Published by

British Journal of Contemporary Research

BEXFORD PUBLISHING

Microbiological Quality and Public Health Risk Assessment of Commercially Processed Milk Sold in Ilorin Metropolis, North Central Nigeria

Original Research Article | Volume 1 | Issue 3 | 2026 | Article Number: 069

Accepted: 01 August 2026 | Published: 10 August 2026 | ISSN: 2979-8582 (Online)

Crossref : **https://doi.org/10.67693/BJCR-KXTNHQYU**

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Abstract

Processed milk is popular due to the nutritional benefits it provides, but it can be subject to microbial contamination during processing, packaging, storage and distribution, which could cause potential health risks to the public. This study evaluated the microbiological quality of milk products marketed in the Ilorin metropolis of Kwara state, Nigeria, which is commercially processed. Specifically, the study identified the presence of bacteria and their morphology and Gram stain. An experimental design method of laboratory type was used. Standard microbiological methods were used to determine the composition of two retail milk samples that were commercially processed. Bacterial isolation was done in nutrient Agar and MacConkey Agar both under aerobic and anaerobic conditions. Pure isolates were identified on the basis of their Gram reaction and cellular morphology by Gram staining and microscopic examination. Overall, seven isolates of bacteria were recovered in the analysis. Three (42.9%) were Gram-positive, three (42.9%) were Gram-negative and one (14.2%) could not be conclusively classified by Gram staining. Gram-positive isolates were found mainly on MacConkey Agar under aerobic conditions, and were in the form of clustered cocci and short cocci and long rod. The gram-negative isolates were principally found on Nutrient Agar, both aerobically and anaerobically, and were generally described as short rods and clusters of cells. Both Gram positive and Gram negative bacteria were detected suggesting that processed milk products sold inside the study area are still prone to microbial contamination even after processing. Based on the study, it is concluded that substandard hygienic practices in the processing, packaging, transportation and retailing of commercially processed milk can affect the microbiological quality of such milk. To enhance the safety of processed milk and minimize potential public health risks, it is recommended that there is regular microbiological surveillance, good manufacturing practices, improved storage conditions and strengthened regulatory monitoring. Enumeration of microorganisms and biochemical identification and molecular techniques should be included in future studies in order to achieve a comprehensive characterization of the bacterial isolates.

Keywords: Processed Milk, Microbial Contamination, Gram-Positive Bacteria, Gram-Negative Bacteria, Food Safety

1. INTRODUCTION

Milk is a vital food for man as it contains protein, fat, calcium, vitamins and other nutrients essential for growth and development. It is used as fresh, pasteurised, sterilised, powdered and fermented. Processed milk is easily available in Nigeria via supermarkets, retail outlets and open markets. Because of its high nutrient level and near neutral pH, however, it is conducive to the growth of microorganisms under sub-optimal processing, storage, and handling conditions (Martin et al., 2023).

Pasteurisation, sterilisation and drying are processing techniques used to minimize microbial numbers and increase the shelf life. However, there is still a risk of processed milk being contaminated by inadequate heat treatment, resistant organisms surviving or contamination after processing. Packaging, transportation, storage, reconstitution and retail handling may lead to contamination, particularly by use of contaminated water, equipment, surfaces and packaging materials (Mogotu et al., 2022).

Microbial contaminants of milk are the presence of bacteria, yeasts and molds in milk. Escherichia coli, Staphylococcus aureus, Bacillus cereus, Salmonella species and Listeria monocytogenes are common bacterial organisms associated with milk products. Fungi contaminants can be Aspergillus spp., Penicillium spp., and Candida spp. These organisms can lead to spoilage, shorten the shelf life of milk, change the taste, smell and color of milk. Some will also release toxins or cause food poisoning, especially in children, pregnant women, elderly, and persons with immune deficiency.

Foodborne diseases continue to be a significant public health challenge, especially in low and middle-income countries. Pathogens from food products can cause many illnesses and pathogens in milk can survive the refrigeration process, as well as forming biofilms or being able to persist on processing equipment (World Health Organization, 2024). Oluwafemi et al. (2023) reported L. monocytogenes in various dairy products in Africa such as pasteurised milk and powdered milk, indicating that processed milk products may also be a microbiological risk.

Hygiene during production and distribution has an impact on the safety of the milk. Microbial contamination can be increased by poor hand washing, contaminated containers, failure to clean equipment properly, contact with dust, and long storage and no refrigeration. Deddefo et al (2023) found that environmental and hygiene related practices were significant factors in the contamination of milk with bacteria. Similarly, in their study, Mogotu et al. (2022) reported that all the distribution channels of milk had lower microbial quality due to poor hygiene and inadequate cooling facilities.

Microbial contamination of milk products has also been found in studies done in Nigeria. Ezugwu and Agbakoba (2021) reported the presence of bacterial contamination in cow milk sold in Nnewi, while Ghali-Mohammed et al. (2023) found the presence of toxigenic and antimicrobial resistant E. coli O157 in sold cow milk in Kwara State. Some of these investigations were conducted on raw milk products, but the results are still applicable since processed milk products can be contaminated by raw materials, water, packaging or post processing handling.

The market for locally produced and imported milk products in the Ilorin metropolis is growing, both in the formal and informal sector. They may be affected by their microbiological quality by differences in storage temperature, packaging integrity, hygiene and environmental exposure. But recent information about bacteria and fungi in processed milk sold in the metropolis is still scarce.

Thus, microbiological assessment is required to ensure the safety and quality of processed milk provided to the consumers. The microbial quality of commercially processed milk available in the metropolis of Ilorin was evaluated for the presence of bacteria and fungi with a view to characterising the microorganisms detected. The results should help with food safety monitoring and better handling, storage and regulatory practices.

2. LITERATURE REVIEW

2.1 Microbiological Quality of Processed Milk

Microbiological quality refers to the presence of the microorganisms in the milk and reflects the quality of production, processing, storage and handling. Milk is a medium that promotes the growth of microbes due to its content of water, proteins, carbohydrates, fats, minerals and vitamins. Freshly obtained milk can have a relatively low number of microorganisms, but can be contaminated from the animal, water, soil, handling, processing equipment and production area. The microbial quality of raw milk is of special interest because it can affect the quality and shelf life of the processed milk product (Martin et al. 2023).

Processed milk refers to pasteurized, sterilized, ultra-high-temperature-treated (UHT), evaporated and powdered milk. Thermal processing will kill vegetative microorganisms, however, may not kill heat-resistant enzymes or bacterial spores. Psychotropic bacteria may also multiply during refrigerated storage and generate enzymes which survive heat treatment. Some bacteria, such as the genus Bacillus, are able to survive processing and then return to their vegetative state when conditions are favorable. So, the microbial quality of processed milk is determined by the quality of the raw milk used as well as by the prevention of contamination after processing (Martin et al., 2023).

Microbial counts are frequently used as an indicator of milk quality. High total viable counts are generally associated with poor sanitation, inappropriate processing or storage conditions. Coliform bacteria are commonly employed as a measure of water, equipment or unhygienic handling contamination. But the interpretation of the microbial counts must take into account the type of milk, processing method, packaging system and storage period.

2.2 Sources and Routes of Microbial Contamination

There are multiple points of potential microbial contamination in the dairy production and distribution system. Microorganisms can be introduced into milk before processing from infected udders, animal skin, faecal matter, feed, soil and contaminated water. When cleaning and disinfecting are not thorough, milking equipment, storage tanks and transportation containers can also serve as reservoirs. According to Martin et al. (2023), environmental sources and contaminated equipment are significant sources of bacteria in milk for processing.

Post-processing contamination may be particularly serious because it can add organisms to products that may have been subjected to microbial reduction during processing. This can be due to inadequate filling equipment sanitation, packaging defects, contaminated surfaces or poor handling. Biofilms can grow on processing equipment, making it difficult to clean the equipment and causing microorganisms to be continuously released into milk products.

Microbial quality may be affected by other conditions in retail and storage environments. High temperatures, dust, moisture, torn packaging and multiple handling can promote contamination or microbial multiplication. Microbial growth is more likely to occur in many developing environments if there is insufficient refrigeration or a failure in the cold chain. Some hygiene factors, environmental factors, and cleanliness of surfaces that come in contact with milk were found to be significant factors in bacterial contamination by Deddefo et al. (2023). This means milk safety should be ensured throughout the milk processing, milk transport and milk retailing, and at the household level, not just at the milk production stage.

2.3 Milk Contaminated with Bacterial Organisms

Processed milk can be contaminated with both gram positive and gram negative bacteria. Significant Gram-positive organisms are Staphylococcus aureus, Bacillus cereus, and lactic acid bacteria and Bacillus spp. that form spores. S. aureus can be introduced into milk via contaminated equipment, handlers and infected animals. Some strains are capable of producing enterotoxins that are resistant to heat (heat-stable enterotoxins), so may be present in the product even after the bacterial cells have been destroyed.

Bacillus species are significant because they have spores that can endure adverse environmental conditions and some types of heat. They can grow causing undesirable flavors, coagulation and shorten shelf life. It is important to note, therefore, that the presence of Gram-positive rods in processed milk could be a sign of spore-forming bacteria presence or a post-processing cross-contamination.

Another organism of public health importance is Listeria monocytogenes, which can grow at refrigeration temperatures and survive in the dairy-processing environment. A systematic review conducted by Oluwafemi et al. (2023) showed that L. monocytogenes was present in various milk products in Africa, such as raw, pasteurised and powdered milk. This indicates that even if sanitation, packaging and storage controls are not adequate, processing does not eliminate risk completely.

The microorganism contaminants of milk are gram-negative bacteria such as *Escherichia coli, Salmonella, Klebsiella*, Pseudomonas and other *Enterobacteriaceae.* Occurrence of E.coli or coliforms could be associated with faecal contamination, contaminated water or lack of good hygiene. Pseudomonas spp. are mainly spoilage organisms but are significant due to the fact that some species grow at refrigeration and produce heat-resistant proteolytic and lipolytic enzymes. These enzymes may also continue to act on milk proteins and fats during processing, causing bitterness, rancidity and decreased shelf stability.

Ghali-Mohammed et al. (2023) isolated *E. coli* O157 from market raw cow milk in Kwara State and reported toxigenic and antimicrobial resistant isolates. Processed milk is treated even more, but the same organisms could be introduced in the dairy supply chain because of contaminated raw milk or unhygienic practices during post processing.

2.4 Fungal Contamination of Milk Products

Milk products have yeast and moulds as significant spoilage and/or unsuitable storage indicators. Contamination can happen via the air, dust, contaminated packing materials, processing equipment or from extended exposure after opening. Fungi are a special threat to powdered milk when it is not sealed properly or stored in damp or humid conditions as the moisture allows the fungi to grow.

Aspergillus, Penicillium, Mucor, Rhizopus and Candida spp are common types of fungi that have been found as contaminants of milk and dairy products. Yeasts can lead to fermentation reactions, production of gases and undesirable taste, whereas moulds can lead to discoloration, changes in odour and product spoilage. Some species of mould can produce mycotoxins, however the amount of toxin produced is dependent on the type of mould, the temperature, humidity, substrate and length of storage.

Fungal counts can thus help assess the quality of the storage and packaging. If they are found in processed milk, it is likely that the milk was exposed to moisture or the sanitary conditions were inadequate or that the milk was stored for too long under unsuitable conditions. Culture and morphological examination is essential for reliable identification of fungi, and molecular techniques can give a more precise species-level confirmation.

2.5 Health Implications of Contaminated Milk

Milk that is contaminated may spread food-borne pathogens and may make its way into the consumer's body and cause them to ingest bacterial toxins or fungal metabolites. Clinical manifestations may involve diarrhoea, vomiting, abdominal discomfort and fever and serious infections in children, pregnant women, older people and those with impaired immunity. Unsafe foods pose a significant health risk and can lead to over 200 diseases worldwide (WHO, 2024).

The presence of potentially antimicrobial resistant bacteria in milk is another concern. The resistant organisms can be spread to humans via the food chain, and resistance genes can be transferred to other bacteria. The link between milk hygiene and antimicrobial resistance was reported by Ghali-Mohammed et al. (2023) who reported antimicrobial resistance among E. coli O157 isolated from marketed milk in Kwara State.

Microbial contamination also has economic impacts. Spoilage contributes to a decreased shelf-life of the product, a consumer rejection and losses for the manufacturer or retailer. Therefore, maintaining microbiological quality is essential to ensure safety to consumers and to ensure that the dairy industry and public confidence in commercially produced milk products are not lost.

2.6 Control and Prevention of Milk Contamination

The whole dairy chain from animals to hygienic milk collection should be included in control measures. Equipment and contact surfaces should be regularly cleaned and disinfected and water used for cleaning and processing should be acceptable microbiological quality. Hygienic packaging is required to avoid recontamination, and the appropriate heating is necessary.

The temperature of storage is also very important. Liquid milk should be kept in the recommended cold chain and powdered milk should be stored in dry conditions and away from dampness. Retailers to check packaging for integrity, keep away from prolonged sun exposure and remove damaged and/or expired products from sale. Consumers should also store products as directed and not use products that have damaged seals, unusual odours or any visible signs of deterioration.

Hazard Analysis and Critical Control Point (HACCP) systems can be used to identify and control hazards during critical stages of food production. Microbiological monitoring and compliance with regulatory requirements and training of food handlers are also important. Tarrah et al. (2024) highlighted the importance of considering microbial contamination, antimicrobial resistance, and environmental conditions throughout the dairy production process to ensure milk safety.

2.7 Research Gap

The available studies have proven that milk may contain microorganisms that can cause spoilage, foodborne pathogens and antimicrobial resistant microorganisms. But most of the recent findings in Nigeria and other African countries have focussed on raw milk, fermented milk and/or informal dairy production. There is limited current evidence available about the microbiological quality of commercially processed milk brands available to the population in retail outlets of the Ilorin metropolis.

Moreover, some studies have already been conducted on identifying organisms, while others have not looked at the presence of both bacteria and fungi under various cultural conditions. Thus local evidence is needed to establish the microbial properties of processed milk that is made available to consumers in Ilorin. To fill this gap, the present study examined bacterial and fungal contamination and characterised the microbial isolates from commercially processed milk sold in the metropolis of Ilorin.

3. MATERIALS AND METHODS

3.1 Study Design and Location

The microbiological quality of processed milk samples collected in Ilorin metropolis, Kwara state, Nigeria was evaluated in this laboratory experimental study. Bacteria were isolated and preliminary characteristics under aerobic and anaerobic conditions were analyzed. The workflow is illustrated on Fig 1.

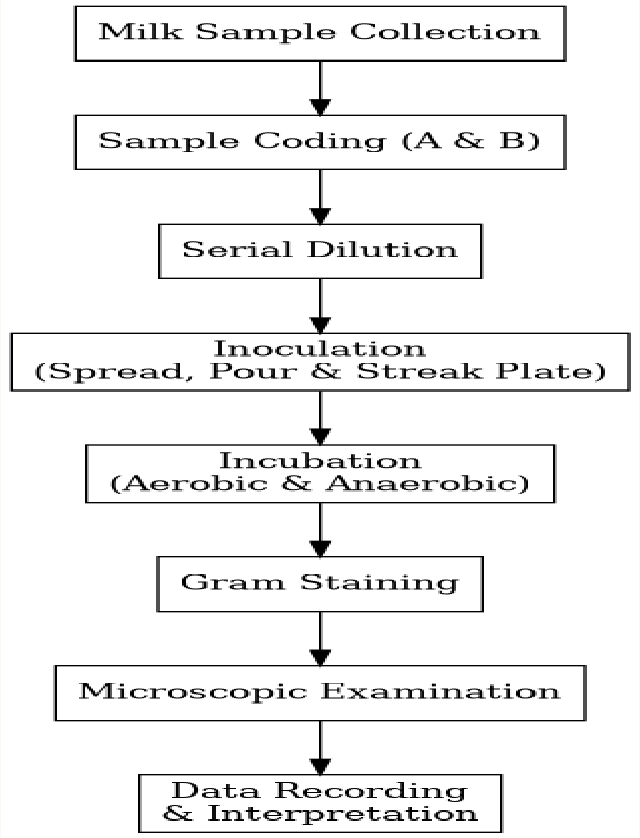

Figure 1. **Workflow for the Microbiological Analysis of Processed Milk Samples**

3.2 Sample Collection and Identification

Two retail processed milk samples were collected in the metropolis of Ilorin. All samples were picked up in the sample containers and were analysed immediately to reduce alteration of the microbial composition. For uniformity in the laboratory analysis, they were labeled as Sample A and Sample B.

3.3 Materials, Media and Reagents

Materials used were: sterile Petri dishes, test tubes, conical flasks, beakers, sterile syringes, inoculating loop, glass slides, cotton wool, aluminium foil, paper tape and distilled water. Other equipment consisted of a microscope, spirit lamp, hot-air oven and autoclave.

General bacterial organisms were cultured on Nutrient Agar and gram-negative enteric bacteria were cultured, isolated and differentiated on MacConkey Agar. For Gram staining crystal violet, iodine solution, ethanol and safranin were used. Culture media and reagents were prepared as per manufacturers' instructions.

3.4 Aseptic Procedures and Sterilization

The glassware was washed, dried, wrapped in aluminium foil and sterilised in a hot-air oven for 30 minutes at 160°C. All culture media and other heat-stable materials were sterilised by autoclave at 121ºC for 15 minutes. 70% ethanol was used to disinfect work surfaces prior to and after analysis. A spirit lamp was lit to minimize the chances for environmental contamination during inoculation.

3.5 Preparation of Culture Media

The nutrient agar was made by adding 7 g of dehydrated nutrient agar to 250 mL distilled water. MacConkey Agar was made at the concentration indicated by the manufacturer. All media were stirred and heated until they were completely dissolved and then sterilised at 121°C for 15 minutes.

Media after autoclaving were cooled down to ~ 45-50°C before being poured aseptically into sterile Petri dishes. These plates were allowed to solidify and were labeled based on the sample, culture medium and incubation condition.

3.6 Samples Preparation and Serial Dilutions

All the milk samples were shaken well before analysis. Withdrawn aseptically in sterile syringes and serially diluted with sterile distilled water and measured volumes were withdrawn. To get countable and well-isolated colonies on the culture plates, the microbial concentration was reduced by serial dilution.

3.7 Inoculation of Milk Samples

Spread-plate, pour-plate and streak-plate techniques were used to inoculate the milk samples. In the spread-plate method, 0.1 mL of the diluted milk sample was spread on the surface of solidified nutrient and macconkey agars, and distributed evenly using a sterile spreader.

1 mL of the diluted sample was added to a sterile Petri dish and then the molten agar was poured into the dish at a temperature of about 45°C for the pour-plate method. The plate was slowly rotated so as to spread the inoculum evenly. The samples were streaked onto prepared agar plates using a sterile inoculating loop for the purpose of isolation of discrete colonies.

3.8 Incubation Conditions

Inoculated plates were incubated for 24-48 hrs at 37°C. Aerobic cultures were grown at room air. Sealed jars were used to create anaerobic conditions by reducing the amount of oxygen available by having a burning candle. Plates were then observed for microbial growth after incubation, to see how the bacteria grew and whether there were any differences between aerobic and anaerobic cultures.

3.9 Gram Staining and Microscopic Examination

Representative colonies were picked from the culture plates for Gram staining. A small amount of each colony was emulsified in a drop of sterile distilled water on a clean glass slide. The smear was allowed to air dry and heat fixed by running the slide quickly through the flame.

The fixed smear was stained with crystal violet for 1 minute, stained with iodine solution for about 30 seconds and decoloured with ethanol for about 10 seconds. Safranin was used as a counterstain for 1 minute. The slides were rinsed, air-dried and examined microscopically using the oil-immersion objective lens.

Purple stained cells were considered Gram-positive and pink or red cells were considered Gram-negative. The cellular morphology was described as cocci, short rods, long rods or clusters of organisms.

3.10 Identification and Presentation of Isolates

The bacterial isolates were preliminary identified based on their growth medium, incubation condition, Gram reaction and micro-morphology. Confirmatory biochemical or molecular tests were not performed and organisms were not identified to species level. Data was summarized with tables to indicate distribution and frequency of Gram-positive, Gram-negative and unclassified isolates.

3.11 Quality-Control Measures

All analyses were carried out with aseptic procedures. Inoculating loops were flame-sterilised prior to and after inoculation, and culture media were checked for sterility prior to inoculation. Sterile equipment was used for each sample to minimise cross-contamination. Culture plates and slides were correctly labeled for identification and results to be recorded.

4. RESULTS AND DISCUSSION

The morphological and Gram's characteristics of bacterial isolates were analyzed.Morphological and Gram's characterization of bacterial isolates were studied.

Table 1. The aim of this study was to determine the morphological and Gram characteristics of bacterial isolates recovered from samples of processed milk.This study was designed to find out the morphological and Gram characteristics of the bacterial isolates obtained from the samples of processed milk.

Table 1: **Morphological and Gram Characteristics of Bacterial Isolates Recovered from Processed Milk Samples**

Sample	Culture Medium	Incubation Condition	Gram Reaction	Cell Morphology
Milk Sample 13	MacConkey Agar	Aerobic	Gram-positive	Clustered cocci
Unidentified Sample A	MacConkey Agar	Aerobic	Gram-positive	Long rods
Sample A	MacConkey Agar	Aerobic	Gram-positive	Short cocci
Sample A	MacConkey Agar	Anaerobic	Not determined	Short rods
Sample B	Nutrient Agar	Aerobic	Gram-negative	Clustered cells
Sample B	Nutrient Agar	Anaerobic	Gram-negative	Short rods
Milk Sample B	Nutrient Agar	Aerobic	Gram-negative	Short rods

The bacteriological examination revealed the presence of both gram-positive and gram-negative bacteria in the samples of processed milk analysed. Gram-positive isolates were mostly obtained from MacConkey Agar under aerobic conditions, and Gram-negative isolates were mostly obtained from Nutrient Agar under both aerobic and anaerobic conditions. Microbial diversity was observed in the milk samples with different morphology of cells such as cocci, short cocci, long rods and short rods. One anaerobic isolate was not reliably identified because it was not possible to differentiate based on Gram reaction, and required additional confirmatory identification using biochemical or molecular methods.

Presence of both Gram-positive and Gram-negative bacteria suggest that the bacteria may have been present prior to processing or during post processing handling. Commercial milk processing methods are effective in minimizing the number of microorganisms, but contamination can occur due to inadequate hygienic practices, defective packaging, contaminated equipment, during milk transportation or storage conditions. After thermal treatment, the milk may be contaminated with microorganisms, therefore post-pasteurization contamination is one of the major causes of loss of microbiological quality in commercially processed dairy products, which was explained by Martin et al. (2023).

The predominance of Gram-positive cocci and rod-shaped organisms suggests the possible occurrence of environmental contaminants such as Staphylococcus spp. and Bacillus spp. These bacteria are typically found in dairy products and dairy processing areas. The spores of Bacillus spp. are able to survive heat treatment and germinate during storage when the environmental conditions are favourable. Staphylococcus aureus can also be spread by food handlers or contaminated food processing equipment and has been implicated in food poisoning outbreaks due to enterotoxin production (Martin et al., 2023).

The Gram-negative isolates found in the present study could be members of the Enterobacteriaceae family such as Escherichia coli and Klebsiella species that are commonly associated with poor sanitary conditions. Species level identification was not attempted in this investigation but the presence of Gram negative rods usually indicates contamination from water, processing equipment or handling practices. Ghali-Mohammed et al. (2023) similarly reported the occurrence of E. coli O157 in marketed milk in Kwara State and highlighted concerns regarding contamination within the dairy production chain.

The recovery of bacterial isolates under both aerobic and anaerobic conditions further demonstrates the ability of different microorganisms to survive under varying environmental conditions. Facultative bacteria are bacteria usually found in milk that can grow in the presence or absence of oxygen, and thus can increase the likelihood of milk spoilage during storage. The unclassified anaerobic isolate found in this study may be due to staining failure, mixed cultures and/or the early microscopic diagnosis. Complementary biochemical and molecular analyses are important as similar observations have been reported where Gram staining alone failed to provide definitive identification of bacterial species.

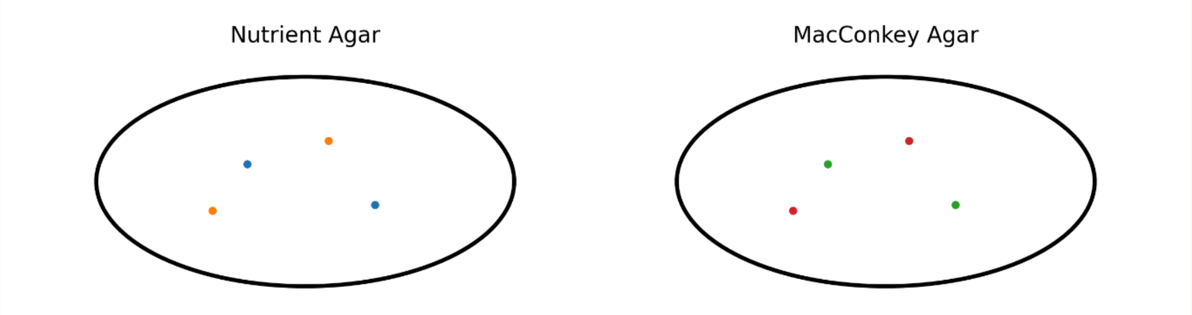

Figure 2: Culture Plate Illustration

Figure 2 illustrates the culture media used for bacterial isolation. Nutrient Agar was used as a general-purpose medium for the growth of a wide range of bacteria, while MacConkey Agar was used as a selective and differential medium for Gram-negative enteric organisms. The illustration supports the description of the culture procedures but should not be interpreted as an actual photograph of the experimental plates.

4.2 Distribution of Gram Reaction Among the Isolates

Table 2. Frequency Distribution of Gram Reactions

Gram Reaction	Frequency	Percentage (%)
Gram-positive	3	42.9
Gram-negative	3	42.9
Not determined	1	14.2

Gram Reaction	Frequency	Percentage (%)
Total	**7**	**100.0**

The distribution of bacterial isolates was 42.9% Gram positive and 42.9% Gram negative with one isolate (14.2%) not identified after Gram staining. This distribution indicates that both groups of bacteria play a significant role in the microbial contamination of processed milk in the study area.

The almost equal distribution of Gram positive and Gram negative bacteria is indicative of the complex microbiological ecology of processed milk. Gram-positive bacteria are more likely to be found in the environment, on equipment surfaces, and in spore-forming organisms, while Gram-negative bacteria are more likely to be found in water, poor sanitation and/or inadequate handling practices. In addition to the processing efficiencies, the quality of milk is also affected by environmental hygiene practices which have been maintained during milk production, packaging and distribution, Martin et al. (2023).

It is important to consider the presence of Gram – negative bacteria because some of these are indicators of poor hygienic conditions. Their presence indicates that there is a potential problem in sanitary or post-processing handling in the plant, which can pose a health risk to consumers. Likewise, if Gram-positive organisms are found, it could be due to the presence of heat-resistant spores or contamination post-processing. The present study results support the findings of Oluwafemi et al. (2023) who stated that processed dairy products can still be contaminated with microorganisms in the storage and distribution phase if the product is contaminated during industrial heat treatment.

Figure 3: Gram-Stained Bacterial Morphologies During Microscopic Examination

Figure 3 shows the basic microscopic appearances of Gram-positive and Gram-negative bacterial cells. Gram-positive organisms retain the primary crystal violet stain, while Gram-negative organisms take up the counterstain after decolorizations. The figure supports the interpretation of the isolates based on Gram reaction and morphology, including cocci and rod-shaped cells. As this is an illustration, it does not represent the actual microscopic fields obtained during the study.

4.3 Importance of Public Health

The variety of bacteria found in the samples of processed milk illustrates that even when good food hygiene is not observed, commercially available milk can be a vehicle for the spread of microbes. While preliminary bacteriological characterisation was carried out in the present study, the presence of both Gram-positive and Gram-negative bacteria suggests the possibility of food safety issues, which need to be monitored regularly.

The consumption of contaminated milk may lead to gastrointestinal infections which may affect children, elderly, pregnant women and immunocompromised people. The World Health Organization (2024) classifies contaminated food as a major contributor to preventable illnesses worldwide, and it is recommended to monitor dairy products for microbiological safety on a regular basis to reduce foodborne diseases.

The results also underscore the need to ensure proper sanitation practices during milk production, packaging, transport and retail distribution. Food handlers should continue to follow good manufacturing and hygienic practices, and the regulatory bodies should enhance their routine inspections of dairy products in retail outlets. Future studies would require total viable bacterial count, fungal count, biochemical characterization and molecular identification of isolates to have a better understanding of the microbiological quality of processed milk.

5. CONCLUSION

The study revealed both Gram-positive and Gram-negative bacteria in the processed milk samples sold in the study area (Ilorin metropolis). All the isolates exhibited varying cell shapes both under aerobic and anaerobic conditions, such as cocci and rods. The equal distribution of Gram-positive and Gram-negative isolates indicates that the contamination could be from several origins such as inadequate processing, environmental exposure, poor handling, contaminated equipment, damaged packaging and unsuitable storage conditions.

The presence of the organisms, which were not identified to species level, indicates that the microbiological quality and safety of the milk products analyzed is of concern. The results thus suggest that milk safety is not assured by processing alone, if hygienic control is inadequate at the stage of packaging, transport, retail and storage. Microbiological monitoring is required routinely to ensure the safety of the consumer and consumer confidence in commercially processed milk products.

5.1 Recommendations

Milk producers should ensure that hygienic controls are put in place during milk processing, packaging and distribution to reduce post-processing contamination. Equipment, containers and work surfaces should be cleaned and disinfected as appropriate and packaging materials checked for damage before sold.

Processed milk should be kept at the recommended temperature and humidity, protected from dust and sunlight and should be withdrawn from sale if damaged or past the expiration date. Microbiological testing of milk products sold in supermarkets, retail shops and open markets in the Ilorin metropolis should be carried out occasionally by the regulatory agencies and regular inspection of milk products in the supermarket, retail shops and open markets in the area by regulatory agencies should also be carried out.

It is important to provide continuous training for food handlers and vendors on personal hygiene, safe storage and proper handling of dairy products. Consumers should also be urged to check the packaging for any signs of damage and the expiration date and instructions for storage prior to buying and eating milk products.

Further research is needed on a greater number of milk brands and retail outlets. They should also contain total bacterial and fungal counts, biochemical identification, susceptibility testing of isolates to antimicrobial agents, and molecular confirmation of isolates. The additional analyses would yield more conclusive information to determine the organisms present and their possible public health importance.

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