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Research Article

Bacteriological Quality and Bacterial Contaminants of Foreign and Exotic Apples Sold in Port Harcourt, Nigeria

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Abstract

Apples are widely consumed because of their nutritional value and availability, but they may become contaminated with bacteria during cultivation, transportation, storage, handling, and marketing. This study assessed the bacteriological quality and bacterial contaminants of foreign and exotic apples sold in selected fruit markets in Port Harcourt Metropolis, Rivers State, Nigeria. A laboratory-based cross-sectional study was conducted between July and December 2025. Sixteen (16) apple samples were collected from Kaduna Street Fruit Garden Market and Ogbunabali Fruit Market, with samples comprising foreign and exotic apples. The samples were analyzed for total heterotrophic bacterial count using standard microbiological procedures. Bacterial isolates were obtained by culture and identified based on cultural and morphological characteristics, Gram staining, and biochemical tests. The results showed that, at Station 1, the foreign apples recorded a bacterial load of (1.5×10^4 cfu/g), while the Exotic apples had a higher count of (2.8×10^4 cfu/g). A similar trend was observed at Station 2, where the foreign apples had the lowest microbial load of (8×10^3 cfu/g), whereas the Exotic apples maintained a relatively high count of (1.8×10^4 cfu/g). Exotic apples generally had higher bacterial loads than foreign apples across the two sampling stations. The bacterial isolates recovered from the samples included Staphylococcus spp., Bacillus spp., Klebsiella spp., and Lactobacillus spp. Staphylococcus spp. were the most frequently isolated organisms, followed by Lactobacillus spp., Bacillus spp., and Klebsiella spp. The presence of these bacterial groups indicates that apples sold in the selected markets may be exposed to contamination from human handling, environmental sources, and market conditions. The findings show that both foreign and exotic apples sold in Port Harcourt may carry bacterial contaminants, with exotic apples generally showing higher bacterial loads. Improved hygiene during handling, transportation, storage, and marketing, together with proper washing of apples before consumption, is recommended to reduce the risk of bacterial exposure among consumers.

Keywords

Apples, Bacterial Contamination, Total Heterotrophic Bacterial Count, Staphylococcus Spp., Bacillus Spp., Klebsiella Spp., Food Safety, Nigeria

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1. Introduction

Fruits are important components of the human diet because they provide vitamins, minerals, dietary fibre, and other nutrients needed for normal growth and health. Fresh fruits are commonly consumed because they are readily available and are often eaten without further processing. However, the same characteristics that make fresh fruits desirable may also increase food safety concerns, particularly when they are consumed raw or with minimal washing. Fresh produce can become contaminated with microorganisms at different stages, including cultivation, harvesting, transportation, storage, handling, and marketing [1, 2].

Apples (*Malus domestica*) are among the commonly consumed fruits worldwide and are widely available in many urban markets. They are usually consumed fresh, and in many cases, the peel is eaten together with the flesh. This creates an important food safety concern because microorganisms present on the surface of the fruit may be transferred directly to consumers when the fruits are not properly washed before consumption [3, 4]. Although the surface of apples may appear clean, microorganisms can remain attached to the peel and may survive during transportation, storage, and marketing.

The bacterial quality of fresh fruits is influenced by several factors. During production, fruits may come into contact with bacteria from soil, irrigation water, manure, animals, insects, and the surrounding environment. Contamination may also occur after harvest through contact with contaminated containers, water, equipment, and human hands [5, 6]. During transportation and marketing, repeated handling and exposure to dust and other environmental materials may further increase the bacterial load of fruits. Physical damage to the fruit surface may also create favourable sites for bacterial attachment and survival [7, 8]. Total heterotrophic bacterial count is commonly used to assess the general bacteriological quality of food and environmental samples. Although a high heterotrophic bacterial count does not necessarily indicate the presence of a specific pathogen, it may suggest poor sanitary conditions, improper handling, inadequate storage, or contamination from different sources [8, 9]. The enumeration of heterotrophic bacteria can therefore provide useful information on the microbiological condition of fresh fruits and the level of exposure to bacterial contamination before they reach consumers.

Different bacterial species have been isolated from fresh fruits and vegetables. These include members of the genera *Bacillus*, *Staphylococcus*, *Pseudomonas*, *Enterobacter*, *Klebsiella*, *Escherichia*, and *Salmonella*, among others [9-11]. Some of these bacteria are part of the natural microbial population associated with plants and the environment, while others may indicate contamination from soil, water, animals, or human handling. The presence of potentially pathogenic bacteria on ready-to-eat fruits is of public health concern because such fruits may be consumed without adequate washing or any form of heat treatment capable of reducing bacterial contamination [12, 13].

Bacterial contamination of fruits may occur at several points along the supply chain. Contaminated irrigation water and organic fertilizers can introduce microorganisms during cultivation, while poor hygienic practices during harvesting and postharvest handling may increase contamination [13, 14]. In addition, storage conditions can affect the survival and multiplication of bacteria. Temperature, moisture, duration of storage, and physical damage to fruits may influence bacterial growth and overall fruit quality [15]. Apples imported from other countries may also pass through extended periods of transportation, storage, and distribution before reaching retail markets, creating additional opportunities for contamination if appropriate hygienic and storage conditions are not maintained.

In Nigeria, apples are commonly sold in open markets, supermarkets, roadside stalls, and other retail outlets. The conditions under which these fruits are displayed may vary considerably. Fruits displayed in open environments may be exposed to dust, repeated handling by vendors and prospective buyers, contaminated surfaces, and other environmental sources of microorganisms. In Port Harcourt, these concerns may be more pronounced because of the busy commercial activities, heavy traffic, and environmental conditions within the metropolis. Inadequate storage facilities and poor handling practices may further affect the microbiological quality of fruits sold to consumers.

The increasing availability of locally produced or Exotic apples alongside imported apples has also created the need to examine whether differences exist in their bacteriological quality. Consumers may make assumptions about the safety and quality of fruits based on their source or appearance. However, the bacteriological condition of a fruit is not always evident from its physical appearance [16]. Both foreign and Exotic apples may be exposed to bacterial contamination through different routes before they are purchased and consumed [17-19].

Previous studies have reported bacterial contamination of different fresh fruits and vegetables, demonstrating the importance of microbiological assessment of ready-to-eat produce [10, 20, 21]. However, information on the comparative bacteriological quality of foreign and Exotic apples sold in Port Harcourt remains limited. There is also a need to identify and characterize bacteria associated with these apples in order to provide information on the types of organisms to which consumers may be exposed.

This study was therefore undertaken to assess the bacteriological quality and bacterial contaminants of foreign and Exotic apples sold in selected fruit markets in Port Harcourt, Nigeria. Specifically, the study determined the total hetero-

trophic bacterial count of the apple samples and isolated, identified, and characterized bacteria associated with foreign and Exotic apples. The findings will provide information on the microbiological quality of apples available to consumers and may contribute to improved food hygiene practices, consumer awareness, and monitoring of fresh fruits sold within the study area.

2. Materials and Methods

2.1. Study Area

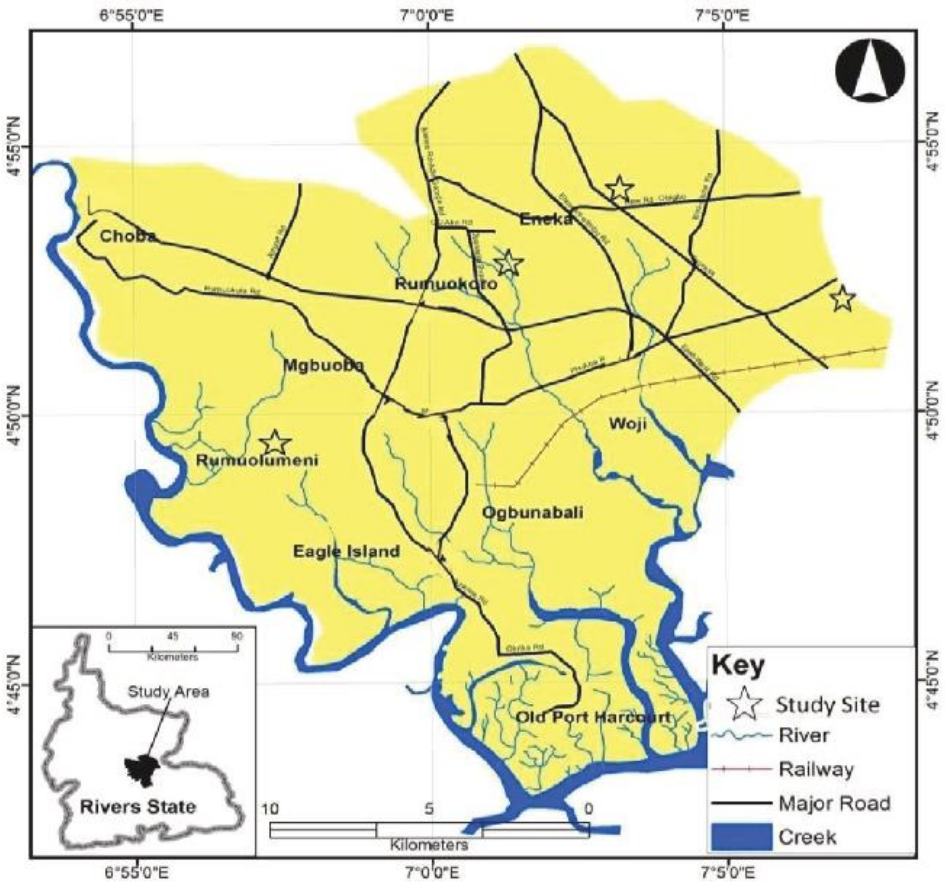

Figure 1. Map of Port Harcourt Metropolis showing study locations.

The study was conducted in Port Harcourt metropolis, Rivers State, Nigeria, located in the Niger Delta region at approximately 4.8472 ° N and 6.9746 ° E. Port Harcourt is a major commercial city with active markets involved in the distribution and sale of different agricultural products, including fresh fruits. Apple samples were obtained from two fruit markets within the metropolis: Kaduna Street Fruit Garden Market and Ogbunabali Fruit Market. The markets were selected because both foreign and Exotic apples were available for sale at the time of the study.

2.2. Study Design and Sample Collection

A laboratory-based cross-sectional study was carried out between July and December 2025. Sixteen apple samples were purchased from the two selected markets. Eight samples were collected from each market, comprising four foreign apples and four Exotic apples.

Disposable gloves were used during sample collection to reduce the risk of contamination. Each apple was placed separately in a sterile polythene bag and labelled according to the market, apple type, date of collection, and sample code. The samples were transported to the laboratory in an insulated ice box. Laboratory analysis was carried out within 24 hours of collection. Where immediate processing was not possible, the samples were stored at 4 ℃ until analysis.

2.3. Bacteriological Analysis

The bacteriological analysis was conducted to determine

the total heterotrophic bacterial count and identify bacterial contaminants associated with foreign and Exotic apples.

2.3.1. Sample Preparation

Each apple sample was aseptically handled, and approximately 25 g comprising portions of the peel and pulp was excised and transferred into a sterile stomacher bag containing 225 mL of sterile buffered peptone water (BPW). The samples were homogenized for 2-3 minutes to obtain the initial sample suspension.

2.3.2. Enumeration of Total Heterotrophic Bacteria

Tenfold serial dilutions of the homogenized samples were prepared using sterile buffered peptone water up to 10^{-5}. Aliquots of 0.1 mL from appropriate dilutions were inoculated onto sterile nutrient agar plates using the spread plate technique. The plates were incubated at 35 ±2 ℃ for 24-48 hours.

Following incubation, plates containing 30-300 colonies were selected for enumeration. The total heterotrophic bacterial count was expressed as colony-forming units per gram (CFU/g) using the formula:

$$\text{THBC (CFU/g)} = \frac{\text{(Number of colonies} \times \text{Dilution factor)}}{\text{Volume plated (mL)}} \quad (1)$$

2.4. Isolation of Bacteria

Colonies showing distinct cultural characteristics on nutrient agar were selected and sub-cultured onto fresh nutrient agar plates to obtain pure cultures. Repeated sub-culturing was carried out where necessary until pure isolates were obtained.

2.5. Identification and Characterization of Bacterial Isolates

The bacterial isolates were identified based on their cultural, morphological, and biochemical characteristics. Cultural characteristics, including colony appearance, were observed following incubation.

Morphological characterization included Gram reaction, cell shape, cellular arrangement, spore formation, and motility. Gram staining was performed on purified isolates, and the stained preparations were examined microscopically under oil immersion.

Further identification of the isolates was carried out using standard biochemical tests, including catalase, oxidase, coagulase, indole, and citrate utilization tests. The results obtained from the cultural, morphological, and biochemical characteristics were compared with standard identification guides to determine the probable identity of the bacterial isolates.

2.6. Study Variables

The main outcome measures were the total heterotrophic bacterial count and the types and frequency of bacterial isolates recovered from the apple samples. The isolates were characterized based on their cultural, morphological, and biochemical properties.

The main explanatory variables were apple type, categorized as foreign or Exotic, and sampling station.

2.7. Statistical Analysis

Data generated from the laboratory analysis were summarized using descriptive statistics. Total heterotrophic bacterial counts were expressed as colony-forming units per gram (CFU/g). The distribution of bacterial isolates across apple types and sampling stations was presented descriptively, while the overall occurrence of bacterial isolates was summarized using frequencies and percentages based on the total number of isolates recovered.

2.8. Quality Assurance

All laboratory procedures were carried out under aseptic conditions to reduce the possibility of external contamination. Sterile materials and culture media were used throughout the analysis, while media preparation and incubation were conducted according to standard laboratory procedures.

Serial dilutions and plating were carried out carefully, and countable plates containing 30-300 colonies were used for bacterial enumeration. Selected colonies were repeatedly sub-cultured to obtain pure isolates before identification and biochemical characterization. Where applicable, analyses were performed in duplicate or triplicate to improve the reliability of the findings.

2.9. Ethical Considerations

The study did not involve human participants or experimental animals. The apple samples were purchased from publicly accessible fruit markets, and no personal information was collected from the vendors. All laboratory procedures were conducted in accordance with standard laboratory safety practices.

3. Results

Table 1 presents the total heterotrophic bacterial count of apple samples. At Station 1, the foreign apples recorded a bacterial load of (1.5×10^4 cfu/g), while the Exotic apples had a higher count of (2.8×10^4 cfu/g). A similar trend was observed at Station 2, where the foreign apples had the lowest microbial load of (8×10^3 cfu/g), whereas the Exotic apples maintained a relatively high count of (1.8×10^4 cfu/g). The bacterial count on Exotic apples at Station 2 was therefore more than three times higher than that of the foreign apples. This consistency across both stations shows that Exotic apples generally carried a heavier microbial load than foreign apples, irrespective of

location.

Table 1. *Total Heterotrophic Bacterial Count of Apple Samples.*

Stations	Foreign Apples (cfu/g)	Exotic Apples (cfu/g)
Station 1	1.5×10^4	2.8×10^4
Station 2	8×10^3	1.8×10^4

Table 2 shows the bacteria isolated from apple samples. The bacterial isolates showed clear variations between the apple types and sampling stations. *Staphylococcus* sp appeared in all samples, making them the most consistently encountered organism on both foreign and Exotic apples across Stations 1 and 2. *Bacillus* sp were present on both apple types at Station 1 but were found only on the Exotic apples at Station 2. At Station 2, the foreign apples also contained *Klebsiella* sp, which were not detected in any other sample. The Exotic apples at Station 2 exhibited the highest variety of organisms, *Staphylococcus*, *Bacillus*, and *Lactobacillus* sp, showing a broader range of microbial presence compared to the foreign apples.

Table 2. *Bacteria Isolated from Apple Samples.*

Stations	Foreign Apples	ExoticApples
Station 1	*Staphylococcus* sp, Bacillus sp.	*Staphylococcus* sp, *Bacillus* sp
Station 2	Staphylococcus sp, Klebsiella sp	Staphylococcus sp, Bacillus sp, Lactobacillus sp

Table 3 shows the morphological characteristics of isolated organisms. The morphological characteristics of the isolated organisms showed distinct features that align with their expected taxonomic groups. *Staphylococcus* sp appeared as Gram-positive cocci arranged in clusters, producing creamy, circular colonies typical of the genus. *Bacillus* sp were identified as Gram-positive, rod-shaped bacteria occurring singly or in chains, with visible spore formation and large, irregular colonies, consistent with their known morphology. *Klebsiella* sp were distinguished by their Gram-negative rod shape, lack of motility, and the characteristic mucoid, glistening colonies associated with capsule production. *Lactobacillus* sp were observed as Gram-positive rods occurring singly or in chains, forming small, smooth white colonies and lacking spores and motility.

Table 3. *Morphological Characteristics of Isolated Organisms.*

Organism	Gram Reaction	Cell Shape	Arrangement	Spore Formation	Motility	Colony Appearance
Staphylococcus sp.	Gram-positive	Cocci	Clusters (grape-like)	Non-spore forming	Non-motile	Creamy, circular, convex
Bacillus sp.	Gram-positive	Rods	Single or chains	Spore-forming	Motile	Large, flat, irregular
Klebsiella sp.	Gram-negative	Rods	Single	Non-spore forming	Non-motile	Mucoid, glistening colonies
Lactobacillus sp.	Gram-positive	Rods	Single or chains	Non-spore forming	Non-motile	Small, white, smooth

Table 4 shows the biochemical characteristics of isolated organisms. The biochemical characteristics of the isolated organisms demonstrated patterns consistent with their typical genus traits. *Staphylococcus* sp were catalase-positive, oxidase-negative, and coagulase-positive, while testing negative for indole and citrate utilization, confirming their classification as catalase-producing, coagulase-variable cocci. *Bacillus* sp were catalase- and oxidase-positive, coagulase-negative, and tested positive for indole but negative for citrate, reflecting their metabolic versatility and spore-forming nature.

Klebsiella sp were catalase-positive, oxidase- and coagulase-negative, and tested positive for both indole and citrate utilization, characteristics typical of Gram-negative enteric rods. *Lactobacillus* sp were negative for all the biochemical tests listed, which aligns with their identity as lactic acid bacteria with limited enzyme-mediated reactions. These biochemical profiles support the accurate identification of the bacterial isolates from the apple samples.

Table 4. Biochemical Characteristics of Isolated Organisms.

Organism	Catalase Test	Oxidase Test	Coagulase Test	Indole	Citrate
Staphylococcus sp.	Positive	Negative	Positive	Negative	Negative
Bacillus sp.	Positive	Positive	Negative	Positive	Negative
Klebsiella sp.	Positive	Negative	Negative	Positive	Positive
Lactobacillus sp.	Negative	Negative	Negative	Negative	Negative

Figure 2 shows the frequency of occurrence of isolated organisms. *Staphylococcus* sp were the most frequently isolated, with 36 occurrences (52.1%), indicating they were present in more than half of the samples. *Lactobacillus* sp were the next most common, occurring 14 times (20.2%), followed by Bacillus sp with 12 occurrences (17.3%). *Klebsiella* sp had the lowest frequency, being isolated only 7 times (10.1%). Overall, the chart indicates that *Staphylococcus* sp dominated the bacterial population on the apple samples, while *Klebsiella* sp were comparatively rare.

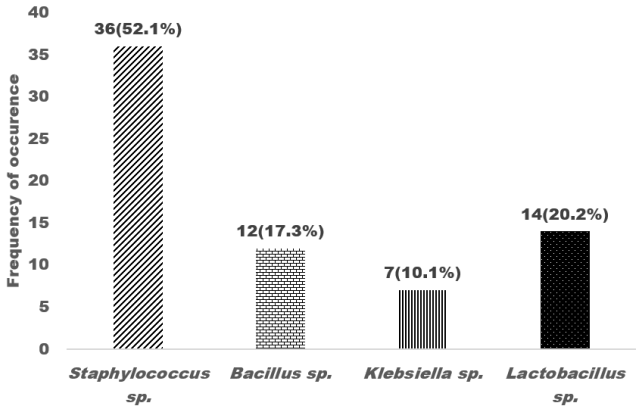

Figure 2. Frequency of Occurrence of Isolated Organisms.

4. Discussion

The present study showed that both foreign and exotic apples sold in selected fruit markets in Port Harcourt were contaminated with heterotrophic bacteria. The higher bacterial load found on exotic apples may be linked to differences in handling, storage, duration of display, packaging, and exposure to the market environment. Fruits sold in open markets are often exposed to repeated handling, dust, contaminated surfaces, and other sources of microorganisms. Similar factors have been reported to influence the microbial quality of fresh fruits [12, 21].

Furthermore, the higher bacterial load observed on exotic apples agrees with previous reports that fruits kept under ambient market conditions may develop increased microbial loads during storage and display [22]. Studies [20, 23] reported that bacterial loads on apples may increase with prolonged storage, particularly where temperature control is poor. This may explain the higher contamination observed among the exotic apples in the present study. Repeated handling by vendors and consumers may also increase the transfer of bacteria to fruit surfaces. Also a study [24] reported that the microbial communities found on fruits are affected by environmental conditions and human activities along the food supply chain.

The lower bacterial load observed on foreign apples may be related to differences in post-harvest handling, packaging, transportation, and storage before the fruits reach the local markets. Imported fruits may pass through more controlled storage and transportation conditions, which can reduce opportunities for bacterial contamination. Similar findings found lower bacterial counts in imported apples than in locally sourced apples and related the difference to post-harvest handling and transportation practices [23, 25]. However, imported apples may still become contaminated after arrival in the local market through handling, storage, and contact with contaminated surfaces.

The differences observed between the two sampling stations also suggest that market conditions may affect the bacteriological quality of apples. Factors such as cleanliness of the selling environment, storage practices, handling by vendors, and exposure to dust and other contaminants may differ between markets. A study [26] reported that poor hygiene and environmental exposure contribute to microbial contamination of fresh fruits sold in Nigerian markets. Improving sanitation and handling practices at fruit markets may therefore help to reduce bacterial contamination. The bacterial isolates identified in this study also provide useful information on possible sources of contamination. Staphylococcus spp. were the most frequently isolated organisms. These finding agrees with earlier reports of Staphylococcus species on fresh fruits and other ready-to-eat foods [27-29]. The frequent occurrence of Staphylococcus may be associated with direct contact during harvesting, transportation, marketing, and purchase because these organisms are commonly found on human skin and in the nasal passages. Their presence on apples may therefore indicate poor personal hygiene or repeated handling of the fruits [30, 31].

The isolation of Bacillus spp. from the apple samples is also consistent with the environmental distribution of these organisms. Bacillus species are commonly found in soil, dust, water, and other environmental sources and may be transferred to

fruits during cultivation, transportation, storage, or market display [32-34]. Their ability to form spores also allows them to survive under unfavourable conditions. Similar findings have been reported in studies of fresh produce, where Bacillus species were associated with environmental contamination [34, 35]. Similarly, the presence of Lactobacillus spp. may be related to the natural microbial population of fruits. Lactic acid bacteria can occur naturally on plant surfaces and may grow in fruits because of their sugar content. Their presence does not necessarily indicate poor hygiene. However, the occurrence of Lactobacillus together with other bacterial groups shows that the microbial population of the apples may have originated from both natural fruit microflora and contamination acquired during handling and marketing [36-38].

Although Klebsiella spp. were less frequently isolated, their presence is important from a food safety perspective. Klebsiella species may occur in soil, water, and the intestinal environment and can be introduced onto fruits through contaminated water, surfaces, or poor handling practices. Similar findings have been reported in studies of fresh fruits sold in markets, where enteric bacteria were associated with poor sanitation and environmental exposure [39, 40]. The presence of these organisms on fruits that may be eaten without cooking highlights the importance of proper washing before consumption. The morphological and biochemical characteristics of the isolates supported their identification as Staphylococcus, Bacillus, Klebsiella, and Lactobacillus spp. Gram staining, colony characteristics, and biochemical reactions were useful in distinguishing the bacterial groups recovered from the apple samples. The recovery of both Gram-positive and Gram-negative bacteria suggests that contamination may have come from different sources, including natural fruit surfaces, soil, the market environment, and human handling [41, 42].

5. Conclusion and Recommendations

This study assessed the bacteriological quality and bacterial contaminants of foreign and exotic apples sold in selected fruit markets in Port Harcourt Metropolis. The findings showed that both types of apples carried heterotrophic bacteria, although exotic apples generally had higher bacterial loads than foreign apples across the two sampling stations. This suggests that differences in handling, storage, environmental exposure, and market conditions may influence the bacteriological quality of apples.

The study also identified a range of bacterial contaminants associated with the apple samples. Staphylococcus spp. were the most frequently isolated organisms, followed by Lactobacillus spp., Bacillus spp., and Klebsiella spp. The presence of these organisms indicates that the apples may be exposed to bacteria from human handling, the surrounding environment, soil, and other sources during transportation, storage, and sale. The detection of Staphylococcus and Klebsiella is of particular food safety interest because some members of these genera are associated with human infections. The morphological and biochemical characteristics of the isolates supported their identification as Staphylococcus, Bacillus, Klebsiella, and Lactobacillus spp. The occurrence of these bacterial groups on apples sold in the selected markets shows that fruits intended for raw consumption may become contaminated along the supply chain. Proper handling, storage, market sanitation, and washing of apples before consumption are therefore important for reducing potential exposure to bacterial contaminants.

Based on the findings of this study, the following recommendations are proposed:

1) Fruit vendors should maintain good hygienic practices, including proper hand hygiene, clean clothing, clean display surfaces, and appropriate handling of apples to reduce the transfer of bacteria.
2) Apples should be protected from dust, dirty surfaces, and other environmental contaminants during transportation, storage, and display in the markets.
3) Appropriate storage conditions should be maintained, particularly by avoiding prolonged exposure of apples to unsuitable temperatures and poor storage environments.
4) Consumers should wash apples thoroughly with clean running water before consumption, particularly because apples are commonly eaten raw.
5) Routine microbiological monitoring of fresh fruits sold in local markets should be encouraged by relevant food safety and public health authorities to identify contamination and support appropriate control measures.
6) Fruit vendors should receive regular food hygiene education on safe handling, storage, and display of fresh fruits.

6. Strengths and Limitations

A major strength of this study is the comparative assessment of the bacteriological quality of foreign and exotic apples obtained from two fruit markets in Port Harcourt Metropolis. The study combined the determination of total heterotrophic bacterial counts with the isolation and characterization of bacterial contaminants using cultural, morphological, and biochemical methods. This provided information not only on the level of bacterial contamination but also on the types of bacteria associated with the apple samples. The study also assessed apples from more than one market location, allowing differences in bacterial contamination between sampling stations to be observed. The findings therefore provide useful baseline information on the bacteriological quality of apples available to consumers in selected markets in Port Harcourt.

However, the study has some limitations. The number of apple samples and sampling locations was relatively small, which may limit the extent to which the findings can be generalized to all fruit markets in Port Harcourt or other parts of Nigeria. The study also relied on conventional culture-based methods for bacterial isolation and identification. These methods may not detect bacteria that are difficult to culture under the conditions used in the study. In addition, the study identi-

fied bacterial isolates to the genus level and did not use molecular methods to confirm species-level identification. The study also did not assess specific pathogenicity, antimicrobial resistance, or the actual health outcomes associated with consumption of the contaminated apples.

Despite these limitations, the study provides useful baseline information on the bacteriological quality of foreign and exotic apples sold in selected markets in Port Harcourt Metropolis. The findings highlight the need for improved hygiene during fruit handling, storage, transportation, and marketing and provide a basis for further studies on the microbiological safety of fresh fruits in Nigeria.

Abbreviations

BPW	Buffered Peptone Water
CFU/g	Colony-forming Units Per Gram
THBC	Total Heterotrophic Bacterial Count

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Author Contributions

Victor Naomi Imomotimi: Conceptualization, Formal Analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing

Kurokeyi Ebimene Teddy: Formal Analysis, Investigation, Methodology, Resources, Writing – review & editing

Olatunde Raimi: Formal Analysis, Methodology, Visualization, Writing – review & editing

Conflicts of Interest

The authors declare no conflicts of interest.

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