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Comparative Analysis of Microbial Growth in Raw and Pasteurized Cow and Camel Milk During Chilled Storage

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Abstract

Camel milk has been an integral component of diets in the Middle East for millennia. The current study aimed to evaluate microbial changes in pasteurized camel and cow milk using culture-based methods. We examined bacterial growth in raw and pasteurized camel and cow milk during 17 days of refrigerated storage at 4 °C. Raw camel milk had a mean initial bacterial count of 4.13×10^3 CFU/mL, peaking at 2.87×10^6 CFU/mL by day 17. Pasteurization reduced the count to 2×10^1 CFU/mL, rising to 40×10^4 CFU/mL by day 17. Raw cow milk started at 1.08×10^4 CFU/mL, reaching 3.15×10^6 CFU/mL, while pasteurized cow milk increased from 31.12 CFU/mL to 4.06×10^6 CFU/mL. Coagulase-positive *Staphylococcus aureus* and *Lactobacillus* spp. exhibited significant proliferation in raw camel and cow milk. The growth reached a high point of 5.27×10^4 CFU/mL for coagulase-positive *S. aureus* and 3.74×10^4 CFU/mL for *Lactobacillus* spp. in raw camel milk. In raw cow milk, it reached a high point of 1.20×10^5 CFU/mL for coagulase-positive *S. aureus* and 5.0×10^5 CFU/mL for *Lactobacillus* spp., these results show that these microorganisms grow in different ways in camel milk and cow milk. This shows how vulnerable raw milk is to microbial growth. Pasteurized samples showed no *S. aureus* or *Lactobacillus* spp. growth, confirming pasteurization's effectiveness. The study detected no fungal or pathogenic contamination. In conclusion, camel milk exhibited higher initial bacterial counts and slower bacterial growth than cow milk, but supported more sustained microbial proliferation over time. Pasteurization was equally effective for both types, eliminating *Lactobacillus* spp. and reducing bacterial loads significantly.

Keywords: Livestock, *In vitro* Study, Bacterial Infection, Food-borne Pathogen, Food Industry

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INTRODUCTION

Milk is an important part of the human diet and due to its many health and nutritional benefits; milk is a rich source of protein and essential nutrients, such as calcium, along with various vitamins and minerals crucial for health. It is widely consumed worldwide by over 6 billion people.[1] Milk is rich in calcium, proteins (caseins and whey proteins), fats, and vitamins such as B1 and B12. Worldwide, cattle are the major source of consumed milk at 81%, followed by buffalo milk at 15.1%, goat milk at 2.2%, and sheep milk at 1.3%, whereas camel milk is only 0.4%.[2]

A review of the literature by Givens *et al*.[3] has shown that milk consumption is beneficial to human beings. It is known to promote growth in infants and children and milk consumption has been inversely correlated with childhood obesity and overweight. Milk calcium promotes the development of excellent bone density and teeth in infants and children.[3] Calcium is also beneficial to adult humans, with milk consumption associated with strong bones and reduced risks of osteoporosis [4] and improvements in cognitive abilities and reduced risks of developing Alzheimer's disease.[5] Milk also has other therapeutic benefits.[6] It can help with diabetes,[7] high blood pressure[8], inflammation,[6] and cancer.[9] It can also help the heart and metabolism.[10] Additionally, it has been shown to improve digestion, and positively affect the immune and nervous systems in humans.[11]

Nutritionally, milk predominantly contains protein, fat, lactose, and minerals irrespective of the source, whether it is from humans or different animals. However, the levels of these key milk components can be variable.[2] This is because they are affected by different factors such as the geographical location of the source animals, climate, animal breed and age, management practices, type of feed, and lactation stage.[12,13] For comparative purposes, the composition of dairy milk and camel milk ranged from 3.0-3.9 and 2.4-4.2 (protein), 3.3-5.4 and 2.0-6.0 (fats), 4.4-5.6 and 3.5-5.1 (lactose) and 0.7-0.8 and 0.69-0.9 (ash), respectively.[2] Studies that looked at camel milk and cow milk found that the proteins in camel milk have very different electrophoretic patterns than proteins in cow milk and human milk.[14] Moreover, it was mentioned that camel milk is a viable and safe substitute for cow's milk in children with allergies.[15] Additionally, researchers identified physicochemical differences between camel milk and the milk of cows and buffaloes. Camel milk had a lower specific gravity compared to buffalo milk and a viscosity greater than cow milk but less than that of buffalo milk. The average surface tension was recorded as 58.39 dyne/cm, while the freezing point (-0.518 °C) was lower than that of both cow and buffalo milk. Moreover, camel milk had much greater electrical conductivity than cow and buffalo milk.[16]

The nutritional status of milk makes it an excellent substrate for microbial growth. The microflora of milk can either be endogenous or introduced from environmental sources.[17] Non-endogenous sources of milk contamination encompass the animal's environment, including bedding and skin, as well as external factors such as milking machines, personnel, milk storage tanks, and containers.[18,19] Therefore, raw milk is rich in different microbial groups, some of which are beneficial, spoilage, or harmful.[20,21]

The common bacterial groups found in milk include *Pseudomonas, Micrococcus, Lactobacillus, Bacillus, Corynebacterium, Streptococcus, Staphylococcus*, *Arthrobacter*, and *Bifidobacterium* spp.[6,11,17,20,21] Focusing on bacteria, some of the key pathogens identified in milk and milk products include *Staphylococcus* spp. (coagulase-positive), *Escherichia coli* (Shiga-toxin-producing species), *Listeria monocytogenes, Streptococcus* sp. and *Salmonella* sp.[22-25] These different pathogenic groups have been known to cause milk-borne diseases such as anthrax (*Bacillus anthracis*), botulinum (*Clostridium botulinum*), listeriosis (*Listeria monocytogenes*), gastroenteritis (*E. coli*, *Campylobacter* spp., *Shigella* spp. and *Salmonella* spp.), strep throat (*Streptococcal pharyngitis*) and scarlet fever (*Streptococcus pyogenes*).[20] Similarly, spoilage bacteria belonging to *Acinetobacter, Bacillus, Micrococcus, Flavobacterium, Lactobacillus, Clostridium* and *Pseudomonas* groups have been identified in these products.[21,22] The activities of these bacteria often result in milk and milk products being discolored, developing off-flavor with undesirable gas production, curdling, ropiness, and sliminess.[21]

Therefore, the activities of these spoilage and pathogenic bacteria not only pose significant health risks but also result in substantial economic losses associated with milk and dairy products. This is why different techniques have been developed to reduce or eliminate these bacterial groups to ensure the safety of milk and extend its shelf life without loss of quality. While there are different methods in use for milk preservation, pasteurization remains one of the most popular approaches.[20,26] Pasteurization, a thermal treatment, aims to eradicate pathogenic microorganisms and prolong the shelf life of milk.[26]

There have been many reports on the effectiveness of pasteurization for milk bacterial groups. While it initially reduces total bacterial counts,[27] multiple studies have shown that the bacterial counts tend to increase afterwards, even under cold storage conditions. For example, the viable bacterial count of pasteurized bovine milk stored at 4 °C increased from 1.3 $\log_{10}$ CFU/mL on day 0 to 4.2 $\log_{10}$ CFU/mL on day 16, demonstrating accelerated microbial growth during the storage period.[26] A similar trend has been observed by other authors in bovine milk stored at higher temperatures (6, 8, and 10 °C) for up to 35 days.[28,29] This suggested that the effects of pasteurization may wear off over time. However, questions remain about whether this trend is the same in other non-bovine milk types. Middle Eastern countries like Saudi Arabia widely consume camel milk, making it especially important. Additionally, camel milk is thought to be a potential probiotic candidate given that it contains probiotics such as lactic acid bacteria and bifidobacteria and postbiotics such as exopolysaccharides, short-chain fatty acids, teichoic acids, and peptides.[6] Despite extensive research on milk microbiology, limited studies have compared microbial dynamics in pasteurized camel and cow milk during extended storage. This study aimed to comprehensively assess the microbial dynamics of non-pasteurized and pasteurized camel and cow milk over a three-week period using culture-based methodologies, providing valuable insights into their preservation strategies and implications for food safety.

MATERIALS AND METHODS

Collection of milk samples

Two types of milk were analyzed in this study: camel and cow milk. Fresh samples of both camel and cow milk were obtained from the university's farm facility in Qassim, Saudi Arabia. The milk samples were transported to the food pilot plant at the Department of Food Science and Human Nutrition, Qassim University, in ice-filled containers and immediately stored in a refrigerator at 4 °C. Under aseptic conditions, the samples were divided into two groups: one group was kept raw (non-pasteurized), while the other was pasteurized.

Pasteurisation and experimental setup

Pasteurization was carried out for both cow (bovine) and camel milk. Briefly, pasteurization was done by high-temperature short time (HTST) which involves heating the milk to at least 80 °C for 10 seconds by using (The system model HTST) Savery USA.[30] Triplicate samples of raw (unpasteurized) and pasteurized cow and camel milk were stored in 1 L sterile glass bottles and incubated at 4 °C for duration of 17 days.

Microbial Sampling and quantification

Triplicate samples were aseptically taken on days 0, 3, 7, 10, 14, and 17 from pasteurised and unpasteurized samples of cow and camel milk. On each sampling day, 1 ml of milk was taken for each type of culture-based microbial analysis. Five different culture-based assays were carried out. These assays were carried out to detect and count different bacterial species; Baird Parker agar (Scharlau, Spain) for *Staphylococcus aureus*, Brilliant Green agar (Oxoid, England) for *Salmonella* spp., Plate Count Agar (Oxoid, England) for total count bacteria, Rose Bengal Chloramphenicol agar (Scharlau, Spain) for yeast and moulds, MacConkey agar (Oxoid, England) to detect *Enterobacteriaceae* family including *E. coli*, and MRS medium (de Man, Rogosa, and Sharpe) for the cultivation and detection of *Lactobacillus* spp. in milk. Each culture medium was prepared according to the manufacturer's prescription.

Table 1. Mean total bacterial counts (CFU/mL) of raw and pasteurized camel and cow milk

Day	Raw Camel Milk	Pasteurized Camel Milk	Raw Cow Milk	Pasteurized Cow Milk	BGA	ROSE	MAC	ANOVA p-value	Significance
0	4.13×10^3	19.43	1.08×10^4	31.12	0.0	0.0	0.0	0.13834	n.s.
3	1.35×10^4	189.45	3.75×10^4	516.63	0.0	0.0	0.0	0.13834	n.s.
7	2.02×10^4	473.59	3.94×10^4	1.13×10^3	0.0	0.0	0.0	0.13834	n.s.
10	1.09×10^5	7.86×10^3	1.99×10^5	1.45×10^4	0.0	0.0	0.0	0.13834	n.s.
14	2.13×10^5	2.71×10^4	2.12×10^6	4.38×10^5	0.0	0.0	0.0	0.13834	n.s.
17	2.87×10^6	3.81×10^5	3.15×10^6	4.06×10^6	0.0	0.0	0.0	0.13834	n.s.

Mean of three replicates, BGA: Brilliant green agar, a selective for the detection of *Salmonella* spp. In milk samples, ROSE: Rose Bengal Chloramphenicol Agar is used for the selective for detection of yeasts and molds. MAC: MacConkey agar, a selective media used here for detection of *Enterobacteriaceae*. Incubation of milk was in cooled condition at 4 °C, n.s. : not significant at $p \geq 0.05$

The standard plate count method was used for the enumeration of bacterial and fungal colonies on the general purpose and selective media. One millilitre (1 ml) of a chosen sample was serially diluted using phosphate buffer diluent until the target microbial groups were diluted enough to be accurately counted (up to 10^6 dilutions). The microbial counts were expressed as colony-forming units per ml of milk (CFU/ml). For bacterial detection and counting 100 µl of milk was used as inoculum and the plates were incubated at 25 °C for up to 48 hours before being counted. For Rose Bengal Chloramphenicol agar, plates were incubated at 25 °C for up to 7 days before the colonies were counted.[31]

RESULTS

The study carried out a comparative investigation of the growth of bacteria in cow and camel milk throughout a 17-day period of chilled storage. The bacterial counts were evaluated at six interval times during cooled storage at 4 °C: day 0, day 3, day 7, day 10, day 14, and day 17, as shown in Table 1. We also used three selective media to identify specific microbes that are typically associated with milk contamination. We found no bacterial contaminants in any of the milk samples. These include BGA (Brilliant Green Agar) for *Salmonella* spp., ROSE (Rose Bengal Chloramphenicol Agar) for yeasts and molds, and MAC (MacConkey Agar) for *Enterobacteriaceae*. The results presented in Table 1 reveal the following: For raw camel milk, the initial total bacterial count was 4.13×10^3 CFU/mL. By the third day, the count decreased to 1.35×10^4 CFU/mL, perhaps due to the initial phase in which bacteria adapt to the environment. By day 7, the bacterial count had a significant increase to 2.02×10^4 CFU/mL, indicating a rapid growth phase. The count steadily rose, eventually reaching 2.87×10^6 CFU/mL on day 17. The increase suggests that the milk provided a perfect environment for the growth of bacteria, likely due to the availability of nutrients and favorable conditions for the rapid proliferation of microorganisms. Following pasteurization, the bacterial count in camel milk decreased significantly to 19.43 CFU/mL, illustrating the efficacy of pasteurization in minimizing microbial proliferation. Over time, the bacterial population gradually increased but remained much lower than that of raw milk, reaching 3.81×10^5 CFU/mL by day 17. The gradual increase suggests that while pasteurization reduces the initial quantity of germs, it does not entirely eliminate all bacteria, and the remaining ones may multiply, especially under favorable conditions.

The initial bacterial count in unpasteurized cow milk was 1.08×10^4 CFU/mL, which was lower than the bacterial count in raw camel milk. By the third day, the count increased to 3.94×10^4 CFU/mL, and by the seventh day, it reached 3.94×10^4 CFU/mL. By day 14, there was a significant increase in the number of colony-forming units per milliliter (CFU/mL), reaching 2.12×10^6 CFU/mL. By day 17, the count increased to 3.15×10^6 CFU/mL. The substantial rise in numbers suggests that raw cow milk provides an extremely favorable environment for the rapid growth of bacteria, similar to raw camel milk. The initial bacterial

Table 2. Assessment of coagulase-positive *Staphylococcus aureus* growth in raw and pasteurized cow and camel milk using Baird-Parker agar

Days	Mean Count of Coagulase-positive *Staphylococcus aureus* Growth (CFU/mL)				ANOVA p-value	Significance
	Raw Camel Milk	Pasteurized Camel Milk	Raw Cow Milk	Pasteurized Cow Milk		
0	1.24×10^3	0.0	7.18×10^2	0.0	7.63×10^{-9}	Sign.
3	4.55×10^3	0.0	7.26×10^3	0.0	7.63×10^{-9}	Sign.
7	1.38×10^4	0.0	9.37×10^3	0.0	7.63×10^{-9}	Sign.
10	2.47×10^4	0.0	2.89×10^4	0.0	7.63×10^{-9}	Sign.
14	4.35×10^4	0.0	3.28×10^4	0.0	7.63×10^{-9}	Sign.
17	5.27×10^4	0.0	3.74×10^4	0.0	7.63×10^{-9}	Sign.

Mean of three replicates, Incubation of milk was in cooled condition at 4 °C, Sign.: Significant at $p \geq 0.05$

count of pasteurized cow milk was 31.12 CFU/mL. The count steadily increased over time, ultimately reaching 4.06×10^6 CFU/mL on day 17. Similar to pasteurized camel milk, pasteurized cow milk also exhibited a significantly reduced bacterial load in comparison to raw milk, illustrating the effectiveness of pasteurization. However, the progressive increase highlights the ability of bacteria to reproduce. The investigation into potential milk contamination revealed no evidence of fungal or bacterial growth on BGA, ROSE, and MAC media throughout the entire investigation period. This indicates a complete absence of any contamination sources and the absence of *Salmonella* spp., yeasts, and molds, as well as *E. coli*, in both raw and pasteurized samples of camel and cow milk. The results suggest that while the total number of normal bacteria increased with time, the milk samples analyzed did not contain any visible growth of these spoilage-causing microbes.

Baird-Parker agar was utilized for the isolation and enumeration of coagulase-positive *Staphylococcus aureus*, with the results presented in Table 2. The initial *S. aureus* count for raw camel milk on day 0 was 1.24×10^3 CFU/mL. On the third day, the microbial growth had reached a level of 4.55×10^3 CFU/mL. There was a substantial increase to 1.38×10^4 CFU/mL by day 7, which then further rose to 2.47×10^4 CFU/mL by day 10. On day 14, the count reached 4.35×10^4 CFU/mL, which ended at 5.27×10^4 CFU/mL on day 17. Camel milk that had undergone pasteurization did not exhibit any observable development of bacteria for the whole 17-day period. This suggests that pasteurization is very successful in eradicating the existence of microorganisms. On the other hand, the initial *S. aureus* count for raw cow milk on day 0 was 7.18×10^2 CFU/mL. On the third day, the count had raised to 7.26×10^3 CFU/mL. There was a significant increase to 9.37×10^3 CFU/mL on day 7, which further rose to 2.89×10^4 CFU/mL on day 10. The bacteria count was 3.28×10^4 CFU/mL on day 14 and increased to 3.74×10^4 CFU/mL on day 17. Similarly, there was no growth of bacteria seen in pasteurized cow milk from day 0 to day 17, which further confirms the effectiveness of pasteurization in preserving the microbiological safety of the milk.

Table 3 showing the growth of *Lactobacillus* spp. in raw and pasteurized cow and camel milk over a 17-day period, using Baird-Parker agar as the growth medium. The milk samples were incubated at a temperature of 5 °C. For the raw camel milk at the start of day 0, the average number of *Lactobacillus* spp. in raw camel milk was 9.40×10^3 (CFU/mL). On day 3, the count had climbed to 5.00×10^4 CFU/mL, and it further raised to 5.50×10^4 CFU/mL on day 7. On day 10, the count reached 6.30×10^4 CFU/mL, and further grew to 7.10×10^4 CFU/mL on day 14. On day 17, the count reached its highest point at 1.20×10^5 CFU/mL. There is a consistent increase in the population of *Lactobacillus* spp. in raw camel milk over the 17-day period. Unlike pasteurized camel milk, there was no proliferation of *Lactobacillus* spp. seen for the whole 17-day duration. The count stayed consistently at zero on all days examined (days 0, 3, 7, 10, 14, and 17). These findings indicate that pasteurization successfully

Table 3. Assessment of *Lactobacillus* spp. growth in raw and pasteurized cow and camel milk using MRS medium (de Man, Rogosa, and Sharpe)

Days	Mean Count of *Lactobacillus* spp. Growth (CFU/mL)				ANOVA p-value	Significance
	Raw Camel Milk	Pasteurized Camel Milk	Raw Cow Milk	Pasteurized Cow Milk		
0	9.40×10^3	0.0	8.50×10^3	0.0	0.000008	Highly significant
3	5.00×10^4	0.0	9.10×10^4	0.0	0.000008	Highly significant
7	5.50×10^4	0.0	1.10×10^4	0.0	0.000008	Highly significant
10	6.30×10^4	0.0	9.30×10^4	0.0	0.000008	Highly significant
14	7.10×10^4	0.0	1.50×10^5	0.0	0.000008	Highly significant
17	1.20×10^5	0.0	5.00×10^5	0.0	0.000008	Highly significant

Mean of three replicates, Incubation of milk was in cooled condition at 4 °C, Significant at $p \geq 0.05$

prevents the development of *Lactobacillus* spp. in camel milk. The initial average count of *Lactobacillus* spp. in raw cow milk was 8.50×10^3 colony forming units per milliliter on day 0. The count had a substantial rise to 9.10×10^4 CFU/mL on day 3, and further rose to 1.10×10^4 CFU/mL on day 7. On the tenth day, the count reached 9.30×10^4 CFU/mL. There was a significant rise in the count of bacteria on day 14, with a measurement of 1.50×10^5 CFU/mL, and it reached its highest point of 5.00×10^5 CFU/mL on day 17. This illustrates a substantial and steady increase of *Lactobacillus* spp. in unpasteurized bovine milk over a period of time. Just like pasteurized camel milk, pasteurized cow milk did not show any development of *Lactobacillus* spp. over the 17-day period. The average count was zero on all days examined (days 0, 3, 7, 10, 14, and 17). This further corroborates the efficacy of pasteurization in inhibiting the proliferation of *Lactobacillus* spp.

DISCUSSION

The findings of the current study indicate that raw milk from both cows and camels supports bacterial proliferation over a 17-day period at 4 °C. In contrast, pasteurization significantly reduces bacterial counts, although some bacteria may still multiply over time (Table 1). Milk of all types serves as an excellent substrate for microbial growth due to its nutrient-rich composition, including lactose, caseins, proteins, essential amino acids, lipids, vitamins, and minerals. This nutrient profile promotes the growth of diverse microorganisms introduced from the farm environment, udder surfaces, and milking equipment.[22,32] Pasteurization is essential for all kinds of milk. Recent study has examined and shown the significant role of unpasteurized milk intake on the incidence of infections, atopy, asthma, rectal cancer, and respiratory illnesses.[33]

According to the total bacterial count, our raw milk (cow and camel) were in agreement with the international standards, as the initial total counts for both camel and cow milk were less than 3×10^5 CFU/mL. The international standard for acceptable quality raw milk is not to exceed a total bacterial count of 1×10^5 CFU/mL.[34] Nevertheless, several countries have implemented other criteria that are better suited to their own circumstances. The Pasteurized Milk Regulations in the United States restrict the bacterial count in grade "A" raw milk to 100×10^3 CFU/mL for each farmer and 300×10^3 CFU/mL for commingled raw milk.[35] Good hygiene significantly impacts the total bacterial counts in milk. It has been reported that when the initial bacterial counts in milk are low and the milk is stored at temperatures ≤4 °C, the bacterial levels remain acceptable for up to 96 hours.[36] Therefore, milk with high bacterial contamination spoils faster due to rapid bacterial growth, causing off-flavors and curdling. Proper hygiene and storage at ≤4 °C help maintain low bacterial counts and extend milk's shelf life.[37] The total bacterial count test for raw and pasteurized milk is important, but it doesn't fully determine milk's bacterial quality. Therefore, we conducted several additional experiments to get a clearer picture. Camel milk is white and opaque, with a somewhat salty flavor, with a pH range of 6.2 to 6.5, which

is lower than that of cow milk (6.5-6.7). The fat content is minimal, including 96% triglycerides and around 30 mg of cholesterol per 100 g of dry matter. Its fat contains fewer short-chain fatty acids compared to cow's milk. Moreover, the average size of fat globules is lower in comparison to those seen in cattle, buffalo, and goat milk. Due to the great digestibility of camel's milk, it may provide challenges in the food industry.[38]

Our study demonstrated that pasteurization effectively eradicates coagulase-positive *Staphylococcus aureus* in both camel and cow milk, as no bacterial growth was detected during the 17-day storage period at 4 °C. In contrast, raw milk exhibited significant bacterial growth, underscoring the importance of pasteurization for milk safety, and interestingly our results revealed that coagulase-positive *Staphylococcus aureus* in raw camel milk is higher than that of cow milk (Table 2). Previous investigations have confirmed that coagulase-positive *S. aureus* is prevalent in camel milk and causing significant mastitis in camels, with certain risk factors found to be associated with its occurrence.[39,40] *S. aureus* is more common in dairy cows' mammary gland infections because it can live in the keratin layers of the teat canal.[41] Unpasteurized camel or cow milk may include several kinds of *Staphylococcus* bacteria, most commonly as a result of inadequate hygiene during the milking process. Camel milk obtained directly from farms and intended for consumption often includes both beneficial and harmful coagulase enzymes. There is a significant incidence of pathogenic coagulase-positive *Staphylococcus aureus* in milk and dairy products obtained from informal sectors in developing nations.[42] Enhancing milk quality and ensuring its safety for consumption by people requires implementing improved methods, strict adherence to good manufacturing standards and rigorous hygiene measures.[43,44]

Our findings demonstrated that unpasteurized camel milk promotes substantial multiplication of *Lactobacillus* spp., but pasteurization effectively inhibits their development. Unprocessed cow milk also shows a significant increase compared to low *Lactobacillus* in camel milk (Table 3). Lactic acid bacteria comprise more than 60 distinct genera, with key genera frequently involved in food fermentation including *Lactobacillus, Leuconostoc, Lactococcus, Streptococcus, Enterococcus, Weissella, Pediococcus*, among others.[45] Their metabolic processes vary when utilizing glucose as the primary carbon source: homofermentative bacteria like *Lactococcus* spp. and *Streptococcus* spp. produce two molecules of lactate from one glucose molecule, whereas heterofermentative bacteria like *Leuconostoc* spp. and *Weissella* spp. produce lactate along with ethanol and carbon dioxide.[46] Camel milk serves as an excellent reservoir for isolating lactic acid bacteria with potent probiotic properties. Compared to cow's milk, camel milk contains higher levels of natural antimicrobial compounds.[47] Generally, in camel milk, the predominant species of lactic acid bacteria are typically *Lactobacillus bulgaricus*, *Lactobacillus casei*, and *Lactobacillus plantarum*. Whereas cow milk tends to harbor *Lactobacillus acidophilus* and *Lactobacillus bulgaricus* as the main lactic acid bacteria species.[48]

CONCLUSION

The current comparative study highlights significant differences in microbial growth between raw and pasteurized cow and camel milk during chilled storage. Both types of raw milk demonstrated rapid bacterial proliferation; however, pasteurization significantly reduced bacterial counts and effectively inhibited the growth of spoilage-causing microorganisms, including *Staphylococcus aureus* and *Lactobacillus* spp. Pasteurized milk, although not entirely sterile, showed significantly lower bacterial loads over the 17-day period, reaffirming the importance of pasteurization for maintaining milk safety. The absence of *Salmonella* spp., *E. coli*, yeasts, and molds across all samples indicates excellent hygiene practices during milk handling. These findings support the need for pasteurization as a critical process in extending milk's shelf life and ensuring its microbiological safety during chilled storage. Considering the observed bacterial growth in both raw and pasteurized milk during extended storage, it is recommended that pasteurized milk be consumed within a shorter timeframe or stored under more stringent conditions to mitigate bacterial resurgence. Improved packaging and advanced preservation

methods, such as the use of antimicrobial coatings or active packaging technologies, could further enhance milk safety and extend shelf life. Future research should investigate alternative approaches, such as high-pressure processing or ultraviolet (UV) treatment, as adjuncts or substitutes for pasteurization to enhance microbial control and ensure greater safety and quality in milk preservation. Additionally, investigating the potential of natural preservatives or probiotics that can inhibit bacterial growth while maintaining the nutritional and sensory quality of milk could offer valuable insights for the dairy industry. Long-term studies examining the effects of various storage conditions and temperatures on microbial dynamics across different types of milk will provide valuable insights for developing more effective milk preservation strategies.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTION

Both authors listed have made a substantial, direct, and intellectual contribution to the work and approved the final manuscript for publication.

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DATA AVAILABILITY

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

ETHICS STATEMENT

Not applicable.

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