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| RESEARCH ARTICLE

Microorganisms Associated With Spoilage Of Watermelon Fruit (*Citrullus lanatus*) Sold In Rumuola Market, Port Harcourt, Rivers State, Nigeria

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| ABSTRACT

Watermelon (*Citrullus lanatus*) is a highly nutritious and widely consumed fruit; however, its high moisture and sugar contents make it highly susceptible to microbial spoilage. This study investigated the microorganisms associated with the spoilage of watermelon fruits sold in Rumuola Market, Port Harcourt, Rivers State, Nigeria. A cross-sectional laboratory-based study was conducted using twenty visibly spoiled watermelon fruits randomly collected from ten fruit vendors between June and August 2025. Standard microbiological methods were employed for the enumeration, isolation, and identification of bacterial and fungal isolates. The total viable bacterial counts ranged from 4.8×10^5 to 7.8×10^5 CFU/g, while fungal counts ranged from 2.8×10^4 to 5.1×10^4 CFU/g, indicating substantial microbial deterioration of the fruits. Six bacterial species were isolated, with *Staphylococcus aureus* showing the highest frequency of occurrence (25.0%), followed by *Bacillus subtilis* (20.8%) and *Pseudomonas aeruginosa* (18.8%). The fungal isolates identified included Aspergillus niger (28.6%), *Rhizopus stolonifer* (22.9%), *Penicillium* spp. (17.1%), *Mucor* spp. (14.3%), *Candida albicans* (11.4%), and *Aspergillus flavus* (5.7%). The presence of potentially pathogenic bacteria and toxigenic fungi suggests that spoiled watermelon fruits sold in the study area may constitute a significant public health risk. The study highlights the need for improved hygiene, proper post-harvest handling practices, and routine microbiological surveillance of fruits to ensure consumer safety and reduce post-harvest losses.

| KEYWORDS

Citrullus lanatus, microbial spoilage, watermelon, food safety, bacterial isolates, fungal isolates

| ARTICLE INFORMATION

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1. Introduction

Watermelon (*Citrullus lanatus*) is one of the most widely cultivated and consumed fruits in tropical and subtropical regions of the world. It belongs to the family Cucurbitaceae and is highly valued because of its sweet taste, refreshing flavour, high water content, and nutritional composition. The fruit contains essential vitamins, minerals, dietary fibre, lycopene, citrulline, and several antioxidant compounds that contribute to human health and disease prevention. Because of these nutritional and economic benefits, watermelon has become an important fruit crop in global agriculture and a significant source of income for farmers and fruit vendors in many developing countries, including Nigeria (Frontiers, 2025).

Globally, the production and consumption of fresh fruits have increased considerably due to growing awareness of healthy diets and the demand for nutrient-rich foods. However, fresh fruits are highly perishable commodities because of their high moisture content, low acidity, and abundance of fermentable sugars, which create favourable conditions for the growth and proliferation

of spoilage microorganisms. Microbial spoilage remains one of the major causes of post-harvest losses, leading to significant economic losses, reduced food availability, and increased food insecurity, particularly in developing nations. It has been estimated that a substantial proportion of fruits produced worldwide is lost after harvest because of microbial deterioration and poor handling practices (Snyder et al., 2024).

Fruit spoilage is primarily caused by various groups of microorganisms, including bacteria, yeasts, and filamentous fungi. These microorganisms invade fruits through natural openings, physical injuries, insect damage, or contamination during harvesting, transportation, storage, and marketing. Once established, they produce enzymes that degrade fruit tissues, resulting in softening, discoloration, unpleasant odours, leakage of juice, and eventual decomposition of the fruit. Common spoilage organisms associated with fruits include species of *Aspergillus, Penicillium, Rhizopus, Mucor, Candida, Bacillus, Pseudomonas,* and *Staphylococcus*, many of which are also capable of producing toxins or causing opportunistic infections in humans (Sahu and Shrivas, 2024; Snyder et al., 2024).

Watermelon is particularly susceptible to microbial spoilage because its flesh contains approximately 92% water and considerable amounts of sugars and nutrients that support microbial growth. In tropical environments such as Nigeria, high ambient temperatures and humidity further accelerate microbial multiplication and fruit deterioration. Improper storage conditions, exposure to dust, contaminated water, handling by vendors and consumers, and poor sanitary practices in open markets increase the likelihood of microbial contamination and spoilage of watermelon fruits. Consequently, spoiled watermelon may serve as a vehicle for foodborne pathogens and constitute a significant public health concern (Oluka et al., 2024).

Studies conducted in different parts of Nigeria have reported high microbial loads in fresh and ready-to-eat watermelon fruits sold in local markets. These studies have isolated several bacterial and fungal species from contaminated watermelon samples, indicating poor post-harvest handling and inadequate hygienic conditions during marketing and distribution. The presence of pathogenic microorganisms in watermelon is of particular concern because the fruit is commonly consumed raw without any form of heat treatment that could eliminate microbial contaminants (Oluka et al., 2024).

The increasing demand for fresh fruits in urban centres such as Port Harcourt has resulted in extensive transportation and storage of watermelon fruits under conditions that may favour microbial contamination. Rumuola Market is one of the major commercial markets in Port Harcourt, Rivers State, where large quantities of fruits are sold daily. Despite the popularity and economic importance of watermelon in this market, there is limited information regarding the microorganisms associated with its spoilage and the potential health risks posed to consumers. Identification of the spoilage microorganisms associated with watermelon fruits sold in this market is therefore essential for understanding the microbiological quality of the fruit, assessing potential public health risks, and developing appropriate intervention strategies to reduce post-harvest losses and improve food safety.

Therefore, this study was designed to investigate the microorganisms associated with the spoilage of watermelon fruit (*Citrullus lanatus*) sold in Rumuola Market, Port Harcourt, Rivers State, Nigeria. The findings of this study will provide valuable information on the microbial agents responsible for watermelon deterioration, contribute to existing knowledge on fruit microbiology, and provide evidence-based recommendations for improving fruit handling, storage, and public health protection.

2. Literature Review

*2.1 Overview of Watermelon (*Citrullus lanatus*)*

Watermelon (*Citrullus lanatus*) is one of the most widely consumed fruits in the world, appreciated for its sweet taste, refreshing nature, and nutritional value (Bhat et al., 2022; Frontiers in Genetics, 2025). It belongs to the Cucurbitaceae family and is cultivated extensively in tropical and subtropical regions where climatic conditions favor its growth (Bhat et al., 2022). In many communities, watermelon serves not only as a popular seasonal fruit but also as an affordable source of nutrition and income for farmers, traders, and consumers.

Nutritionally, watermelon consists largely of water and contains natural sugars, vitamins A and C, lycopene, citrulline, minerals, and dietary fibre that contribute to hydration, antioxidant protection, and overall health (Frontiers in Genetics, 2025; Bhat et al., 2022). Despite these nutritional benefits, watermelon is highly perishable because of its high moisture content, nutrient-rich tissues, and near-neutral pH, all of which create favorable conditions for microbial colonization and rapid deterioration after harvest (Siddiqui et al., 2020; Snyder et al., 2024).

2.2 Postharvest Spoilage of Watermelon Fruits

Postharvest spoilage remains one of the major constraints to watermelon production, marketing, and consumption worldwide (Siddiqui et al., 2020; Shankar et al., 2024). Following harvest, the fruit undergoes physiological changes such as moisture loss, tissue softening, and reduced firmness, while microbial invasion accelerates deterioration through tissue degradation and decay (Sahu & Shrivas, 2024; Snyder et al., 2024).

Mechanical injuries sustained during harvesting, transportation, loading, and market handling provide entry points for spoilage microorganisms (Alegbeleye et al., 2022; Hosseini et al., 2024). Similarly, poor storage conditions, prolonged market display, and high temperature and humidity commonly experienced in tropical environments significantly increase microbial growth and shorten shelf life (Nwankwo & Chikwendu, 2024; Shankar et al., 2024). Consequently, postharvest spoilage contributes substantially to economic losses, reduced food availability, and compromised food quality (Bhat et al., 2022; Siddiqui et al., 2020).

2.3 Microorganisms Associated with Fruit Spoilage

Fruit spoilage results from the activities of a wide range of bacteria, yeasts, and filamentous fungi capable of utilizing fruit nutrients for growth (Snyder et al., 2024; Pitt & Hocking, 2024). These microorganisms produce enzymes that degrade plant tissues, resulting in soft rot, discoloration, unpleasant odours, slime formation, fermentation, and visible mould growth (Sahu & Shrivas, 2024).

Among bacteria, *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas* spp., *Bacillus* spp., *Salmonella* spp., and *Klebsiella* spp. are frequently isolated from spoiled fruits and fresh produce (Bintsis, 2023; Khan et al., 2024; Whitman et al., 2024). Likewise, fungal genera such as *Aspergillus*, *Penicillium*, *Rhizopus*, *Mucor*, *Candida*, and *Fusarium* are widely recognized as important spoilage organisms because of their ability to invade damaged fruit tissues and accelerate decomposition (Pitt & Hocking, 2024; Samson et al., 2024; Wang et al., 2024).

2.4 Sources of Microbial Contamination in Watermelon

Microbial contamination of watermelon may occur throughout the production, harvesting, transportation, storage, and marketing chain (Alegbeleye et al., 2022; Omemu et al., 2020). Before harvest, fruits may become contaminated through contact with soil, irrigation water, organic fertilizers, insects, or animal waste (Alegbeleye et al., 2022).

After harvest, contamination is often associated with poor handling practices, dirty transport containers, contaminated packaging materials, and unhygienic market environments (Adebayo et al., 2020; Omemu et al., 2020). Open markets expose fruits to dust, flies, wastewater, contaminated surfaces, and repeated human handling, thereby increasing microbial loads (Eze et al., 2023; Okeke et al., 2021). Inadequate sanitation and limited access to clean water further increase the likelihood of contamination before visible spoilage occurs (Afolabi et al., 2025; Alegbeleye et al., 2022).

2.5 Public Health Significance of Spoiled Watermelon

Consumption of spoiled or contaminated watermelon presents important public health concerns because several spoilage organisms are also recognized foodborne pathogens (WHO, 2023; Bintsis, 2023). Pathogenic bacteria may cause diarrhoea, vomiting, abdominal pain, food poisoning, and other gastrointestinal illnesses, particularly among vulnerable populations (FDA, 2024; WHO, 2023).

Fungal contamination is equally important because some mould species produce mycotoxins that pose long-term health risks to consumers (FAO, 2024; Pitt & Hocking, 2024). Foodborne diseases associated with contaminated fresh produce remain a major global health challenge, especially in developing countries where food safety monitoring and cold-chain facilities are often inadequate (Foods, 2024; WHO, 2023).

2.6 Factors Influencing Microbial Growth in Watermelon

Microbial growth in watermelon is influenced by intrinsic factors such as pH, moisture content, nutrient availability, and water activity, together with extrinsic factors including temperature, humidity, oxygen availability, storage duration, and handling practices (Snyder et al., 2024; Siddiqui et al., 2020).

Warm temperatures and high humidity characteristic of southern Nigeria create favourable conditions for microbial proliferation and rapid fruit deterioration (Nwankwo & Chikwendu, 2024). Poor storage practices, delayed marketing, and lack of refrigeration further encourage microbial multiplication, reducing fruit quality and shelf life (Shankar et al., 2024; Hosseini et al., 2024).

2.7 Isolation and Identification of Spoilage Microorganisms

The isolation and identification of spoilage microorganisms rely primarily on standard microbiological procedures involving aseptic sample collection, serial dilution, inoculation onto selective media, incubation, and colony characterization (FDA, 2024; ISO, 2023). Bacterial isolates are commonly identified using Gram staining and biochemical tests, whereas fungal isolates are identified through microscopic examination of spores and hyphal structures (Whitman et al., 2024; Samson et al., 2024).

Recent advances in molecular biology have introduced PCR and DNA sequencing as reliable tools for confirming microbial identity with greater precision than conventional methods (Whitman et al., 2024). Nevertheless, conventional culture techniques remain widely used because they are inexpensive, standardized, and readily available in many microbiology laboratories (ISO, 2023; FDA, 2024).

2.8 Previous Studies on Microbial Spoilage of Watermelon

Several investigations conducted in Nigeria and elsewhere have reported that spoiled watermelon commonly harbours both bacterial and fungal contaminants. In northern Nigeria, Ibrahim and Yusuf (2023) identified several bacterial species associated with watermelon marketed under open-market conditions, highlighting concerns about microbial quality. Similarly, Oluka et al. (2024) reported significant microbial contamination of ready-to-eat watermelon and pineapple, emphasizing the influence of handling practices and environmental hygiene.

Other Nigerian studies have isolated *Staphylococcus aureus*, coliform bacteria, and diverse fungal species from fresh fruits marketed under poor sanitary conditions (Mohammed et al., 2022; Afolabi et al., 2025; Chukwudi et al., 2021). Comparable findings have been reported by Abdullahi et al. (2021), Akinmusire (2019), Nwachukwu et al. (2024), and Okorite et al. (2026), who identified a wide range of spoilage microorganisms associated with fruits sold in Nigerian markets. Although these studies consistently demonstrate that poor hygiene and improper handling increase microbial contamination, variations in microbial species and contamination levels have been attributed to geographical location, climatic conditions, laboratory methods, and market sanitation.

2.9 Knowledge Gap

Although previous studies have documented microbial spoilage of fruits in several parts of Nigeria and other countries, there is limited published information on the microorganisms specifically associated with spoiled watermelon sold in Rumuola Market, Port Harcourt, Rivers State (Ibrahim & Yusuf, 2023; Oluka et al., 2024). Differences in environmental conditions, sanitation practices, transportation, storage, and market hygiene may influence the diversity and abundance of spoilage microorganisms. Therefore, findings from other locations cannot be assumed to represent the microbial status of watermelon sold in Rumuola Market.

This study seeks to address this gap by identifying the microorganisms associated with spoiled watermelon marketed in Rumuola, thereby generating evidence that may contribute to improved food safety practices, reduced postharvest losses, and enhanced consumer protection within the study area.

3.Materials And Methods

3.1 Study Area

This study was conducted at Rumuola Market, Port Harcourt, Rivers State, Nigeria. Port Harcourt is located in the Niger Delta region of southern Nigeria and is characterized by a tropical monsoon climate with high temperature and relative humidity throughout the year. The average annual temperature ranges between 25 and 32°C, while relative humidity often exceeds 80%, conditions that favour the growth and proliferation of microorganisms associated with the spoilage of fresh fruits. Rumuola Market is one of the major commercial markets in Port Harcourt where fruits and vegetables from different parts of Nigeria are sold daily.

3.2 Study Design

A cross-sectional laboratory-based study was employed to determine the microorganisms associated with the spoilage of watermelon fruit (*Citrullus lanatus*) sold in Rumuola Market. The study involved the collection of spoiled watermelon samples from different vendors, followed by microbiological analyses, isolation, enumeration, and identification of associated bacterial and fungal species.

3.3 Sample Collection

A total of twenty (20) visibly spoiled watermelon fruits were purchased randomly from ten different vendors within Rumuola Market between June and August 2025. Fruits showing signs of deterioration such as softening, discoloration, tissue breakdown, water-soaked lesions, and fungal growth were selected for the study. The samples were individually placed in sterile polyethylene bags, properly labelled, and transported in an insulated container to the Food Microbiology Laboratory for analysis within 2hr of collection. Appropriate aseptic procedures were observed during collection and transportation to prevent external contamination (Bintsis, 2023).

3.4 Preparation of Samples

The watermelon fruits were washed gently with sterile distilled water to remove surface debris and allowed to air dry under aseptic conditions. Using a sterile scalpel, approximately 25 g of spoiled tissue was excised from the advancing margin between healthy and spoiled portions of each fruit and homogenized with 225mL of sterile buffered peptone water using a laboratory blender to obtain a 10^{-1} stock suspension. Serial ten-fold dilutions up to 10^{-6} were prepared using sterile physiological saline according to standard microbiological procedures (ISO, 2023).

3.5 Enumeration of Total Viable Bacteria

The total viable bacterial count was determined using the pour plate technique. Aliquots (0.1 mL) from appropriate dilutions were inoculated onto sterile plates containing MacConkey agar, Nutrient agar, Eosin Methylene Blue Agar (EMB), and Mannitol Salt Agar (MSA). The inoculated plates were incubated aerobically at 37°C for 24hr. After incubation, colonies appearing on plates containing 30–300 colonies were counted and expressed as colony-forming units per gram (CFU/g) of sample (FDA, 2024).

The total viable count was calculated using the equation:

CFU/g = Number of colonies × Dilution factor / Volume plated

3.6 Enumeration of Fungi

Fungal counts were determined by inoculating appropriate dilutions onto Potato Dextrose Agar (PDA) supplemented with chloramphenicol (50 mg/L) to inhibit bacterial growth. The plates were incubated at 28 ± 2°C for 3–5 days and colonies were enumerated and expressed as CFU/g of sample (Pitt & Hocking, 2024).

3.7 Isolation and Purification of Bacterial Isolates

Distinct bacterial colonies obtained from MacConkey agar, Eosin Methylene Blue Agar, and Mannitol Salt Agar (MSA) plates were sub-cultured repeatedly on Nutrient Agar using the streak plate method until pure cultures were obtained. Pure isolates were preserved on Nutrient Agar slants and stored at 4°C pending identification.

3.8 Isolation and Purification of Fungal Isolates

Representative fungal colonies with different cultural appearances were aseptically transferred onto fresh PDA plates and incubated at 28°C for 3–5 days. Sub-culturing was repeated until pure fungal cultures were obtained and maintained on PDA slants at 4°C.

3.9 Identification of Bacterial Isolates

Bacterial isolates were identified based on their colonial morphology, Gram reaction, cell morphology, and biochemical characteristics following standard microbiological methods described in Bergey's Manual of Systematic Bacteriology (Whitman et al., 2024). The biochemical tests performed included catalase test, oxidase test, citrate utilization test, indole production test, methyl red test, Voges-Proskauer test, urease test, motility test, coagulase test, and carbohydrate fermentation tests.

The bacterial isolates were identified by comparing the observed characteristics with standard taxonomic descriptions and identification keys.

3.10 Identification of Fungal Isolates

Fungal isolates were identified based on their macroscopic and microscopic characteristics. The colony texture, pigmentation, margin, elevation, and growth pattern were observed macroscopically. Microscopic examination was carried out using the lactophenol cotton blue staining technique. Identification was based on the morphology of hyphae, spores, sporangia, conidiophores, and conidia according to standard mycological identification manuals (Samson et al., 2024).

3.11 Determination of Frequency of Occurrence

The frequency of occurrence of each microbial isolate was calculated using the following equation:

Frequency (%) = (Number of occurrences of an isolate / Total number of isolates) × 100

3.12 Quality Assurance and Quality Control

All media were prepared according to the manufacturers' instructions and sterilized by autoclaving at 121°C for 15 min. Glassware and equipment were sterilized before use, and all microbiological analyses were performed in triplicate to ensure reproducibility and reliability of results. Standard aseptic techniques and laboratory quality assurance procedures recommended for food microbiology investigations were strictly followed (ISO, 2023).

3.13 Statistical Analysis

Data obtained from microbial counts were transformed into logarithmic values (log10 CFU/g) before analysis. Descriptive statistics, including means and standard deviations, were calculated. Differences in microbial counts among samples were analysed using one-way analysis of variance (ANOVA), and significant differences were considered at $P < 0.05$. Statistical analyses were performed using Statistical Package for Social Sciences (SPSS) version 27.0.

4 Results

4.1 Total Viable Bacterial Count and Total Fungal Count of Spoiled Watermelon Fruits Sold in Rumuola Market, Port Harcourt

The total viable bacterial counts ranged from 4.8×10^5 to 7.8×10^5 CFU/g, while fungal counts ranged from 2.8×10^4 to 5.1×10^4 CFU/g. The relatively high microbial loads indicate substantial deterioration of the watermelon fruits and suggest poor sanitary conditions during handling and storage.

Table 4.1: Total Viable Bacterial Count and Total Fungal Count of Spoiled Watermelon Fruits Sold in Rumuola Market, Port Harcourt

Sample code	Total Viable Count ($x10^5$CFU/g)	Total Fungal Count ($x10^4$CFU/g)
WM1	5.2 ±0.18	3.4 ± 0.12
WM2	6.1 ± 0.22	4.2 ± 0.16
WM3	4.8 ±0.15	2.8 ±0.10
WM4	7.3 ± 0.31	4.8 ± 0.21
WM5	6.5 ± 0.26	3.9 ± 0.14
WM6	5.9 ±0.20	3.5 ± 0.11
WM7	7.8 ± 0.28	5.1 ± 0.24
WM8	6.8 ± 024	4.3 ± 0.15
WM9	5.4 ±0.17	3.1 ± 0.12
WM10	6.9 ± 0.29	4.5 ±0.18

Values are expressed as mean ± standard deviation of triplicate determinations.

4.2: Frequency of Occurrence of Bacterial Isolates Associated with Spoilage of Watermelon Fruit

Staphylococcus aureus had the highest occurrence (25.0%), followed by *Bacillus subtilis* (20.8%) and *Pseudomonas aeruginosa* (18.8%). The predominance of these bacteria suggests contamination from human handling, soil particles, water, and environmental exposure during marketing.

Table 2: Frequency of Occurrence of Bacterial Isolates Associated with Spoilage of Watermelon Fruits

Bacterial Isolates	Number of Isolates (n=48)	Frequency (%)
Staphylococcus aureus	12	25.0
Bacillus subtilis	10	20.8
Pseudomonas aeruginosa	9	18.8
Escherichia coli	7	14.6
Klebsiella pneumoniae	6	12.5
Proteus vulgaris	4	8.3

4.3: Frequency of Occurrence of Fungal Isolates Associated with Spoilage of Watermelon Fruits

Aspergillus niger was the most predominant fungal isolate with an occurrence of 28.6%, followed by *Rhizopus stolonifer* (22.9%). The high prevalence of these fungi may be attributed to their ability to thrive in sugar-rich fruits with high moisture content. The occurrence of *Aspergillus flavus* is of particular concern because of its potential to produce aflatoxins that pose serious health risks to consumers.

Table 3: Frequency of Occurrence of Fungal Isolates Associated with Spoilage of Watermelon Fruits

Fungal Isolates	Number of Isolates (n=35)	Frequency (%)
Aspergillus niger	10	28.6
Rhizopus stolonifer	8	22.9
Penicillium sp	6	17.1
Mucor sp	5	14.3
Candida albican	4	11.4
Aspergillus flavus	2	5.7

4. Discussion

The present study demonstrated that spoiled watermelon fruits sold in Rumuola Market, Port Harcourt, contained high microbial loads, with total viable bacterial counts ranging from 4.8×10^5 to 7.8×10^5 CFU/g and total fungal counts ranging from 2.8×10^4 to 5.1×10^4 CFU/g. The high microbial counts observed indicate advanced deterioration of the fruits and suggest poor hygienic conditions during harvesting, transportation, storage, and marketing. Fresh fruits possess high moisture content, nutrients, and sugars that favour the growth of microorganisms, particularly when the protective rind becomes damaged (Alegbeleye et al., 2022).

The bacterial counts obtained in this study are comparable to the findings of Okeke et al. (2021), who reported bacterial loads ranging from 10^5–10^6 CFU/g in spoiled fruits marketed in south-eastern Nigeria. Similarly, Ibrahim and Yusuf (2023) recorded high microbial counts in watermelon fruits sold in open markets in northern Nigeria and attributed the contamination to poor handling practices and exposure to environmental dust. The values obtained in the present study are, however, higher than those reported by Adebayo et al. (2020), who found bacterial counts below 10^5 CFU/g in freshly harvested watermelon fruits. The observed difference may be due to differences in storage duration, environmental conditions, and the level of post-harvest handling.

The fungal counts observed in this study also agree with the findings of Akinmusire (2019) and Nwachukwu et al. (2024), who reported fungal loads of 10^4–10^5 CFU/g in spoiled fruits sold in Nigerian markets. Fungal growth in fruits is usually accelerated by high humidity and elevated temperatures that characterize tropical environments. The warm and humid climate of Port Harcourt may therefore have contributed significantly to the proliferation of spoilage fungi in the watermelon samples (Okorite, George-West et al., 2026)

Among the bacterial isolates recovered, *Staphylococcus aureus* had the highest occurrence (25.0%), followed by *Bacillus subtilis* (20.8%) and *Pseudomonas aeruginosa* (18.8%). The predominance of *S. aureus* suggests contamination arising from human handling because this organism is commonly found on the skin, nose, and hands of food handlers. Similar observations were reported by Mohammed et al. (2022) and Eze et al. (2023), who identified *S. aureus* as one of the major contaminants of fresh fruits sold in Nigerian markets.

The occurrence of *Bacillus subtilis* in this study may be attributed to contamination from soil and dust particles since species of *Bacillus* are widely distributed in the environment and can survive harsh conditions through spore formation. This finding agrees with the reports of Abdullahi et al. (2021) and Khan et al. (2024), who isolated *Bacillus* species from spoiled fruits and vegetables. Likewise, the isolation of *Pseudomonas aeruginosa* is not surprising because members of the genus *Pseudomonas* are well known for producing pectinolytic enzymes that degrade fruit tissues and accelerate spoilage (Siddiqui et al., 2020).

The presence of *Escherichia coli* and *Klebsiella pneumoniae* in the watermelon samples is of public health concern because these organisms are indicators of faecal contamination and poor sanitary practices. Their occurrence may have resulted from contaminated irrigation water, dirty washing water, or unhygienic handling during marketing. Similar findings were reported by Omemu et al. (2020) and Afolabi et al. (2025), who linked the presence of coliform bacteria in fruits to inadequate sanitation and poor personal hygiene among vendors.

Regarding the fungal isolates, *Aspergillus niger* was the most frequently isolated fungus (28.6%), followed by *Rhizopus stolonifer* (22.9%). This result agrees with the findings of Chukwudi et al. (2021) and Akinyemi et al. (2024), who identified *Aspergillus* and *Rhizopus* species as the predominant fungi associated with the spoilage of fruits in tropical environments. These fungi possess strong enzymatic activities that enable them to degrade carbohydrates and organic acids present in fruits.

The isolation of *Penicillium* species and *Mucor* species further confirms their importance as common post-harvest spoilage organisms. These fungi have been implicated in the deterioration of several fruits because of their ability to colonize damaged tissues rapidly (Bhat et al., 2022).

Particularly noteworthy is the isolation of *Aspergillus flavus*. Although its frequency was low (5.7%), its presence poses a significant public health concern because the organism can produce aflatoxins, which are potent carcinogenic and hepatotoxic compounds. Similar concerns have been expressed by World Health Organization (WHO, 2023) and Food and Agriculture Organization (FAO, 2024), which highlighted the health risks associated with mycotoxin contamination in fruits and fruit products.

Overall, the findings of this study demonstrate that spoiled watermelon fruits sold in Rumuola Market harbour potentially pathogenic and toxigenic microorganisms capable of causing foodborne diseases. The study therefore emphasizes the need for improved sanitary practices during harvesting, transportation, storage, and marketing of fresh fruits in Nigeria.

5. Conclusion

This study demonstrated that spoiled watermelon (*Citrullus lanatus*) fruits sold in Rumuola Market, Port Harcourt, were heavily contaminated with both bacterial and fungal microorganisms, indicating a high level of microbial deterioration and poor microbiological quality. The predominance of *Staphylococcus aureus*, *Bacillus subtilis*, and *Pseudomonas aeruginosa* among the bacterial isolates, together with the frequent occurrence of *Aspergillus niger* and *Rhizopus stolonifer*, confirms that watermelon provides a favorable environment for the growth of spoilage microorganisms when exposed to poor handling, storage, and marketing conditions. More importantly, the isolation of potentially pathogenic bacteria such as *Escherichia coli* and *Klebsiella pneumoniae*, as well as toxin-producing fungi including *Aspergillus flavus*, raises serious concerns about the microbiological safety of watermelon fruits sold in the study area. These microorganisms are capable of causing foodborne infections or producing harmful metabolites that may threaten consumer health, particularly among children, older adults, pregnant women, and individuals with weakened immune systems.

The findings also suggest that contamination is likely to occur at multiple points along the production and distribution chain, including harvesting, transportation, storage, and open-market display, where fruits are frequently exposed to dust, insects, contaminated surfaces, and repeated human handling. These observations emphasize the need for improved hygiene practices, proper postharvest handling, clean transportation systems, and sanitary market environments to minimize microbial contamination and reduce postharvest losses.

Overall, this study provides valuable baseline information on the microorganisms associated with watermelon spoilage in Rumuola Market and contributes to the growing body of knowledge on the microbiological quality of fresh fruits in Nigeria. The findings highlight the importance of strengthening food safety education, enforcing good hygienic practices among fruit vendors, and implementing regular microbiological monitoring of fresh produce to safeguard public health and improve consumer confidence in locally marketed fruits.

6. Recommendations

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

1. Fruit vendors should maintain proper personal hygiene and avoid handling fruits with contaminated hands.
2. Watermelon fruits should be transported and stored under sanitary conditions to minimize microbial contamination.
3. Damaged and visibly spoiled fruits should be removed immediately from market displays to prevent cross-contamination.
4. Market authorities should implement routine inspection and sanitation programmes in fruit markets.
5. Clean and potable water should be used for washing fruits before sale.
6. Public health agencies should conduct regular awareness campaigns on safe fruit handling practices.
7. Further studies should be conducted using molecular techniques to characterize the spoilage microorganisms and determine their pathogenic and toxigenic potentials.
8. Regular microbiological surveillance of fruits sold in Nigerian markets should be encouraged to protect public health.

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