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Physicochemical and Microbiological Quality of Fresh and Smoked Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*) in Ibadan, Nigeria

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Authors' contributions

This work was carried out in collaboration between the two authors. Author FTA designed the study. Authors FTA and FKF managed the experimental process. Author FKF wrote the first draft of the manuscript and performed the statistical analyses with contribution from author FTA. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: This study aimed to determine the microbiological quality of fresh and smoked Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*) collected randomly from two fish markets (Asejire and Eleyele) and University of Ibadan fish farm.
Study Design: Microbiological analyses of the samples were done using standard microbiological procedures.
Place and Duration of Study: Fresh Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*) species fish samples were collected at Eleyele, Asejire and University of Ibadan fish farm. All samples were collected randomly and placed in sterile polythene bags. The fresh fish samples were also collected in clean plastic containers and transported to the Postgraduate Laboratory of the Department of Microbiology, University of Ibadan for analyses.
Methodology: The fish samples were cultured and isolates were obtained from the flesh, gills and guts. The pH was determined by weighing 3g of the fish samples and the samples were washed in

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sterile distilled water. The fish samples were also analyzed to determine their proximate composition. The fish samples were analysed using standard microbiological procedures.
Results: A total of 90 bacterial isolates were obtained from the different fish samples with their bacterial count ranging from $1.0 \times 10^2 - 5.0 \times 10^5$ CFU/g. The bacterial diversity were; *Staphylococcus aureus*, *Salmonella* sp., *Shigella* sp., *Pseudomonas aeruginosa*, *Klebsiella pneumonia*, *Klebsiella oxytoca*, *Klebsiella ozaenae*, *Acinetobacter baumanii*, *Proteus vulgaris*, *Escherichia coli*, *Enterobacter aerogenes*, *Citrobacter freundii* and *Moraxella catarrhalis*. A total of 51 fungal isolates were obtained also with the fungal counts ranging from $1.0 \times 10^2 - 6.0 \times 10^4$ CFU/g. The three (3) species obtained from the samples were identified as *Aspergillus* sp., *Fusarium* sp. and *Penicillium* sp. The frequency of occurrence of the bacterial isolates was highest (27%) for *Shigella* sp. and least (1%) for both *Proteus vulgaris* and *Pseudomonas aeruginosa*.
Conclusion: In the current study the fish samples obtained from the different locations could be contaminated with pathogenic microorganisms and therefore Catfish and Tilapia fish should be properly washed, cooked and smoked before consumption.

Keywords: Microbial load; Clarias gariepinus; Oreochromis niloticus; fresh fish; smoked fish.

1. INTRODUCTION

A fish is any member of a paraphyletic group of organisms that consists of all gill bearing aquatic craniates animals that lack limbs with digits. Fish are abundant in most sources of water. Most fish exchange gases using gills on either side of the pharynx. Fish is an important source of protein which is consumed by a large number of people in the world, it provides high quality protein and contains many vitamins and minerals, Fish has a relative 10 % calories content which makes its role in nutrition recognized [1]. Fish is a very vital source of high quality protein and constitutes an important part of man's diet. Fresh fish is generally made of muscle which contains about 15-20% protein and less than 1% carbohydrates [1]. It is the most important animal protein food available in the tropics, and it represents about 14% of all animal protein on a global basis [2,3,4,5].

Freshly caught fish are usually sterile, but the skin, gills and alimentary tracts all carries substantial amount of bacteria. However, spoilage soon sets in which is occasioned by an increase in the ambient temperature that triggers favourable conditions for microorganisms to thrive. Thus, the quality of fish as well as its potential keeping time deteriorates rapidly leading to food loss with regards to acceptable quality. This deterioration is due to growth of microorganisms or non-microbial causes such as lipid oxidation [6]. Essuman [7] stated that Africa is endowed with rich sources of numerous species of fresh fish. Such species include *Clarias* spp, *Bagrus* spp., *Tilapia* spp amongst others [8,9].

In Nigeria, the short supplies of animal protein together with the increasing human population have raised the cost of animal protein to a level almost beyond the reach of the low income group [10]. As a result, there is a considerable increase in the demand for fish being the cheapest source of animal protein [11]. Fish has a great advantage because it is easily digestible.

Fish flesh naturally contains very low levels of carbohydrates and these are further depleted during the death struggle of the fish [12]. This has two important consequences for spoilage. Firstly, it limits degree of post mortem acidification of the tissue so that the ultimate pH of the muscles is 6.2-6.5 [12] Secondly, the absence of carbohydrate means that bacteria present on the fish will immediately resort to using the soluble pool of readily assimilated nitrogenous material, producing off-odour, [12,13].

The rate at which spoilage occurs is also dependent on the initial microbial load on the fish which implies that the higher the microbial load, the sooner spoilage occurs [12]. The activities of man in water bodies such as sewage disposal increases the risk of contamination with enteric microorganisms, and because of the filter feeding habit of Tilapia, they are more prone to infection with these organisms [12]. Also, during handling of the commodity, the natural flora of the environment may be contaminated with organisms associated with man such as members of the Enterobacteriaceae and *Staphylococcus aureus* which can grow well at 30-37°C [14].

Clarias gariepinus is a popular fish for aquaculture because of its hardiness, ease of larval production in captivity and good market price. Tilapia (*Oreochromis niloticus.)* is the second most common farm raised food fish in the world [15]. It also has rapid growth rate, bottom feeders and high tolerance to environmental conditions. Thus, this study aimed at assessing the microbial quality of fresh and smoked fish samples in some locations within Ibadan metropolis.

2. MATERIALS AND METHODS

2.1 Samples Collection and Processing

Fish samples, fresh Catfish (*Clarias gariepinus*) and Tilapia (*Oreochromis niloticus*.) species were collected at Eleyele, Asejire and University of Ibadan fish farm. Smoked Catfish and Tilapia fish samples were also obtained and were placed in sterile polythene bags. Fourteen (14) fish samples were analysed with five (5) being fresh and nine (9) being smoked. The fresh fish samples were collected in clean plastic containers and transported to the Postgraduate laboratory of the Department of Microbiology, University of Ibadan for analysis. The fish samples were aseptically placed on sterile foil paper with sterile hand gloves and the muscle was swabbed with 90% ethanol. The fish samples were carefully dissected with sterile scissors and blade to reveal the flesh, the gills and the gut. Sterile scissors was also used to carefully cut the desired grams that would be used for serial dilution.

2.2 Laboratory Smoking of Fish Samples

Fresh Catfish and Tilapia species were collected from Asejire and Eleyele River. The fishes were washed with sterile distilled water and then dried in the oven under low heat for a period of 4 – 5 hours.

2.3 Determination of pH and Proximate Analysis

The pH was determined by weighing 3g of the fish samples and the samples were washed in sterile distilled water. The washed samples were then macerated with the aid of mortar and pestle and were then placed into the sterile conical flask into which 4 ml of sterile distilled water was poured. The digital pH-meter (Melter Delton 340 pH meter) was calibrated and then used to determine the pH of the fish samples by allowing the electrode to touch the sample. The pH was determined in triplicates. The fish samples were also analyzed to determine their proximate composition according to the method of the Association of Official Analytical Chemist [16].

2.4 Microbiological Examination

The bacterial counts on the muscle, gills and guts were estimated as follows; 1 g of muscle, gut and gills were weighed and then placed into 9 ml of sterile distilled water in McCartney bottles and it served as the stock solution. Six McCartney bottles also containing 9 ml of sterile distilled water were also placed on the table. The stock solution was well shaken to allow for equal distribution throughout the solution. 1 ml of the stock solution was placed in the first bottle and was serially diluted. Viable aerobic bacterial counts were enumerated on plate count agar after incubation at 37°C for 24 hours [17].

2.5 Isolation and Identification of Isolates Obtained from the Fish Samples

The samples were serially diluted and appropriate dilution factors were used for microbiological examination using standard pour plate method. The pour plates were used using Nutrient Agar (NA), Eosin Methylene Blue Agar (EMB), Salmonella/Shigella Agar (SSA) and Malt Extract Agar (MEA). Eosin Methylene Blue Agar (EMB), Salmonella/Shigella Agar (SSA) were used for the enumeration of *Salmonella* and *Shigella*. Nutrient Agar was used for total aerobic counts, while MacConkey Agar (MAC) was used to isolate the total Enterobacteriaceae counts and Malt Extract Agar for (MEA) was used for total fungal count respectively. The plates were incubated at 37°C for 24 hours except for fungal plates that were incubated at 27°C for 3-5 days. The discrete colonies were then sub-cultured unto fresh agar plates aseptically to obtain pure colonies of isolates. Gram staining was done for all bacterial isolates and their gram reaction was viewed through the microscope, cultural characteristics of colonies were observed and biochemical tests were also carried out. The biochemical tests were; catalase test, oxidase test, indole test, methyl red test, vogues proskauer test, citrate utilization test, urease tests, coagulase test, sugar fermentation test etc. The bacterial isolates were then identified by comparing their morphological and biochemical characteristics with those of known taxa as described by [18]. The fungal isolates were identified based on their cultural and

morphological characteristics with reference to the Compendium of soil fungi [19].

2.6 Statistical Analysis

The proximate analysis data obtained in triplicates were subjected to descriptive statistics (i.e mean and standard error).

3. RESULTS

3.1 Proximate Analysis of Fish Samples

Table 1 shows the proximate analysis of different fish samples obtained from different locations. Fresh Catfish from UI farm had the highest moisture content of 79.12 ± 0.022% while smoked Tilapia from Asejire had the lowest moisture content of 15. 82 ± 0.012%. Smoked Tilapia from Asejire had the highest crude protein content of 51.36 ± 0.012% while fresh Tilapia from Asejire had the lowest crude protein content of 13.42 ± 0.020%. Smoked Catfish from Asejire had the highest crude fat content of 28.83 ± 0.009% while fresh Catfish from UI farm had the least crude fat content of 4.11 ± 0.004%. Table 1 also revealed that the crude fibre content was zero. Smoked Tilapia from UI farm had the highest ash content of 15.44 ± 0.009 while the fresh Catfish from Asejire had the least ash content with the value of 1.37 ± 0.006%. For the pH, Asejire fresh Catfish had the highest pH value of 7.84 while smoked Tilapia fish Asejire had the least pH value of 5.73.

3.2 Total Bacterial and Fungal Counts

Table 2 shows the microbial load of isolates obtained from different fish samples from University of Ibadan fish farm. The microbial load was in the range of 1.0×10^2 - 8.0×10^2 CFU/g. Table 2 also revealed that the microbial load in the gill was more in both fresh Catfish and Fresh Tilapia.

Table 3 shows the microbial load of isolates obtained from fish samples at Eleyele. The bacterial load was in the range of $1.0 \times 10^2 – 9.0 \times 10^4$ CFU/g. Low Fungal growth was recorded for the fresh and smoked Catfish samples.

Table 4 shows the microbial load of isolates obtained from different fish samples at Asejire. The gills had more microbial load than the muscle and gut. The fresh catfish had no fungal count and the smoked catfish had no count for the total aerobic count. The microbial load was within the range of $1.0 \times 10^2 – 6.0 \times 10^2$ CFU/g.

Table 5 shows the microbial load of laboratory smoked Catfish and Tilapia obtained from University of Ibadan Fish Farm and Asejire. The microbial load was very low as compared to the commercially smoked ones with majority having no microbial count. The microbial load was within the range of $1.0 \times 10^1 – 6.0 \times 10^1$ CFU/g.

Table 1. Proximate analysis of different fish samples obtained from different locations

Sample code	Moisture	Crude protein	Crude Fat	Crude fibre	Ash	pH
	←		%		→	
A	*78.15±0.018	13.42 ± 0.020	5.17 ± 0.009	0	3.26 ± 0.006	7.53
B	70.68 ± 0.048	16.98 ± 0.007	10.97 ± 0.020	0	1.37 ± 0.01	7.84
C	78.92 ± 0.009	14.14 ± 0.007	2.96 ± 0.009	0	3.97 ± 0.004	7.12
D	79.17 ± 0.022	15.21 ± 0.009	4.11 ± 0.004	0	1.50 ± 0.009	7.26
E	15.82 ± 0.012	51.36 ± 0.012	22.21 ± 0.009	0	10.61 ± 0.009	5.73
F	20.17 ± 0.009	46.73 ± 0.035	28.83 ± 0.009	0	4.28 ± 0.072	5.88
G	16.11 ± 0.009	51.13 ± 0.009	17.32 ± 0.009	0	15.44 ± 0.009	5.65
H	18.76 ± 0.012	49.38 ± 0.021	27.02 ± 0.009	0	4.84 ± 0.03	5.82

± = Standard error of mean
**= values are triplicate means of parameters.*
Key: A= Fresh Tilapia Asejire, B= Fresh Catfish Asejire, C= Fresh Tilapia UI farm, D= Fresh Catfish UI farm, E=Tilapia Smoked Asejire, F= Catfish Smoked Asejire, G= Tilapia Smoked UI farm, H= Catfish Smoked UI fish farm.

Table 2. Microbial load of isolates obtained from different fish samples at University of Ibadan fish farm

Location	Type of fish	Microbial load	Muscle ←	GUT (CFU/g)	GILL →
U.I Fish Farm	Fresh Catfish	Total aerobic count	2.0×10^2	1.2×10^5	1.4×10^5
		Total Enterobacteriaceae	1.0×10^2	-	1.2×10^5
		Total fungi	3.0×10^2	1.0×10^2	2.0×10^2
	SmokedCatfish	Total aerobic count	1.4×10^3	1.0×10^2	8.0×10^2
		Total Enterobacteriaceae	1.2×10^3	1.0×10^2	2.0×10^2
		Total fungi	4.0×10^2	4.0×10^2	3.0×10^2
	Fresh Tilapia	Total aerobic count	8.0×10^4	5.0×10^2	1.4×10^5
		Total Enterobacteriaceae	2.0×10^2	2.0×10^2	1.0×10^5
		Total fungi	3.0×10^2	4.0×10^2	1.0×10^2
	Smoked Tilapia	Total aerobic count	-	1.0×10^2	-
		Total Enterobacteriaceae	-	-	-
		Total fungi	4.0×10^2	3.0×10^2	1.0×10^2

- = *No Growth (NG)*

Table 3. Microbial load of isolates obtained from catfish samples at Eleyele

Location	Type of fish	Microbial load	Muscle ←	GUT CFU/g	GILL →
Eleyele	Fresh catfish	Total aerobic count	5.0×10^4	3.0×10^5	7.0×10^4
		Total Enterobacteriaceae	2.0×10^4	1.5×10^5	1.0×10^4
		Total fungi	-	2.0×10^2	2.0×10^2
	Smoked catfish	Total aerobic count	1.0×10^2	4.0×10^2	2.0×10^2
		Total Enterobacteriaceae	-	1.0×10^2	1.6×10^2
		Total fungi	5.0×10^2	3.0×10^2	3.0×10^2

- = *No Growth (NG)*

Table 4. Microbial load of isolates obtained from different fish samples at Asejire

Location	Type of fish	Microbial load	Muscle ←	GUT CFU/g	GILL →
Asejire	Fresh Catfish	Total aerobic count	6.0×10^3	2.0×10^2	5.0×10^5
		Total Enterobacteriaceae	1.2×10^5	1.0×10^3	1.6×10^3
		Total fungi	-	-	-
	Smoked Catfish	Total aerobic count	6.0×10^3	2.0×10^2	1.0×10^2
		Total Enterobacteriaceae	-	-	-
		Total fungi	1.0×10^2	3.0×10^2	-
	Fresh Tilapia	Total aerobic count	2.0×10^5	3.0×10^4	5.0×10^4
		Total Enterobacteriaceae	1.0×10^4	2.0×10^4	1.0×10^4
		Total fungi	6.0×10^2	6.0×10^4	3.0×10^4
	Smoked Tilapia	Total aerobic count	2.0×10^2	-	3.0×10^2
		Total Enterobacteriaceae	-	-	-
		Total fungi	6.0×10^4	-	5.0×10^4

KEY

- = *No Growth(NG)*

3.3 Frequency of Occurrence of Bacterial Isolates

Fig. 1 shows the frequency of occurrence of bacterial isolates from the different fish samples. The isolates that were obtained from the different sampling site; Asejire, Eleyele and University of Ibadan fish farm were identified as *Staphylococcus aureus*, *Salmonella* sp., *Shigella* sp., *Acinetobacter baumanii*, *Citrobacter freundii*, *Enterobacter aerogenes*, *Pseudomonas aeruginosa*, *Proteus vulgaris*, *Escherichia coli*, *Moraxella catarrhalis*, *Klebsiella pneumoniae*, *Klebsiella oxytoca* and *Klebsiella ozaenae*. The frequency of occurrence of bacterial isolates showed *Shigella* sp. 25 (27.78%) being the highest which was closely followed by *Acinetobacter baumanii* 22 (24.44%) and then *Salmonella* sp., and the least was *Proteus vulgaris* and *Citrobacter freundii* 1(1.11%) and *Klebsiella pneumonia* and *Escherichia coli* 2 (2.22%).

Table 6 revealed the different parts within which the isolates were obtained, and it revealed that the gills had the highest occurrence 46 (51.11%), which was closely followed by the muscle at 23 (25.56%) and the least was the gut 21 (23.33%). The majority of the isolates were obtained from the University of Ibadan fish farm at 46 (51.11%), which were closely followed by Eleyele 28 (31.11%) and then Asejire 16 (17.78%).

3.4 Frequency of Occurrence of Fungal Isolates

Table 7 shows the frequency of occurrence of fungal isolates isolated from different fish parts obtained from Asejire, Eleyele and University of Ibadan Fish Farm. Table 7 also revealed that a total of 51 fungal isolates were obtained and they include *Penicillium* sp., *Aspergillus* sp., and *Fusarium* sp. The *Fusarium* sp. had the highest occurrence with 31 (60.78%), which was closely followed by *Aspergillus* sp. at 18 (35.29%). The least occurrence could be observed in *Penicillium* sp. at 2 (3.92%).

Fig. 2 shows that University of Ibadan Fish Farm had the highest fungal population of 22 (43.14%), which was closely followed by Asejire at 20 (39.22%) while the least population could be observed in fish sample obtained from Eleyele at 9 (17.65%).

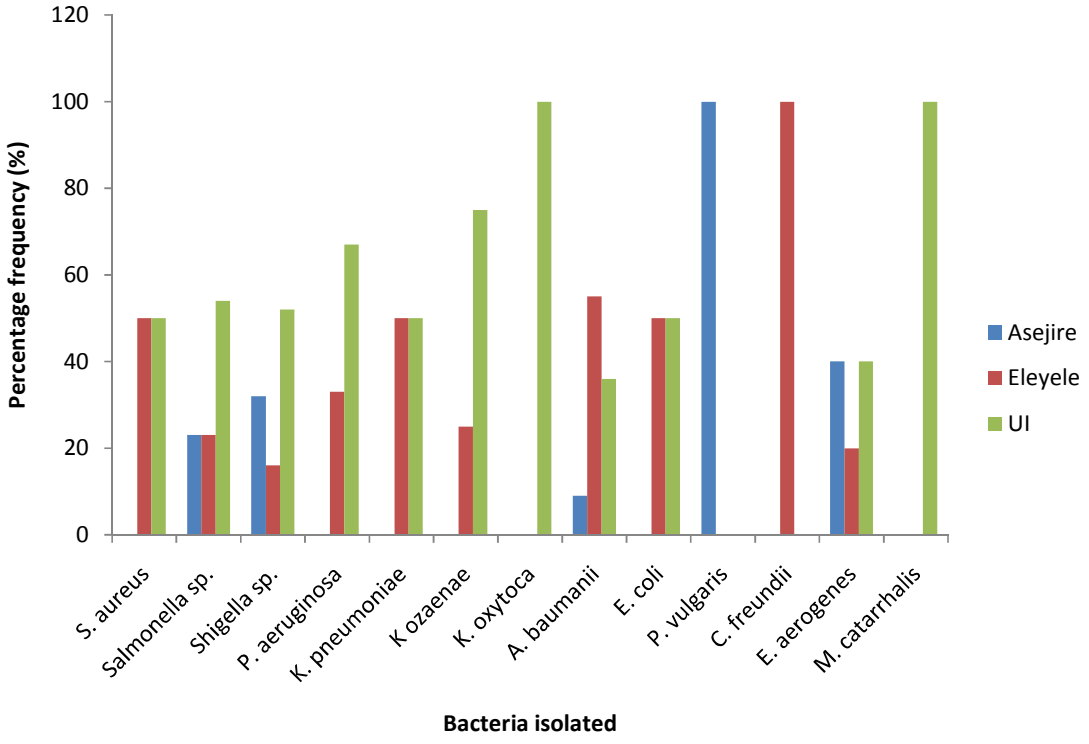

Fig. 1. Frequency of occurrence of bacterial isolates obtained from the fish samples

Table 5. Microbial load of isolates from laboratory smoked fish samples from UI fish farm and Asejire

Location	Type of fish	Microbial load	Muscle ←	GUT CFU/g	GILL →
U.I fish farm	Laboratory smoked Catfish	Total aerobic count	-	1.0×10^1	-
		Total Enterobacteriaceae	-	-	-
		Total fungi	1.0×10^1	2.0×10^1	3.0×10^1
	Laboratory smoked Tilapia	Total aerobic count	-	-	-
		Total Enterobacteriaceae	-	-	-
		Total fungi	-	-	3.0×10^1
Asejire	Laboratory smoked Catfish	Total aerobic count	-	-	2.0×10^3
		Total Enterobacteriaceae	-	-	-
		Total fungi	4.0×10^1	-	4.0×10^1
	Laboratory smoked Tilapia	Total aerobic count	-	-	-
		Total Enterobacteriaceae	-	-	-
		Total fungi	1.0×10^1	-	1.0×10^1

- = *No Growth (NG)*

Table 6. The frequency of occurrence of bacterial isolates in the fish samples

Isolates	No (%)	Fish Parts		Total
	Gills	Gut	Muscle	
Staphylococcus aureus	4 (66.67)	1 (16.67) 0(0.00	1(16.66)	6
Salmonella sp.	7 (53.85)	2 (15.38)	4 (30.77)	13
Shigella sp.	14(56.00)	6 (24.00)	5(20.00)	25
Pseudomonas aeruginosa	1 (33.33)	0 (0.00)	2 (66.67)	3
Klebsiella pneumoniae	1 (50.00)	1 (50.00)	0 (0.00)	2
Klebsiella ozaenae	2 (50.00)	1 (25.00)	1 (25.00)	4
Klebsiella oxytoca	2 (66.67)	1 (33.33)	0 (0.00)	3
Acinetobacter baumanii	11(50.00)	5 (22.73)	6(27.27)	22
Escherichia coli	2 (100)	0 (0.00)	0 (0.00)	2
Proteus vulgaris	0 (0.00)	0 (0.00)	1 (100.00)	1
Citrobacter freundii	0 (0.00)	1 (100)	0 (0.00)	1
Enterobacter aerogenes	-	2 (40.00)	3 (60.00)	5
Moraxella catarrhalis	2 (66.67)	1 (33.33)	-	3
Total	46(51.11)	21(23.33)	23(25.56)	90

Table 7. The frequency of occurrence of fungal isolates

Isolates	No (%)	Fish parts		Total
	Gills	Gut	Muscle	
Penicillium sp.	0 (0.00)	0 (0.00)	2 (100.00)	2
Aspergillus sp.	4 (22.22)	5 (27.78)	9 (50.00)	18
Fusarium sp.	9 (29.03)	10 (32.26)	12 (38.71)	31
Total	13 (25.50)	15 (29.41)	23 (45.10)	51

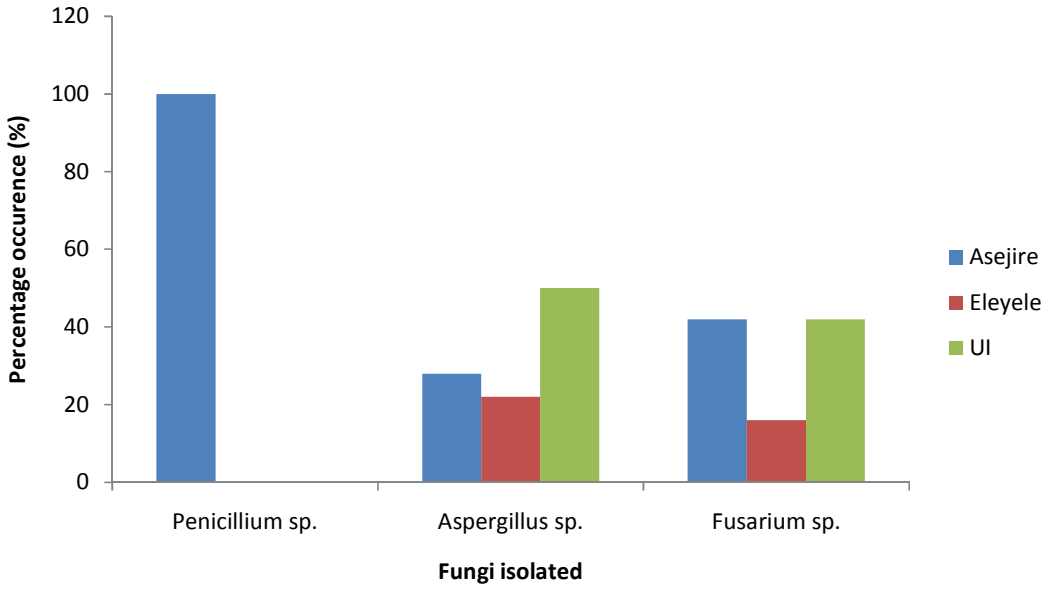

Fig. 2. Frequency of occurrence of fungal isolates obtained from the fish samples

4. DISCUSSION

Catfish and Tilapia fish are good sources of protein and this was revealed from the result of the proximate analyses. The proximate analyses showed that the moisture content in the smoked fish samples were greatly reduced as compared with the fresh fish samples, it was also observed that the protein content in the smoked fish samples were retained and this was in agreement with the work of Akinwumi [20], who reported that smoking demonstrated a better efficient method of fish processing in terms of protein retention and reduction in moisture content.

The difference in the protein and fats contents in the proximate analysis of fish samples may be attributed majorly to environmental factors and the type of nutrients being fed to the fishes as in the case of University of Ibadan Fish farm. All the different fish samples had no value for crude fibre which was not in agreement from the findings of Effiong and Tafa [21] who reported low crude fibre value for smoked Catfish species. It was generally observed that the pH in the smoked fish samples were lower compared to that of the fresh fish samples and this was in accordance with Doe [22].

The bacterial isolates that were obtained from the different sampling site; Asejire, Eleyele and University of Ibadan fish farm were isolated from the muscle, gut and gills of the fishes, the bacterial population isolated were mainly *Staphylococcus aureus*, *Klebsiella* species, *Salmonella* species, *Shigella* species, *Acinetobacter baumanii*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Proteus vulgaris* and *Moraxella catarrhalis* and this was in agreement with the work of several researchers such as Osungbemiro et al. [23] and Adebayo-Tayo et al. [24] who also isolated *Shigella* species, *Staphylococcus aureus*, *Salmonella* spp. and *Pseudomonas aeruginosa* from Catfish samples; while Shinkafi and Ukwaja [25], also isolated *Staphylococcus* sp. and *Salmonella* sp.

from fresh Tilapia fish. The presence of *Salmonella* sp. indicates faecal contamination of water from which the fishes were harvested. The presence of the microorganisms isolated from the fish samples was in accordance with the report of Draser and Hill [26] that fish lives in water habitat full of microorganism. Okpokwasili and Alapiki [27] also confirmed that bacteria flora associated with a Nigerian water culture include the genera, *Bacillus, Lactobacillus, Staphylococcus, Escherichia, Micrococcus, Proteus* and others.

The pathogenic microorganisms isolated from the different fish samples in the course of this research work are of public health importance;

Escherichia coli have been known to cause kidney damage as well as uncomplicated community acquired Urinary Tract Infection while *Salmonella* sp. causes gastroenteritis and also Typhoid fever amongst others. The presence of *Aspergillus* sp. could be an indicating factor to aflatoxin production, therefore, adequate processing and storage as well as thorough cooking should be done or at best such fish products in which moulds are present should be discarded because most of the toxins are heat stable.

It was observed generally that the fresh fish had more microbial load than the smoked fish and this could be attributed to the temperature and heat which would have killed some of the microorganisms in the smoked fish. The microbial population in the gill generally was more than that of the flesh and gut and this could be due to the water supply and the rich nutrients in its immediate environment. It was also observed generally that the fungal population in the fresh fish was low as compared with the commercially smoked fish. The higher population in the commercially smoked fish could be attributed to poor handling, lack of hygiene and improper smoking methods and this was also observed by Abolagba and Igbinevbo [28].

Laboratory smoking of Catfish and Tilapia fish were also done so as to compare the microbial load as against that of commercially smoked fishes. The microbial load was very low to non-existence after the plate count and this could be due to improved smoking pattern and processing as against that of commercially smoked fish. This was in agreement with what was also observed by Abolagba and Igbinevbo [28] who recorded low load of microorganisms in Catfish smoked by them as against the commercially smoked Catfish. The bacterial and fungal population isolated from these fish samples may have been attributed to the human activities in the water bodies from which the samples were taken such as disposal of sewage, industrial and municipal effluents, handling, processing and storage. The fungal isolates were obtained from different fish samples. The fungi were majorly *Aspergillus* sp., *Fusarium* spp., and *Penicillium* sp. and this was in agreement with Adebayo-Tayo et al. [24] who reported the occurrence of *Aspergillus* sp. and *Penicillium* sp. from Catfish samples.

5. CONCLUSION

From this research work, the laboratory smoked fish samples showed a considerable low load of microorganisms compared with the commercially smoked fish samples, it was concluded that better smoking methods as well as storage and handling of smoked fish samples should be employed in the processing of fish.

There is therefore, a need to educate the fish mongers and handlers on proper fish processing and storage. The general public should also be educated via the health officials and the appropriate government establishments on the proper storage and cooking of fish products.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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