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Article

Effect of Two Heat Treatments on the Microbiological Quality of Raw Camel Milk from Bechar City-Algeria

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Abstract: This study aimed to evaluate the effect of two heat treatments on the reduction of the microbial load in raw camel milk. Raw camel milk samples were subjected to two different heat treatments—the first at 65 °C for 30 min and the second at 72 °C for 15 s—and then underwent microbiological analyses. These analyses focused on the detection and enumeration of total aerobic flora, thermotolerant coliforms, *Enterobacteriaceae*, yeasts and moulds, and psychrotrophic flora, as well as the detection of *Salmonella*, coagulase-positive staphylococci, and sulphite-reducing spores. The results showed that the raw camel milk exhibited varying microbial loads depending on the flora: total aerobic flora (5.820 ± 0.152 $\log_{10}$ CFU/mL), thermotolerant coliforms (3.183 ± 1.440 $\log_{10}$ CFU/mL), *Enterobacteriaceae* (1.935 ± 1.884 $\log_{10}$ CFU/mL), yeasts and moulds (3.226 ± 0.931 $\log_{10}$ CFU/mL), and psychrotrophs (3.842 ± 1.587 $\log_{10}$ CFU/mL). Pathogens and spores were absent. Both treatments completely eliminated psychrotrophic flora. the 72 °C/15 s , treatment significantly reduced all other microbial populations, with residual loads of 3.893 ± 1.607 $\log_{10}$ CFU/mL for total aerobic flora, 0.827 ± 1.221 $\log_{10}$ CFU/mL for thermotolerant coliforms, 0.466 ± 0.977 log10 CFU/mL for *Enterobacteriaceae*, 0.154 ± 0.595 $\log_{10}$ CFU/mL for yeasts and moulds. The 65 °C/30 min treatment significantly reduced total aerobic flora, *Enterobacteriaceae*, and yeasts and moulds, with residual loads of 4.382 ± 1.222 $\log_{10}$ CFU/mL, 0.501 ± 1.047 $\log_{10}$ CFU/mL, and 0.725 ± 1.515 $\log_{10}$ CFU/mL, respectively; however, it did not significantly reduce thermotolerant coliforms (2.287 ± 1.515 $\log_{10}$ CFU/mL). Although both treatments substantially reduced the microbial load and eliminated psychrotrophic flora, residual contamination persisted for the other microbial groups. Therefore, the treatments at 65 °C for 30 min and at 72 °C for 15 s correspond to the LTLT and HTST pasteurisation parameters, respectively, but further storage studies are needed before either process can be recommended as a reference for camel milk.

Keywords: camel milk; microbial load; heat treatments; pasteurisation

1. Introduction

Camel milk occupies an essential place in the diet of populations living in arid and semi-arid areas of North Africa, the Middle East and certain regions of Asia. Considered a functional food, it is distinguished by a unique biochemical composition and recognised therapeutic virtues, in particular antidiabetic, antibacterial, antiviral and immunomodulatory effects (Gemeda & Nigussie, 2023; Abdullahi, 2019). Its richness in bioactive proteins (lactoferrin and immunoglobulins), unsaturated fatty acids, vitamins

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(especially C and B), and minerals (iron, zinc, calcium) makes it an interesting nutritional alternative, especially for people intolerant to cow's milk (Alhassani, 2024).

However, raw camel milk frequently exhibits high microbial loads due to traditional production conditions, often rudimentary milking equipment, and insufficient cooling after milking (Bekele et al., 2025). In addition, a physiological characteristic unique to the species—namely that milk let-down is triggered only in the presence of the calf, which complicates the implementation of standard hygiene protocols. Raw milk contamination can be of faecal or environmental origin, or linked to mammary infections, and involves various pathogenic or spoilage microorganisms (Doutoum et al., 2024; Lezzoum-Atek et al., 2023; Iqbal & Ashraf, 2023; Adugna & Asresie, 2014).

Consumption of raw milk without prior treatment therefore represents a risk to public health, especially when the conditions of milking and storage hygiene are insufficient (Bekele et al.,2025; Iqbal & Ashraf, 2023; Melini et al., 2017).

To ensure the microbiological safety of dairy products, heat treatment is an essential step. Pasteurisation or UHT treatment helps to reduce or eliminate pathogenic flora, while extending the shelf life of milk (Melini et al., 2017; Dhahir et al., 2021).

Two pasteurisation protocols are commonly used: the LTLT (Low Temperature Long Time) treatment at 65 °C for 30 min, and the HTST (High Temperature Short Time) treatment at 72 °C for 15 s. While these protocols have been widely validated for cow's milk, their effectiveness on camel milk—which differs significantly in composition and physicochemical properties—requires specific evaluation, as excessive treatment can alter its nutritional and functional qualities (Mohamed et al., 2022; Konuspayeva & Faye, 2021).

Although several studies have examined the effect of pasteurisation on camel milk, most only report the total aerobic flora or a limited number of microbial groups (Aladhadh & Abdallah, 2025; Dhahir et al., 2021; Eissa & Hamid, 2017). Few studies detail the effect of thermal treatments on targeted microbial groups, particularly thermotolerant coliforms, *Enterobacteriaceae*, yeasts and moulds, and psychrotrophic flora, as well as pathogenic bacteria, even though these groups are key indicators of hygiene, safety, and shelf life. Furthermore, very few studies have been dedicated to camel milk from the Bechar region (southwest Algeria), where the breeding, milking, and storage conditions are specific (Bekki, 2023) and where microbiological data on raw and processed milk remain limited. In particular, the levels of residual contamination by group after these two treatments are not documented.

Thus, the present study aimed to evaluate and compare the effectiveness of LTLT (65 °C/30 min) and HTST (72 °C/15 s) pasteurisation on the reduction of the microbial load of raw camel milk collected in the Bechar region (Algeria), specifically detailing the targeted microbial groups (total aerobic flora, thermotolerant coliforms, *Enterobacteriaceae*, yeasts and moulds, psychrotrophic flora, as well as the detection of *Salmonella*, coagulase-positive staphylococci, and sulphite-reducing clostridia), with particular attention to the residual load by group.

2. Materials and Methods

2.1. Sampling

The raw camel milk samples used in this study were collected from three sites in Bechar region (southwestern Algeria), each comprising 15 lactating camels of the Sahrawi breed. These animals are raised in a semi-extensive system typical of the Bechar region (southwestern Algeria), and are mainly fed on local natural pasture, predominantly composed of *Acacia raddiana* leaves, a dominant plant species in arid areas. At each site, the milk of 3 camels was pooled, giving 5 pooled samples per site and 15 independent pooled samples in total (n = 15). From each pool, 5 samples were taken. The milk was collected manually, early in the morning, under rigorous hygiene conditions, using sterile containers.

After collection, the samples were immediately placed in isothermal coolers at 4 °C, then transported to the laboratory for microbiological analyses within a maximum period of 6 h in order to preserve their initial quality.

2.2. Applied Thermal Treatments

In order to assess the impact of heat treatment on microbiological properties of camel milk, the samples were subjected to three experimental groups: two heat treatment and one control. Each treatment has been applied to a volume of 100 mL of milk, previously homogenised, using a controlled thermostatic water bath:

T0 (control): Unheated raw milk, kept at 4 °C.
T1: Low temperature pasteurisation at 65 °C for 30 min.
T2: High-temperature pasteurisation at 72 °C for 15 s.

After each treatment, the samples were quickly cooled to 4 °C to avoid any thermal degradation

2.3. Microbiological Analyses

Microbiological analyses focused on the following criteria:

- Total aerobic bacterial count
- Enumeration of psychrotrophic bacterial flora
- Enumeration of thermotolerant coliforms
- Enumeration of Enterobacteriaceae
- Enumeration of yeasts and moulds
- Enumeration of coagulase-positive staphylococci
- Enumeration of sulphite-reducing clostridia
- Detection and enumeration of *Salmonella* spp.

2.3.1. Preparation of Samples

Before seeding the bacteria onto agar plates, decimal dilutions were prepared for each sample according to the Algerian standard (IANOR, 2021c).

2.3.2. Total Aerobic Bacterial Count

The total aerobic bacterial count was conducted in accordance with the Algerian standard (IANOR, 2023). Appropriate serial dilutions were plated in duplicate on plate count agar (PCA) agar supplemented with skim milk, followed by incubation at 30 °C for 72 h.

2.3.3. Psychrotrophic Bacterial Flora

The psychrotrophic bacterial flora count was conducted in accordance with the Algerian standard (IANOR, 2021b). Appropriate serial dilutions were plated in duplicate on plate count agar (PCA) agar supplemented with skim milk, followed by incubation at 6.5 °C for 10 days.

2.3.4. Thermotolerant Coliforms

The enumeration of thermotolerant coliforms was performed according to the Algerian standard (IANOR, 2022b) employing violet red bile lactose agar (VRBL) as the selective medium and incubating the plates at 44 °C for a duration of 24 h. Typical colonies were counted as thermotolerant coliforms.

2.3.5. *Enterobacteriaceae*

The enumeration of *Enterobacteriaceae* was conducted in accordance with the Algerian standard (IANOR, 2019) employing violet red bile glucose (VRBG) agar as the selective medium and incubating the plates at 37 °C for a duration of 24 h. The typical colonies underwent a biochemical confirmation test, in which the oxidase-negative and glucose-positive colonies were confirmed as *Enterobacteriaceae.*

2.3.6. Yeasts and Moulds

Dichloran rose bengal chloramphenicol (DRBC) agar was employed to conduct yeast and mould counts in accordance with the Algerian standard (IANOR, 2010). The cultures were incubated at 25 °C for a period of five to seven days.

2.3.7. Coagulase-Positive Staphylococci

The enumeration of coagulase-positive staphylococci was carried out according to the Algerian standard (IANOR, 2022a), using Baird- Parker agar supplemented with potassium tellurite, bovine fibrinogen, rabbit plasma and trypsin inhibitor. Plates were incubated at 37 °C for 24 to 36 h.

2.3.8. Sulphite-Reducing Clostridia

Using tryptone-sulphite-cycloserine (TSC) agar, the sulphite-reducing clostridia were counted in accordance with the AFNOR standard (AFNOR, 2009). An aliquot of milk was placed in a sterile tube, heated for 10 min at 80 °C to kill vegetative cells and activate bacterial spores, and then rapidly cooled in an ice bath. One milliliter of each prepared dilution was aseptically transferred into sterile screw-cap tubes. After adding molten TSC agar, the cultures were incubated anaerobically at 46 °C for 24 ± 2 h. Only colonies encircled by a black halo, which is indicative of sulphite reduction, were included in the final count.

2.3.9. *Salmonella* spp.

The detection and enumeration of *Salmonella* spp. were carried out in accordance with the Algerian standard (IANOR, 2021a), following a method consisting of four successive and complementary steps. The procedure commences with a pre-enrichment phase, wherein 25 mL of milk was inoculated into buffered peptone water and subsequently incubated at 37 °C for 16 to 20 h to facilitate the recovery of damaged cells. Next, the selective enrichment phase is carried out by transferring a portion of the obtained culture into two media: Rappaport–Vassiliadis broth, incubated at 41.5 °C, and Muller–Kauffmann broth with tetrathionate–novobiocin, incubated at 37 °C, each for 24 h. At the end of the enrichment, an isolation step was performed by inoculating the media on XLD agar and brilliant green agar, followed by incubation at 37 °C for 24 h to allow the appearance of characteristic colonies. Finally, a confirmation step was carried out using specific biochemical and serological tests to reliably identify suspected *Salmonella* colonies.

2.4. Statistical Analysis

The obtained data were expressed as $\log_{10}$ CFU/mL and analysed using R software (R.4.4.3). A repeated-measures ANOVA followed by Tukey's HSD test was used to evaluate the significant differences between treatments. Each pooled sample (n = 15) was considered an independent biological replicate. For each treatment, five technical replicates were performed per pooled sample, and the mean of these replicates was used for statistical analysis. The experimental unit was therefore the pooled sample (n = 15). The statistical unit was the pooled sample (n = 15), the significance level was set at $p < 0.05$

3. Results and Discussion

Table 1 presents the microbial loads (mean ± standard deviation, $\log_{10}$ CFU/mL) of raw camel milk and milk treated at 65 °C/30 min (LTLT) and 72 °C/15 s (HTST), as well as the exact *p* values from ANOVA. Both treatments significantly reduced the load of total aerobic flora, thermotolerant coliforms, *Enterobacteriaceae*, and yeasts/moulds ($p < 0.05$), and completely eliminated the psychrotrophic flora. No significant difference was observed between LTLT and HTST for most parameters ($p > 0.05$). For thermotolerant coliforms, Tukey's HSD test showed a significant difference between the milk treated at 72 °C/15 s and the other two groups: the logarithmic load was significantly lower after treatment at 72 °C/15 s than in the raw milk and after treatment at 65 °C/30 min. In contrast, the difference between raw milk and milk treated at 65 °C/30 min was not statistically significant ($p = 0.1221$).

The initial load of total aerobic flora in raw milk (5.820 ± 0.152 $\log_{10}$ CFU/mL) falls within the range reported by Abou-Soliman et al. (2025) (5.46 ± 0.15 $\log_{10}$ CFU/mL) and is lower than those described by Mohamed and El Zubeir (2014) (3.02×10^{10} CFU/mL) and Chethouna et al. (2022) (9.5×10^{6} CFU/mL), but higher than that reported by Ahmed et al. (2022) (3.92 $\log_{10}$ CFU/mL). This variability reflects the decisive influence of breeding conditions, milking practices, and the delay before refrigeration on the initial microbiological quality of camel milk (Adugna & Asresie, 2014; Odongo et al., 2016; Leone et al., 2022).

After treatment, the total aerobic flora was reduced to 4.38 ± 1.22 $\log_{10}$ CFU/mL (LTLT) and 3.89 ± 1.61 $\log_{10}$ CFU/mL (HTST), representing reductions of approximately 1.44 and 1.93 log, respectively. These reductions are lower than those reported by Chethouna et al. (2022), who obtained residual loads of 3.6×10^{5} CFU/mL at 65 °C and 3.7×10^{3} CFU/mL at 72 °C (corresponding to reductions of approximately 1.42 log and 3.4 1log respectively), and by Abou-Soliman et al. (2025), who reached 2.90 ± 0.05 $\log_{10}$ CFU/mL at 63 °C and 2.00 ± 0.00 $\log_{10}$ CFU/mL at 72 °C / 15 s. This lower efficiency could be partly explained by a less homogeneous temperature rise in the water bath (Albattah Alhusni & Krishnan, 2025) or by a higher prevalence of thermoresistant microorganisms in our context (Taher et al., 2022) possibly linked to traditional practices of milking she-camels, where the presence of the calf is necessary for the milk let-down. However, neither the uniformity of the temperature within the milk nor the thermoresistance of the

residual isolates was evaluated in the present study, and these hypotheses therefore remain speculative. The residual persistence of the total aerobic flora (3.89–4.38 $\log_{10}$ CFU/mL) further suggests possible post-treatment contamination during cooling, transfer, or manipulation of samples (Martin et al., 2018).

Table 1. Microbiological analysis of raw camel milk and heated camel milk.

		Raw Camel Milk (n = 15)	Heated Camel Milk 65 °C/30 min (n = 15)	Heat Camel Milk at 72 °C/15 s (n = 15)	*p* Value (Anova Test)	Significance
Total aerobic bacterial	Mean ±SD CI 95%	5.820 ± 0.152 [a] [5,736; 5.904]	4.382 ± 1.222 [b] [3.705; 5.058]	3.893 ± 1.607 [b] [3.003; 4.783]	0.000274	***
Psychrotrophic bacterial flora	Mean ±SD CI 95%	3.842 ± 1.587 [2.963; 4.720]	- -	- -	-	-
Thermotolerant coliform	Mean ±SD CI 95%	3.183 ± 1.440 [a] [2.385; 3.980]	2.287 ± 1.515 [a] [1.448; 3.126]	0.827 ± 1.221 [b] [0.151; 1.503]	0.0000446	***
Enterobacteriaceae	Mean ±SD CI 95%	1.935 ± 1.884 [a] [0.891; 2.979]	0.501 ± 1.047 [b] [0; 1.080]	0.466 ± 0.977 [b] [0; 1.007]	0.00673	**
Moulds and yeast	Mean ± SD CI 95%	3.226 ± 0.931 [a] [2.711; 3.742]	0.725 ± 1.515 [b] [0; 1.564]	0.154 ± 0.595 [b] [0 ; 0.483]	1.55×10^{-9}	***
Coagulase-positive staphylococci	Mean ± SD	-	-	-	-	-
Salmonella	Mean ± SD	-	-	-	-	-
Sulphite-reducing clostridia	Mean ± SD	-	-	-	-	-

Values are expressed as $\log_{10}$ CFU/mL. [a], [b], [c]: Means with different superscript letters are significantly different according to Tukey's test at $p < 0.05$. Means sharing the same letter are not significantly different according to Tukey's test at $p < 0.05$; CI: confidence interval. ***: $p < 0.001$—highly highly significant difference; **: $p < 0.01$—highly significant difference

The psychrotrophic flora was only detected in raw milk (3.84 ± 1.59 $\log_{10}$ CFU/mL), with an intermediate value compared to the literature: Mohamed and El Zubeir (2014) reported a significantly higher load (1.7×10^8 CFU/mL), while Chethouna et al. (2022) described a much lower value (5.1×10^3 CFU/mL). This variability highlights the considerable impact of production conditions and milking hygiene on the development of psychrotrophic microorganisms, which proliferate during prolonged refrigerated storage. After treatment, no psychrotrophic flora was detected, whether at 65 °C/30 min or at 72 °C/15 s. This complete elimination contrasts with the observations of Mohamed and El Zubeir (2014), who reported residual loads of 6.7×10^5 CFU/mL at 65 °C and 7.7×10^5 CFU/mL at 72 °C, and with those of Chethouna et al. (2022), who reached 7.5×10^1 CFU/mL at 65 °C and 2.0×10^1 CFU/mL at 72 °C without complete elimination. The superior elimination observed in our study could be explained by a moderate initial load, combined with sufficient thermal efficiency to destroy psychrotrophs, generally considered thermosensitive. This complete absence constitutes a favourable result, ensuring better stability of the final product during refrigerated storage and reducing the risks of post-pasteurisation enzymatic alteration.

Thermotolerant coliforms and *Enterobacteriaceae* share the same hygienic significance (faecal and environmental contamination) and the same thermal behaviour (heat sensitivity). Their persistence after pasteurisation therefore constitutes a major warning signal.

The initial load of thermotolerant coliforms was 3.18 ± 1.44 $\log_{10}$ CFU/mL, an intermediate value compared to the literature: Chethouna et al. (2022) reported a significantly higher contamination (3.6×10^5 CFU/mL), Mohamed and El Zubeir (2014) a massive load (1.1×10^7 CFU/mL), while Elhasan et al. (2022) described a much lower contamination (2.11×10^3 MPN/L) and Doutoum et al. (2024) observed no presence of thermotolerant coliforms. More recently, Bekele et al. (2025) recorded a higher load (5.22 ± 0.02 $\log_{10}$ CFU/mL). This contamination may be linked to the often traditional milking conditions in arid areas, the quality of the water, or the environment (sand, dust) (Abdulsalam & Alghamdi, 2024; Omer & Ateye, 2022).

After treatment, the load decreased to 2.29 ± 1.52 $\log_{10}$ CFU/mL (LTLT) and 0.83 ± 1.22 $\log_{10}$ CFU/mL (HTST), representing reductions of approximately 0.9 and 2.4 log, respectively. The transformed microbial load was significantly lower after treatment at 72 °C/15 s compared to the raw milk and after treatment at 65 °C/30 min.

These results suggest that treatment at 72 °C/15 s leads to the most significant microbial reduction among the three conditions studied, but insufficient to eliminate these microorganisms completely. This persistence may be influenced by an initially high microbial load and a possible lack of temperature uniformity within the milk during heating in the laboratory water bath.

In comparison, Mohamed and El Zubeir (2014) reported much higher residual loads (4.2×10^5 CFU/mL and 1.3×10^4 CFU/mL), while Chethouna et al. (2022) achieved a reduction to 3.5×10^1 CFU/mL after treatment at 65 °C/ 30 min and complete elimination (0 CFU/mL) after pasteurisation at 72 °C/15 s; similarly, Elhasan et al. (2022) reported a complete absence of thermotolerant coliforms after treatment at 68 °C and 72 °C, demonstrating that a well-controlled pasteurisation schedule can lead to their complete absence.

The *Enterobacteriaceae* load in raw milk was 1.94 ± 1.88 $\log_{10}$ CFU/mL, an intermediate value compared to the literature data: Chethouna et al. (2022) reported a higher load (5.3×10^4 CFU/mL), Bekele et al. (2025) a load of 4.30 ± 0.03 $\log_{10}$ CFU/mL, while Aladhadh and Abdallah (2025) described a complete absence of *Enterobacteriaceae* contamination in their raw camel milk samples. This considerable disparity highlights the extreme variability in the microbiological quality of camel milk, which is closely dependent on milking hygiene conditions, the breeding environment, and local practices, with the mandatory presence of the camel calf during milking constituting a particular risk factor for faecal contamination. Pasteurisation at 65 °C reduced the load to 0.50 ± 1.05 $\log_{10}$ CFU/mL, while treatment at 72 °C lowered it to 0.47 ± 0.98 $\log_{10}$ CFU/mL, representing reductions of approximately 1.4 and 1.5 log, respectively. Although the results show a trend toward a reduction in bacterial load after thermal treatments, Turkey's test revealed no significant difference between the two treatments ($p > 0.05$). Chethouna et al. (2022) achieved complete elimination (0 CFU/mL) as early as the treatment at 65 °C, with a total absence also at 72 °C, demonstrating that well-conducted pasteurisation effectively eradicates this microbial family. Robinson (1990) and Joklik et al. (1992) emphasised that no bacteria from this family truly resist heat, which explains why they are all easily eliminated from milk by pasteurisation or comparable thermal treatments.

The residual persistence of *Enterobacteriaceae* (0.47–0.50 $\log_{10}$ CFU/mL, or approximately 3 CFU/mL) and thermotolerant coliforms (0.83 $\log_{10}$ CFU/mL, or approximately 7 CFU/mL at 72 °C) after treatment is concerning, as effective pasteurization should theoretically eliminate these thermosensitive microorganisms (expected load of 0 or <1 CFU/mL). Their presence indicates either post-pasteurisation contamination during cooling, transfer, or handling of the samples, or uneven heating in the laboratory water bath, with areas not reaching the target temperature for the required duration. This residual contamination has direct consequences for product quality, as it impairs the organoleptic properties of milk and drastically reduces its shelf life, sometimes to less than 7 days instead of the expected 10 to 14 days (Martin et al., 2018); moreover according to Sissoko et al. (2023), the reappearance of these bacteria does not result from resistance to pasteurisation, but from contaminations occurring after the heating stage. Mainly from packaging lines, poorly cleaned valves, the factory environment, and inadequate personnel hygiene. These observations highlight the need to control the temperature at the core of the product, ensure rapid cooling and rigorous hygiene after treatment, and validate the thermal schedule through controlled trials.

The load of yeasts and moulds in raw milk was 3.23 ± 0.93 $\log_{10}$ CFU/mL, an intermediate value compared to the contrasting data in the literature: Abou-Soliman et al. (2025) reported an average load of 2.69 ± 0.09 $\log_{10}$ CFU/mL and Bekele et al. (2025) of 3.86 ± 0.21 $\log_{10}$ CFU/mL, both within the range observed in our study; Ahmed et al. (2022) reported a complete absence of yeast and mould contamination, suggesting that impeccable microbiological quality is achievable under rigorous production conditions; El-Ziney and Al-Turki (2007) detected yeast and mould in 19 of the 33 samples, with average and maximum values of 1.9 and 5.65 $\log_{10}$ CFU/mL (approximately 8×10^1 to 4.5×10^5 CFU/mL), indicating frequent and highly variable contamination in the context of traditional camel milk production.

Tukey's HSD test showed that the load of raw milk was significantly higher than that of the two thermal treatments ($p < 0.001$), while no significant difference was observed between LTLT and HTST ($p = 1.000$). These results indicate that both treatments led to a substantial reduction in yeast and mould load. In comparison, Mohamed and El Zubeir (2014) obtained residual loads of 1.1×10^4 CFU/mL after LTLT and 1.3×10^4 CFU/mL after HTST, values higher than those observed in our study, suggesting a better efficiency of our treatments or a lower initial load. More recently, Abou-Soliman et al. (2025) reported residual loads of less than 1 $\log_{10}$ CFU/mL, indicating particularly high thermal efficiency; however, neither our study nor that of Mohamed and El Zubeir (2014) achieved complete elimination. The residual persistence of yeasts and moulds after pasteurisation (0.154 ± 0.595 at 72 °C/15 s) remains concerning for the stability of the final product, as these microorganisms can multiply during refrigerated storage and cause alterations (fermentations, gas production, odour and taste defects) (Asadi et al., 2026). This persistence is explained by the relative thermoresistance of certain fungal species, particularly sporulating moulds (Rico-Munoz et al., 2015).

The microbiological analysis revealed no contamination by sulphite-reducing spores, *Salmonella*, or coagulase-positive staphylococci, either in raw milk or in thermally treated samples.

These results are particularly favourable and indicate a satisfactory hygienic quality of the studied camel milk, at least concerning these pathogenic or risk indicator microorganisms. In comparison with the literature, our results partially align with those of Ahmed et al. (2022), who did not detect *Clostridium* in their camel milk samples, suggesting that contamination by sulphite-reducing anaerobic spores is not systematic and strongly depends on hygiene conditions and the production environment. Similarly, Doutoum et al. (2024) and Omer and Eltinay (2008) did not detect *Salmonella* in their samples, which aligns with our observations. However, these authors reported the absence of *Clostridium perfringens* but highlighted the presence of *Staphylococcus aureus* in their samples, emphasising that staphylococcal contamination is a recurring problem in the camel milk sector, unlike our results which show a complete absence of this microorganism. Indeed, Abou-Soliman et al. (2025) and El-Ziney and Al-Turki (2007) reported a mean contamination by *Staphylococcus aureus* of 4.90 $\log_{10}$ CFU/mL and 2.74 $\log_{10}$ CFU/mL, respectively, while Benkerroum et al. (2003) observed that all of their samples were positive for this microorganism, with a high mean of 5.1 log CFU/mL, indicating a very significant prevalence in certain regions and production conditions. Abdulsalam & Alghamdi (2024) and Serda et al. (2018) reported a mean of 4.7×10^2 CFU/mL and 4.2×10^4 CFU/mL respectively, for the samples positive for *Staphylococcus aureus*, confirming the persistence of this pathogen in raw camel milk. The variable prevalence of *Staphylococcus aureus* can be explained by its possible transmission from the udder (subclinical mastitis) or by external contamination during milking, risk factors that are particularly significant in camels due to traditional milking conditions (El Kindoussy et al., 2026) and the presence of the camel calf. Regarding *Salmonella*, our results of total absence are in agreement with Doutoum et al. (2024) and Abdulsalam & Alghamdi (2024), but contrast with those of Zarei Yam et al. (2014), who detected *Salmonella* in 8 camel milk samples, demonstrating that this pathogen can occasionally contaminate raw milk depending on local sanitary conditions. The absence of these microorganisms after treatment confirms the effectiveness of the pasteurisation standards used, provided that the temperature was uniformly reached at the core of the product.

Across all the analysed microbiological parameters, both the 65 °C/30 min and the 72 °C/15 s treatments effectively reduced the microbial load of camel milk. Both protocols were equally effective in achieving complete elimination of psychrotrophs and preserving the absence of the targeted pathogens.

The complete elimination of psychrotrophs by both treatments is particularly interesting in the context of camel milk preservation. Indeed, Rukke et al. (2016) reported that thermised and rapidly cooled milk can be stored in the refrigerator for an additional three days, given that thermisation significantly reduces thermolabile psychrotrophic bacteria responsible for low-temperature spoilage (spoilage without acidification). These microorganisms produce proteases, lipases, and thermostable phospholipases at low temperatures, which degrade the quality of the milk during prolonged storage. The objective of thermisation is precisely to reduce the population of *Pseudomonas fluorescens*, the main spoilage psychrotrophic bacterium, while inhibiting the development of *Salmonella spp*. and *Listeria monocytogenes*. (Nefasa et al., 2023). Our results show that pasteurisation, whether carried out at 65 °C /30 min or at 72 °C/15 s, allows for the complete elimination of these psychrotrophs, thus ensuring better stability of the final product during refrigerated storage.

Two main hypotheses can be put forward to explain this. The first is a possible lack of temperature uniformity within the milk during laboratory water bath heating: in a static water bath, temperature gradients can develop between the wall of the container and the centre of the milk volume, so that some portions of the milk may not reach the target temperature for the entire duration of the holding period (Albattah Alhusni & Krishnan, 2025; Wu et al., 2024; Lopez-Fandiño et al., 1996). The second is post-pasteurisation contamination, occurring during cooling, transfer, or handling of samples, or due to an insufficiently sterile work environment; such contamination would reintroduce thermosensitive microorganisms into an already treated product, which would also explain the residual presence of several microbial groups. These two hypotheses are consistent with the survival of several thermosensitive groups in our study

4. Conclusions

This study evaluated the effect of two different heat treatments on the microbial load of raw camel milk. The results showed that the raw milk exhibited varying levels of contamination but was free of *Salmonella*, sulphite-reducing spores, and coagulase-positive staphylococci

Both treatments were microbiologically effective to differents extent: the the 72 °C/15 s treatment significantly reduced all microbial groups tested ($p < 0.05$), whereas the 65 °C/30 min treatment

significantly reduced total aerobic flora, *Enterobacteriaceae*, and yeasts/moulds ($p < 0.05$) but did not significantly reduce thermotolerant coliforms ($p = 0.1221$). Both treatments completely eliminated psychrotrophic bacteria. However, residual contamination by *Enterobacteriaceae*, thermotolerant coliforms, and yeasts/moulds persisted after both treatments, indicating that pasteurisation was not fully effective under the tested conditions and highlighting the need for stricter control of thermal treatment and post-treatment hygiene. Neither of the two treatments can therefore be recommended as a "reference process" without further validation.

Several aspects have not been addressed in the present study and require further investigation: the effects of the two treatments on the nutritional and functional quality of the milk, the effect on thermoresistant enzymes and spores, and the shelf life after pasteurisation under refrigerated storage conditions, which is the subject of a separate investigation.

This research will clarify whether the two treatments constitute an appropriate technological alternative for the preservation of camel milk, beyond their demonstrated microbiological effectiveness.

Author Contributions

N.S.: Conceptualisation, Methodology, Investigation, Data Curation, Writing—Review & Editing. N.A.: Formal Analysis, Data Curation. Z.H.: Supervision, Resources. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

Ethical review and approval were waived for this study, due to the fact that the study involved only the collection of milk during routine, natural milking in the presence of the calf, without any invasive procedure, pharmacological treatment, or additional stress to the animals. The sampling procedures were reviewed and validated by Laboratory for the Valorization of Biological Resources and Food Safety, University of Bechar. The study was conducted in accordance with standard animal welfare practices and the principles of the 3Rs (Replacement, Reduction, and Refinement).

Informed Consent Statement

Not applicable.

Data Availability Statement

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author

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Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

No AI tools were utilized for this paper.

References

Abdullahi, A. (2019). Camel Milk—A Review. *Journal of Animal Sciences and Livestock Production*, *3*(1), 13–18. https://doi.org/10.36648/2577-0594.3.2.5.

Abdulsalam, N. M., & Alghamdi, E. M. (2024). 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. *Saudi Medical Journal*, *45*(9), 882–890. https://doi.org/10.15537/smj.2024.45.9.20240387.

Abou-Soliman, N. H. I., Abd-Rabou, H. S., Awad, S., & Ibrahim, A. A. (2025). Impact of thermal treatment on the quality, total antioxidant and antibacterial properties of fermented camel milk. *Scientific Reports*, *15*(1), 8533. https://doi.org/10.1038/s41598-025-91548-1.

Adugna, M., & Asresie, A. (2014). Physicochemical and microbiological quality of one humped camel (*Camelus dromedarius*) milk: A Review. *Journal of Biology Agriculture and Healthcare*, *4*(23), 119–124.

Ahmed, H. A., Abd El-Rahim, A. M., Mohran, M. A., Mahmoud, N. E. H. H., & Hassan, E. A. (2022). Chemical Composition and Microbiological Quality of Camel Milk. *Assiut Journal of Agricultural Sciences*, *53*(4), 1–11. https://doi.org/10.21608/ajas.2022.127560.1116.

Aladhadh, M., & Abdallah, E. M. (2025). Comparative Analysis of Microbial Growth in Raw and Pasteurized Cow and Camel Milk During Chilled Storage. *Journal of Pure and Applied Microbiology*, *19*(1), 323–332. https://doi.org/10.22207/jpam.19.1.23.

Albattah Alhusni, H., & Krishnan, S. (2025). Time-Dependent Heat Transfer Coefficients of Standard Cans during Pasteurization. *ACS Omega*, *10*(37), 43252–43263. https://doi.org/10.1021/acsomega.5c07256.

Alhassani, W. E. (2024). Camel milk: Nutritional composition, therapeutic properties, and benefits for human health. *Open Veterinary Journal*, *14*(12), 3164–3180. https://doi.org/10.5455/ovj.2024.v14.i12.2.

Asadi, A., Sarand, I., Spuul, P., Fanning, S., & Macori, G. (2026). Mapping spoilage microbiota in complex food systems: Organisms, mechanisms, and omics-based characterization. *Food Research International*, *242*, 119633. https://doi.org/10.1016/j.foodres.2026.119633.

Association Française de Normalisation (AFNOR). (2009). Microbiologie des aliments—Dénombrement en anaérobiose des bactéries sulfito-réductrices par comptage des colonies à 46 °C [Microbiology of food and animal feeding stuffs—*Anaerobic enumeration* of sulfito-reducing bacteria by colony count technique at 46 °C] (*NF V08-061*). https://www.boutique.afnor.org/en-gb/standard/nf-v08061/microbiology-of-food-and-animal-feeding-stuffs-anaerobic-enumeration-of-sul/fa160464/34336.

Bekele, B., Eshetu, M., Wolkero, T., Berhe, T., Galmessa, U., & Gadissa, S. (2025). Hygienic Practices and Determination of Microbial Quality and Safety of Raw Camel Milk in Borana Zone, Southern Ethiopia. *Journal of Food Quality*, *2025*(1), 2486717. https://doi.org/10.1155/jfq/2486717.

Bekki, M. Y. (2023). *Etude rétrospective sur l'élevage camelin au niveau de la wilaya de Béchar* [Retrospective study on camel breeding in the wilaya of Béchar] [Doctoral Dissertation, The University of Blida 1].

Benkerroum, N., Boughdadi, A., Bennani, N., & Hidane, K. (2003). Microbiological quality assessment of Moroccan camel's milk and identification of predominating lactic acid bacteria. *World Journal of Microbiology and Biotechnology*, *19*(6), 645–648. https://doi.org/10.1023/a:1025114601811.

Chethouna, F., Haroun Boudjenah, S., Beld, N., & Siboukeur, O. (2022). Comparative study of the physico-chemical and microbiological characteristics of raw and pasteurized camel milk. *Emirates Journal of Food and Agriculture*, *34*(10), 850–858. https://doi.org/10.9755/ejfa.2022.v34.i10.2942.

Dhahir, N., Feugang, J., Witrick, K., Shamimul, H., & AbuGhazaleh, A. (2021). Camel Milk Composition and Microbial Reduction with Different Pasteurization Methods. *American Journal of Food Science and Technology*, *9*(4), 134–141. https://doi.org/10.12691/ajfst-9-4-4.

Doutoum, A. A., Allamine, H. M., Nazal, A. M., Sakhaïroun, A., & Mahamadou, C. (2024). Microbiological Quality of Raw Camel Milk Consumed in the Zinder Region (Niger). *International Journal of Microbiology and Biotechnology*, *9*(4), 112–118. https://doi.org/10.11648/j.ijmb.20240904.13.

Eissa, O. E. H., & Hamid, O. I. A. (2017). Quality characteristics of camel milk during different heat treatments. *Journal of Agriculture and Veterinary Sciences*, *10*, 1–5. https://www.iosrjournals.org/iosr-javs/papers/Vol10-issue8/Version-3/A1008030105.pdf.

El Kindoussy, F., Boukria, O., & de Souza, P. M. (2026). Camel milk microbiota: Safety risks, natural antimicrobial defenses, and detection strategies. *International Dairy Journal*, *174*, 106501. https://doi.org/10.1016/j.idairyj.2025.106501.

Elhasan, S. M., Bushara, A. M., Abdelhakam, K. E., Farahat, F. H., Ezzeldein, M., ElKhir, N. M., & Mohamed, A. A. (2022). Effect of heat treatment on the bacterial load and sensory attributes of different types of milk. *Journal of the Saudi Society for Food and Nutrition (JSSFN)*, *15*, 79–86.

El-Ziney, M. G., & Al-Turki, A. I. (2007). Microbiological quality and safety assessment of camel milk (*Camelus dromedaries*) in Saudi Arabia (*Qassim region*). *Applied Ecology and Environmental Research*, *5*(2), 115–122. https://doi.org/10.15666/aeer/0502_115122.

Gemeda, F., & Nigussie, Z. (2023). Review on Composition, Nutritional and Medicinal Value of Camel. *Journal of Covid Research and Treatment*, *2*(1). https://doi.org/10.58489/2836-3604/008.

Institut Algérien de Normalisation (IANOR). (2019). Microbiologie de la chaîne alimentaire—Méthode horizontale pour la recherche et le dénombrement des *Enterobacteriaceae* Partie 2: Technique par comptage des colonies [Microbiology of the food chain—Horizontal method for the detection and enumeration *of Enterobacteriaceae*—Part2:Colony-counttechnique] *(NA 19164-2019)*. https://www.ianor.dz/wp-content/uploads/2024/02/CTN-43-Hygiene-alimentaire.pdf#1#4#1.

Institut Algérien de Normalisation (IANOR). (2010). Microbiologie des aliments—Méthode horizontale pour le dénombrement des levures et moisissures—Partie 1: Technique par comptage des colonies dans les produits à activité d'eau supérieure à 0, 95 [Microbiology of food and animal feeding stuffs — Horizontal method for the enumeration of yeasts and moulds—Part 1: Colony count technique in products with water activity greater than 0,95] (*NA 1210-2010*). https://www.ianor.dz/wp-content/uploads/2024/02/CTN-43-Hygiene-alimentaire.pdf#1#4#1.

Institut Algérien de Normalisation (IANOR). (2021a). Microbiologie de la chaîne alimentaire—Méthode horizontale pour la recherche, le dénombrement et le sérotypage des Salmonella—Partie 1: Recherche des *Salmonella* spp. Amendement 1: Extension de la plage de températures pour l'incubation, amendement du statut de l'Annexe D et correction de la composition des milieux MSRV et SC [Microbiology of the food chain—Horizontal method for the detection, enumeration and serotyping of Salmonella—Part 1: Detection of *Salmonella* spp.—Amendment 1: Broader range of incubation temperatures, amendment to the status of Annex D, and correction of the composition of MSRV and SC] (*NA 1203-2021*). https://www.ianor.dz/wp-content/uploads/2024/02/CTN-43-Hygiene-alimentaire.pdf#1#4#1.

Institut Algérien de Normalisation (IANOR). (2021b). Microbiologie de la chaîne alimentaire—Méthode horizontale pour le dénombrement des microorganismes psychrotrophes [Microbiology of the food chain—Horizontal method for the enumeration of psychrotrophic microorganisms] (*NA 15168-2021*). https://www.ianor.dz/wp-content/uploads/2024/02/CTN-43-Hygiene-alimentaire.pdf#1#4#1.

Institut Algérien de Normalisation (IANOR). (2021c). Microbiologie de la chaîne alimentaire—Préparation des échantillons, de la suspension mère et des dilutions décimales en vue de l'examen microbiologique—Partie 5: Règles spécifiques pour la préparation du lait et des produits laitiers [Microbiology of the food chain—Preparation of test samples, initial suspension and decimal dilutions for microbiological examination—Part 5: Specific rules for the preparation of milk and milk products] (*NA 15514-2021*). https://www.ianor.dz/wp-content/uploads/2024/02/CTN-43-Hygiene-alimentaire.pdf#1#4#1.

Institut Algérien de Normalisation (IANOR). (2022a). Microbiologie de la chaîne alimentaire—Méthode horizontale pour le dénombrement des staphylocoques à coagulase positive (*Staphylococcus aureus* et autres espèces)—Partie 1: Méthode utilisant le milieu gélosé de Baird-Parker [Microbiology of the food chain—Horizontal method for the enumeration of coagulase-positive staphylococci (*Staphylococcus aureus* and other species)—Part 1: Method using Baird-Parker agar medium] (*NA 15164-2022*). https://www.ianor.dz/wp-content/uploads/2024/02/CTN-43-Hygiene-alimentaire.pdf#1#4#1.

Institut Algérien de Normalisation (IANOR). (2022b). Microbiologie des aliments—Dénombrement des coliformes thermotolérants par comptage des colonies obtenues à 44 °C [Microbiology of food and animal feeding stuffs—Enumeration of thermotolerant coliforms by colony-count technique at 44 °C] (*NA 19184-2022*). https://www.ianor.dz/wp-content/uploads/2024/02/CTN-43-Hygiene-alimentaire.pdf#1#4#1.

Institut Algérien de Normalisation (IANOR). (2023). Microbiologie de la chaîne alimentaire—Méthode horizontale pour le dénombrement des microorganismes—Partie 2: Comptage des colonies à 30 °C par la technique d'ensemencement en surface—Amendement 1: Clarification du domaine d'application [Microbiology of the food chain—Horizontal method for the enumeration of microorganisms—Part 2: Colony count at 30 °C by the surface plating technique—Amendment 1: Clarification of the scope] (*NA 15530-2023*). https://www.ianor.dz/wp-content/uploads/2024/02/CTN-43-Hygiene-alimentaire.pdf#1#4#1.

Iqbal, M. N., & Ashraf, A. (2023). Microbial Contamination of Raw Camel Milk and Potential Public Health Hazards Related to its Consumption. *PSM Microbiology*, *8*(2), 53–55. https://psmjournals.org/index.php/microbiol/article/view/734.

Joklik, W., Willett, H., Amos, D., & Wilfert, C. (1992). *Zinsser microbiology*. Appleton and Lange.

Konuspayeva, G., & Faye, B. (2021). Recent Advances in Camel Milk Processing. *Animals*, *11*(4), 1045. https://doi.org/10.3390/ani11041045.

Leone, C., Thippareddi, H., Ndiaye, C., Niang, I., Diallo, Y., & Singh, M. (2022). Safety and Quality of Milk and Milk Products in Senegal—A Review. *Foods*, *11*(21), 3479. https://doi.org/10.3390/foods11213479.

Lezzoum-Atek, S., Belhout, C., Bouchenafa, H., & Bouayad, L. (2023). Assessment of Contamination of Raw Camel Milk by *Listeria* spp. and *Staphylococcus* spp. *Biology and Life Sciences Forum*, *22*(1), 9. https://doi.org/10.3390/blsf2023022009.

Lopez-Fandiño, R., Villamiel, M., Corzo, N., & Olano, A. (1996). Assessment of the Thermal Treatment of Milk during Continuous Microwave and Conventional Heating. *Journal of Food Protection*, *59*(8), 889–892. https://doi.org/10.4315/0362-028x-59.8.889.

Martin, N. H., Boor, K. J., & Wiedmann, M. (2018). Symposium review: Effect of post-pasteurization contamination on fluid milk quality. *Journal of Dairy Science*, *101*(1), 861–870. https://doi.org/10.3168/jds.2017-13339.

Melini, F., Melini, V., Luziatelli, F., & Ruzzi, M. (2017). Raw and Heat-Treated Milk: From Public Health Risks to Nutritional Quality. *Beverages*, *3*(4), 54. https://doi.org/10.3390/beverages3040054.

Mohamed, I. M. A., & El Zubeir, I. E. Y. M. (2014). Effect of heat treatment on keeping quality of camel milk. *Annals: Food Science & Technology*, *15*(2), 239.

Mohamed, H., Ayyash, M., & Kamal-Eldin, A. (2022). Effect of heat treatments on camel milk proteins—A review. *International Dairy Journal*, *133*, 105404. https://doi.org/10.1016/j.idairyj.2022.105404.

Nefasa, A. N., Christwardana, M., Abdurrahman, Z. H., Rohman, F., & Afif, A. (2023). A Mini Review on Technique of Milk Thermization. *Journal of Bioresources and Environmental Sciences*, *2*(3), 140–144. https://doi.org/10.14710/jbes.2023.19916.

Odongo, N. O., Lamuka, P. O., Matofari, J. W., & Abong, G. O. (2016). Risk factors associated with the post-harvest loss of milk along camel milk value chain in Isiolo County, Kenya. *African Journal of Agricultural Research*, *11*(8), 674–682. https://doi.org/10.5897/ajar2015.9988.

Omer, A. G., & Ateye, M. D. (2022). Analysis of physical and microbiological quality of raw camel milk in the Somali regional state of Ethiopia. *Online Journal of Animal and Feed Research*, *12*(6), 372–378. https://doi.org/10.51227/ojafr.2022.49.

Omer, R. H., & Eltinay, A. H. (2008). Microbial quality of camel's raw milk in central & southern regions of United Arab Emirates. *Emirates Journal of Food and Agriculture*, *20*(1), 76–83. https://doi.org/10.9755/ejfa.v20i1.5182.

Rico-Munoz, E., Houbraken, J., & Samson, R. A. (2015). Detection and Enumeration of Heat-Resistant Molds. In *Compendium of Methods for the Microbiological Examination of Foods* (pp. 251–263). American Public Health Association. https://doi.org/10.2105/mbef.0222.027.

Robinson, R. K. (Ed.). (1990). Dairy Microbiology (2nd ed., Volume 1, pp. 37–77, 163–208). Department of Food Science and Technology, University of Reading.

Rukke, E. O., Sørhaug, T., & Stepaniak, L. (2016). Heat Treatment of Milk: Thermization of Milk. In *Reference Module in Food Science*. Elsevier. https://doi.org/10.1016/b978-0-08-100596-5.00809-x.

Serda, B., Bekele, A., & Abebe, D. (2018). Prevalence and Contamination Level of Staphylococcus aureus in Raw Camel Milk and Associated Risk Factors in Jigjiga District, Eastern Ethiopia. *Journal of Veterinary Science & Technology*, *9*(01), 501. https://doi.org/10.4172/2157-7579.1000501.

Sissoko, A., Samake, F., Maïga, B. D. A., Dembele, S., Kone, F., & Tembely, S. (2023). Evaluation de la qualite microbiologique du lait frais pasteurise et du lait local transforme (Thiakry) vendus dans District de Bamako, Mali [Assessment of the Microbiological Quality of Fresh Pasteurized Milk and Local Processed Milk (Thiakry) Sold in the District of Bamako, Mali]. *Agronomie Africaine*, *35*(2), 323–332.

Taher, E. M., Veltman, T., & Petrovski, K. R. (2022). Presence of Bacillus species in pasteurised milk and their phenotypic and genotypic antimicrobial resistance profile. *International Journal of Dairy Technology*, *76*(1), 63–73. https://doi.org/10.1111/1471-0307.12919.

Wu, J., Chen, S., & Van der Meeren, P. (2024). Heat Stability Assessment of Milk: A Review of Traditional and Innovative Methods. *Foods*, *13*(14), 2236. https://doi.org/10.3390/foods13142236.

Zarei Yam, B. A., Khomeiri, M., Sadeghi Mahoonak, A., & Jafari, S. M. (2014). Hygienic Quality of Camel Milk and Fermented Camel Milk (Chal) in Golestan Province, Iran. *Journal of Microbiology Research*, *4*(2), 98–103.