Original Research Article

Microbial Profile of smoked fish sold in selected markets in Ibadan metropolis, Oyo State, Nigeria

Abstract

Aim

Smoked fish is a widely consumed food and protein source prepared in various cultures around the world. The aim of this study was to determine microbial load of smoked fish sold in select markets in Ibadan, Oyo State.

Methodology

A total of 36 samples of 4 different fish species; Mackerel (*Scomber scombrus*), Sardine (*Sardinela eba*), Panla (*Gadus morhua*) and Cat fish (*Clarias gariepinus*) were sourced from three different market locations. Three pieces of whole smoke-dried fish samples of each of these four species was collected at three different markets. These samples were purchased from Taska market, Adelabu market, and Molete market, all situated in Ibadan Metropolis.

Results

The study identified microorganisms; *Listeria monocytogenes* (15%), *staphylococcus aureus* (15%), *Vibrio paraheamolyticus* (10%),, *Salmonella sp.* (15%),, *Pseudomonas sp.* (15%), *Aeromonas sp* (15%)., and *Escherichia coli* (15%) from the samples. The presence of these bacteria pose a health risk as some of them have been reported in previous studies as hazardous for human consumption. The Multiple Antibiotics Resistance (MAR) Index of bacterial isolates showed some isolates displayed high resistance (e.g., *Listeria monocytogenes* with a MAR Index of 1.0) and others showing lower resistance levels (e.g., *Vibrio parahaemolyticus* and *Salmonella sp.*, both with a MAR Index of 0.1).

Conclusion

The presence of these bacteria in smoked-fish sample is a cause for concern because it suggests that the fish is contaminated with pathogenic bacteria that have survived the smoking process.

Caution should be exercised in consuming smoked-dried fish displayed openly, reheating and prolonged cooking may be necessary to deactivate such micro-organisms before consumption.

Keywords: *Microbial profile, Bacteria, Fish, Pathogenic microorganisms, Ibadan.*

1. Introduction

Fishes are a rich source of protein commonly consumed as an alternative source of protein due to the higher cost of meat and other sources of animal protein [1]. Consumption of fish and fish products are highly recommended due to good digestibility and the high content of polyunsaturated fatty acids. Yet fish is a highly perishable food and so, many strategies have been developed to limit its spoilage [1]. While there are various food preservation techniques to improve microbial safety and extend shelf-life of fish including freezing, chemical preservation, salting, smoking, frying and filleting, smoking still remains a popular method of fish processing [2].

Smoking is one of such strategies used to preserved fish over a long period of time [3]. Smoked fish is a widely consumed food item that has been prepared and enjoyed for centuries in various cultures around the world [4]. The smoking process not only imparts unique flavors but also provides a method of preservation, allowing fish to be stored for longer periods without spoilage [5]. Consumption of smoked and smoke-dried fish both with and without further cooking is common in Nigeria [5]. It has been reported that smoke-dried fish are often contaminated with microorganisms such as bacteria, yeasts and mould from the processing units to market centers [3]. It has also been noticed that good storage practices are not used by most wholesalers of smoked and smoke-dried fishes [4]. Studies have also observed that post processing microbial contaminations originates from poor handling practices, while some could be from the air, the source of the fish, or from other degrading substances [5,6].

Food is unsafe when microbial pathogens or contaminants that can invade human body (e.g *Salmonella*, *Escherichia coli*, *Listeria monocytogenes*, etc.) are present in the food. The presence of toxin producing microbes such as *Staphylococcus aureus, Clostridium botulinum* and *Bacilus cereus* are also injurious to human health [7, 8]. This study was set out to determine the microbial profile of smoked fish sold in select markets within Ibadan which is the largest black city in terms of land mass in West Africa with an estimated population of over 4 million residents.

2. MATERIALS AND METHODS

2.1 Sample Collection and Processing

This study was carried out as a cross-sectional study within the city of Ibadan, Oyo state, Nigeria. Samples of smoked fish sold were collected from three markets namely; *Taska market, Adelabu market, and Molete market* within Ibadan. These markets were chosen due to their popularity and significant presence in the city. They represent different areas within Ibadan metropolis and provide a diverse range of smoked fish products.

A total of 36 samples of smoked fish was collected in sterile plastic bags and transported using ice packs to the microbiology laboratory at Lead City University, Ibadan for microbial analysis. The sample included three replicates of four different types of smoke-dried fish: mackerel *(Scomber scombrus)*, sardine *(Sardinela eba)*, Panla *(Gadus morhua)*, and catfish *(Clarias gariepinus).*

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2.2 Serial dilution, biochemical tests, Gram staining and cell morphology

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According to the methods of Begum et al., 202110g of each fish sample was carefully weighed aseptically and homogenized in 90ml sterile peptone water for serial dilutions. Serial dilution was carried out with dilution factors 10^{-3}, 10^{-5} and 10^{-7} [21]. Diluents were then spread-plated on plates of nutrient agar (for total viable counts); salmonella-shigella agar (for salmonella and shigella species); Mannitol salt agar (for *staphylococcus spp*); listeria agar base (for *Listeria monocytogenes*); and MacConkey agar (for *E. coli* and other enteric bacteria).

The agar plates were prepared in triplicates and incubated at 37°c for 24hours. Total number of cells per gram of samples was then estimated after counting the colonies on the plates. Distinct colonies on the plates were then picked and sub-cultured on nutrient agar plates to ensure purity of cultures. The different pure cultures were then transferred to nutrient agar slants. To confirm the presence of bacteria, a series of biochemical tests were performed, including indole, methyl red, voges-proskauer (VP), and citrate tests, as well as oxidase, hydrogen sulfide production, lactose fermentation, gas production, catalase, sugar fermentation tests and coagulase tests. Gramm staining was also done to determine gram reaction while the cell morphology was determined using microscopy.

2.3 Pathogenicity test

All the isolates within this study were subjected to pathogenicity test using blood agar. Tryptic soy agar (TSA) was prepared and supplement with 5% sheep blood and this was done following manufacturer's instructions. Pure cultures of the bacterial strains under investigation were obtained using sterile inoculating loop or needle to pick a colony from the fresh culture and streak it onto the surface of the blood agar plate. Inoculated blood agar plates were put into the incubator set at 37°c for all the bacteria isolates in this study. The plates were incubated for 18-24 hours, to allow bacterial growth. After the incubation period, the blood agar plates was

examined for signs of hemolysis, this is indicated by changes in the appearance of the blood surrounding the bacterial growth.

2.4 Antibiotics susceptibity tests (AST)

Disk diffusion (kirby-bauer) method was used to determine the susceptibility of bacterial isolates to various antibiotics and identify multidrug-resistant strains. Bacterial isolates were spread on Mueller-Hinton agar plates. Antibiotic-impregnated disks were placed on the surface, and plates were incubated. Zones of inhibition around the disks were measured to determine susceptibility. Multiple antibiotics resistance index (MAR index) was also done and calculated in this study. MAR index is the ratio of number of antibiotics to which organism is resistant to total number of antibiotics to which the organism is exposed. Where the numerator is the aggregate antibiotic resistance score of the isolate from the sample and denominator is the total number of antibiotics used.

3. Results and Discussion

The bacterial load on fish from different market locations in Ibadan metropolis are presented in **Table 1,** displays the results of the bacterial load in fish samples obtained from various markets. The highest bacterial load of 0.35±0.11 x 10^3cfu/g was observed in fish samples from Taska, followed by samples from Molete market with a count of 0.12±0.10 x 10^3cfu/g. On the other hand, the lowest bacterial load was recorded in fish samples from Adelabu, measuring 0.07±0.04 x 10^3cfu/g. **Figure 1,** presents the bacterial load found in different fish types across the Ibadan metropolis. The highest bacterial count was detected in panla (*Gadus morhua*) with a value of 0.27±0.19 x 10^3 cfu/g, followed closely by sardine (*Sardinela eba*) with a value of 0.25±0.20 x 10^3 cfu/g. Conversely, the lowest bacterial count was observed in catfish (*Clarias gariepinus*)

samples with value 0.14±0.10 x 10^3 cfu/g. Nevertheless, statistical analysis using ANOVA revealed no significant difference ($p>0.05$) in the microbial load among the various fish species sold in the Ibadan metropolis.

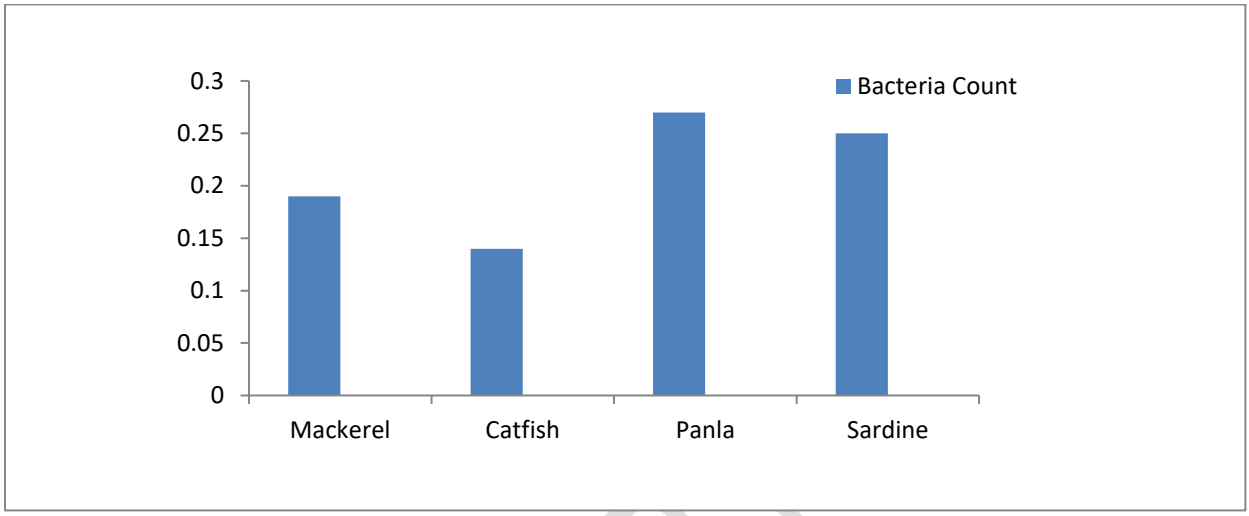

Figure 1 : Microbial count on different types of fishes in Ibadan, oyo state (x 10^3 cfu/g)

Table 1: Microbial load on fish from different market location in ibadan

Market	Tvc (cfu/g)
Taska	0.35±0.11 x 10^3
Adelabu	0.07±0.04 x 10^3
Molete	0.12±0.10 x 10^3

F-statistic: 82.89
P-value: 7.09×10^{-21}

Table 2: Biochemical characteristics of gram positive isolates

Isolate code	Gram stain	Cell morphology	Catalase	Oxidase	Citrate	Lactose	Glucose	Arabinose	Sucrose	Mannitol	V.p tests
T3e	+	Rods	+	+	-	-	+	-	-	+	_
T2e	+	cocci	+	+	-	-	+	-	-	+	
Ad1av	+	Rods	+	+	-	-	+	-	-	+	_
T3v	+	Cocci	+	+	-	-	+	-	-	+	_
M4v	+	Cocci	+	+	-	-	+	-	-	+	_
Ad6e	+	Rods	+	+	-	-	+	-	-	+	_

Key: + = positive reaction, - = negative reaction, v = variable

Samples were coded based on the market the sample was collected from and the number of isolates which were grown from samples from that market

Table 3: Biochemical characteristics of gram negative isolates

Isolate code	Gram stain	Cell morphology	Catalase	Oxidase	Citrate	Lactose	Glucose	Arabinose	Sucrose	Mannitol	V.p tests	Indole
M3v	_	Curved Rods	+	+	+	+	+	+	+	+	+	V
M2e	_	rods	_	_	_	_	+	_	_	_	+	_
M6e	_	Rods	+	+	+	+	+	+	+	-	+	_
M6v	_	Rods	+	+	-	-	+	-	+	V	V	_

M5v	_	Rods	+	_	_	+	+	_	_	+	_	+
Ad3v	_	Rods	+	_	_	+	+	_	_	+	_	+
M4v	_	Rods	_	_	_	_	+	_	_	_	+	_
Ad6v	_	Rods	+	+	+	+	+	+	+	-	+	_
Ad6ae	_	Rods	+	+	-	-	+	-	+	V	V	_
Ad1bv	_	Rods	+	_	_	+	+	_	_	+	_	+
M3e	_	Rods	+	+	-	-	+	-	+	V	V	V
T3v	_	Rods	+	+	+	+	+	+	+	-	+	V
T3e	_	Rods	_	_	_	_	+	_	_	_	+	V
M3v	_	Curved Rods	+	+	+	+	+	+	+	+	+	V

Key: + = positive reaction, - = negative reaction, v = variable

Table 4: Suspected identity of gram positive isolates based on biochemical tests

Isolate code	Suspected isolate identity
T3e	*Listeria monocytogenes*
T2e	*Staphylococcus aureus*
Ad1av	*Listeria monocytogenes*
T5v	*Staphylococcus aureus*
M4v	*Staphylococcus aureus*
Ad6e	*Listeria monocytogenes*

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135 **Table 5: Suspected identity of gram negative isolates based on biochemical tests**

Isolate code	Suspected isolate identity
M3v	*Vibrio paraheamolyticus*
M2e	*Samonella sp.*
M6e	*Pseudomonas sp.*
M6v	*Aeromonas sp.*
M5v	*Escherichia coli*
Ad3v	*Escherichia coli*
M4v	*Samonella sp.*
Ad6v	*Aeromonas sp.*
Ad6ae	*Pseudomonas sp.*
Ad1bv	*Escherichia coli*
M3e	*Aeromonas sp.*
T3v	*Pseudomonas sp.*
T3e	*Samonella sp.*
M3v	*Vibrio paraheamolyticus*

Table 6: Antibiotics susceptibility tests for gram positive isolates

Antimicrobial Agent	T3v	T2e	Ad1av	Ad3v	M4v	Ad6e
Apx	^{0}mm	0mm	14mm	0mm	0mm	14mm
Z	0mm	0mm	17mm	19mm	14mm	17mm
Am	15mm	0mm	16mm	17mm	17mm	16mm
R	17mm	0mm	18mm	18mm	15mm	18mm
Cpx	19mm	19.5mm	17mm	19mm	18.5mm	17mm
S	17mm	16mm	17mm	19mm	15mm	17mm
Sxt	17mm	20mm	14.5mm	18mm	14mm	14.5mm
E	14mm	18mm	16mm	13mm	12mm	16mm
Pef	15mm	19mm	14mm	18mm	15mm	14mm
Cn	20mm	19mm	19mm	17mm	16mm	19mm

Key: Apx: Ampicillin, Z: Azithromycin , Am: Amoxicillin, R: Rifampin, Cpx: Ciprofloxacin, S: Sulfamethoxazole, Sxt: Trimethoprim-sulfamethoxazole, E: Erythromycin, Pef: Pefloxacin Cn: Clindamycin

Table 7: Antibiotics susceptibility tests for gram negative isolates

Antimicrobial Agent	M3v	M2e	M6e	M6v	M5v	T3 e	M4v	Ad6v	Ad6ae
Apx	0	0	14mm	0	0	0	0	0	0
Z	0	0	17mm	19mm	14mm	0	0	0	17mm
Am	15mm	0	16mm	17mm	17mm	17mm	16.5mm	18mm	19mm
R	17mm	0	18mm	19mm	15mm	16mm	15mm	13mm	15mm
Cpx	19mm	19.5mm	17mm	19mm	18.5mm	16mm	16mm	14mm	17mm
S	17mm	16mm	17mm	19mm	15mm	15.5mm	17mm	18mm	16mm
Sxt	17mm	20mm	14.5mm	18mm	14mm	14mm	18mm	17mm	13mm
E	14mm	18mm	16mm	13mm	12mm	13mm	19mm	15mm	15mm
Pef	15mm	19mm	14mm	18mm	15mm	15mm	17.5mm	16mm	17mm
Cn	20mm	19mm	19mm	17mm	16mm	16mm	18mm	17mm	11mm

Key: Apx: Ampicillin, Z: Azithromycin , Am: Amoxicillin, R: Rifampin, Cpx: Ciprofloxacin, S: Sulfamethoxazole, Sxt: Trimethoprim-sulfamethoxazole, E: Erythromycin, Pef: Pefloxacin Cn: Clindamycin

Table 8 : Antibiotics susceptibility tests for gram negative isolates

Antimicrobial Agent	Ad1bv	M3e	T5v	T3e	M3v
Apx	0	14mm	0	15mm	0
Z	0	17mm	0	15mm	13mm
Am	12mm	15mm	12mm	14mm	15mm
R	13mm	16mm	16mm	16mm	16mm
Cpx	16mm	16mm	15mm	16mm	15mm
S	16.5mm	14mm	15mm	18mm	17mm
Sxt	14mm	15mm	14mm	17mm	16mm
E	15mm	15mm	14mm	14mm	14mm
Pef	16mm	16mm	13mm	16mm	15mm
Cn	15mm	14mm	11mm	15mm	15mm

Key: Apx: Ampicillin, Z: Azithromycin , Am: Amoxicillin, R: Rifampin, Cpx: Ciprofloxacin, S: Sulfamethoxazole, Sxt: Trimethoprim-sulfamethoxazole, E: Erythromycin, Pef: Pefloxacin Cn: Clindamycin

Table 9: Pathogenicity test for gram positive isolates

Isolate code	Isolate Name	Alpha Hemolysis	Beta Hemolysis	Nil Hemolysis
T3e	*Listeria monocytogenes*	-	+	-
T2e	*Staphylococcus aureus*	-	_	-
Ad1av	*Listeria monocytogenes*	-	_	-
T3v	*Staphylococcus aureus*	-	+	-
M4v	*Staphylococcus aureus*	_	_-	-
Ad6e	*Listeria monocytogenes*	-	+	-

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151 **Table 10: Pathogenicity test for gram negative isolates**

Isolate code	Isolate Name	Alpha Hemolysis	Beta Hemolysis	Nil Hemolysis
M3v	*Vibrio paraheamolyticus*	-	-	-
M2e	*Samonella sp.*	-	-	-
M6e	*Pseudomonas sp.*	-	-	-
M6v	*Aeromonas sp.*	-	+	-
M5v	*Escherichia coli*	-	_	-
T3 e	*Escherichia coli*	-	+	-
M4v	*Samonella sp.*	-	_	-
Ad6v	*Aeromonas sp.*	-	_	-
Ad6ae	*Pseudomonas sp.*	-	_	-
Ad1bv	*Escherichia coli*	-	+	-
M3e	*Aeromonas sp.*	-	_	-
T3v	*Pseudomonas sp.*	-	_	-
T3e	*Samonella sp.*	-	+	-

M3v	*Vibrio paraheamolyticus*	-	_	-

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153 **Table 11: Multiple Antibiotics Resistance Index of isolates in this study**

S/N	Isolate code	Suspected isolate identity	MAR Index
1	**T3e**	*Listeria monocytogenes*	1.0
2	**T2e**	*Staphylococcus aureus*	0.4
3	**Ad1av**	*Listeria monocytogenes*	1.0
4	**T5v**	*Staphylococcus aureus*	0.2
5	**M4v**	*Staphylococcus aureus*	0.2
6	**Ad6e**	*Listeria monocytogenes*	1.0
7	**M3v**	*Vibrio paraheamolyticus*	0.1
8	**M2e**	*Samonella sp.*	0.1
9	**M6e**	*Pseudomonas sp.*	0.4
10	**M6v**	*Aeromonas sp.*	0.1
11	**M5v**	*Escherichia coli*	0.1
12	**Ad3v**	*Escherichia coli*	0.1

13	**M4v**	*Samonella sp.*	0.1

Table 12: Multiple Antibiotics Resistance Index of isolates in this study (*Cont.*)

S/N	Isolate code	Suspected isolate identity	MAR index
14	**Ad6v**	*Aeromonas sp.*	0.2
15	**Ad6ae**	*Pseudomonas sp.*	0.1
16	**Ad1bv**	*Escherichia coli*	0.2
17	**M3e**	*Aeromonas sp.*	1.0
18	**T3v**	*Pseudomonas sp.*	0.2
19	**T3e**	*Samonella sp.*	1.0
20	**M3v**	*Vibrio paraheamolyticus*	0.1

MAR index is calculated as the ratio of number of antibiotics to which organism is resistant to total number of antibiotics to which the organism is exposed. Where the numerator is the aggregate antibiotic resistance score of all isolates from the sample and denominator is the total number of antibiotics used.

Smoking fish is a preservation method that involves exposing the fish to smoke and heat to extend its shelf life. However, smoking alone might not be sufficient to eliminate all potential pathogens [14]. Smoked fish that is improperly processed, stored, or handled can become contaminated with bacteria, including those with pathogenic potential [15]. Consuming smoked

fish contaminated with pathogenic bacteria can lead to foodborne illnesses in humans, causing symptoms such as gastroenteritis, nausea, vomiting, diarrhea, and abdominal cramps [20].

The findings of this study show the microbial load of fish samples collected from three markets locations in Ibadan, Oyo state. The result shows no statistical difference in the amount of microorganisms present from the different markets which were sampled. This indicates that generally the samples from different markets had microbial loads which were similar. The Codex guidelines for fish and fishery products (Codex Standard 244-2007) provide microbial limits for various types of fish, including smoked fish, and these codes are used globally. According to this standards the recommended limit of < 10^6 CFU/g (colony-forming units per gram) is the limit acceptable for smoked fish and based on this recommendation, the samples in this study are still well within acceptable limits for health and safety as values for microbial load of samples ranged from 0.12 to 0.35 10^3 CFU/g [19].

Figure 1 shows the microbial load on various types of smoked fish collected from markets in Ibadan, Oyo State. The microbial counts are expressed as colony-forming units per gram (cfu/g), multiplied by 10^3, and panla (*Gadus morhua*) can be clearly seen to carry the highest microbial load followed by sardine (*Sardinela eba*),, mackerel (*Scomber scombrus*), and then lastly catfish (*Clarias gariepinus*). The elevated microbial loads can impact shelf life and pose health risks. The results of our study underscore the need for improved sanitary measures in fish handling and storage at the markets, as well as routine microbiological assessments to ensure consumer safety. Regular monitoring and stricter control measures during smoking and post-processing are recommended to reduce microbial contamination and enhance the quality of smoked fish sold in these markets.

The study identified suspected microorganisms that were both gram positive and gram negative isolates associated with smoke-dried fishes sold in different markets in Ibadan, using biochemistry, Gram staining and microscopy to include; *Listeria monocytogenes*, *Staphylococcus aureus*, *Vibrio paraheamolyticus*, *Salmonella species*, *Pseudomonas species*, *Aeromonas species*, and *Escherichia coli*. The presence of these bacteria in the fish samples is an issue of concern as some of these isolates pose significant health risks and have been reported in previous studies as hazardous for human consumption.

The Codex guidelines for fish and fishery products (Codex Standard 244-2007) recommended the total absence of *Salmonella spp.* as it is a harmful pathogen, yet unfortunately it was identified as one of the isolates in our sample [19]. The same can be said for *Listeria monocytogenes* which was present in our samples and has been seen to be particularly dangerous to the health of people within the vulnerable population such as pregnant women, infants and the elderly. *Staphylococcus aureus* was present in our samples although we did not calculate the levels of the isolate within our samples [13].

Studies [9,10] have reported that the spoilage of fish is primarily caused by the activity of psychotropic gram-negative bacteria such as *pseudomonas species*. Similarly, studies have also reported that fish and fish products can spoil due to specific spoilage organisms that vary depending on the treatment, preservation, and storage conditions, including temperature [11, 12]. These findings of this study suggest that the presence of some of the organisms implicated in causing spoilage of fish such as *pseudomonas sp. Aeromonas sp., vibrio sp.* and *enterobacteriaceae* which were identified in the fish samples can lead to spoilage and potential health hazards if consumed.

Examples of specific spoilage organisms (SSO) commonly found in different fish and fish products include *pseudomonas, Aeromonas hydrophila, vibrionaceae, enterobacteriaceae*, yeast, and moulds etc. were similar to the isolates identified within our study [9]. According to studies which were conducted in artisanal fishery, freshly caught fish are often covered with damp sacks or mixed with wet grass or water weeds to lower the temperature [17]. This method can increase the risk of contamination with microorganisms such as *Salmonella sp* and other microorganisms meaning that fish spoilage can begin just after a fish has been caught or even while it is still within the aquatic ecosystem.

During the smoke drying process, the use of smoking kilns and overcrowding of fish on trays can lead to improper processing, which promotes fungal growth. Furthermore, inadequate storage practices, such as poor ventilation and pest infestation, during the storage of smoked dried fish products can further contribute to microbial contamination [13]. The environment in which fish are displayed in the market is often unhygienic, providing another pathway for microbial contamination. It is common to find retailers displaying smoke-dried fish samples in open trays near gutters or refuse heaps. This practice encourages the growth of fungi and bacteria, which can lead to the production of toxins.

Bacteria isolates within our study such as *listeria monocytogenes* and *staphylococcus aureus* displayed beta hemolysis positive in the pathogenicity test while bacteria isolates such as *Aeromonas sp., Salmonella sp.,* and *Escherichia coli* showed beta hemolysis as Gram negative isolates. The presence of hemolytic bacteria in a smoked-fish sample is a concern because it suggests that the fish may be contaminated with harmful bacteria with virulent factors and characteristics and yet, that have survived the smoking process. The presence of beta-positive

gram-positive bacteria in a smoked-fish sample may indicate a need for closer inspection of the fish processing and handling practices.

In our study Multiple Antibiotics Resistance (MAR) Index of bacterial isolates from smoked fish in markets were evaluated to determine the resistance level of the isolates to various antibiotics. The MAR Index is a valuable indicator in assessing the resistance patterns in bacteria and highlights the potential health risks posed to consumers. The MAR Index values of the isolates ranged significantly, with some isolates displaying high resistance (e.g., *Listeria monocytogenes* with a MAR Index of 1.0) and others showing lower resistance levels (e.g., *Vibrio parahaemolyticus* and *Salmonella sp.*, both with a MAR Index of 0.1). Notably, isolates such as *Staphylococcus aureus* had variable resistance profiles, with MAR Index values of both 0.2 and 0.4 across different isolates, indicating inconsistency in resistance patterns among different strains within the same species.

High MAR Index values, such as those observed for *Listeria monocytogenes* and *Pseudomonas sp.* with a MAR Index of 1.0, suggest that bacteria in our study is highly resistant to multiple antibiotics, posing a greater risk of persistence. These results indicate the need for strict monitoring of antibiotic resistance in smoked fish to safeguard public health, as well as the importance of judicious antibiotic use in food production and processing environments. Many of the bacteria isolated within this study can be harmful to humans and cause foodborne diseases, hence their presence in smoked fish samples is quite concerning.

Notably, *vibrio parahaemolyticus,* which was present within the samples in this study has been frequently linked to seafood contamination and can result in gastroenteritis when consumed by people [16]. If correct food safety procedures are not followed, the study has corroborated the

findings of other studies that contamination will occur while the fish is being processed, handled, or stored. A lack of precautions could allow bacteria found in raw fish to survive the smoking process, continue alive, and endanger the health of consumers [17, 18].

Conclusion

The study findings revealed that smoked-dried fishes in Taska, Adelabu, and Molete markets in Ibadan, Oyo state, are contaminated with microorganisms. However, the microbial load observed still falls within the recommended limits for ready-to-eat foods, indicating that the fish sold in different markets within Ibadan metropolis is safe for human consumption. Therefore in order to prevent contamination of smoked fish products, it is recommended that fish sellers be educated on processing and handling of their fish wares.

Recommendation

There is need for sensitization on post- processing handling of the smoked catfish products on how to ensure that they are well packed in well ventilated baskets and transported in proper sanitized trucks. The adoption of good processing practice and the use of controlled temperature in processing and preserving of the smoked catfish are highly recommended.

Disclaimer (Artificial intelligence)

Authors hereby declare that No generative AI technologies such as large language models such as ChatGPT and COPILOT etc. as well as text to image generators were used in the writing or editing of this manuscript.

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