

Research Article

Microbiological Quality of Periwinkle (*Tympanotonus fuscatus*) Sold in Selected Markets Across Bwari Area Council, Federal Capital Territory, Nigeria: Public Health Implications

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Abstract

Background: Periwinkle (*Tympanotonus fuscatus*) is a widely consumed seafood and an important protein source in Nigeria, particularly in inland urban markets. However, microbial contamination during harvesting, transportation, and retail handling poses significant public health risks. Limited microbiological data exist for inland markets in the Federal Capital Territory. This study sought to isolate, quantify, and characterise pathogenic microorganisms present in periwinkle samples sold across three major markets in Bwari Area Council, Abuja.

Methods: A total of 60 periwinkle samples were randomly purchased from Dutse Market (DM), Bwari Central Market (BM), and Sabon-Gari Market (SGM). Standard microbiological methods including serial dilution, spread-plate technique, and biochemical characterisation (Gram staining, catalase, coagulase, citrate, indole, urease, TSI, and motility tests) were employed in accordance with Cheesbrough (2005). Fungal isolates were identified using morphological and microscopic examination guided by Barnett and Hunter (1992).

Results: Total bacterial counts (TBC) ranged from 2.73×10^7 to 8.3×10^9 CFU/mL, with the highest load recorded at Dutse Market (DM2): 8.3×10^7 CFU/mL. Six bacterial genera were isolated: *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella spp.*, *Bacillus spp.*, *Salmonella spp.*, and *Shigella spp.* Fungal isolates included *Aspergillus spp.* and *Penicillium spp.* The presence of faecal indicator bacteria and recognised foodborne pathogens confirms significant contamination risk.

Conclusion: Periwinkle samples from all three Bwari Area Council markets harboured multiple pathogenic and indicator microorganisms at levels exceeding acceptable food safety thresholds. Strict enforcement of hygiene standards along the entire supply chain from harvest to retail is urgently required to protect public health.

1. Introduction

Periwinkles (*Tympanotonus fuscatus* Linnaeus, 1758) are small marine gastropods widely consumed across West African countries, where they constitute an integral component of traditional diets [1]. They are highly valued for their unique taste, affordability, and nutritional profile, rich in protein, essential minerals, and omega-3 fatty acids with low fat content, making them a staple in dishes such as Edikang Ikong, Okro Soup, and Afang Soup [2, 3]. In Nigeria's Niger Delta region, the periwinkle is locally known as "ISAM" or "PIOM PIOM" and is harvested predominantly from estuarine and mangrove ecosystems [4].

Despite their widespread consumption and nutritional benefits, the microbiological safety of periwinkles as a food source remains a growing public health concern. As benthic, filter-feeding molluscs that inhabit brackish intertidal zones, *T. fuscatus* bioaccumulates bacteria, viruses, and fungi from their surrounding aquatic environment [5]. If harvested from waters contaminated with faecal matter or industrial effluents, periwinkles may harbour dangerous pathogens such as *Escherichia coli*, *Salmonella spp.*, *Vibrio cholerae*, *Shigella spp.*, and *Listeria monocytogenes*, all of which pose significant health risks to consumers [6]. Foodborne diseases linked to contaminated shellfish consumption include gastroenteritis, cholera, typhoid fever, and hepatitis A, which can be particularly severe in immunocompromised individuals, young children, and the elderly [3].

In Nigeria and other developing countries, the microbial contamination of seafood is intensified by inadequate sanitation, water pollution, and improper handling practices during harvesting, transportation, and retail [3]. The absence of cold storage infrastructure in open markets creates environments that promote bacterial proliferation, increasing foodborne illness risk [7]. Although periwinkles are typically cooked before consumption, inadequate cooking and post-processing cross-contamination remain significant hazards [6]. Cross-contamination, which is the transfer of pathogens between foods, surfaces, or hands, is one of the most common causes of food poisoning globally [8, 9].

The Bwari Area Council, located in the northeastern Federal Capital Territory (FCT) of Nigeria, hosts several vibrant markets where periwinkles obtained from remote coastal regions are sold under conditions that may not maintain microbial safety [10]. Despite prevailing concerns regarding water pollution, poor hygiene, and inadequate storage in these markets, empirical microbiological data on periwinkle safety in this inland urban setting are limited, representing a critical knowledge gap [11]. Previous studies in Nigeria have documented high levels of pathogenic bacteria in molluscs and other shellfish exceeding permissible limits [12], but these have been concentrated in coastal and Niger Delta regions.

This study was undertaken to address that knowledge gap by: (i) isolating and quantifying pathogenic microorganisms in periwinkle samples from three major Bwari Area Council markets; and (ii) characterising the identified organisms to assess their potential public health significance.

2. Methods

2.1. Study Area

This study was conducted in three selected markets within Bwari Area Council, Federal Capital Territory (FCT), Nigeria. Bwari Area Council is located in the northeastern part of the FCT, situated between latitudes 9.25°N to 9.5°N and longitudes 7.10°E to 7.35°E, sharing boundaries with Kwali, Gwagwalada, and Abuja Municipal Area Councils, as well as Niger State to the north [13]. The three markets selected were: Dutse Market (DM), Bwari Central Market (BM), and Sabon-Gari Market (SGM). All microbiological analyses were conducted in the Microbiology Laboratory, Veritas University, Abuja.

2.2. Sample Collection and Transportation

A total of 60 periwinkle specimens (*Tympanotonus fuscatus*) were randomly purchased from the three study markets, 20 samples per market. Samples were collected in sterile polyethylene bags and transported immediately to the Veritas University Microbiology Laboratory for analysis. Sample collection was designed to represent routine retail conditions at each market.

2.3. Sample Processing

Periwinkle specimens were organised into three groups of 20 based on market source. Fresh samples were thoroughly washed, scrubbed, and rinsed to remove surface debris using sterile distilled water. The washing fluid was retained as the stock homogenate. One-millilitre aliquots of the stock underwent serial ten-fold dilutions in sterile distilled water to reduce microbial load prior to plating [14].

2.4. Culture Media Preparation

The following media were prepared in accordance with manufacturers' instructions: Plate Count Agar (PCA) for total heterotrophic bacterial enumeration, MacConkey Agar (MCA) for isolation of Gram-negative enteric bacteria, Salmonella-Shigella Agar (SSA) for selective isolation of Salmonella and Shigella, and Potato Dextrose Agar (PDA) supplemented with gentamicin for fungal isolation. All media were dissolved by boiling, dispensed into conical flasks, and sterilised by autoclaving at 121°C for 15 minutes [15].

2.5. Bacterial Culture and Isolation

Aliquots of 0.1 mL from the 10⁻⁵ and 10⁻⁸ serial dilutions were introduced onto pre-prepared, solidified PCA, MCA, and SSA plates in sterile Petri dishes in triplicate using the spread-plate technique. Inoculated plates were incubated at 37°C for 24–48 hours. Distinct colonies were subcultured onto fresh Nutrient Agar (NA) plates using the quadrant streaking technique to obtain pure isolates, which were then maintained on agar slants as stock cultures [14, 15].

2.6. Fungal Culture and Isolation

Aliquots of 0.1 mL from the 10⁻⁵ and 10⁻⁸ dilutions were spread onto PDA supplemented with gentamicin (to inhibit bacterial growth). Plates were incubated at 37°C for 7–14 days until visible fungal growth appeared. Distinct fungal colonies were subcultured onto fresh PDA for further characterisation [16].

2.7. Enumeration of Isolates

Visible colonies were counted using a colony counter. Only plates yielding 30–300 colonies were considered for enumeration. Microbial load was calculated as:

$$\frac{\text{CFU}}{\text{mL}} = \frac{\text{(Number of colonies)}}{\text{(Dilution factor} \times \text{Volume plated)}}$$

2.8. Biochemical Characterisation and Identification of Bacteria

Bacterial isolates were identified using a combination of morphological and biochemical tests following [15, 17]. Tests performed included: Gram staining (to determine cell morphology and wall structure [18]; Catalase test (3% H₂O₂, effervescence = positive, Al-Joda and Jasim, 2021); Coagulase test (slide method with rabbit plasma, agglutination = *S. aureus* positive, [19]; Motility test (semi-solid agar stab culture, diffuse growth = motile positive, [20]); Citrate utilisation test (Simmons' citrate agar, Prussian blue colour change = positive, [21]); Indole test (peptone water broth incubated 48 h, Kovac's reagent, cherry-red ring = positive); Urease test (urea agar, colour change from yellow to pink = positive, [22]); and Triple Sugar Iron (TSI) test (stab and slant inoculation, 24 h at 37°C, yellow butt/yellow slant = A/A for lactose/sucrose fermentation; alkaline slant/yellow butt = K/A indicating glucose-only fermentation; black precipitate = H₂S production).

2.9. Identification of Fungal Isolates

Fungal isolates were characterised using macroscopic (colony colour, reverse colour, edge, texture, pigmentation) and microscopic (lactophenol-cotton blue wet mount, examination of hyphae, conidiophore structure, and spore morphology) features. Genera were identified using fungal atlases and the reference text by Barnett and Hunter [23].

3. Results

3.1. Total Heterotrophic Bacterial Count

Table 1 presents the total heterotrophic bacterial counts (THBC) from periwinkle samples collected across the three markets. Bacterial counts ranged from 2.73×10^7 CFU/mL (SGM1) to 8.3×10^9 CFU/mL (DM2). The highest count was recorded at Dutse Market sample 2 (DM2: 8.3×10^9 CFU/mL), followed by Bwari Market sample 2 (BM2: 7.0×10^9 CFU/mL). All six samples exceeded standard food safety thresholds for ready-to-eat shellfish.

Table 1: Total Heterotrophic Bacterial Count (CFU/mL) of Periwinkle Samples

Sample Code	Plate 1 (colonies)	Plate 2 (colonies)	Plate 3 (colonies)	Average	Mean Plate Count (CFU/mL)
BM1	90	65	80	78.3	7.83×10^7
BM2	76	81	59	70	7.0×10^9
DM1	80	94	68	80.6	8.06×10^7
DM2	117	78	54	83	8.3×10^9
SGM1	TNTC	50	108	27.3	2.73×10^7
SGM2	141	73	40	44.6	4.46×10^9

Keys: BM = Bwari Central Market; DM = Dutse Market; SGM = Sabon-Gari Market; TNTC = Too Numerous To Count

3.2. Colony Visual Characteristics

Table 2 presents the visual (macroscopic) characteristics of bacterial colonies observed on isolation media. Notable features include mucoid colonies on MacConkey Agar at DM1, iridescent colonies at SGM1, and pink coloration on MacConkey Agar at BM1 and SGM2, consistent with lactose-fermenting Gram-negative organisms.

Table 2: Visual (Macroscopic) Colony Characteristics

Feature	BM1	BM2	DM1	DM2	SGM1	SGM2
Size	Medium	Large	Medium	Medium	Medium	Medium
Shape	Round	Irregular	Round	Round	Irregular	Round
Elevation	Convex	Umbonate	Convex	Raised	Flat	Convex
Edge	Entire	Filamentous	Entire	Entire	Undulate	Entire
Optical characteristics	Opaque	Opaque	Opaque	Opaque	Iridescent	Opaque
Colony surface	Glistening	Rough	Mucoid	Moist	Smooth	Moist
Pigmentation	Grey (NA)	White	Pink (MCA)	Milky	Grey	Pink (MCA)

Keys: NA = Nutrient Agar; MCA = MacConkey Agar; BM = Bwari Market; DM = Dutse Market; SGM = Sabon-Gari Market

3.3. Biochemical Identification of Bacterial Isolates

Table 3 presents the results of biochemical characterisation of the six bacterial isolates. Each isolate was identified to genus level on the basis of Gram reaction, cell morphology, and pattern of biochemical test results consistent with Bergey's Manual of Systematic Bacteriology [15, 17].

Table 3: Biochemical Analysis and Identification of Bacterial Isolates

Code	Shape	Gram	Ca	Coag	Mot	Cit	TSI	Ind	Ure	Probable Organism
BM1	Rods	-	+	-	+	-	A/A+gas	+	-	<i>Escherichia coli</i>
BM2	Rods	+	+	-	+	+	-	-	-	<i>Bacillus spp.</i>
DM1	Cocci (clusters)	+	+	+	-	-	-	-	+	<i>Staphylococcus aureus</i>
DM2	Rods	-	+	-	-	+	A/A	-	+	<i>Klebsiella spp.</i>
SGM1	Rods	-	+	-	+	+	K/A	-	-	<i>Salmonella spp.</i>
SGM2	Rods	-	+	-	-	-	K/A	-	-	<i>Shigella spp.</i>

Keys: Ca = Catalase; Coag = Coagulase; Mot = Motility; Cit = Citrate; Ind = Indole; Ure = Urease; A/A = Acid slant/Acid butt; K/A = Alkaline slant/Acid butt; + = Positive; - = Negative

3.4. Fungal Isolates

Table 4 presents macroscopic and microscopic features of six fungal isolates. Two genera were identified across all markets: *Aspergillus spp.* (four isolates: BM1, BM2, DM2, SGM2) and *Penicillium spp.* (two isolates: DM1, SGM1). *Aspergillus* isolates displayed conidiophores ending in swollen vesicles with septate hyphae; *Penicillium* isolates showed branched, brush-like conidiophores with chains of round conidia.

Table 4: Fungal Macroscopic and Microscopic Examination

Code	Colour	Reverse	Edge	Surface	Microscopy	Organism
BM1	Blue-green	Pale yellow	Slightly lobed	Powdery	Septate hyphae; long conidiophores, swollen vesicle	<i>Aspergillus spp.</i>
BM2	Black	Brownish	Entire	Velvety	Long, unbranched, smooth conidiophores	<i>Aspergillus spp.</i>
DM1	Green	Pale yellow	Filamentous	Cottony	Branched conidiophores, brush-like structures	<i>Penicillium spp.</i>
DM2	Dark brown	Pale yellow	Circular	Granular	Septate hyphae; long conidiophores, swollen vesicle	<i>Aspergillus spp.</i>
SGM1	Pale green	Cream	Irregular	Velvety	Branching hyphae; brush-tip ends, chains of round spores	<i>Penicillium spp.</i>
SGM2	Black	Pale yellow	Filamentous	Powdery	Vesicle with phialides; chains of rough, spherical conidia	<i>Aspergillus spp.</i>

Figure 1 showed *S. aureus* was isolated from Dutse Market samples (DM1), confirmed by its Gram-positive coccus-in-clusters morphology, catalase positivity, positive coagulase reaction, and urease positivity, with a non-fermentative TSI profile.

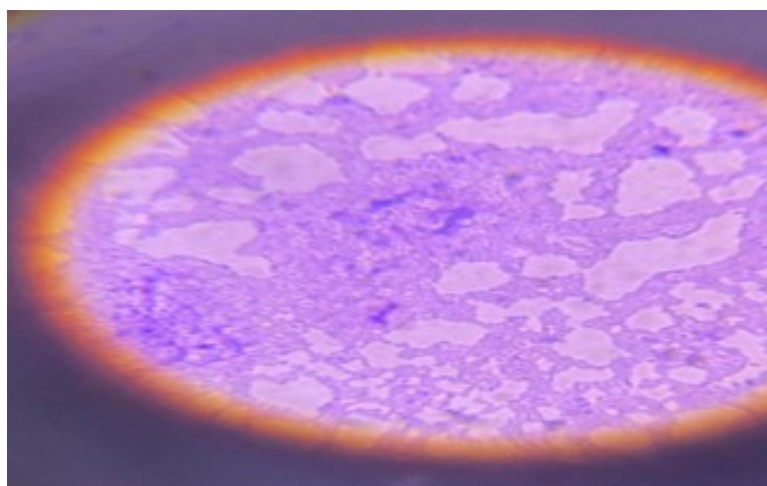


Figure 1: Microscopic examination of *Staphylococcus spp.*

Bacillus spp. was isolated from Bwari Central Market samples (BM2), confirmed by its Gram-positive rod morphology, catalase positivity, motility, and citrate positivity, with a non-fermentative TSI profile as shown in Figure 2.

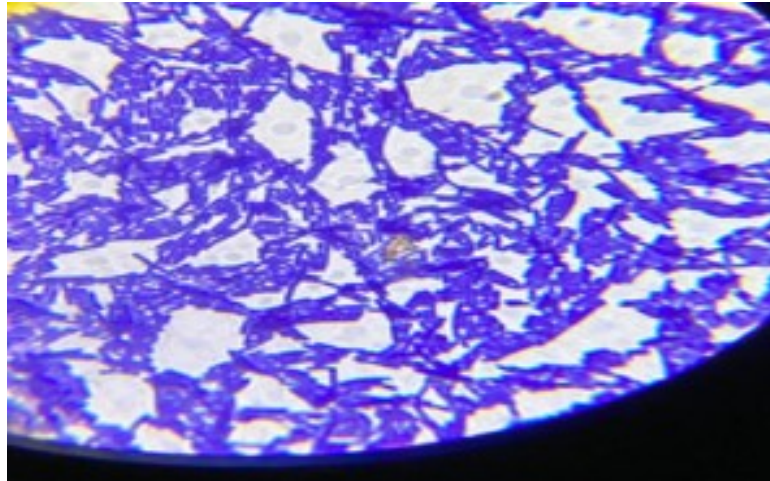


Figure 2: Microscopic examination of *Bacillus spp*

Figure 3 shown that *Aspergillus spp.* were isolated from BM1, BM2, DM2, and SGM2. It was identified on the basis of macroscopic colonial morphology and microscopic characteristics consistent with established fungal identification keys.

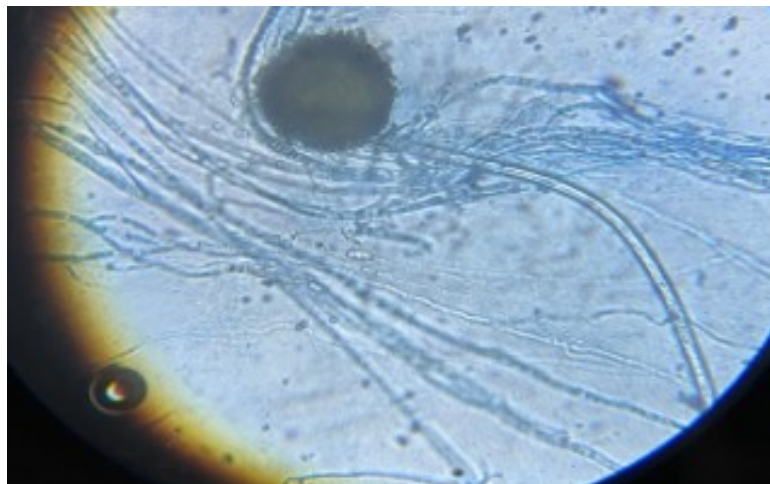


Figure 3: Microscopic examination of *Aspergillus spp*

4. Discussion

4.1. Total Bacterial Counts

The total heterotrophic bacterial counts (THBC) recorded in this study ranged from 2.73×10^7 to 8.3×10^9 CFU/mL, with all values substantially exceeding the maximum acceptable limits for ready-to-eat shellfish as stipulated by international food safety standards, which typically allow no more than 10^4 – 10^5 CFU/g [24]. The highest count was recorded at Dutse Market DM2 (8.3×10^9 CFU/mL), a finding consistent with the high level of market activity and open-air display conditions characteristic of that site. This value is considerably higher than the results reported by Oghenemowho and Ahaotu [6] in their assessment of periwinkles from Port Harcourt, and markedly above the 3.39 – $7.74 \log_{10}$ CFU/g range documented by Omorodion and Emmanuel [25] in processed and unprocessed periwinkles from Port Harcourt markets. The greater THBC in the present study may reflect the additional hazard introduced by long-distance inland transport from coastal harvest zones to Bwari markets, during which temperature control and sanitary conditions are not maintained, providing extended time for microbial multiplication before retail [10]. The finding that even the lowest recorded count (2.73×10^7 CFU/mL at SGM1) substantially exceeds acceptable thresholds confirms that all sampled markets pose an unacceptable microbial risk to consumers and that raw consumption of these periwinkles without a kill step such as adequate boiling would be a significant public health hazard.

Escherichia coli

E. coli was isolated from Bwari Central Market samples (BM1), identified by its Gram-negative rod morphology, catalase positivity, motility, indole positivity, and characteristic A/A+gas TSI pattern consistent with acid and gas production from glucose, lactose, and sucrose fermentation [15, 17]. The presence of *E. coli* in periwinkle samples is of particular public health significance because it serves as a standard indicator of faecal contamination of water or food [25]. The organism is a normal inhabitant of the gastrointestinal tracts of warm-blooded animals and humans; its detection in seafood implies contamination of harvesting waters with faecal matter, consistent with the widespread practice of defecating in or near the creeks from which Bwari market periwinkles are sourced [12].

Alfred-Ockiya [26] previously isolated *E. coli* from partially processed periwinkles in Port Harcourt markets. Nwiyi and Okonkwo [27] similarly reported *E. coli* in periwinkles from Yenegoa and Oron creeks, attributing its presence to poor hygiene during harvesting and handling, and to water contamination. Omenwa et al. [28] found *E. coli* in both raw and processed farm-reared periwinkles from Buguma, observing its persistence even after boiling, an observation that underscores the inadequacy of incomplete cooking as a control measure. The pathogenic significance of *E. coli* in this context encompasses the causation of infantile diarrhoea, neonatal meningitis, pneumonia, urinary tract infections, and, in susceptible populations, haemolytic uraemic syndrome (HUS), which can lead to acute kidney failure [6, 29]. The detection of *E. coli* in Bwari Area Council periwinkle samples is directly consistent with the pattern of faecal contamination previously documented in coastal Nigerian markets and confirms that the contamination risk is not limited to coastal harvesting environments but persists through the inland supply chain to final point of sale.

Staphylococcus aureus

S. aureus was isolated from Dutse Market samples (DM1), confirmed by its Gram-positive coccus-in-clusters morphology, catalase positivity, positive coagulase reaction, and urease positivity, with a non-fermentative TSI profile consistent with established identification criteria. The isolation of *S. aureus* from periwinkles in this study is consistent with findings across multiple Nigerian studies. Alfred-Ockiya [26] found *S. aureus* to be the most predominant organism (24.9%) in periwinkle from Port Harcourt markets. Asemota et al. [30] identified it in *T. fuscatus* var. *radula* in Nasarawa State, and [5] isolated it from periwinkles in Yenegoa markets. These studies collectively link *S. aureus* occurrence to poor personal hygiene of vendors, inadequate temperature management, and post-harvest cross-contamination.

In Bwari markets, the contamination pathway is likely multi-factorial. Vendors routinely use bare hands to measure, remove shells, and repeatedly immerse fingers in containers of periwinkle, providing a direct route for skin-borne *S. aureus* to contaminate the product [25]. Samples are displayed in open basins exposed to ambient air, dust, and insects. Vendors with open wounds, skin lesions, or respiratory symptoms may inadvertently transfer enterotoxigenic strains to the periwinkle [5, 30]. At ambient market temperatures in Abuja (typically 28–35°C), *S. aureus* proliferates rapidly and can produce heat-stable enterotoxins within 3–4 hours; once formed, these toxins are not destroyed by subsequent cooking, making post-contamination heating an unreliable safeguard [31]. *S. aureus* enterotoxin ingestion causes staphylococcal food poisoning characterised by rapid-onset vomiting, diarrhea, and abdominal cramping, and in children, enterotoxigenic strains have been implicated in cerebrospinal fluid shunt infections [5]. The findings in this study confirm that vendor handling practices and lack of hygienic storage are contributing factors to *S. aureus* contamination of periwinkles in Bwari Area Council.

Klebsiella spp.

Klebsiella spp. was isolated from Dutse Market samples (DM2), characterised by its Gram-negative rod morphology, catalase positivity, non-motility, citrate positivity, urease positivity, and A/A TSI profile without gas production, consistent with the biochemical profile of this genus [15]. Omorodion and Emmanuel [25] reported *Klebsiella spp.* in periwinkles from Port Harcourt markets, attributing its presence to faecal matter in water or transfer from human skin during handling. The moist, humid display environments characteristic of Bwari Area Council markets, where periwinkles are often stored in water-filled containers at ambient temperature, provide conditions that favour *Klebsiella* persistence and multiplication. *Klebsiella spp.* can cause diarrhea, pneumonia, bloodstream infections, pyogenic infections, and urinary tract infections, with particular severity in immunocompromised individuals and hospital patients [32]. The increasing prevalence of antimicrobial-resistant *Klebsiella pneumoniae* strains globally, including ESBL-producing variants, renders the detection of *Klebsiella* in ready-to-eat shellfish a concern of growing clinical relevance.

Bacillus spp.

Bacillus spp. was isolated from Bwari Central Market samples (BM2), confirmed by its Gram-positive rod morphology, catalase positivity, motility, and citrate positivity, with a non-fermentative TSI profile [17]. *Bacillus* species are aerobic, spore-forming organisms ubiquitous in soil and air and are commonly deposited on exposed foodstuffs via airborne contamination during handling in open-air markets. Asemota et al. [30] found *Bacillus spp.* in *T. fuscatus* var. *radula* in Nasarawa State, and Oghenemowho and Ahaotu [6] identified *B. flexus* in freshly harvested and packaged periwinkles. The spore-forming capability of *Bacillus* confers resistance to heat treatments such as boiling, enabling survival through incomplete cooking. Certain *Bacillus* species, particularly *B. cereus*, produce enterotoxins that cause two distinct food poisoning syndromes: an emetic syndrome (rapid-onset vomiting) and a diarrhoeal syndrome, both posing serious risks to consumers of periwinkle containing large populations of this organism [3]. The detection of *Bacillus spp.* in Bwari markets reflects the open-air market conditions that expose periwinkles to airborne and environmental contamination.

Salmonella spp. and Shigella spp.

Salmonella spp. was isolated from Sabon-Gari Market samples (SGM1), identified by its Gram-negative rod morphology, catalase positivity, motility, citrate positivity, and K/A TSI profile, alkaline slant with acid butt and H₂S production characteristic of *Salmonella* [15]. *Shigella spp.* was isolated from SGM2, identified by its Gram-negative rod, catalase positivity, non-motility, non-citrate utilisation, and K/A TSI profile without H₂S production [17]. Both organisms are important enteric pathogens whose detection in periwinkles has been previously documented in Nigerian studies. Adebayo-Tayo et al. [12, 33] detected *Salmonella* in periwinkles from multiple Nigerian creeks, attributing its presence to the organism's ability to survive and persist in aquatic environments and its association with sewage contamination and reptile hosts. The infectious dose of *Salmonella* is estimated at as few as 10–100 cells [34], meaning even low levels in food represent a significant hazard.

The detection of *Shigella* in periwinkle samples is particularly significant because it reflects direct faecal contamination of harvesting waters from anthropogenic activities including bathing, open defecation in creeks, and inadequate sewage management. Showcasing periwinkle meat without packaging in open markets further exposes the product to contamination from flies and environmental microorganisms. Consumption of *Shigella*-contaminated periwinkles without thorough cooking can lead to bacillary dysentery characterised by bloody diarrhea, severe abdominal cramps, and fever, a disease with potential for epidemic spread in poor hygiene settings [35]. *Salmonella* infection

can cause typhoid fever, non-typhoidal salmonellosis with gastroenteritis and diarrhea, and in severe cases bacteremia with life-threatening complications [36, 37]. The joint detection of *Salmonella* and *Shigella* at the same market (SGM) points to a shared contamination pathway likely rooted in the quality of the water used at that market for rinsing and storing periwinkles.

4.2. Fungal Isolates

Aspergillus spp.

Aspergillus spp. were isolated from BM1, BM2, DM2, and SGM2, and *Penicillium spp.* from DM1 and SGM1. Both genera were identified on the basis of macroscopic colonial morphology and microscopic characteristics consistent with established fungal identification keys [23]. The presence of *Aspergillus spp.* across all three markets is consistent with results from [5], who reported *A. niger* and *A. flavus* in dried periwinkles from Yenagoa open markets, and with [3], who found both genera in dried periwinkle stored in humid, warm environments in local markets. The warm, humid conditions of Bwari area markets, typical of the Nigerian savanna climate with temperatures frequently exceeding 30°C and relative humidity of 60–80% in market environments create ideal conditions for *Aspergillus* sporulation and colonisation of periwinkle [38]. *Aspergillus spp.*, particularly *A. flavus* and *A. niger*, produce aflatoxins and mycotoxins with potent carcinogenic, hepatotoxic, teratogenic, and mutagenic properties, and can cause aspergillosis in immunocompromised individuals [19].

Penicillium spp.

Penicillium spp., identified at DM1 and SGM1, are common seafood contaminants that produce ochratoxins with nephrotoxic and potentially carcinogenic properties [39]. Their presence in periwinkle is commonly associated with prolonged storage under suboptimal conditions. A study cited by Omenwa et al. [28] isolated *Penicillium* from freshly harvested and smoked periwinkles, identifying water, soil, and air as probable contamination sources, all of which are abundantly present in the open-air market environments of Bwari Area Council. The co-occurrence of *Aspergillus* and *Penicillium* across multiple markets in this study is therefore consistent with the broader body of evidence on fungal contamination of periwinkle in Nigerian markets, and underscores the importance of monitoring mycotoxin-producing fungi in seafood sold under uncontrolled storage conditions.

4.3. Public Health Implications

The collective findings of this study reveal high bacterial loads, multiple foodborne pathogens (*E. coli*, *S. aureus*, *Salmonella spp.*, *Shigella spp.*), toxin-producing spore-formers (*Bacillus spp.*), opportunistic pathogens (*Klebsiella spp.*), and mycotoxin-producing fungi (*Aspergillus spp.*, *Penicillium spp.*). This confirms a serious and multi-dimensional public health risk associated with the consumption of periwinkles from Bwari Area Council markets. The population at greatest risk includes immunocompromised individuals, young children, the elderly, pregnant women, and individuals who consume periwinkle without adequate cooking or who purchase periwinkle products from vendors with poor hygiene practices. The detection of *E. coli* across markets confirms faecal contamination at source; the detection of *S. aureus* and *Klebsiella* confirms additional contamination during post-harvest handling at market level; the detection of *Salmonella* and *Shigella* at Sabon-Gari market identifies that site as a particularly high-risk point of sale requiring urgent intervention.

These findings are broadly consistent with the pattern of microbial contamination documented in periwinkle studies from coastal Nigerian markets [5, 12, 25], but represent the first systematic microbiological survey of inland FCT markets, demonstrating that the contamination risk extends well beyond coastal harvest zones. The inland context introduces an additional hazard: periwinkles transported long distances from coastal harvest areas to Bwari markets undergo extended periods at ambient temperature without cold chain management, providing extended time for microbial multiplication and toxin formation before reaching consumers [10].

5. Conclusion

This study demonstrates that periwinkles (*Tympanotonus fuscatus*) sold in selected markets across Bwari Area Council, Abuja, are extensively contaminated with multiple pathogenic and indicator microorganisms at levels that pose significant public health risks. Total bacterial counts ranging from 2.73×10^7 to 8.3×10^9 CFU/mL substantially exceeded acceptable food safety thresholds across all three sampled markets. Six bacterial genera were isolated including *Escherichia coli*, *Staphylococcus aureus*, *Klebsiella spp.*, *Bacillus spp.*, *Salmonella spp.*, and *Shigella spp.* alongside fungal isolates of *Aspergillus spp.* and *Penicillium spp.* The spectrum of pathogens identified encompasses agents of gastroenteritis, typhoid fever, dysentery, staphylococcal food poisoning, and mycotoxicoses, confirming a multi-dimensional foodborne disease risk.

The presence of faecal indicator organisms (*E. coli*, *Salmonella spp.*, *Shigella spp.*) points to contamination of harvesting water sources through poor sanitation and open defecation, while the presence of *S. aureus* and *Klebsiella spp.* implicates inadequate post-harvest handling and hygiene at market level. The detection of *Aspergillus* and *Penicillium* across all three markets reflects the absence of appropriate storage conditions in the tropical inland market environment. These findings provide the first systematic microbiological evidence of periwinkle contamination in Bwari Area Council markets and confirm that the public health hazard associated with periwinkle consumption is not confined to coastal harvest regions but extends throughout inland urban supply chains. Urgent and coordinated action by food safety authorities, market management, and vendors is required to implement hygiene standards and reduce the burden of foodborne illness in this population. Continued microbiological surveillance, consumer education, vendor training, and cold chain infrastructure investment are essential components of an effective food safety response.

Recommendations

The National Agency for Food and Drug Administration and Control (NAFDAC) and FCT food safety authorities should establish a systematic microbiological monitoring programme for periwinkles sold in Bwari Area Council and other FCT inland markets, with mandatory condemnation of consignments exceeding internationally accepted thresholds for faecal coliforms and pathogens. All periwinkle

vendors in Bwari Area Council markets should undergo mandatory food safety training covering proper hand hygiene, use of food-grade gloves, avoidance of open-wound contact with product, and separation of raw and processed shellfish, in accordance with WHO/FAO Codex Alimentarius guidelines [40]. Likewise, market authorities and government agencies should prioritise the provision of low-cost cold storage facilities (refrigeration or ice boxes) at Bwari Area Council market sites, with particular urgency at Dutse Market where the highest bacterial loads were recorded. Additionally, markets should be equipped with clean, potable running water for vendor use in rinsing periwinkles and maintaining personal hygiene; the current practice of using untreated or reused water for rinsing must be eliminated. Furthermore, public health campaigns should educate consumers on the risks of consuming raw or inadequately cooked periwinkle, with emphasis on thorough boiling as the minimum required kill step and the hazard of purchasing periwinkle exposed to poor hygiene conditions. Future studies should determine antibiotic susceptibility profiles of all isolated bacteria, particularly *E. coli*, *Klebsiella spp.*, and *S. aureus*, to inform clinical management of infections arising from periwinkle consumption and to monitor the contribution of seafood markets to antimicrobial resistance dissemination.

Article Information

Disclaimer (Artificial Intelligence): The author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.), and text-to-image generators have been used during writing or editing of manuscripts.

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