



BACTERIOLOGICAL QUALITY OF PASTEURIZED MILK SOLD IN MAIDUGURI METROPOLIS, BORNO STATE, NIGERIA

ABSTRACT

The microbial quality of milk products is essential because it determines the presence and concentration of microorganisms, which can impact their safety and shelf life. The diverse array of nutrients present in milk makes it an optimal environment for the proliferation of microorganisms, leading to spoilage. This study aimed to evaluate the bacteriological quality and microbial load of pasteurized milk and yogurt samples retailed in

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Maiduguri Metropolis. In total, 100 samples were collected and subjected to bacteriological analysis to identify the presence of pathogens and spoilage microorganisms. Five different brands of commercial milk samples, including pasteurized milk and yogurt, were purchased from retail outlets in Metropolis at the five selected markets. The samples were analysed for standardization using the method of the International Organization for Standardization (ISO 4833-1:2013) for the enumeration of total bacterial counts (TBC) and specific microbial flora, including fecal coliforms, and pathogenic microorganisms. The prepared samples were aseptically inoculated into the appropriate culture media. After an appropriate incubation period of 72 hours at 30°C in an incubator, a colony counter was employed to calculate the colonies of microorganisms on each culture plate. The microbial population was quantified and recorded as CFU/mL. The results indicated that certain pasteurized milk and yogurt samples from Maiduguri metropolitan markets exhibited elevated microbial loads, including contamination with total coliforms. However, no pathogenic microorganisms such as *Salmonella* spp., *Shigella* spp., and *Staphylococcus aureus* were detected in any of the tested samples. The highest mean total bacterial count (TBC) observed was 5.15 log₁₀ CFU/mL whereas the lowest mean total bacterial count was 4.68 log₁₀ CFU/mL, 20% non-compliance with the SON benchmark limit ($p < 0.001$). Both pasteurized milk (0.85 log₁₀ CFU/mL) and yogurt (0.78 log₁₀ CFU/mL) exceeded the acceptable SON standards for total coliform counts ($p = 0.384$). All samples indicated the absence of targeted pathogenic microorganisms, making them safe for consumption.

Keywords: Pasteurized milk, yogurt, Coliforms, Pathogens, Contamination, Microbial Quality, Shelf life.

Authors' Contributions

IOO: Conceptualization, methodology, supervision writing—original draft, writing—review, and editing. HY, HAA, DM, BMM, and AAB: validation, data analysis, and writing—original draft and preparation of the manuscript. HAM, RSA, HMK, YSA, and KAL: writing—original draft, writing—review, and editing. HIA: Conceptualization, methodology, data analysis, writing—original draft, writing—review, and editing. All authors read and approved the final version of the manuscript for submission.



Introduction

Milk is a nutrient-dense food product derived from healthy livestock, including bovines, caprines, ovines, and buffaloes, produced under hygienic conditions (Oluchi *et al.*, 2022). It is a nutritionally complete food because it contains high-quality proteins, all essential fatty acids, lactose, vitamins, and minerals to meet the needs of all age groups (Muhammad *et al.*, 2023; Nnenna & Nneka, 2021). However, its high moisture content and neutral pH create an environment that allows microorganisms to grow, including beneficial species such as *Lactobacillus* and *Bifidobacterium*, as well as potentially pathogenic species such as *Salmonella* spp., *Escherichia coli*, *Listeria monocytogenes*, and *Staphylococcus aureus* (Oluchi *et al.*, 2022; Wulgo *et al.*, 2022). Contamination can also occur during milking, processing, storage, and distribution. Raw milk is vulnerable to contamination by unsafe handling of milk, unsanitary equipment and utensils, unsafe drinking water, or environmental exposure (Shu'aibu *et al.*, 2021).

Therefore, to reduce microbial hazards and extend the shelf life of raw milk, it must be pasteurized. Pasteurization is considered a heat treatment, which can include milk that is heated to 63–66 °C for 30 min and/or to 72–74 °C for 15 s, cooled to between 4 °C and 8 °C. The Gulf Standard (GSO 984:2015) suggests pasteurization to be a heat treatment that the milk will receive (Al-Farsi *et al.*, 2021). In this process, pathogenic microorganisms including *Mycobacterium tuberculosis* are destroyed, while retaining the nutritional and sensory properties of milk (Al-Farsi *et al.*, 2021; Nnenna & Nneka, 2021). The shelf life and safety of pasteurized milk depend on the quality of the raw milk, the effectiveness of heat treatment, storage conditions, and post-pasteurization contamination (Osman *et al.*, 2020).

Yoghurt is one of the most consumed dairy products globally and is manufactured by fermenting milk using starter cultures of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus* to convert lactose into lactic acid, coagulating milk proteins, and developing characteristic taste and texture (Raji & Jiya, 2019). Yoghurt is an excellent source of protein, calcium, and bioactive compounds, and may be the preferred dairy product for individuals who are unable to tolerate lactose (Frew *et al.*, 2024). However, like milk, yoghurt is at risk of microbial contamination from molds, yeasts, coliforms, and pathogenic bacteria, such as *Salmonella* spp., *Listeria monocytogenes*, and *Escherichia coli* (Osman *et al.*, 2020; Raji & Jiya, 2019).

Microbial contamination of milk and yoghurt can occur at any point during production, from milking of the animal to packaging of the completed product. Contamination can originate from the skin of the animal, equipment surfaces, water, or the hands of people handling milk (Muhammad *et al.*, 2023; Shu'aibu *et al.*, 2021). The pathogenic



microorganisms frequently identified include *Salmonella* spp., *Listeria monocytogenes*, *E. coli* O157:H7, *Staphylococcus aureus*, *Campylobacter jejuni*, *Bacillus cereus*, and molds such as *Aspergillus* and *Penicillium* species (Morooft *et al.*, 2023; Olaniran *et al.*, 2022; Oluchi *et al.*, 2022). Several pathogenic microorganisms produce toxins that lead to serious illnesses, including enterohemorrhagic *E. coli* strains, which have been associated with life-threatening illnesses such as hemolytic uremic syndrome (Wulgo *et al.*, 2022). Furthermore, some fungi such as *Aspergillus* spp. can produce aflatoxins, which are known carcinogens (Olaniran *et al.*, 2022).

Sources of contamination in dairy production can be water, utensils, or employee handling (Olaniran *et al.*, 2022). Contaminants are capable of surviving in oxygen-rich environments, particularly in acidic foods such as yoghurt. Once contaminants are introduced, color, texture, and flavor can change, leading to overall product quality and consumer health issues (Olaniran *et al.*, 2022). There may be contamination that does not lead to spoilage, which underscores the need for pasteurization to eradicate any pathogens of concern. However, if pasteurized milk is spoiled by bacterial growth because it is not handled hygienically during processing, or if the milk is recontaminated after pasteurization, the purpose of pasteurization can be compromised (Al-Farsi *et al.*, 2021; Osman *et al.*, 2020).

According to the Standards Organization of Nigeria, milk intended for human consumption should not have more than 50,000 cfu/mL ($4.6 \log_{10}$ cfu/mL) for total aerobic plate count, which is consistent with the Codex Alimentarius standards of $<5.0 \log_{10}$ cfu/mL (Codex Alimentarius Commission, 2022; Standards Organization of Nigeria, 1996). Although standards exist, dairy products remain a major contributor to foodborne illness. In 2010, the World Health Organization (WHO) estimated that foodborne pathogens caused 600 million illnesses and led to over 418,000 deaths globally (WHO, 2020), with Africa having the greatest burden of foodborne illnesses per capita (Asfaw *et al.*, 2023). Diarrheal diseases caused by *Salmonella* spp., *Escherichia coli*, and *Listeria monocytogenes* still remain among the most widely reported (Frew *et al.*, 2024; Morooft *et al.*, 2023).

Although several studies have assessed the microbiological quality of milk and yoghurt in Nigeria, there is a paucity of data on the prevalence and diversity of contaminants in commercially packaged pasteurized milk and yoghurt in Maiduguri, a major dairy distribution hub in north-eastern Nigeria. Moreover, little is known about the compliance of these products with established microbiological safety standards in this region. Addressing this knowledge gap is critical to safeguarding public health and consumer trust. Therefore, this study investigated the microbiological quality of pasteurized milk and yoghurt marketed in Maiduguri, northeastern Nigeria, with the objectives of



determining their bacterial loads, identifying predominant contaminants, and assessing compliance with regulatory safety limits.

MATERIALS AND METHODS

Study Area and Design

This research was performed in Maiduguri, the capital city of Borno State, Nigeria. Five retail outlets in the city were visited, and two packs of pasteurized milk and three packs of yogurt were randomly purchased from each outlet. These products had different batch numbers, manufacturing dates, and expiration dates. A total of one hundred samples (100 samples) comprising pasteurized milk (50 samples) and yogurt (50 samples) were obtained for analysis. The study employed a stratified random sampling method to select representatives of pasteurized milk and yogurt samples.

Sample Collection, Transportation, and Preparation

Pasteurized milk and yogurt samples were collected in sterile polythene bags from five locations and transported in an ice container to the University of Maiduguri, Department of Microbiology. Prior to the microbiological analysis, the milk specimens were refrigerated at 4 °C and swabbed with 70% ethanol to ensure sterility. The samples were analyzed for total aerobic plate count (ISO-4833-1:2013), total coliform count, fecal coliform count using Plate Count Agar (PCA; HiMedia, India) incubated at 30°C for 72 ± 3 hours. MacConkey Agar (MAC; Fluka-Biochemika, Germany) was used for coliforms, Eosin Methylene Blue Agar (EMB; Micromaster, India) for fecal coliforms (including *E. coli*), and Deoxycholate Citrate Agar (DCA; Lab M, UK) for *Salmonella* and *Shigella* and Mannitol salt agar (MSA; HiMedia Pvt Ltd Co., Mumbai, India) for *Staphylococcus aureus* detection. All media were prepared per manufacturers' guidelines, and each sample was analyzed individually.

Enumeration of Microbial Loads and Detection of Pathogens

Microbial populations in milk samples were quantified using a modified standard plate count method per ISO-4833-1:2013 (Marri *et al.*, 2020). Samples were diluted tenfold in sterile saline, and 100 µL from 10⁻² to 10⁻⁵ dilutions was aseptically spread onto pre-solidified plate count agar (PCA; HiMedia Pvt. Ltd., Mumbai, India) using a sterile L-shaped spreader, maintaining aseptic conditions. Plates were inverted and incubated at 30°C for 72 ± 3 hours to enumerate mesophilic aerobic bacteria. Plates with 25–250 colonies were counted using a colony counter, with results expressed as colony-forming units per milliliter (CFU/mL) (Ahmed *et al.*, 2022). For pathogen detection, presumptive *Staphylococcus* colonies were subcultured on mannitol salt agar (MSA; HiMedia Pvt. Ltd.,



Mumbai, India) and identified through biochemical tests. MacConkey Agar (Fluka-Biochemika, Germany) was used to detect coliforms. Fecal coliforms, such as non-pathogenic *Escherichia coli*, were detected on EMB Agar (Micromaster, Maharashtra, India). Colonies that appeared as black metallic sheen were counted and recorded as CFU/mL. The presence or absence of specific microorganisms was determined by quantitative analysis using selective medium. *Salmonella* and *Shigella* were detected on DCA Agar (Lab M. Ltd, UK). Colonies that appeared black and pink in colour were counted and recorded as CFU/mL.

Statistical Data Analysis

Data were analyzed using SPSS version 20 (IBM Corp., USA). One-way ANOVA was performed to assess differences in mean microbial contamination levels ($\log_{10}$ CFU/mL) across market locations, with significance set at $p \leq 0.05$. Tukey's HSD post-hoc test identified specific differences between locations ($p < 0.05$). One-sample t-tests, with Bonferroni corrected ($\alpha = 0.01$), compared each location's mean contamination against the SON limit ($5.00 \log_{10}$ CFU/mL).

RESULTS

In this study, a total of 100 samples comprising pasteurized milk ($n = 50$) and yogurt ($n = 50$) were analyzed for bacterial contamination from five retail outlets in Maiduguri. The present study revealed significant variations in total bacterial counts (TBC) across the different market locations examined (**Table 1**). The findings of this study demonstrated that bacterial contamination levels varied considerably among the five retail outlets investigated. In the present study, Baga Road Market (BRM) exhibited the highest level of bacterial contamination with a mean TBC of $5.15 \log_{10}$ CFU/mL, resulting in 90% non-compliance with SON standards (**Table 1**). Similarly, Abbaganaram Market (AM) showed elevated bacterial counts with a mean of $5.12 \log_{10}$ CFU/mL and 85% non-compliance rate. Both locations significantly exceeded the acceptable safety limits ($p = 0.031$ and $p = 0.018$, respectively) (**Table 1**). In contrast, this study found that Milk Shop (MS) exhibited the most favorable microbiological profile with the lowest mean bacterial count of $4.68 \log_{10}$ CFU/mL and only 20% non-compliance, performing significantly below the SON limit. The present study also revealed that Unimaid Commercial Centre (UCC) showed relatively good performance with a mean TBC of $4.81 \log_{10}$ CFU/mL and 35% non-compliance rate, also performing below the benchmark standard ($p = 0.015$) (**Table 1**). The results of this study indicated that Bama Station (BS) fell within the compliant range with a mean bacterial count of $4.97 \log_{10}$ CFU/mL and 55% non-compliance rate, showing no significant difference from the SON standard ($p = 0.737$) (**Table 1**). The microbiological analysis



revealed non-compliance in total coliform counts for both pasteurized milk ($0.85 \log_{10}$ CFU/mL) and yogurt ($0.78 \log_{10}$ CFU/mL), exceeding SON limits ($p > 0.05$) (**Table 2**). Pathogens (*E. coli*, *Salmonella* spp., *Shigella* spp., and *Staphylococcus aureus*) were absent in both sample types, indicating compliance with zero-tolerance standards for these pathogens (**Table 2**). The study revealed no significant difference in coliform levels between milk and yogurt ($p = 0.384$), suggesting similar contamination risks. Despite meeting pathogen safety criteria, elevated coliforms indicate potential hygiene lapses during processing or storage. Strengthened sanitation protocols are recommended to achieve full compliance (**Table 2**). The results indicated that some samples of pasteurized milk and yogurt sold in the Maiduguri metropolitan area had a relatively high microbial load and were contaminated with indicator bacteria such as coliforms and fecal coliforms (*E. coli*), while all samples were free from the pathogenic microorganisms investigated. The present study revealed that 57% of all samples analyzed across the five retail outlets demonstrated varying degrees of non-compliance with Nigerian food safety standards, indicating significant public health concerns regarding the microbiological quality of pasteurized dairy products in Maiduguri.

Table 1: Total Bacterial Counts for Pasteurized Milk and Yogurt Samples from Selected Markets in Maiduguri

Market Locations	No. of Samples	TBC Range ($\log_{10}$ CFU/mL)	Mean $\pm$ SD ($\log_{10}$ CFU/mL)	% Non-Compliant	SON Limit	P-value
AM	20	4.66-5.35	5.12 ± 0.23	85	Exceeds	0.031
BRM	20	4.66-5.43	5.15 ± 0.26	90	Exceeds	0.018
BS	20	4.45-5.38	4.97 ± 0.39	55	Compliant	0.737
MS	20	4.36-5.20	4.68 ± 0.22	20	Below	<0.001
UCC	20	4.45-5.49	4.81 ± 0.32	35	Below	0.015

Key: TBC = Total Colony Count, CFU = Colony forming unit, No. = Number, SD = Standard Deviation, SON = Standard Organization of Nigeria, P = Probability, AB = Abbaganaram Market, BRM = Baga Road Market, BS = Bama Station, MS = Milk Shop, UCC = Unimaid Commercial Centre.

$P < 0.05 \rightarrow$ Significant difference from SON limit

Exceeds: Mean $> 5.0 \log_{10}$ CFU/mL (non-compliant)

Table 2: Microbiological Analysis of Pasteurized Milk and Yogurt Samples from Selected Markets in Maiduguri

Microbiological Parameter	Sample Type (n = 50)	Min-Max ($\log_{10}$ CFU/mL)	Value	Mean $\pm$ SD ($\log_{10}$ CFU/mL)	Compliance Status	P-value
TCC	Pasteurized Milk	0.30 - 1.65		0.85 ± 0.42	Non-Compliant	0.384
	Yogurt	0.00 - 1.58		0.78 ± 0.38	Non-Compliant	



Fecal coliform (E. coli)	Pasteurized Milk	-	-	Compliant	×
	Yogurt	-	-	Compliant	×
Staphylococcus aureus	Pasteurized Milk	-	-	Compliant	×
	Yogurt	-	-	Compliant	×
Salmonella	Pasteurized Milk	-	-	Compliant	×
	Yogurt	-	-	Compliant	×
Shigella	Pasteurized Milk	-	-	Compliant	×
	Yogurt	-	-	Compliant	×

Key: TCC = Total Coliform Count, CFU = Colony forming unit, n = Number, SD = Standard Deviation, SON = Standard Organization of Nigeria, P = Probability, - = Not detected, × = No t-tests were performed,

P < 0.05 → Significant difference from SON limit,

Exceeds: Mean > 1 log₁₀ CFU/mL (non-compliant)

DISCUSSION

The current study revealed that the mean total bacterial count (TBC) of pasteurized milk and yoghurt sold in Maiduguri markets was between 4.68 and 5.15 log₁₀ CFU/mL with overall mean of 4.95 log₁₀ CFU/mL, while 20% of the samples had a total bacterial load of ≥4.6 log₁₀CFU/mL, which did not conform to Standards Organisation of Nigeria (SON) criteria. The highest total bacteria load was found in Baga Road Market (5.15 log₁₀ CFU/mL), while the lowest total bacteria load was in Milk Shop (4.68 log₁₀ CFU/mL), indicating that there were likely to be effects due to location based on the quality of the dairy handling and storage at those locations.

The mean total bacterial counts (TBC) values in the present study were higher than observed in Oman for pasteurized milk that had been displayed for sale and was nearing end of shelf life (<1 CFU/mL) (Al-Farsi *et al.*, 2021), but lower than the counts for raw milk in Sudan before the process of pasteurization (5.02 log₁₀ CFU/mL) (Osman *et al.*, 2020). Oluchi *et al.* (2022) also demonstrated that unpackaged milk had a higher bacterial load in Ethiopia, which could reflect the impact of packaging and regulated processing on bacterial load. In comparison to Khartoum where TBC values (counts) would reach up to 5.25 log₁₀ CFU/mL as a result of post pasteurization contamination (Osman *et al.*, 2020), our TBC values were slightly less as this could be due to on-farm hygiene variations in production and maintenance of the cold chain.

Coliform counts were found to be an average of 0.85 log₁₀CFU/mL in pasteurized milk, and 0.78 log₁₀CFU/mL in yoghurt both of which exceeded the SON and Codex Alimentarius guidelines for pasteurized dairy products of ≤ 1.0 log₁₀CFU/mL. These coliform counts are comparable to reports from Sudan, which show mean coliform counts in stirred yoghurt



of $0.66 \log_{10}$ CFU/mL at mixing but were below detection limits after processing (Osman *et al.*, 2020). However, reports from Nigeria (Nnenna & Nneka, 2021) and Ghana (Akindele *et al.*, 2024), accompanied by higher counts, from market-sold commercial yoghurt through mishandling after processing and temperature abuse of storage. When employed as an indicator of fecal contamination, *Escherichia coli* was absent from all samples. This finding aligns with the results reported from Jabalpur, India, where no *E. coli* was absent in pasteurized milk (Tripathi and Sarkar, 2020), as well as in Oman (Al-Farsi *et al.*, 2021), where it was determined that effective pasteurization and hygienic packaging effectively prevented its occurrence. Furthermore, the absence of pathogenic *E. coli* O157:H7 was also consistent with findings in packaged milk from Egypt (Meshref *et al.*, 2024) and Sudan (Osman *et al.*, 2020), as opposed to the high prevalence of fecal contamination in raw milk reported in studies conducted in Nigeria and Ethiopia, which was associated with the use of unclean water and fecal contamination issues related to poor sanitation and hygiene at the farm level (Oluchi *et al.*, 2022; Tadesse *et al.*, 2025).

No *Staphylococcus aureus* was identified in any of the 100 examined samples, complying with SON requirements (<100 CFU/mL) and favorably compared with detection rates of 2 – 3.6% in pasteurized milk from Turkey (Taban *et al.*, 2021) and Nigeria (Oludairo *et al.*, 2020). This indicates the successful elimination of *S. aureus* during processing and minimal post-pasteurization contamination resulting from handlers or equipment.

The statistically significant difference in total bacterial counts (TBC) between the market locations, ($p < 0.001$) the lowest being Milk Shop at $4.68 \log_{10}$ CFU/mL and the highest being Baga road market at $5.15 \log_{10}$ CFU/mL and Abbaganaram market at $5.12 \log_{10}$ CFU/mL show the importance of retail storage conditions and turnover rates as it relates to remained microbial load at point of sale. In addition, there was no statistically significant difference in coliform levels between milk and yoghurt ($p = 0.384$), indicating that both products pose similar levels of contamination risks. Additionally, data from Ghana, which showed no product-type effect on the prevalence of coliforms, further support this observation (Akindele *et al.*, 2024).

From a public health perspective, the observed levels of total bacterial counts (TBC) and coliforms were low relative to raw milk data, underscoring the susceptibility of pasteurized products to post-processing contamination from environmental sources. Pasteurization is not intended to make products sterile; it can be effective against pathogens but does not render the finished products sterile, as previously mentioned by Osman *et al.* (2020).

Considering the significance of milk and yoghurt as commonly eaten foods in Maiduguri, the potential benefits for population health, especially for vulnerable groups (children, pregnant women, immune-compromised individuals) from slight improvements in



microbial quality, would be substantial. The study did not account for milk handling and storage, which could also impact microbial patterns. Future research that includes these factors would enhance the risk assessment and management strategies.

CONCLUSIONS

Bacteriological analysis confirmed the absence of pathogenic microorganisms, ensuring safety for consumption. Bacterial concentrations varied significantly across markets, likely due to non-standardized pasteurization equipment, challenging quality consistency and contamination source identification. While fecal coliforms (including *E. coli*) were absent, total coliform counts remained elevated. Improved hygiene practices are essential for safe raw milk production. Developing rapid microbial detection methods would enhance quality control, alongside regular monitoring and vendor training. These findings revealed post-pasteurization hygiene lapses despite pathogen-free products, necessitating regulatory enforcement of stricter practices throughout Maiduguri's dairy supply chain.

Ethics Declarations

Ethical approval and participant consent were not applicable for this study.

Competing Interests

The authors declare that they do not have any competing interests.

Consent for publication

All authors approved the submission of this manuscript for publication.

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