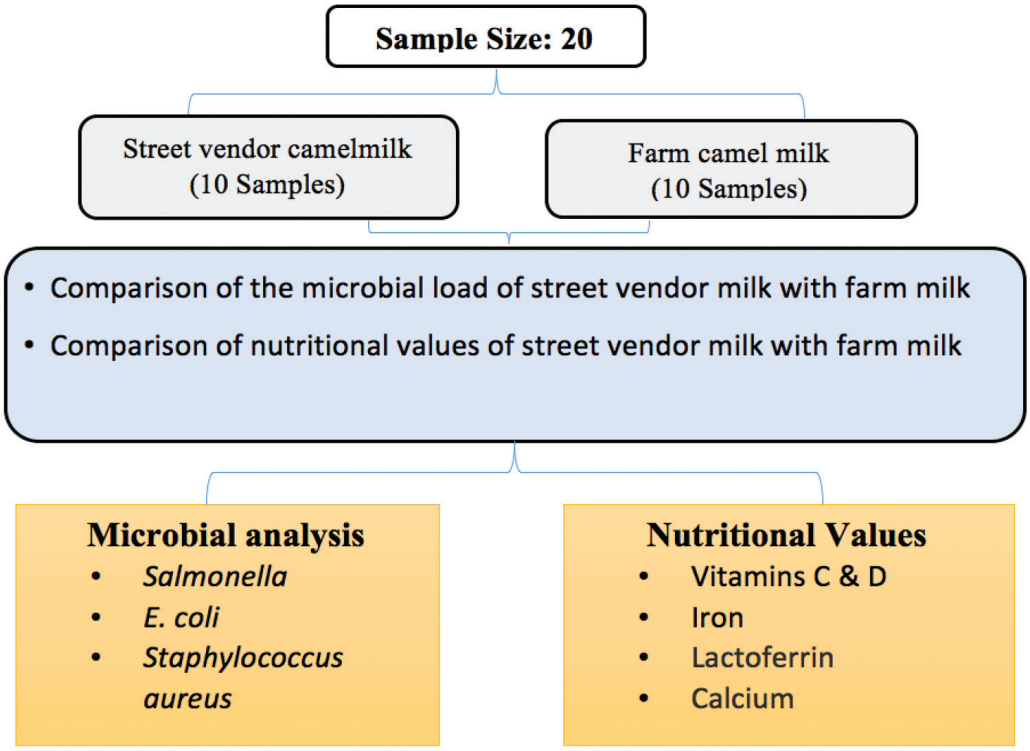

Figure 1 - Study design of camel milk for nutritional quality and microbial contamination analysis *E. coli*: *Escherichia coli*

To accurately reflect the variance in camel milk handling and storage, different collection strategies were used for samples from street vendors and farms. Street vendor samples were collected in their commercial form (plastic bags or bottles) mirroring typical consumer conditions. Farm samples were collected in sterilized plastic containers to minimize contamination. This dual approach captured inherent differences in milk quality and safety between the 2 sources.

Upon collection, rigorous measures-maintained sample integrity. Samples were immediately cooled with ice bags to preserve freshness, prevent bacterial growth, and maintain compositional fidelity, ensuring they remained as close to their original state as possible upon reaching the laboratory.

The study carried out a comparative analysis of raw camel milk from street vendors and local farms in Jeddah, Saudi Arabia. A total of 20 samples (10 from each source) were meticulously collected to ensure broad representation (Figure 1). This strategy aimed to uncover differences in microbial load and nutritional content based on the milk source. All samples were from dromedary camels, the predominant species in the region, aligning with the study's focus on real-world milk quality and safety.

The sampling protocol facilitated in-depth analysis of microbial presence and nutritional values. Each 100 mL sample was divided into two 50 mL aliquots. One aliquot was split for direct and diluted microbial analysis. The second aliquot was used exclusively for chemical property assessment, including pH, acidity, vitamin content, and mineral composition (Figure 2). This comprehensive approach provided a holistic understanding of camel milk's nutritional profile and potential health benefits.

The dilution of camel milk samples is crucial for accurate microbiological analysis, enabling reliable bacterial isolation and colony counting. By reducing bacterial concentration, dilutions allow precise microbial enumeration and identification. The preparation involved dissolving 15 g of peptone in 1 L of distilled water. An initial 100 µL from each undiluted milk sample was reserved for culturing. The first dilution created a 1:10 ratio by adding 100 µL of the milk sample to sterile tubes containing 900 µL of 1% peptone water. Further dilution improved microbial analysis accuracy.

The culturing and purification process was carried out in a controlled laboratory setting to ensure precise microbial identification. The laboratory hood was sanitized with 70% alcohol before culturing various

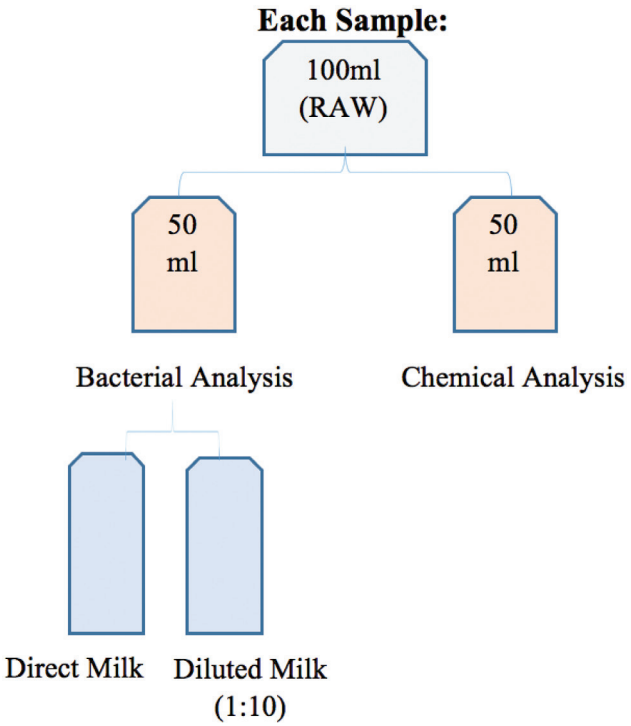

Figure 2 - Sample devision of camel milk for nutritional quality and microbial contamination analysis.

bacteria using diverse media to identify specific species based on colony characteristics. Plates were labeled, stored, and incubated for 24 hours to ensure media sterility. A glycerol-based solution, comprising glycerol (30 mL), distilled water (170 mL), and skim milk powder (2 g), was prepared for preserving bacterial strains and stored at -80°C.[12]

Experiments were carried out at 2 specialized facilities (the Pharmacy College laboratory and the Centre of Excellence in Genomic Medicine Research at King Abdulaziz University, Jeddah) under room temperature conditions to replicate real-world environments, ensuring consistent and applicable findings. The sample collection process involved washing bottles, sterilizing them at 121°C for 15 minutes, and drying them in a laboratory oven to maintain sample integrity.

The standard plate count method was used to determine viable counts of *Salmonella*, *E. coli*, and *Staphylococcus aureus* (*S. aureus*). Samples were suspended in sterile peptone water at a 1:9 volume/volume ratio, and 1 mL of appropriately diluted samples was inoculated onto sterile Petri plates. Selective media (Hektoen enteric agar for *Salmonella*, violet red bile agar for *E. coli*, and Baird Parker agar for *S. aureus*) were incubated at 37°C for 72 hours. Colony counts were recorded as the logarithm of colony-forming units per milliliter (log10 CFU mL-1).

After a 72-hour incubation, bacterial colonies were enumerated and cultured on sheep blood agar for an additional 24 hours to confirm purity. The Vitek® MS system(Model no.: 410895, Al-Jeel Medical Co.), utilizing MALDI-TOF technology, identified bacterial strains, capable of identifying up to 192 isolates per run. Samples were placed on Vitek® MS slides, treated with a matrix solution, and analyzed for specific bacterial identities. Remaining colonies were preserved in glycerol tubes at -80°C, with a Vortex mixer used to ensure homogeneous mixing prior to storage.

To detect pathogens, *Salmonella* was identified on hektoen enteric agar, incubated at 37°C for 72 hours, showing distinctive blue-green colonies.[11] *Escherichia coli* counts followed the Association of Official Analytical Chemists (AOAC) guidelines, using violet red bile agar, incubated at 37°C for 24 hours, showing pink colonies.[13] *Staphylococcus aureus* was isolated using Baird Parker agar, showing shiny black colonies with clear zones.[14]

The pH of camel milk samples was measured using a calibrated HANNA instruments PH211 pH meter. Acidity was determined using the AOAC method, mixing 20 mL of each milk sample with 40 mL of distilled water and 2 mL of phenolphthalein indicator (1%), titrated with sodium hydroxide solution until a pink color persisted.[15]

The vitamin C content in milk samples was assessed using an enzyme-linked immunosorbent assay (ELISA), following Ncube et al.[16] Using the G10s UV-vis spectrophotometer (serial No.: 2L5N340004), 50 µL of each milk sample was added to assay plate wells, followed by 50 µL of detection reagent A. After mixing and incubating at 37°C for one hour, the wells were aspirated and washed 3 times. Then, 100 µL of detection reagent B was added and incubated for 30 minutes at 37°C. After washing 5 times, 90 µL of substrate solution was added. The reaction was stopped with 50 µL of stop solution, and optical density was measured at 450 nm.

For vitamin D, following Ncube et al,[16] 50 µL each of standard solution, milk sample, and biotin conjugate antigen were added to the wells. After one hour at 37°C and 3 washes, 100 µL of streptavidin-HRP was added. Following a 30-minute incubation and 5 washes, 90 µL of substrate solution was added. The reaction was stopped with 90 µL of stop solution, and optical density was measured at 450 nm.

Iron (Fe3+) concentration was estimated using ELISA.[16] After equilibrating reagents and samples to room temperature, 50 µL of each milk sample, standard, or distilled water was added to wells, followed by 50 µL each of reducing reagent, reaction buffer, and dye

reagent. Absorbance was read at 510 nm. Iron content was calculated using the formula:

Iron (µmol/mL) = (ODSample - ODBlank)/(ODStandard - ODBlank)

Calcium levels were determined via ELISA.[16] For each sample, 50 µL of calcium standard and milk sample were added to wells, followed by 50 µL of assay buffer and 100 µL of colorimetric solution. Plates were incubated in darkness for 5-10 minutes at room temperature before measuring at 570 nm.

Lactoferrin quantification followed Shen et al,[17] 50 µL of standard and 10 µL of milk sample were added to the MicroELISAStripplate, followed by 100 µL of HRP-conjugate. After 60 minutes at 37°C and 5 washes, 50 µL each of chromogen solutions A and B were added, followed by a 15-minute incubation at 37°C. The reaction was stopped with 50 µL of stop solution, and absorbance was measured at 450 nm within 15 minutes.

Statistical analysis. The statistical analysis for this study was carried out using the Statistical Package for the Social Sciences software, version 26 (IBM Corp., Armonk, NY, USA). To discern the differences in raw camel milk obtained from street vendors versus farms, an independent t-test was employed. The integrity of the results was further ensured by verifying the normal distribution and homogeneity of variances across the data sets. For data not adhering to a normal distribution, the Mann-Whitney test was applied as an alternative to accommodate non-parametric variables. A significance threshold was established at a *p*-value of <0.05.

Results. This study's comparative analysis of microbial content in camel milk from street vendors versus farms unveiled significant disparities in microbial loads. Milk sourced from street vendors demonstrated considerably higher bacterial counts across all tested media than milk from farms. Specifically, Baird Parker agar media, indicative of the highest levels of bacterial content, showed street vendor samples harboring an average bacterial count of 21,215±193,563 cfu/mL, starkly contrasted by farm samples with a much lower average of 470±1055 cfu/mL (**Table 1**).

In this study, the Vitek® MS system, leveraging advanced mass spectrometry technology, was utilized to identify pathogenic bacteria in untreated camel milk samples sourced from both street vendors and farms. This cutting-edge system facilitates the rapid and precise identification of microorganisms, essential for delineating the microbial landscape of these samples.

The investigation into the bacterial content of raw, untreated camel milk samples from street vendors and farms unveiled the presence of pathogenic bacteria. Farm samples revealed *Streptococcus agalactiae* in 2 out of 10 samples. Conversely, street vendor samples showcased a broader array of pathogens, with *Klebsiella pneumoniae* detected in 4 out of 10 samples and *Mycobacterium marinum* in 1 out of 10 samples.

Table 1 - Comparison of microbial number between street vendor milk and farm milk (cfu/mL).

Media Agar	Street vendors samples	Farm samples
	Raw milk*	
Baird Parker	21215±193563	470±1055
Sheep blood	12690±618153	1075±928
BHI	13175±361240	195±880
Violet red bile	1240±29398	0±13
Hektoen enteric	2515±60690	0±13

Values are presented as mean ± standard deviation (SD). *Raw refers to untreated samples from street vendors. BHI: brain heart infusion

In this investigation, the plate count method was employed to quantitatively assess the microbial load of pathogenic bacteria, specifically *S. aureus*, *E. coli*, and *Salmonella*, in raw camel milk samples procured from street vendors and farms. This technique facilitated a detailed quantitative analysis of the microbial contamination present in these samples.

To discern the variations in microbial contamination levels between milk sourced from street vendors and that from farms, the study applied the Mann-Whitney test. The findings, summarized in **Table 2**, revealed significant differences in the median bacterial counts and interquartile ranges for each examined pathogen. Samples from street vendors consistently showed elevated levels of contamination across all 3 bacteria types when compared to farm samples. The disparity was most pronounced for *S. aureus*, which exhibited a Mann-Whitney U value of 0.00 and a statistically significant *p*-value of <0.001. *Escherichia coli* (U=9, *p*=0.001) and *Salmonella* (U=13, *p*=0.004) also demonstrated notable differences in contamination levels between the 2 sources, underscoring the higher risk associated with milk from street vendors.

This study assessed the chemical composition of raw camel milk from street vendors and farms, focusing on acidity, pH, total ascorbic acid (vitamin C), calciferol (vitamin D), iron, calcium, and lactoferrin. According to the results in **Figure 3**, there was no significant difference in total ascorbic acid content between the 2 groups (*p*=0.775). However, a marginally significant difference was observed in calciferol levels, with higher concentrations in farm samples (*p*=0.095). Iron content was slightly higher in street vendor samples, but not to a statistically significant degree (*p*=0.261). Calcium

Table 2 - Presence of pathogenic bacteria in raw (untreated) camel milk samples from street vendors and farms (plate count method CFU/ml).

Pathogenic bacteria	Groups	Numbers	Median	Interquartile range	U	*P*-values
Staphylococcus aureus	Street vendors	10	21215	19356	0.00	0.000
	Farm	10	470	1055		
E. coli	Street vendors	10	1240	2939	9	0.001
	Farm	10	0	13		
Salmonella	Street vendors	10	2515	60690	13	0.004
	Farm	10	0	13		

E. coli: *Escherichia coli*

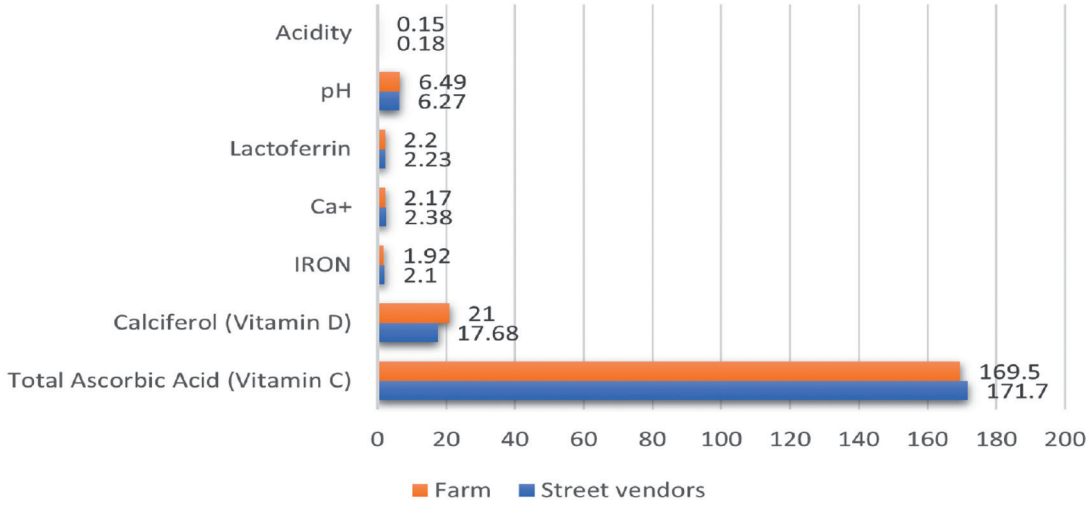

Figure 3 - Differences in acidity, potential of hydrogen, total ascorbic acid (vitamin C), calciferol (vitamin D), iron, calcium, and lactoferrin between raw (untreated) camel milk samples from street vendors and farms. pH: potential of hydrogen, Ca+: calcium.

(p=0.342) and lactoferrin (p=0.930) levels were similar between both groups. The pH values of street vendor samples were slightly lower compared to farm samples, yet this difference was not statistically significant (p=0.209). Acidity levels also showed no significant variation between street vendors and farms (p=0.468). Overall, the results indicate minimal variation in these chemical properties between the camel milk samples from different sources.

Discussion. The comprehensive analysis of microbial content in camel milk from street vendors versus farms revealed marked differences, most notably when assessed using Baird Parker agar media. Samples from street vendors demonstrated significantly higher bacterial counts, suggesting potential lapses in hygiene practices during handling and storage. This discrepancy in bacterial counts, with street vendor samples showing an average count of 21,215±193,563 cfu/ml compared to farms' 470±1055 cfu/ml, underscores the heightened microbial risk associated with milk sourced from street vendors. These study's findings are in line with Berhe et al's[18] outcome that the milk obtained from vendors had the highest proportion of contamination (n=33/51, 64.7%), compared with the dairy farms (n=32/96, 33.3%). According to Berhe et al,[18] business type significantly impacts milk contamination, with vendors and cafeteria owners having nearly 3 times more contaminated milk compared to dairy farmers.

The global concern over foodborne pathogens is underscored by our findings, which indicate the presence of bacteria such as *Streptococcus agalactiae* in farm samples and diverse pathogens including *Mycobacterium marinum* and *Klebsiella pneumoniae* in street vendor samples. Azwai et al[19] highlight the health implications of raw milk's association with

Klebsiella pneumoniae, particularly in products failing to meet international microbiological standards. The research also sheds light on antibiotic resistance in *Klebsiella pneumoniae*, with many isolates showing resistance to multiple antibiotics.

While the absence of pathogens such as *Campylobacter jejuni*, *Acinetobacter baumannii*, and *Listeria monocytogenes* is reassuring, it does not diminish the significance of the pathogens identified. The need for improved hygienic practices and stringent monitoring is paramount to ensure the safe production and distribution of camel milk. Given its nutritional value, securing the microbiological safety of camel milk is crucial for consumer health and the preservation of this important nutritional resource. Future research should aim to identify specific sources of contamination and develop strategies to mitigate these risks.

Notably, the study found significant variations in median bacterial counts for *Salmonella*, *S. aureus*, and *E. coli*, with street vendor samples consistently showing higher contamination levels. The prevalence of *Salmonella* in street vendor milk samples (according to plate count method) suggests issues with milking and storage practices. Despite a lower *Salmonella* count compared to other studies, the potential health risk remains, considering its persistence in dairy products and its adverse impact on human health.[11]

The presence of *Staphylococcus* bacteria in all raw camel milk samples (according to plate count method), irrespective of the source, aligns with global trends of staphylococcal food poisoning.[20] The study's findings on *S. aureus*, although lower than some previous research, highlight the bacterium's capacity to cause severe infections in humans and animals, particularly in dairy cows.[21,22]

The detection of *E. coli* in street vendor samples corroborates the findings of Dogondaji et al,[23] emphasizing the public health risk posed by enteropathogenic bacteria in milk products. The geographic factor may influence the prevalence of *E. coli*, as suggested by the variation in results from different studies.

The study's results reflect the impact of hygiene conditions like unwashed hands, unclean milking equipment, and unsuitable storage and transport methods on bacterial presence in milk. In summary, this comparison between camel milk samples from street vendors and farms offers critical insights into quality and safety differences attributable to distinct sourcing and handling practices.

The chemical properties of camel milk, as analyzed in this study, present a detailed comparison with prior research, offering a comprehensive understanding of its compositional attributes. The acidity of raw street vendor camel milk samples, averaging 0.176±0.075, aligns with the findings of Ismaili et al,[11] who reported acidity levels ranging from 0.17-0.20%. Variability in these acidity levels could be attributed to factors such as camel species, breed, lactation stage, and analytical methods, as suggested by El-Hanafy et al,[24] Mohamed et al,[25] and Abdelhak et al.[26] The production of lactic acid by lactic bacteria during storage and transportation of raw camel milk might be responsible for the lower pH values and higher titratable acidity, particularly under high ambient summer temperatures.[11]

The pH values of the camel milk samples from street vendors, corresponding with the range reported by Ogolla et al[27] and Chethouna et al,[28] were found to be lower than value reported by Bouhaddaoui et al.[29] These variations in pH might be influenced by several factors, including environmental conditions, as hypothesized by Bouhaddaoui et al[29] and the ascorbic acid content in camel milk, as both vitamin C levels and pH values are interrelated.

Although the vitamin C content in raw camel milk from street vendors, ranging from 141.00-190.00 mg/L, was lower than the value reported by Seifu,[30] it was notably higher than that reported by Bouhaddaoui et al[29] and aligns with values observed by Benmeziane-Derradji,[31] who noted higher vitamin C concentrations in summer milk compared to other seasons. Swelum et al[9] supported this observation, emphasizing the impact of seasonal changes on camel milk composition.

Interestingly, the calciferol (vitamin D) content in our study was below the detection limit, contrasting with the higher values reported in Alxa Bactrian camel milk by Benmeziane-Derradji.[31] Such variance could be attributed to differences in camel breeds, environmental conditions, and geographical locations.

Iron content in samples from street vendors was observed to be higher than levels reported by Faraz.[32] Conversely, the calcium levels in our analysis fell within the range described by Faye et al.[33] These mineral content variations are likely influenced by the lactation period and environmental factors, as indicated by Swelum et al.[9]

Furthermore, the lactoferrin concentration in camel milk samples from street vendors exceeded levels reported by Hendy et al.[34] Lactoferrin levels can be influenced by breed, parity and lactation stage.[35]

Study limitations. This study focuses on the Jeddah region, offering insights into camel milk quality and safety while acknowledging potential diversity across Saudi Arabia. Although the sample distribution provides

a comprehensive overview, it may not capture all variability. The cross-sectional design offers a snapshot; however, a longitudinal approach might provide a better understanding of evolving factors. Seasonal variations were not examined, suggesting future research is needed.

To improve camel milk safety and quality, especially from street vendors, we recommend strict hygiene protocols, regular microbial and chemical testing, and consumer education on the risks of raw camel milk. Further research should explore how environmental factors and camel breeds affect milk composition.

In conclusion, this study embarked on an in-depth examination of the quality, safety, and nutritional characteristics of camel milk sourced from street vendors and farms within the Jeddah region of Saudi Arabia. Utilizing a comprehensive methodology that included a preliminary pilot study, meticulous sample collection, and thorough laboratory analyses, our research has unearthed notable differences in the microbial load and composition between camel milk from varied sources. Specifically, samples from street vendors were found to have significantly higher bacterial counts and a greater diversity of microorganisms, indicating potential lapses in hygiene and storage practices. The detection of pathogenic bacteria, such as *Klebsiella pneumoniae*, *Streptococcus agalactiae*, and *Mycobacterium marinum*, highlights the inherent public health risks of consuming raw camel milk. Chemically, the study observed only minimal variations in pH, acidity, and key nutritional elements like ascorbic acid and calciferol across the different milk sources, suggesting a relative consistency in these parameters.

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