American Journal of Applied and Natural Sciences
Journal Homepage:https://nicomarcinternationalpublishers.com/index.php/ AJANS/index

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| RESEARCH ARTICLE

Microbiological Analysis And Public Health Significance Of Bacterial And Fungal Isolates Recovered From The Gills Of Croaker Fish Marketed In Elele, Rivers State, Nigeria

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| ABSTRACT

Fish gills serve as important interfaces between aquatic organisms and their environment and may harbor microorganisms of public health significance. This study investigated the microbiological analysis and public health implications of bacterial and fungal isolates recovered from the gills of croaker fish marketed within Madonna University, Elele, Rivers State, Nigeria. A total of twenty (20) croaker fish samples were randomly obtained from two retail outlets (Mini Mart and Boys' Hostel Mart) over an eight-week period and analyzed using standard microbiological procedures. Mean microbial counts revealed slightly higher contamination levels in fish obtained from the Mini Mart, with total aerobic plate count, coliform count, *Escherichia coli* count, and fungal count of 5.8 ± 0.05, 4.0 ± 0.03, 3.4 ± 0.01, and 2.01 ± 0.02 Log_{10} CFU/g, respectively, compared with 5.7 ± 0.03, 3.8 ± 0.02, 3.2 ± 0.03, and 1.97 ± 0.12 Log_{10} CFU/g recorded for the Boys' Hostel Mart samples. Bacterial isolates recovered included *Escherichia coli* (40.0%), *Pseudomonas* spp. (28.0%), *Staphylococcus* spp. (20.0%), and *Streptococcus* spp. (12.0%). Fungal isolates comprised *Aspergillus* spp. (54.5%), *Rhizopus* spp. (27.3%), and *Penicillium* spp. (18.2%). The predominance of *E. coli* suggests possible faecal contamination and poor hygienic handling practices. The study highlights the need for improved sanitation, proper cold storage, and routine microbiological monitoring of fish sold within university communities to reduce foodborne health risks.

| KEYWORDS

Croaker fish, fish gills, microbial quality, food safety, public health

| ARTICLE INFORMATION

ACCEPTED: 11 June 2026 **PUBLISHED:** 16 July 2026

1. Introduction

Fish represents one of the most important and widely consumed sources of high-quality animal protein worldwide, providing essential nutrients required for human growth, development, and overall health. In addition to its rich protein content, fish serves as an important dietary source of polyunsaturated fatty acids, particularly omega-3 fatty acids, vitamins, and essential minerals that contribute significantly to cardiovascular health, cognitive development, and immune function. In many developing countries, including Nigeria, fish plays a pivotal role in food security, poverty alleviation, employment generation, and socioeconomic development owing to its relative affordability and widespread availability compared with other animal protein sources (FAO, 2022).

The continuous increase in population growth and consumer demand for fish and fish products has stimulated rapid expansion in capture fisheries, aquaculture production, processing activities, and retail distribution systems. However, this increase in production and commercialization has simultaneously heightened concerns regarding the microbiological quality and safety of fish intended for human consumption. Fish are continuously exposed to diverse microorganisms present in their aquatic environment throughout their life cycle. Although healthy fish possess innate defense mechanisms capable of limiting microbial invasion, their close interaction with surrounding water predisposes them to colonization by numerous environmental microorganisms, including bacteria, fungi, and parasites.

Among the various anatomical structures of fish, the gills constitute one of the most biologically active and microbiologically significant organs. Their extensive vascularization, delicate epithelial structure, large surface area, and continuous contact with the external aquatic environment create favorable conditions for microbial attachment and proliferation. Consequently, fish gills are highly susceptible to colonization by a wide range of microorganisms, including normal aquatic flora, opportunistic pathogens, and clinically significant foodborne bacteria (Austin & Austin, 2016). Due to these characteristics, the microbial community associated with fish gills has frequently been used as an indicator of environmental water quality and the sanitary status of fish during harvesting, transportation, processing, storage, and retail marketing.

The bacterial population associated with fish gills comprises both harmless commensals and potentially pathogenic organisms of public health importance. Previous studies have reported the isolation of bacterial species such as *Escherichia coli*, *Salmonella* spp., *Vibrio* spp., *Aeromonas* spp., *Pseudomonas* spp., *Staphylococcus aureus*, *Klebsiella* spp., *Proteus* spp., and *Enterococcus* spp. from fish tissues, particularly the gills, skin, and gastrointestinal tract (Abdallah et al., 2024; Moffo et al., 2024). Several of these microorganisms are recognized etiological agents of foodborne illnesses and have been implicated in diseases including gastroenteritis, septicemia, wound infections, urinary tract infections, and systemic infections, especially among immunocompromised individuals, children, and the elderly.

The occurrence of pathogenic bacteria in edible fish often reflects contamination originating from polluted aquatic environments and poor post-harvest handling practices. Sources of contamination may include discharge of untreated domestic and industrial wastewater into water bodies, fecal pollution, contaminated processing equipment, use of unsafe water during washing and handling, poor personal hygiene among vendors, and inadequate temperature control during transportation and storage (Gram & Dalgaard, 2008; Huss, Reilly, & Embarek, 2009). Such contamination not only compromises the microbiological quality of fish but also contributes to the emergence and dissemination of antimicrobial-resistant bacteria within the food chain.

The increasing global burden of antimicrobial resistance has further intensified concerns regarding bacterial contamination of food products, including fish and seafood. The widespread use and misuse of antibiotics in aquaculture production and veterinary practice have facilitated the emergence of resistant bacterial strains capable of transferring resistance genes to human pathogens. Consequently, determining the antibiotic susceptibility profiles of bacterial isolates recovered from fish products has become an important component of food safety monitoring and antimicrobial resistance surveillance programs.

Fish sold within University communities require particular microbiological attention because they constitute a major source of dietary protein for students, academic staff, non-academic staff, and surrounding residents. In many campus environments, fish are often displayed in open markets and exposed to unfavorable sanitary conditions, including repeated washing with contaminated water, prolonged exposure to dust particles, insects, and ambient temperatures, as well as inadequate refrigeration facilities. These conditions can encourage bacterial proliferation, facilitate cross-contamination, reduce product quality, and increase the risk of foodborne disease outbreaks. Studies conducted in various Nigerian fish markets have consistently reported substantial microbial contamination associated with inadequate hygiene practices during fish processing, handling, transportation, and retail marketing (Ogbonna et al., 2024; Odoemelam et al., 2024).

Madonna University, Elele, Rivers State, Nigeria, hosts a rapidly growing population of students, staff members, and neighbouring residents who rely heavily on fish sold by local vendors as an affordable and accessible source of dietary protein. Despite the high level of fish consumption within the university environment, there is limited published information concerning the bacterial quality and antimicrobial resistance characteristics of microorganisms associated with fish gills sold within the campus community. This paucity of data limits accurate assessment of potential microbiological hazards and hinders the development of evidence-based interventions aimed at improving food safety practices.

Therefore, the present study was undertaken to investigate the bacterial profile of microorganisms isolated from the gills of fish sold within Madonna University, Elele , Rivers State, Nigeria. The findings from this study are expected to provide valuable baseline information for food safety assessment, antimicrobial resistance surveillance, public health risk evaluation, and policy formulation. Furthermore, the results may contribute to improving hygienic handling practices among fish vendors and promoting safer fish consumption within the University community and beyond, thereby reducing the burden of foodborne bacterial infections.

2.Literature Review

2.1 Fish as a Source of Nutritious Food

Fish is one of the most important sources of animal protein consumed worldwide due to its high nutritional value, affordability, and availability. It provides essential amino acids, vitamins, minerals, and omega-3 fatty acids that contribute significantly to human health. In Nigeria, croaker fish (*Pseudotolithus* species) is widely consumed because of its desirable taste, nutritional quality, and commercial value. The growing demand for fish has increased fishing, transportation, storage, and marketing activities, exposing fish to various environmental and handling conditions that may compromise its microbiological quality. Although freshly harvested fish are generally regarded as wholesome, they can become contaminated by microorganisms during harvesting, processing, transportation, storage, and retail marketing if appropriate hygienic practices are not maintained (Food and Agriculture Organization of the United Nations [FAO], 2022; Huss et al., 2000).

The gills of fish are particularly susceptible to microbial colonization because they are continuously exposed to surrounding water and suspended organic materials. Their large surface area and constant contact with the aquatic environment create favourable conditions for the attachment and proliferation of bacteria and fungi. Consequently, microbiological examination of fish gills provides valuable information regarding the sanitary quality of fish and the level of environmental contamination in aquatic ecosystems (Austin & Austin, 2016).

2.2 Microbial Flora Associated with Fish Gills

Fish naturally harbour a diverse microbial community on their external surfaces, including the skin, scales, fins, and gills. The composition of this microbiota is influenced by several factors such as water quality, season, temperature, salinity, feeding habits, and environmental pollution. While many microorganisms are harmless components of the normal aquatic flora, others are opportunistic or pathogenic and may cause spoilage or disease in fish and humans (Austin & Austin, 2016).

The gills are among the first organs to interact with microorganisms present in water because they function in respiration, osmoregulation, and waste excretion. As water continuously passes through the gill filaments, microorganisms adhere to the mucosal surfaces and multiply under favourable conditions. Studies have demonstrated that bacterial populations recovered from fish gills are often higher than those isolated from muscle tissues because of the direct exposure of the gills to contaminated aquatic environments (Austin & Austin, 2016; Odoemelam et al., 2024).

2.3 Sources of Bacterial and Fungal Contamination in Marketed Fish

Fish contamination can occur before harvesting, during harvesting, and throughout the post-harvest handling process. Environmental contamination remains one of the primary sources of microorganisms associated with fish. Rivers, lakes, and coastal waters receiving untreated domestic sewage, agricultural runoff, industrial effluents, and animal wastes often contain elevated microbial loads that contaminate aquatic organisms (FAO, 2022; Goh et al., 2024).

Post-harvest handling practices also contribute significantly to microbial contamination. Fish sold in open markets are frequently exposed to dust, flies, contaminated water, dirty utensils, inadequately cleaned storage containers, and repeated handling by vendors and consumers. Poor transportation methods, inadequate refrigeration, and prolonged exposure to ambient temperatures encourage rapid microbial multiplication. In many developing countries, including Nigeria, inadequate cold-chain facilities further increase the risk of microbial proliferation and spoilage during distribution and retail marketing (Huss et al., 2000; Gram & Dalgaard, 2002).

Cross-contamination may also occur through contaminated cutting boards, knives, weighing scales, packaging materials, and market surfaces. Vendors who fail to maintain proper personal hygiene may transfer microorganisms from their hands to fish during processing and sale. Consequently, poor sanitary practices substantially increase the microbial burden of marketed fish (International Commission on Microbiological Specifications for Foods [ICMSF], 2011).

2.4 Common Bacterial Isolates Recovered from Fish Gills

Numerous bacterial species have been isolated from the gills of freshwater and marine fish. Among the most frequently reported organisms are *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Proteus* spp., *Enterobacter* spp., *Aeromonas hydrophila*, *Vibrio* spp., *Bacillus* spp., and *Shigella* spp. The presence of these bacteria often reflects contamination from polluted water, poor handling practices, or inadequate sanitation during marketing (Austin & Austin, 2016; Odoemelam et al., 2024; Ogbonna et al., 2024).

Members of the genus *Pseudomonas* are well known for their role in fish spoilage because of their ability to grow under refrigerated conditions and produce enzymes that degrade fish tissues (Gram & Dalgaard, 2002). *Aeromonas* species are naturally present in aquatic environments and are recognized as opportunistic pathogens capable of causing gastroenteritis, wound infections, and septicemia in humans (Austin & Austin, 2016). The isolation of *Escherichia coli* and other coliform bacteria generally indicates faecal contamination and poor hygienic handling, whereas the occurrence of multidrug-resistant *Pseudomonas aeruginosa* in fish represents an emerging public health concern (Abou Elez et al., 2024; Murray et al., 2022).

2.5 Fungal Isolates Associated with Fish Gills

Fungi are important components of the microbial flora associated with fish and aquatic environments. Although fungal contamination has historically received less attention than bacterial contamination, many fungal species contribute significantly to food spoilage and may produce harmful secondary metabolites. Common fungal isolates recovered from fish include *Aspergillus* spp., *Penicillium* spp., *Candida* spp., *Rhizopus* spp., *Mucor* spp., *Fusarium* spp., and *Cladosporium* spp. (Cheesbrough, 2010).

These fungi contaminate fish through contact with contaminated water, air, soil, storage materials, and market environments. Warm temperatures, high humidity, and poor storage conditions encourage fungal growth on fish surfaces. Certain species of *Aspergillus* and *Penicillium* are capable of producing mycotoxins that may pose serious health risks to consumers if contaminated fish are consumed (Cheesbrough, 2010; Huss et al., 2000).

2.6 Factors Influencing Microbial Load in Fish

Several environmental and handling factors influence the microbial quality of fish. Water temperature, dissolved oxygen, pH, salinity, and organic matter affect the diversity and abundance of microorganisms present in aquatic habitats (Austin & Austin, 2016).

Post-harvest factors such as storage temperature, transportation duration, handling frequency, packaging methods, and market sanitation further determine microbial loads. Fish displayed without adequate icing or refrigeration experience rapid bacterial multiplication due to their high moisture content and nutrient-rich composition (Gram & Dalgaard, 2002; Huss et al., 2000). Seasonal variations, particularly during periods of increased rainfall, also contribute to elevated microbial contamination through runoff carrying sewage and agricultural wastes into aquatic environments (Goh et al., 2024).

2.7 Public Health Significance of Microbial Contamination in Fish

Consumption of contaminated fish poses significant health risks to consumers. Pathogenic bacteria and fungi recovered from fish may cause foodborne diseases ranging from mild gastroenteritis to severe systemic infections. Individuals with weakened immune systems, children, pregnant women, and elderly persons are particularly vulnerable to these infections (FAO, 2022; Huss et al., 2000).

Foodborne pathogens such as *Salmonella*, *Escherichia coli*, *Vibrio*, and *Staphylococcus aureus* have been associated with diarrhoea, abdominal pain, vomiting, septicemia, and other serious infections. The emergence of antimicrobial-resistant bacteria in fish further complicates treatment and poses a growing global health threat (Murray et al., 2022; World Health Organization, 2023; Moffo et al., 2024).

Beyond human health, microbial contamination contributes to reduced shelf life, economic losses, food waste, and declining consumer confidence. Continuous surveillance of microbial contaminants and antimicrobial resistance in marketed fish is therefore essential to safeguard public health (Ogbonna et al., 2024; Goh et al., 2024).

2.8 Microbiological Quality Assessment of Fish

Microbiological quality assessment involves the isolation, identification, and enumeration of microorganisms associated with fish samples. Conventional culture techniques remain widely used because they are reliable and cost-effective for routine laboratory investigations (American Public Health Association, 2017; Cheesbrough, 2010). Selective and differential media, biochemical characterization, and taxonomic identification using standard manuals such as Bergey's Manual are commonly employed for bacterial identification (Holt et al., 2000). Molecular techniques such as 16S rRNA gene sequencing further improve the accuracy of bacterial identification (Janda & Abbott, 2007).

Routine microbiological monitoring, together with antimicrobial susceptibility testing performed according to Clinical and Laboratory Standards Institute (2020, 2024) guidelines, is essential for ensuring fish safety and monitoring the spread of antimicrobial-resistant bacteria (CLSI, 2020, 2024).

Knowledge Gap

Although several studies have investigated the microbiological quality of fish marketed in different parts of Nigeria (Babalola et al., 2011; Taiwo et al., 2017; Ogbonna et al., 2024), relatively few have specifically examined the bacterial and fungal isolates recovered from the gills of croaker fish marketed in Elele, Rivers State. Furthermore, limited information exists on the occurrence of antimicrobial-resistant bacteria associated with fish gills in this locality (Odoemelam et al., 2024). This study therefore seeks to bridge this gap by providing current data on the bacterial and fungal flora associated with croaker fish gills and highlighting their implications for food safety and public health.

3. Materials And Methods

3.1 Study Area

The study was conducted at the Microbiology Laboratory of the Department of Microbiology, Madonna University, Elele Campus, Rivers State, Nigeria. Elele is located in Ikwerre Local Government Area of Rivers State within the humid tropical rainforest zone of southern Nigeria. The campus hosts several fish vendors and retail outlets that serve students, staff, and the surrounding community, making it an appropriate location for investigating the microbiological quality and public health significance of fish sold for human consumption.

3.2 Study Design

A cross-sectional laboratory-based study design was adopted to determine the microbial quality and antibiotic susceptibility patterns of bacterial organisms isolated from the gills of fish sold within Madonna University, Elele Campus. The study involved the collection of fish samples from different vendors, microbiological examination of gill tissues, identification of bacterial isolates, and antimicrobial susceptibility testing of recovered organisms.

3.3 Sample Collection

A total of twenty (20) freshly harvested Croaker fish samples comprising commonly consumed species sold within Madonna University, Elele Campus were purchased randomly from fish vendors and sales points over a period of eight weeks. Samples were aseptically placed in sterile polyethylene bags, appropriately labelled, and transported in insulated ice packs to the laboratory for microbiological analysis within two hours of collection to minimize changes in microbial load and composition (ICMSF, 2011).

3.4 Collection and Preparation of Gill Samples

The external surfaces of the croaker fish were rinsed with sterile distilled water to remove loosely attached contaminants. Using sterile dissecting instruments, the operculum was opened and approximately 10 g of gill tissues were excised aseptically and transferred into sterile stomacher bags containing 90 mL of sterile physiological saline solution (0.85% NaCl). The mixture was homogenized using a laboratory stomacher to obtain a stock suspension equivalent to a 10^{-1} dilution. Serial ten-fold dilutions were subsequently prepared up to 10^{-6} using sterile physiological saline according to standard microbiological procedures (APHA, 2017).

3.5 Enumeration of Total Viable Bacterial Count

Aliquots (0.1 mL) of appropriate serial dilutions were inoculated onto sterile nutrient agar plates using the spread plate technique and incubated aerobically at 37°C for 24 h. Colonies developing on plates containing 30–300 colonies were counted and expressed as colony-forming units per gram (CFU/g) of gill tissue using standard plate count methods (APHA, 2017).

3.6 Isolation of Bacterial Organisms

Distinct colonies obtained from primary culture plates were subcultured repeatedly on freshly prepared nutrient agar to obtain pure isolates. Purified isolates were maintained on nutrient agar slants at 4°C pending further characterization and identification (Cheesbrough, 2010).

3.7 Cultural, Morphological and Biochemical Characterization

Preliminary identification of bacterial isolates was based on colonial morphology, pigmentation, elevation, margin characteristics, Gram reaction, and cellular morphology. The isolates were further subjected to standard biochemical tests including catalase, oxidase, coagulase, citrate utilization, indole production, methyl red, Voges–Proskauer, urease activity, triple sugar iron utilization, motility, and carbohydrate fermentation tests following established microbiological protocols (Holt et al., 2000; Cheesbrough, 2010).

3.10 Data Analysis

Microbial counts were transformed into logarithmic values (log_{10} CFU/g) prior to analysis. Data generated from microbial enumeration and antimicrobial susceptibility testing were analyzed using descriptive statistics including frequencies, percentages, means, and standard deviations. Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 25.0, and significance was established at $p < 0.05$.

4. Results

4.1: Mean Count of Bacterial and Fungal Isolates from the Croaker Fish gills sold at Madonna University, Elele Rivers State, Nigeria.

Table 1 presents the mean microbial counts of bacterial and fungal indicators isolated from the gills of croaker fish sold at different locations within Madonna University, Elele, Rivers State, Nigeria. The results showed that croaker fish obtained from the Mini Mart had the highest Total Aerobic Plate Count (TAPC) of 5.8 ± 0.05 Log_{10} CFU/g, followed closely by samples from the Boys' Hostel Mart with a count of 5.7 ± 0.03 Log_{10} CFU/g. Similarly, the Coliform Count (CC) was higher in samples from the Mini Mart (4.0 ± 0.03 Log_{10} CFU/g) compared to those from the Boys' Hostel Mart (3.8 ± 0.02 Log_{10} CFU/g). The Escherichia coli Count (ECC) and Fungal Count (FC) also followed the same trend, with slightly higher values recorded in the Mini Mart samples (3.4 ± 0.01 and 2.01 ± 0.02 Log_{10} CFU/g, respectively) than in the Boys' Hostel Mart samples (3.2 ± 0.03 and 1.97 ± 0.12 Log_{10} CFU/g, respectively).

Table.1: Mean Count of Bacterial and Fungal Isolates from the Croaker Fish gills sold at Madonna University, Elele Rivers State, Nigeria

		Log_{10}CFU/g		
Locations	**TAPC**	**CC**	**ECC**	**FC**
Mini mart	5.8 ±0.05	4.0±0.03	3.4±0.01	2.01±0.02
Boy's Hostel Mart	5.7±0.03	3.8±0.02	3.2±0.03	1.97±0.12

Keys: TAPC= Total Aerobic Plate Count, CC=Coliform count, ECC= *Escherichia coli* Count, and FC= Fungal Count

4.2: Percentage occurrence of Bacterial isolates obtained from the Croaker Fish gills sold at Madonna University, Elele Rivers State, Nigeria.

Table 2 shows the percentage occurrence of bacterial isolates recovered from the gills of croaker fish sold at Madonna University, Elele, Rivers State, Nigeria. *Escherichia coli* was the predominant isolate with a frequency of 10 (40.0%), followed by Pseudomonas spp. 7 (28.0%), *Staphylococcus* spp. 5 (20.0%), and *Streptococcus* spp. 3 (12.0%). The Mini Mart recorded a higher number of isolates (14; 56.0%) compared with the Boys' Hostel Mart (11; 44.0%).

Table 2: Percentage occurrence of Bacterial isolates obtained from the Croaker Fish gills sold at Madonna University, Elele Rivers State, Nigeria.

Bacterial Isolates	Frequency (%)	Mini mart (%)	Boy's Hostel Mart(%)
Staphylococcus sp	5(20.0)	2	3
Streptococcus sp	3(12.0)	2	1
Escherichia coli	10(40.0)	6	4
Pseudomonas sp	7(28.0)	4	3
Total	**25(100.0)**	**14(56.0)**	**11(44.0)**

Percentage occurrence of Fungal isolates obtained from the Croaker Fish gills sold at Madonna University, Elele Rivers State, Nigeria.

Table 3 shows that *Aspergillus* species were the predominant fungal isolates recovered from the gills of croaker fish sold at Madonna University, Elele, accounting for 6 isolates (54.5%). *Rhizopus* species were the second most frequently isolated fungi with 3 isolates (27.3%), while *Penicillium* species had the lowest occurrence with 2 isolates (18.2%). The Boy's Hostel Mart recorded a higher number of fungal isolates, contributing 7 isolates (63.6%) compared to 4 isolates (36.4%) from the Mini Mart.

Table 3: Percentage occurrence of Fungal isolates obtained from the Croaker Fish gills sold at Madonna University, Elele Rivers State, Nigeria.

Fungal Isolates	Frequency (%)	Mini mart (%)	Boy's Hostel mart (%)
Aspergillus sp	6(54.5)	2	4
Rhizopus sp	3(27.3)	1	2
Penicillium sp	2(18.2)	1	1
Total	**11(100)**	**4(36.4)**	**7(63.6)**

4. Discussion

The present study evaluated the microbiological quality of croaker fish gills sold within Madonna University, Elele, Rivers State, Nigeria, and revealed appreciable levels of bacterial and fungal contamination that may constitute potential public health concerns. The total aerobic plate count (TAPC) obtained from the fish gills ranged from 5.7 ± 0.03 to 5.8 ± 0.05 Log10 CFU/g, indicating a relatively high microbial burden within the sampled fish. The slightly higher bacterial counts observed in samples obtained from the Mini Mart compared with those from the Boys' Hostel Mart suggest variations in handling practices, storage conditions, environmental sanitation, and duration of exposure during retail display.

The bacterial loads recorded in this investigation are comparable with findings reported by Taiwo et al. (2017), who documented elevated microbial counts in imported frozen fish sold in Lagos, Nigeria, and attributed the contamination to poor post-harvest handling and inadequate cold chain maintenance. Similarly, Ogbonna et al. (2024) reported high bacterial loads among fish sold in Port Harcourt markets and linked the findings to poor sanitary practices during fish processing and marketing. The observed agreement may be due to similarities in tropical climatic conditions, fish handling methods, and market sanitation practices prevalent within many Nigerian retail fish outlets.

The coliform counts recorded in this study further indicate possible faecal contamination of the fish or contamination during post-harvest handling. Coliform organisms are widely recognized indicators of hygienic quality and sanitary conditions in foods of animal origin. Their occurrence in fish gills may reflect contamination arising from polluted aquatic environments, contaminated processing water, unclean utensils, or repeated washing during retail display. Similar observations were reported by Babalola et al. (2011), who isolated high coliform populations from commercially sold fish in Lagos markets and associated the contamination with poor hygiene and environmental exposure during marketing. The relatively higher coliform count recorded in the Mini Mart may therefore suggest more extensive handling or prolonged exposure before sale.

Escherichia coli was the predominant bacterial isolate recovered in the present study, accounting for 40.0% of all bacterial isolates. The predominance of *E. coli* is microbiologically significant because the organism is widely accepted as an indicator of faecal contamination and poor sanitary quality. Its occurrence in fish gills may indicate contamination of aquatic habitats with sewage, surface runoff, animal wastes, or contamination introduced during handling and processing. Similar findings were reported by Odoemelam et al. (2024), who isolated *E. coli* from fish gills in Rivers State, and by studies conducted in Nigerian fish markets where *E. coli* represented one of the dominant contaminants recovered from fish tissues. The agreement between these studies may be attributable to comparable environmental contamination levels and similar retail practices employed in local fish markets.

Pseudomonas species constituted the second most prevalent bacterial group (28.0%) isolated in this investigation. Members of this genus are ubiquitous aquatic organisms and are commonly associated with fish spoilage because of their ability to proliferate under refrigerated conditions and produce extracellular enzymes responsible for tissue deterioration. Similar observations have been reported in frozen fish sold in Lagos and other Nigerian fish markets where *Pseudomonas* species represented one of the major bacterial contaminants of fish gills and skin tissues. The agreement observed may be explained by the natural ecological association of *Pseudomonas* species with aquatic environments and their remarkable ability to survive under diverse environmental conditions.

The recovery of *Staphylococcus* species (20.0%) in the present study is suggestive of contamination from human handlers since these organisms form part of the normal flora of the skin, nostrils, and hands of healthy individuals. Their presence therefore reflects poor personal hygiene among vendors and inadequate sanitary handling during fish processing and marketing. Comparable findings have been reported by several Nigerian investigators who isolated *Staphylococcus aureus* from fish sold in open markets and attributed the contamination to direct handling and environmental exposure during sale. The slightly higher occurrence observed in the Boys' Hostel Mart may reflect differences in handling frequency and environmental conditions between the two sampling locations.

The occurrence of *Streptococcus* species, although relatively low (12.0%), is of clinical importance because some species are recognized opportunistic pathogens capable of causing septicemia and invasive infections in susceptible individuals. Their presence may be associated with contamination from water sources or human activities during processing and sale.

Fungal contamination was also evident in the fish gills examined in this study. *Aspergillus* species were the predominant fungal isolates, accounting for 54.5% of all fungal organisms recovered. This finding agrees with previous studies conducted on fish and seafood products in Nigeria, where *Aspergillus* species consistently represented the dominant fungal contaminants associated with fish tissues and fish storage environments. The predominance of *Aspergillus* may be attributed to its ability to produce abundant airborne spores that readily contaminate exposed food products and survive under relatively low moisture conditions. Additionally, some species of *Aspergillus* are capable of producing mycotoxins which constitute significant food safety concerns.

Rhizopus species represented the second most frequently isolated fungi (27.3%) in this study. Their occurrence may be associated with airborne contamination, poor storage conditions, and exposure of fish products to humid environments that favour fungal proliferation. Similar findings have been reported in studies involving fresh and smoked fish products marketed in Nigeria and other tropical regions where *Rhizopus* species commonly occur as spoilage fungi.

Penicillium species exhibited the lowest frequency of occurrence (18.2%). This finding is consistent with previous reports which demonstrated that *Penicillium* species generally occur less frequently than *Aspergillus* in fish and seafood products. Differences in fungal prevalence among studies may be attributable to variations in environmental humidity, season of sampling, fish species investigated, handling procedures, geographical location, and storage practices.

Interestingly, whereas the Mini Mart recorded higher bacterial counts and bacterial isolate frequencies, the Boys' Hostel Mart showed a greater occurrence of fungal isolates. This disparity may reflect differences in environmental conditions surrounding the sales locations. Fungal proliferation is strongly influenced by relative humidity, ventilation, and exposure to airborne spores, while bacterial contamination is more closely associated with handling frequency, contaminated surfaces, and water quality used during processing and washing.

Overall, the findings of this study demonstrate that croaker fish sold within Madonna University, Elele, harbour diverse bacterial and fungal populations of considerable public health significance. The predominance of faecal indicator organisms such as *Escherichia coli* and opportunistic pathogens such as *Pseudomonas* and *Staphylococcus* suggests deficiencies in hygienic handling and sanitary conditions during fish processing and retailing. Consequently, there is a need for improved hygienic practices, proper cold storage facilities, regular microbiological monitoring, and food safety education among fish vendors to minimize contamination and reduce the risk of foodborne diseases among consumers.

5. Conclusion

The present study demonstrated that croaker fish sold within Madonna University, Elele Campus, Rivers State, Nigeria, harboured diverse bacterial and fungal contaminants of potential public health importance. The microbial counts recorded from the fish gills indicated considerable microbial contamination, with samples obtained from the Mini Mart exhibiting slightly higher bacterial loads than those obtained from the Boys' Hostel Mart. The predominance of *Escherichia coli* among bacterial isolates suggests possible faecal contamination and poor hygienic handling practices during fish processing, transportation, storage, and retail marketing. Similarly, the occurrence of *Pseudomonas*, *Staphylococcus*, and *Streptococcus* species further emphasizes the potential microbiological risks associated with the consumption of improperly handled fish products.

Among the fungal isolates, *Aspergillus* species constituted the most predominant contaminants, followed by *Rhizopus* and *Penicillium* species. The presence of these fungi raises concerns regarding spoilage and possible exposure to mycotoxin-producing organisms capable of affecting food quality and consumer health. Overall, the findings indicate that croaker fish marketed within the study area may serve as vehicles for the transmission of foodborne microorganisms if adequate hygienic measures are not maintained.

This study provides important baseline information on the microbiological quality of croaker fish sold within Madonna University, Elele, and highlights the need for continuous surveillance and improved food safety practices to safeguard public health.

6. Recommendations

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

1. Fish vendors and handlers should adopt strict hygienic practices during harvesting, transportation, processing, storage, and retail display of fish products. The use of clean potable water and maintenance of an effective cold chain through adequate refrigeration should be encouraged to minimize microbial contamination, retard microbial growth, and preserve fish quality.
2. Relevant public health and regulatory agencies should implement routine microbiological surveillance of fish and seafood products marketed within university communities and local markets. Regular inspection and monitoring of fish processing and retail outlets should be intensified to ensure compliance with food safety standards and hygienic practices.
3. Continuous food safety education and training programmes should be organized for fish vendors, processors, and handlers to enhance awareness of proper sanitation, personal hygiene, safe food handling practices, and the public health implications of microbial contamination in fish products.

4. Future investigations should incorporate molecular identification techniques, antimicrobial susceptibility testing, and larger sample sizes involving multiple fish species and different seasons to provide a more comprehensive understanding of microbial diversity, antimicrobial resistance patterns, and epidemiological trends associated with fish marketed in Rivers State and Nigeria.

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