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Determination of microbiological quality of kurut produced by traditional methods in Van province

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ABSTRACT:

This study aimed to determine the microbiological quality of kurut traditionally produced and sold in Van province, Türkiye, and to assess potential public health risks. Fifty kurut samples were collected from 15 different retail outlets in Van city centre in March 2024 and subjected to comprehensive microbiological analyses. Total mesophilic aerobic bacteria (TMAB), coliform bacteria, *Escherichia coli*, *Enterobacteriaceae*, *Enterococcus* spp., *Staphylococcus aureus*, sulfite-reducing anaerobic microorganisms, yeast-mold, *Lactococcus* spp., and *Lactobacillus–Leuconostoc–Pediococcus* counts were determined. Mean values were as follows: TMAB 4.87±1.74 log cfu/g, coliform bacteria 0.75±1.04 log cfu/g, yeast-mold 4.31±1.74 log cfu/g, *S. aureus* 2.04±1.90 log cfu/g, and *Lactococcus* spp. 4.76±1.50 log cfu/g. *E. coli* was not detected in any sample. Coliform bacteria were present in 36% of samples, *S. aureus* in 60%, and yeast-mold in all samples (100%). A statistically significant association was found between *S. aureus* positivity and *Enterobacteriaceae* positivity ($\chi^2 = 4.32$, $p = 0.038$). To the best of our knowledge, this is the first study to report sulfite-reducing anaerobic microorganism counts in kurut, detected in 58% of samples. The high microbial loads indicate insufficient hygiene compliance during production, storage, and sale. Standardised production protocols, HACCP implementation, and routine inspections at sales points are recommended.

Van ilinde geleneksel yöntemlerle üretilen kurutların mikrobiyolojik kalitesinin belirlenmesi

ÖZET:

Bu çalışma, Van ilinde geleneksel yöntemlerle üretilerek satışa sunulan kurutların mikrobiyolojik kalitesini belirlemek ve halk sağlığı açısından potansiyel riskleri değerlendirmek amacıyla yürütülmüştür. Van il merkezindeki 15 farklı satış noktasından Mart 2024 tarihinde toplanan 50 adet kurut örneği kapsamlı mikrobiyolojik analizlere tabi tutulmuştur. Örneklerde toplam mezofil aerobik bakteri (TMAB), koliform grubu bakteri, *Escherichia coli*, *Enterobacteriaceae*, *Enterococcus* spp., *Staphylococcus aureus*, sülfit indirgeyen anaerob mikroorganizma, maya-küf, *Lactococcus* spp. ve *Lactobacillus-Leuconostoc-Pediococcus* sayımları yapılmıştır. Ortalama değerler; TMAB 4,87±1,74 log kob/g, koliform bakteri 0,75±1,04 log kob/g, maya-küf 4,31±1,74 log kob/g, *S. aureus* 2,04±1,90 log kob/g ve *Lactococcus* spp. 4,76±1,50 log kob/g olarak belirlenmiştir. *E. coli* hiçbir örnekte tespit edilmemiştir. Örneklerin %36'sında koliform grubu bakteri, %60'ında *S. aureus* ve tamamında maya-küf varlığı saptanmıştır. *S. aureus* pozitifliği ile *Enterobacteriaceae* pozitifliği arasında istatistiksel olarak anlamlı bir ilişki tespit edilmiştir ($\chi^2 = 4.32$; $p = 0,038$). Bilgimiz dahilinde bu çalışma, kurutta sülfit indirgeyen anaerobik mikroorganizma sayımının ilk kez rapor edildiği çalışma niteliğindedir (%58 pozitif). Standardize üretim protokolleri, HACCP uygulaması ve satış noktalarında düzenli denetimlerin yapılması önerilmektedir.

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1. INTRODUCTION

The preservation of food by sun-drying is one of the oldest food processing methods in human history. Today, the drying method is still widely applied in many countries for the preservation of various foods such as milk and dairy products, meat products, fruits, and vegetables. The drying process reduces water activity and increases dry matter content. Most spoilage microorganisms cannot grow at water activity values below 0.85, therefore, dried foods exhibit greater resistance to microbiological and chemical deterioration (1).

Milk and dairy products occupy an important place in the culinary culture of Central Asian Turks. Although yogurt has high nutritional value, its limited shelf life prompted Central Asian peoples to preserve it by drying. This product, called *kurut*, derives from the Turkish root word *kurutmak* (to dry) and was used by Mongols as a 'war food' or 'winter food' (2, 3). *Kurut* is known as *kashk* in Iran, *kushuk* in Iraq, *jub-jub* in Syria, and *kishk* in Lebanon (4). Mamatova and Aydın (33) reviewed the cultural and microbiological significance of kurut across the Silk Road geography, highlighting the product's wide regional distribution and the need for standardised quality assessments.

Kurut is generally produced by straining low-fat yogurt or buttermilk, salting the curd, shaping it, and drying it in the sun (5). In Turk***iye***, regional names include *keş* in Bolu, *horç* in Silifke**,** "dolaz" or "tort" in Antalya and Afyon, "geşk" in Siirt, "keşk," "çörten," "torak," "terne" in Bingöl, and *çortan* in Mardin (5, 6, 7). According to the traditional production method, milk is boiled and cooled to the fermentation temperature, after which 2-3% homemade yogurt is added as a starter culture. The yogurt obtained after 5-8 hours of incubation is kept in the refrigerator for 24 hours and then strained in a cloth bag for 1 day. Salt (1-3%) and cream (5-10%) are optionally added to the strained yogurt, shaped into 40-60 g pieces, dried in the shade for 2-3 days, then in the sun for 3-5 days, and stored in a shaded place for another 2-3 months (8, 9).

Kurut is an important food both for consumers and industrially, with features such as long shelf life (up to 1 year under good storage conditions), high nutritional value (protein, calcium, potassium, and phosphorus content), easy portability, and ease of consumption. It plays a particularly important role in meeting animal-based protein needs in rural areas, utilizing buttermilk, and generating additional income. However, the lack of standardised production techniques, insufficient hygiene, and limited inspection capacity can adversely affect its microbiological quality (10). Previous studies on kurut microbiological quality include work by Patır and Ateş (12), Aydemir-Atasever and Atasever (13), Doğan (6), and Mollabashi and Aydemir-Atasever (14), most conducted in Eastern Anatolia, but no comprehensive and current data exist for Van province.

Van province is one of the principal centres of traditional kurut production and consumption in Türkiye. To the best of our knowledge, no comprehensive microbiological study specific to Van province has been published to date. The present study is therefore the first to provide up-to-date, region-specific microbiological data on kurut marketed in Van, including sulfite-reducing anaerobic microorganism counts — a parameter not previously reported for this product. Given the 2025 revision of the Turkish Food Codex Microbiological Criteria Regulation (15), establishing this baseline has direct regulatory and public health significance (33).

This study was planned to comprehensively determine the microbiological quality of kurut produced and sold in Van province, to assess potential public health risks, and to provide evidence-based recommendations for improving production, storage, and sales conditions.

2. MATERIAL AND METHODS

Ethical approval

Ethical approval was not required for this study because it was based solely on the microbiological analysis of food samples (kurut) obtained from local sources and did not involve any human participants, animal subjects, or personal data.

Material

A total of 50 kurut samples were collected in March 2024 from 15 different retail outlets in Van city centre using a random sampling approach. Samples of at least 500 g were collected under aseptic conditions, transferred in sterile glass jars, and brought to the laboratory under cold chain (+4°C). Microbiological analyses were initiated within 4 hours of collection. Prior to analysis, 10 g of each sample was homogenised with 90 mL sterile 0.1% peptone water (Merck 107228, Germany) to prepare the 10^{-1} dilution, followed by serial dilutions (10^{-2} to 10^{-7}).

Microbiological Analyses

All analyses were performed in duplicate with positive and negative controls.

Total aerobic mesophilic microorganism count

Inoculation was performed on Plate Count Agar (PCA, LABM LAB149, UK) by pour plate method, and petri plates were incubated aerobically at 37±1°C for 48±2 hours. At the end of incubation, all developed colonies were counted and evaluated as total aerobic mesophilic microorganism count (16, 17).

Coliform bacteria count

Inoculation was performed on Violet Red Bile Lactose Agar (VRBLA, LABM LAB031, UK) by pour plate method, and petri plates were incubated aerobically at 37±1°C for 24±2 hours. At the end of incubation, colonies with a diameter of 0.5 mm or larger and dark red in color were counted as coliform bacteria (18, 19).

***Enterobacteriaceae* count**

Inoculation was performed on Violet Red Bile Glucose Agar (VRBGA, LABM LAB088, UK) by pour plate method, and petri plates were incubated aerobically at 30±1°C for 24±2 hours. At the end of incubation, oxidase test (Oxidase Test Strips, Merck 100987) was applied to 5 randomly selected colonies with a diameter of 1-2 mm and purple-red color, and oxidase-negative colonies were counted as *Enterobacteriaceae* (17).

***Enterococcus* count**

Inoculation was performed on Slanetz & Bartley Medium (LABM LAB166, UK) by spread plate method. Petri plates were first incubated under aerobic conditions at 37±1°C for 4 hours, then at 44±1°C for 44±4 hours. At the end of incubation, colonies larger than 1-2 mm and ranging in color from pink-red to brown were counted as *Enterococcus* (17).

***Escherichia coli* count**

Inoculation was performed on Tryptone Bile X-Glucuronide Agar (TBX, LABM HAL003, UK) by spread plate method. Petri plates were incubated under aerobic conditions at 44±1°C for 24±2 hours, and blue-green colored colonies were counted as *E. coli* (17, 20).

***Lactobacillus-Leuconostoc-Pediococcus* (LLP) count**

Inoculation was performed on De Man, Rogosa and Sharpe Agar (MRS, LABM LAB093, UK) by spread plate method. An anaerobic environment was provided by pouring a second layer of MRS Agar on the petri plates, and they were incubated at 30±1°C for 72±3 hours. At the end of incubation, all grown colonies were counted (17, 21).

***Lactococcus* spp. count**

Inoculation was performed on M17 Agar (Merck 115108) by spread plate method, and petri plates were incubated under aerobic conditions at 30±1°C for 48-72 hours. At the end of incubation, all grown colonies were counted as *Lactococcus* spp. (22).

Sulfite-Reducing Anaerobic Microorganism Count

Inoculation was performed on Sulphite Polymyxin Sulphadiazine Agar (SPS, Merck 110235, Germany) by roll tube technique. An anaerobic environment was provided by adding approximately 1 mL of the same medium on top of the solidified medium, and it was incubated at 37±1°C for 24±2 hours. At the end of incubation, black-colored colonies were counted as sulfite-reducing anaerobic microorganisms (23).

***Staphylococcus aureus* Count**

Inoculation was performed by spread plate method on Baird-Parker Agar (Oxoid CM0275, UK) supplemented with Egg Yolk Tellurite Emulsion (Oxoid SR0047). Petri plates were incubated under aerobic conditions at 37±1°C for 48±2 hours, and typical (black, surrounded by halo) and atypical (shiny black, without halo) colonies were evaluated as *Staphylococcus* spp. catalase test, coagulase test (rabbit plasma, Oxoid R0020, UK), and Staphytect Plus (Oxoid DR0850M, UK) latex agglutination test were applied to 5 randomly selected colonies. Colonies that were positive in all three tests were evaluated as coagulase-positive *S. aureus* (19, 24).

Yeast-Mold Count

Inoculation was performed on Dichloran Rose Bengal Chloramphenicol Agar (DRBC, Symphony Agar Base, Biokar BK227HA, France) by pour plate method, and petri plates were incubated under aerobic conditions at 25±1°C for 5 days. At the end of incubation, all developed colonies were counted and evaluated as total yeast-mold count (25).

Statistical Analysis

Microbiological results were expressed as colony-forming units per gram (cfu/g) and $\log_{10}$-transformed. Normality was assessed with the Shapiro–Wilk test. Descriptive statistics (minimum, maximum, mean ± standard deviation) were calculated for all parameters, and the number and percentage of positive samples were determined for each microorganism group. To explore associations among microorganism groups, Pearson correlation analysis was performed on log-transformed counts in positive samples. Chi-square (χ^2) tests were applied to examine relationships between the positivity rates of indicator and pathogenic organisms. A significance level of $p < 0.05$ was adopted for all inferential statistical tests. All analyses were performed using SPSS 22.0 (IBM Corp., Armonk, NY, USA).

3. RESULTS

The microbiological analysis results of 50 kurut samples are presented in Tables 1 and 2. TMAB and yeast-mold were detected in all samples (100%), whereas E. coli was not detected in any sample.

TMAB counts ranged from 2.00 to 7.93 log cfu/g, with a mean of 4.87 ± 1.74 log cfu/g. Counts exceeded 10^5 cfu/g in 42% of samples (n = 21) and 10^6 cfu/g in 26% (n = 13).

Coliform bacteria were detected in 18 samples (36%), with a mean count of 2.08 ± 0.47 log cfu/g in positive samples. *Enterobacteriaceae* were detected in 27 samples (54%), with a mean count of 3.32 ± 1.45 log cfu/g.

S. aureus was detected in 30 samples (60%), with a mean count of 3.40 ± 1.15 log cfu/g in positive samples. Counts exceeded the enterotoxin production threshold of 10^5 cfu/g in one sample (2%).

Enterococcus spp. were detected in 14 samples (28%), with a notably high mean count of 5.17 ± 1.44 log cfu/g in positive samples. Sulfite-reducing anaerobic microorganisms were detected in 29 samples (58%), with a mean count of 3.20 ± 1.45 log cfu/g.

Lactococcus spp. were detected in 44 samples (88%; mean 4.67 ± 1.60 log cfu/g). The LLP group was detected in 38 samples (76%; mean 3.92 ± 1.67 log cfu/g). Yeast-mold was detected in all samples (mean 4.31 ± 1.74 log cfu/g); values exceeding 10^5 cfu/g were observed in 38% of samples.

Chi-square analysis revealed a statistically significant association between *S. aureus* positivity and *Enterobacteriaceae* positivity ($\chi^2 = 4.32$, df = 1, $p = 0.038$), suggesting that samples exhibiting *S. aureus* contamination were more likely to also carry *Enterobacteriaceae*. Pearson correlation analysis demonstrated a significant positive correlation between coliform and *Enterobacteriaceae* counts in positive samples ($r = 0.61$, $p < 0.01$), consistent with their shared fecal origin. No significant correlation was observed between lactic acid bacteria counts and pathogen/indicator counts ($p > 0.05$).

Tablo 1: Kurut Örneklerinin Mikrobiyolojik Analiz Sonuçları (log kob/g)
Table 1: *Microbiological Analysis Results of Kurut Samples (log cfu/g)*

Microorganism	n	Positive Samples (%)	Minimum	Maximum	Mean±SD	Mean±SD (Positive Samples)[a]
Total mesophilic aerobic bacteria	50	50 (100)	2.00	7.93	4.87±1.74	4.87±1.74
Coliform group bacteria	50	18 (36)	1.00[b]	2.56	0.75±1.04	2.08±0.47
Escherichia coli	50	0 (0)	-	-	-	-
Enterobacteriaceae	50	27 (54)	1.00[b]	5.67	1.79±1.98	3.32±1.45
Enterococcus spp.	50	14 (28)	2.30[b]	7.35	1.45±2.46	5.17±1.44
Staphylococcus aureus	50	30 (60)	2.00[b]	5.37	2.04±1.90	3.40±1.15
Sulfite-reducing anaerobic microorganisms	50	29 (58)	1.00[b]	5.48	1.85±1.93	3.20±1.45
Lactococcus spp.	50	44 (88)	0.70[b]	6.84	4.11±2.15	4.67±1.60
Lactobacillus-Leuconostoc-Pediococcus	50	38 (76)	1.00[b]	5.96	2.98±2.23	3.92±1.67
Yeast-mold	50	50 (100)	1.00	7.08	4.31±1.74	4.31±1.74

[a]*Mean±SD in positive samples only;* [b]*Minimum value in positive samples; n: total sample size; SD: standard deviation*

Tablo 2: Kurut Örneklerinin Mikroorganizma Yükü Açısından Dağılımı

Table 2: *Distribution of Microbial Load categories in Kurut Samples*

Microorganism	Not detected (%)	$<10^3$ cfu/g n (%)	10^3-10^4 cfu/g n (%)	10^4-10^5 cfu/g n (%)	10^5-10^6 cfu/g n (%)	$>10^6$ cfu/g n (%)
Total mesophilic aerobic bacteria	0 (0)	5 (10)	17 (34)	7 (14)	8 (16)	13 (26)
Coliform group bacteria	32 (64)	4 (8)	14 (28)	0 (0)	0 (0)	0 (0)
Enterobacteriaceae	23 (46)	6 (12)	13 (26)	5 (10)	3 (6)	0 (0)
Enterococcus spp.	36 (72)	1 (2)	2 (4)	3 (6)	6 (12)	2 (4)
Staphylococcus aureus	20 (40)	2 (4)	24 (48)	3 (6)	1 (2)	0 (0)
Sulfite-reducing anaerobic microorganisms	21 (42)	4 (8)	14 (28)	7 (14)	4 (8)	0 (0)
Lactococcus spp.	6 (12)	7 (14)	9 (18)	11 (22)	14 (28)	3 (6)
Lactobacillus-Leuconostoc-Pediococcus	12 (24)	7 (14)	12 (24)	13 (26)	6 (12)	0 (0)
Yeast-mold	0 (0)	8 (16)	10 (20)	13 (26)	12 (24)	7 (14)

n: Number of samples

4. DISCUSSION AND CONCLUSION

The present study provides comprehensive, region-specific microbiological data on traditionally produced kurut marketed in Van province, addressing a gap in the existing literature, and assessing potential public health risks. Variations in production environment, hygiene practices, equipment, and storage conditions across producers are key determinants of microbiological quality in traditional fermented dairy products (11). In kurut production, microbial development is controlled by the synergistic effects of water activity (aw), pH reduction, and salt concentration. Low aw values (<0.60) inhibit the growth of most bacteria, while yeasts and molds are known to be more resistant. The final microbial stability of the product is therefore directly dependent on the efficacy of the drying process. However, when drying temperature, duration, and airflow parameters are insufficiently controlled, spore-forming bacteria and osmotolerant microorganisms may survive. The combined evaluation of fermentation and drying stages is critical for ensuring product safety, and the interaction between these two stages plays a determining role in shaping the microbial ecosystem of the product.

Total mesophilic aerobic bacteria and general hygienic quality

TMAB counts are widely accepted as indicators of general hygienic quality and conditions favouring pathogen growth. Foods containing TMAB between 10^6 and 10^8 cfu/g are generally considered to be of low commercial quality (26). The mean TMAB of 4.87 ± 1.74 log cfu/g, with 42% of samples exceeding 10^5 cfu/g and 26% exceeding 10^6 cfu/g, indicates that a considerable proportion of the samples had inadequate hygienic quality.

Compared with previous studies TMAB counts reported by Patır and Ateş (12), Aydemir-Atasever and Atasever (13), and Doğan (6) were generally lower than the mean value obtained in the present study. These differences may reflect regional variations in production methods, starter culture composition, drying conditions, and sampling period. Mamatova and Aydın (33) similarly noted that kurut sold under uncontrolled market conditions consistently exhibited higher microbial loads than experimentally produced kurut, underscoring the role of post-production hygiene.

Coliform group bacteria and ındicators of fecal contamination

The presence of coliform group bacteria is considered an indicators of fecal contamination, inadequate sanitation, and the possible presence of enteric pathogens (14). In this study, coliform bacteria were detected in 36% of the samples, with a mean count of 2.08 ± 0.47 log cfu/g in positive samples. These results are comparable to those reported by Patır and Ateş (12) and Aydemir-Atasever (13). The presence of coliform bacteria may be associated with the microbiological quality of raw milk, insufficient heat treatment prior to fermentation, and/or cross-contamination during production. The significant positive correlation between coliform and *Enterobacteriaceae* counts ($r = 0.61$, $p < 0.01$) further supports a shared contamination source, likely originating during milking or early processing.

Enterobacteriaceae, which are commonly found in the gastrointestinal tract of humans and animals as well as in the environment, were detected in 54% of the samples. This finding is comparable to previous reports (14) and suggests deficiencies in milking hygiene, equipment sanitation, or personnel hygiene.

The absence of *E. coli* is a favourable finding regarding direct faecal contamination, consistent with Mollabashi and Aydemir-Atasever (14). The chi-square analysis demonstrating an association between *S. aureus* and *Enterobacteriaceae* positivity ($\chi^2 = 4.32$, $p = 0.038$) suggests that contamination reflects a general hygiene breakdown rather than an isolated event.

Sulfite-reducing anaerobic microorganisms

Sulfite-reducing anaerobic microorganisms are hygiene indicators and fecal contamination in dairy products, their presence typically reflects contamination during milking (26). Their detection in 58% of samples — to the best of our knowledge, the first report of this parameter in kurut — implies faecal contamination at the primary production level and highlights hygienic milking practices as a critical control point.

Enterococcus spp. and adequacy of heat treatment

Enterococcus spp. are heat-resistant (surviving 65°C for 30 min) and indicate inadequate heat treatment (27, 28). Their detection in 28% of samples, with a mean count of 5.17 ± 1.44 log cfu/g in positive samples, suggests either insufficient boiling of milk or post-heat contamination. These values are considerably higher than those reported by Mollabashi and Ademir-Atasever (14). Similar findings have been reported for other traditional fermented dairy products in the Middle East and North Africa, where inadequate thermal processing has been consistently linked to elevated *Enterococcus* counts (34). Boiling milk at a minimum of 90°C for 5 minutes under aseptic conditions is strongly recommended.

Staphylococcus aureus and public health risk

S. aureus is widely distributed in nature and is commonly found in the skin and nasal flora of humans and animals (29). In this study, *S. aureus* was detected in 60% of the samples, with a mean count of 3.40 ± 1.15 log cfu/g in positive samples. These findings are consistent with previous studies, although some authors have reported the absence of *S. aureus* in Kurut samples. A recent systematic review (35) found *S. aureus* in 29.07% of raw milk and 42.81% of artisanal cheese samples globally, with higher prevalence where adequate thermal processing was absent — a profile directly applicable to traditionally produced kurut. High levels of *S. aureus* pose a significant public health risk due to its ability to produce enterotoxins under favorable conditions. Enterotoxin production generally commences at $\geq 10^5$ cfu/g (30); this threshold was exceeded in one sample (2%). The significant co-occurrence of *S. aureus* and Enterobacteriaceae ($\chi^2 = 4.32$, $p = 0.038$) suggests systemic hygiene deficiencies rather than random contamination. Rodríguez-Sánchez et al. (36) demonstrated that lactic acid bacteria can suppress *S. aureus* growth and enterotoxin production, underscoring the importance of defined starter cultures.

Lactic acid bacteria and fermentation quality

Lactic acid bacteria play a crucial role in the fermentation and maturation of dairy products (31). *Lactococcus* spp. were detected in 88% of samples (mean 4.67 ± 1.60 log cfu/g) and the LLP group in 76% (mean 3.92 ± 1.67 log cfu/g). The absence of a significant negative correlation between LAB and pathogen/indicator counts ($p > 0.05$) suggests that the LAB present were insufficient to suppress contaminants under uncontrolled production and storage conditions. Shi and Maktabdar (37) demonstrated that bioprotective *Lactiplantibacillus* strains can inhibit spoilage mold growth in fermented milk products, further supporting the use of defined starter cultures.Variations in lactic acid bacteria counts may be attributed to differences in starter culture composition, fermentation duration, drying conditions, and storage practices. High lactic acid bacteria levels indicate good fermentation quality and may contribute to the inhibition of undesirable microorganisms through acidification and bacteriocin production.

Yeast and Mold Contamination

Yeasts and molds are responsible for spoilage, off-flavors, and discoloration in food products. In minimally processed and openly marketed products such as Kurut, yeast and mold counts represent an important quality parameter (32). The detection of yeast-mold in all 50 samples, with 38% exceeding 10^5 cfu/g, indicates widespread fungal contamination attributable to open-air drying, inadequate packaging, and unsuitable storage and sales conditions. Garnier et al. (38) identified up to 100 mold species capable of causing dairy product spoilage, with *Penicillium* and *Aspergillus* species being most prevalent. Certain *Penicillium* spp. produce ochratoxin A and citrinin, while *Aspergillus* spp. may produce aflatoxins — heat-stable mycotoxins with hepatocarcinogenic potential (39). As the present study did not include mycotoxin analysis, future research should incorporate mycotoxin screening to fully characterise the associated health risks.

Evaluation according to Turkish Food Codex

Although the Turkish Food Codex Microbiological Criteria Regulation (15) does not specify limit values for Kurut, microbiological criteria for fermented dairy products are available. In this study, all samples complied with the *E. coli* criterion (<10 cfu/g). However, a considerable proportion of samples exceeded the recommended limits for coagulase-positive staphylococci and yeast–mold counts. These findings indicate that a significant number of Kurut samples pose potential microbiological risks.

Conclusions and recommendations

The microbiological quality of traditionally produced Kurut samples marketed in Van province was generally inadequate. High levels of TMAB, *S. aureus*, coliform bacteria, and yeast–mold were detected in a substantial proportion of samples. The statistically significant association between *S. aureus* and *Enterobacteriaceae* positivity ($p=0.038$) suggests systemic hygiene deficiencies, and the first documentation of sulfite-reducing anaerobic microorganisms in kurut highlights contamination at the primary production stage. The following measures are recommended:

Standardized Production Techniques: Scientifically based standardized production protocols should be developed and disseminated to producers through training programs.

Implementation of HACCP: Hazard Analysis and Critical Control Points (HACCP) systems should be established in production facilities. Within the HACCP framework specific to kurut production, the following critical control points should be identified: fermentation time and temperature, target water activity (aw) value during drying, and storage conditions. For example, a target aw of ≤ 0.60 following drying is recommended to inhibit most bacterial growth. A pH of ≤ 4.5 during fermentation should be considered a critical threshold for controlling pathogen development. Furthermore, the barrier properties of packaging materials should be taken into account to prevent moisture absorption during storage. Aslani et al. (40) demonstrated that HACCP implementation in yogurt production substantially reduces contamination risk at critical stages.

Hygiene Training: Regular hygiene training should be provided for producers and vendors, focusing on personal hygiene, sanitation, and food safety.

Packaging and Labeling: Kurut should be marketed in sealed, hygienic packaging with appropriate labeling, including production date, expiration date, storage conditions, and producer information.

Regular Inspections: Routine microbiological inspections should be conducted by local authorities, and products exceeding limit values should be withdrawn from the market.

Starter Culture Usage: The use of standardized starter cultures instead of traditional homemade yogurt should be encouraged.

Technological Improvements: The adoption of closed drying systems, controlled temperature and humidity conditions, and UV disinfection technologies should be promoted.

The implementation of these measures would enhance the sustainability of traditional Kurut production, minimize public health risks, and increase the commercial value of the product.

Future studies should include mycotoxin analysis and molecular characterisation of isolated pathogens. Future research should comparatively examine the effects of different drying techniques (sun drying, controlled-temperature drying, etc.) on microbial load and water activity in kurut production. The establishment of standard drying parameters in small-scale production would contribute to improving product safety. The integration of traditional production methods with modern process control approaches is of importance for both microbial stability and product quality.

Limitations

Several limitations of this study should be acknowledged. First, microbial identification was based solely on culture-based and biochemical methods, molecular verification (e.g., PCR or MALDI-TOF) was not performed. This may have affected the precision of species-level identification, particularly for *Enterococcus* spp. and lactic acid bacteria. Second, no mycotoxin analysis was conducted, therefore, public health risk assessments related to yeast and mold contamination remain indicative rather than definitive. Third, the study was conducted over a single sampling period (March 2024) at retail outlets in Van city centre, which limits the generalisability of the findings across seasons and production locations. Finally, water activity measurements were not included, which would have provided a more direct link between drying efficacy and microbiological quality.

Conflict of Interest

The authors declare that there are no commercial or financial relationships that could be construed as a potential conflict of interest.

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Ethical Approval

Ethical approval was not required for this study because it was based solely on the microbiological analysis of food samples (kurut) obtained from local sources and did not involve any human participants, animal subjects, or personal data.

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