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Effect of cassava, wheat and corn flour coatings on microbial properties of smoke-dried tilapia fish (*Oreochromis aureus)*

Nwogu, Okechukwu Godson[1] and Ihemeje, Austin[2]*

[1]Department of Food Science and Technology, Abia State Polytechnic, Aba, Nigeria.
[2]Department of Food Science and Technology, Imo State University, Owerri, Nigeria.

*Corresponding author. Email: ihemeje.austin@yahoo.com

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ABSTRACT: The study aimed to ascertain the effectiveness of cassava, wheat and corn flour coatings on the microbial properties of smoke-dried tilapia fish (*Oreochromis aureus).* Twenty-four (24) tilapia fish weighing 1kg each were used. The unwanted parts of fish were removed, then fish were cut into lengths of 3 - 4cm after which they were washed with water. The processed fish were divided into four, three of which had their cut surfaces respectively coated with corn flour, cassava flour and wheat flour while the other one was not coated. The coat thickness ranged from 3 - 5 mm. The fish were arranged in trays before being smoke-dried. The microbial quality of the samples smoke dried fish samples were evaluated weekly for four weeks. The total bacterial count of the smoke-dried fish samples on nutrient agar ranged from 1.09 x 10^2 cfu/g to 6.80 x 10^6cfu/g. However, the total fungi count of the fish samples on potato dextrose agar (PDA) varied from 0.40 x 10^2cfu/g to 1.11 x 10^6cfu/g. The values of fungal counts in all the fish samples, with the exception of the uncoated smoked dried tilapia fish sample (UCSDTF) stored for 4 weeks, were found to fall within the acceptable limit of colony-forming units per mL. The genera identified were *Bacillus* spp*., Micrococcus* spp*., Enterococcus* spp*., Staphylococcus* spp*., Enterobacter* spp*.* and *Klebsiella* spp. Also, the fungi isolates identified were *Saccharomyces ellipsoideus, Saccharomyces cerevisiae, Mucor* spp*., Aspergillus flavus, Penicillium notatus* and *Penicillium cryseogenum.* The microbial analysis conducted revealed that the use of edible coating materials reduced the rate of microbial proliferation throughout the four-week period of study and could be recommended for both peasant and commercial fish processors.

Keywords: Edible coatings, food preservation, microbial quality.

INTRODUCTION

Fish is a good source of animal protein, often regarded as a healthy meat option, and its harvesting, handling, processing and distribution provide livelihoods for millions of people (Zhang *et al*., 2025). Fish is an important source of nutrients, particularly the long-chain n-3 polyunsaturated fatty acids (n-3 PUFAs). Its incorporation into diets has been shown to have several health benefits, including lowering the risk of cardiovascular disease (McMullan *et al*., 2023). But the global fish industry faces persistent challenges due to the inherent perishability of fish, driven by enzymatic autolysis, lipid oxidation, and microbial proliferation (Lou *et al*., 2021; Wang and Zheng, 2025). Other factors responsible for fish spoilage include unfavourable environmental conditions and inadequate facilities for processing, storage and distribution of the fish, thus, researchers tried a series of coating methods to extend the shelf life of fish. Among all the fish spoilage factors, the impacts of micro-organisms are most conspicuous. The natural microflora of fish that play dominant roles in its spoilage include the genera *Pseudomonas, Vibrio, Micrococcus, Corynebacterium*, *Flavobacterium, Salmonella spp., Listeria monocytogenes, and Aeromonas hydrophila,* among others (Sheng and Wang, 2021). Hence, proper handling,

processing and preservation techniques remain the key to a quality and safe product for mankind. To get rid of these microbes in order to extend the shelf life of the fish before consumption, the fish can be oven-dried, salted, refrigerated, or smoke-dried. Smoking is an ancient traditional practice adopted for the preservation of all kinds of fish. It leads to the destruction of pathogenic microbes, especially on the surface of the fish, and imparts a characteristic flavour to the fish, thus making it very palatable (Mondo *et al*., 2022; Obande *et al*., 2025). Some traditional processors apply some edible flours on the fish before smoking without fully knowing the impact of the coating on the microbial quality of the fish; if the coating actually prevents microbial contamination and proliferation or not, contributes to shelf life extension or not and to what extent. These are yet to be ascertained. Therefore, this work aims at investigating the respective impact of the edible coating materials (corn, cassava and wheat flours) on the microbial qualities of smoke-dried fish.

MATERIALS AND METHODS

Procurement of raw materials

Twenty-four (24) tilapia fish were purchased from Eke-Ukwu Market, Owerri, Imo State. Corn flour, wheat flour and cassava flour were sourced from the laboratory of the Department of Food Science and Technology, Imo State University, Owerri.

Sample preparation/fish processing

Twenty-four (24) tilapia fish were used. The head, internal tract and guts of the fish were removed. The fishes were cut into lengths of 3-4cm after which they were washed to remove unwanted materials from the body. They were divided into four, three of which had their surfaces coated with cassava, wheat and corn flour respectively, while one was not coated with any flour.

Smoking process

The trays containing the coated tilapia fish samples and the control were transferred to a traditionally improved oven for smoking. The firewood was lit and allowed to burn briefly before moist sawdust was applied to smoulder the fire. The temperature (60-70°C for 4 h) of the smoking chamber was maintained by adjusting the firewood and sawdust in the hearth, after which it was cooled overnight.

Microbial analysis

One gram of each ogiri sample was dissolved in 9ml of peptone water and diluted using a ten-fold serial dilution. Zero point one milliliter (0.1ml) of each sample suspension was inoculated on nutrient agar, potato dextrose agar, Salmonella-Shigella agar, Eosin Methylene Blue agar and MacConkey agar and incubated at room temperature (maximum of 35^{o}C) for 24 – 27 hours. The mean of the replicate plating was calculated, and the total viable count (TV) obtained using the formula TV = N/V x D, where N = mean colony, V = volume plated, D = dilution. The result was expressed in colony-forming units per gram (cfu/g). The pure bacterial cultures were characterised by their cultural, morphological and biochemical test which included catalase test, oxidase test, coagulase test, indole test, methyl red test, Voges-Proskauer test, urease test, citrate test, glucose, sucrose, maltose, mannitol, nitrate reduction test and hydrogen sulphide test. Fungi isolates were also identified molecularly using gene sequencing by Center for Agriculture and Bioscience International (CABI).

RESULTS AND DISCUSSION

Enumeration of microorganisms from stored samples on mycological media

The results of the enumeration of microorganisms from Tilapia fish coated with different edible coating materials and stored for a period of four (4) weeks, respectively, are presented in Table 1.

Bacterial growth on nutrient agar

The total bacterial growth of the fish samples on nutrient agar ranged from 1.09 x 10^2cfu/g to 6.80 x 10^6cfu/g as shown in Table 1. The number of microbes in each treatment increased during the storage period. Before the commencement of the storage, it was observed that the bacterial population of the fish samples varied from1.09 x 10^2cfu/g to 1.46 x 10^2cfu/g with uncoated tilapia fish samples (UCSDTF) recording the highest (1.46 x 10^2cfu/ml) bacterial count on nutrient agar (NA) while coated samples had 1.20 x 10^2cfu/g, 1.23 x 10^2cfu/g and 1.46 x 10^2cfu/g respectively. This showed that edible coating could protect the fish products and inhibit microbial growth, as earlier asserted by Zhang and Xu (2022). Edible coating functions as a barrier to control water transfer, oxygen uptake, and lipid transfer, thereby reducing microbial growth. The number of bacteria in all treatments on the first day was found to be within the 1×10^5cfu/g safe limits as recommended by ICMSF (1986). It was observed that the bacterial population of the tilapia fish samples increased with an increase in the storage period. The highest increase was observed in the uncoated fish sample, which had a bacterial count of 6.80 × 10^6cfu/g after four (4) weeks of storage. This could be as a result of direct transfer of water vapour from the environment to the fish sample, which increased microbial activity. It was also observed that the number of bacteria recorded in UCSDTF

Table 1. Enumeration of microorganisms from stored samples on bacteriological and mycological media.

Sample	Bacterial Counts on NA (cfu/g)	Fungi Counts on PDA (cfu/g)	Bacterial Counts on SSA (cfu/g)	Bacterial Counts on EMBA (cfu/g)	Counts on MCA (cfu/g)
UCSDTF					
0 Week	1.46×10^2	1.11×10^2	0	0.40×10^2	1.00×10^2
1 Weeks	3.20×10^3	1.80×10^2	0	1.60×10^2	1.60×10^2
2 Weeks	4.40×10^4	2.40×10^3		1.90×10^2	2.02×10^2
3 Weeks	3.30×10^5	3.60×10^4	0	2.30×10^3	2.60×10^2
4 Weeks	6.80×10^6	1.11×10^6	0	6.60×10^3	2.90×10^2
CFCSDTF					
0 Week	1.09×10^2	0.40×10^2	0	00.21×10^2	0
1 Weeks	4.00×10^2	1.01×10^2	0	0.80×10^2	0
2 Weeks	3.50×10^3	1.65×10^2	0	1.10×10^2	0
3 Weeks	8.30×10^3	6.40×10^2	0	1.40×10^2	0
4 Weeks	4.60×10^4	1.25×10^3	0	1.84×10^2	0
MFCSDTF					
0 Week	1.20×10^2	1.42×10^2	0	0	0.30×10^2
1 Weeks	1.80×10^2	1.10×10^2	0	0	0.50×10^2
2 Weeks	9.20×10^2	1.40×10^2	0	0	0.80×10^2
3 Weeks	4.80×10^3	1.38×10^3	0	0	1.01×10^2
4 Weeks	1.30×10^4	2.90×10^4	0	0	2.00×10^2
WFCSDTF					
0 Week	1.23×10^2	1.71×10^2	0	0	0
1 Week	6.60×10^2	1.20×10^2	0	0	0
2 Weeks	4.20×10^3	1.66×10^2	0	0	0
3 Weeks	4.40×10^4	1.40×10^3	0	0	0
4 Weeks	9.80×10^4	3.80×10^4	0	0	0

NA – Nutrient Agar; **PDA –** Potato Dextrose Agar; **SSA –** Salmonella-Shigella Agar; **EMBA –** Eosine Methylene Blue Agar; **MCA –** MacConkey Agar. **Codes:** UCSDTF: Uncoated tilapia fish sample; CFCSDTF: Cassava flour coated tilapia fish; MFCSDTF: Maize flour coated tilapia fish; WFCSDTF: Wheat flour coated tilapia fish.

exceeded the ICMSF (1986) safe limit for the total plate count (TPC) of fish (1×105cfu/ml). The number of bacteria obtained in the coated samples (CFCSDTF, MFCSDTF and WFCSDTF) still fell below the ICMSF (1986) standard at the fourth week of storage. This showed that edible coating can extend the shelf life of smoked-dried tilapia fish at room temperature. Edible films derived from polysaccharides are capable of both blocking the entry of oxygen and/or reducing the rate of oxygen transmission, thus inhibiting bacterial growth. (Li *et al*., 2024). Higher bacterial counts in the fish samples using Nutrient agar compared to other bacteriological media could be because Nutrient agar is a multi-purpose medium. Nutrient agar is a general-purpose medium supporting growth of a wide range of non-fastidious organisms.

Fungi counts on PDA

The total fungi count of the fish samples on potato dextrose agar (PDA) ranged from 0.40×10^2 cfu/g to 1.11×10^6cfu/g as shown in Table 1. Also, it was observed that the uncoated smoked dried tilapia fish sample (UCSDTF), which served as the control sample, recorded the highest fungal count (1.11×10^6cfu/g) on PDA. The highest fungal count obtained in the uncoated smoked-dried tilapia fish sample (UCSDTF) could be as a result of direct exposure of the tilapia fish sample to the atmosphere during and after the smoking process as a fungus is known to be an aerial contaminant. The values of fungal counts obtained in all the fish samples, with the exception of the uncoated smoked dried tilapia fish sample (UCSDTF) stored for 4 weeks, were found to fall within the acceptable limit of colony-forming units per mL of mould/yeast of processed fish (ICMSF, 1986).

Bacterial counts on SSA

From the results obtained for bacterial counts on

Salmonella Shigella Agar (SSA), it was observed that there was no growth recorded in all the samples UCSDTF, CFCSDTF, MFCSDTF and WFCSDTF, respectively. This implied that, for all the fish samples, there were no *Salmonella* or *Shigella* present since Salmonella-Shigella Agar (SSA) is a selective agar that permits only the growth of *Salmonella* or *Shigella*. Salmonella-Shigella Agar (SS Agar) is a selective and differential medium widely used in sanitary bacteriology to isolate *Salmonella* and *Shigella* from faeces, urine, and fresh and canned foods (Amadi-Wali *et al*., 2020). The absence of *Salmonella* spp. and *Shigella* spp. in all the fish samples was an indication of proper heating processes, since the presence of *Salmonella* spp. and *Shigella* spp. in food is an indicator of improper heating. *Salmonella* spp. and *Shigella* spp. can survive improper heating of meat products during processing. The presence of *Salmonella* spp. and *Shigella* spp. as contaminants could be attributed to inadequate heating of food products during their preparation and/or cross-contamination (Rosniawati *et al*., 2020). Since the Tilapia fish samples underwent smoking and then drying, there was adequate heat treatment, and this was evident in the absence of these contaminants in the samples.

Bacterial counts on EMBA

From the results obtained for bacterial counts on Eosine Methylene Blue Agar (EMBA), it was observed that there were no growths recorded in samples MFCSDTF (Maize flour coated tilapia fish) and WFCSDTF (Wheat flour coated tilapia fish) throughout the four (4) weeks of storage. But significant growth was observed in samples UCSDTF (Uncoated tilapia fish sample) and CFCSDTF (Cassava flour coated tilapia fish) which increased progressively throughout the period of storage with UCSDTF (Uncoated tilapia fish sample) stored for 4 weeks recording the highest (6.60 x 10^3cfu/g) count. Eosin Methylene Blue Agar (EMBA) is both a selective and differential culture medium. It is a selective culture medium for Gram- negative bacteria and is commonly used for the isolation and differentiation of coliforms and faecal coliforms (Lestari *et al*., 2024). This implied that the presence of these organisms in these fish samples where they were identified is an indicator of sewage contamination, which may also occur during different processing steps such as handling.

Bacterial count on MCA

The results obtained for bacterial counts on MacConkey Agar (MCA) revealed that there were no growths recorded in samples CFCSDTF (Cassava flour coated tilapia fish) and WFCSDTF (Wheat flour coated tilapia fish) throughout the four (4) weeks of storage. But significant growth from 1.00 – 2.90 x 102cfu/g and 0.30 – 2.00 x102cfu/g was observed in samples UCSDTF and MFCSDTF, respectively. The presence of bacterial growth in samples UCSDTF (Uncoated tilapia fish sample) and MFCSDTF (Maize flour coated tilapia fish) when inoculated on MacConkey agar was an indication of the presence of enteric bacilli because MacConkey agar is an indicator, a selective and differential culture medium for bacteria designed to selectively isolate Gram-negative and enteric bacilli and differentiate them based on lactose fermentation (Hasan *et al*., 2019).

Colonial and microscopic characteristics of bacterial isolates

The colonial and microscopic characteristics of bacterial isolates from tilapia fish coated with edible coating materials are presented in Table 2. A total of six different genera of Gram-positive and Gram-negative bacteria were isolated from the Tilapia fish samples. The genera were identified as *Bacillus* spp*., Micrococcus* spp*., Enterococcus* spp*., Staphylococcus* spp*., Enterobacter* spp*.* and *Klebsiella* spp. by comparing their colonial and microscopic characteristics with standard reference organisms (Table 1). The presence of these organisms on the tilapia fish samples could be attributed to the fact that fish contained an abundance of all nutrients required for the growth of bacteria in adequate quantities. Microorganisms isolated from the Tilapia fish samples in this study have been earlier found in foods, the environment and other places, and their pattern is similar to previous reports (Reynaldi *et al*., 2019). This shows that microorganisms are ubiquitous in nature. Bacteria grow on solid media as colonies. A colony is defined as a visible mass of microorganisms, all originating from a single mother cell; therefore, a colony constitutes a clone of bacteria all genetically alike. In the identification of bacteria, much emphasis is placed on how the organism grows in or on media. This will help in identifying the cultural characteristics of a bacterium on an agar plate, called colony morphology (Moshtaq, 2016). Although one might not necessarily see the importance of colonial morphology at first, it really can be important when identifying the bacterium. Features of the colonies may help to pinpoint the identity of the bacterium. Different species of bacteria can produce very different colonies. The microscopic morphological study of bacteria requires the use of microscopes. It is an important initial step in identifying a microorganism by determining its shape, size, and staining characteristics.

Gram-positive rods in short chains with central spores and dull, dry, serrated flat cream colonies on nutrient agar were identified as *Bacillus spp.* Another Gram-positive rod with spores and mucoids, and a rough, slimy cream colony on nutrient agar was also identified as *Bacillus spp*. Gram-positive cocci predominantly in tetrads, few in pairs and clusters, with small, smooth, low-convex yellow colonies on nutrient agar were identified as *Micrococcus spp.* They were found to be non- motile and devoid of spores and

Table 2. Colonial and microscopic characteristics of bacterial isolates from the fish samples.

Colony Characteristics	Microscopic morphology	Spores	Motility	Capsules	Possible Organism
Dull and dry serrated flat cream colonies on nutrient agar	Gram positive rods in short chains with central spores	+	+	-	*Bacillus spp.*
Small smooth low convexed yellow colonies on nutrient agar (NA)	Gram positive cocci predominantly in tetrads, few in pairs and clusters	-	-	-	*Micrococcus spp.*
Small circular cream colonies on nutrient agar	Gram positive cocci in chains	-	-	-	*Enterococcus spp.*
Smooth golden yellow colonies on NA	Gram positive predominantly in clusters, few in tetrads and pairs.	-	-	-	*Staphylococcus spp.*
Mucoids, rough and slimy cream colonies on NA	Gram positive rods with spores	+	+	-	*Bacillus spp.*
Gram negative rods in single and short chains		-	+	-	*Enterobacter spp.*
Gram negative short rods in singles		-	+	+	*Klebsiella spp.*

Table 3. Biochemical and sugar fermentation test of bacterial isolates for samples (UCSDTF, CFCSDTF, MFCSDTF and WFCSDTF)

Cat	Oxi	Coag	In	MR	VP	Cit	Ure	NO_3	H_2S	Suc	Lac	Mal	Mann	Glu	Identity of isolates
+	-	-	-	+	-	+	+	-	-	-	-	-	-	-	*Micrococcus luteus*
+	-	-	-	+	-	+	-	+	-	+	+	+	+	+	*Enterococcus faecalis*
+	-	-	-	-	+	+	-	+	-	-	-	-	+	+	*Bacillus subtilis*
+	-	-	-	-	+	+	-	+	-	-	-	-	+	+	*Bacillus cereus*
+	-	-	-	-	+	+	-	+	-	-	+	-	+	+	*Enterobacter*spp.
+	-	-	-	-	+	+	-	+	-	+	+	-	+	+	*Klebsiella*spp.
+	-	+	-	-	+	-	+	+	-	+	+	+	+	+	*Staphylococcus aureus*

Catalase test (Cat), Oxidase test (Oxi), Coagulase test (Coag), Indole test (In), Methyl Red (MR) and Voges-Proskauer (VP), Urease test (Ure), Citrates test (Cit), Glucose (Glu), Sucrose (Suc), Lactose (Lac), Maltose (Mal), Mannitol (Mann), Nitrate Reduction test (NO_3), Hydrogen Sulphide production test (H_2S). **Codes:** UCSDTF = Uncoated smoke-dried tilapia fish; CFCSDTF = Cassava flour coated smoke-dried tilapia fish; MFCSDTF = Maize flour coated smoke-dried tilapia fish; WFCSDTF = Wheat flour coated smoke-dried tilapia fish.

capsules, also found in seafood like fishes (Issa-Zacharia *et al*., 2025). Non- motile, non-spore-forming, and capsule-forming Gram-positive cocci in chains with small circular cream colonies on nutrient agar were identified as *Enterococcus* spp*.* Non-motile, non-spore-forming, and capsule-forming Gram-positive cocci were predominantly in clusters. Few in tetrads and pairs with smooth golden yellow cream colonies on nutrient agar were identified as *Staphylococcus spp.* The findings from this present study agreed with the description of Wu *et al*. (2023) for *Enterococcus* spp*.* and *Staphylococcus* spp*.* respectively. Gram-negative rods in single and short chains with smooth pink colonies on Eosin Methylene Blue Agar (EMBA) were identified as *Enterobacter* spp*.* They were found to be motile, non-spore-forming and capsule-forming. While motile, non-spore forming with capsules, Gram-negative short rods in single chains and circular, mucoid and slimy pink colonies on MacConkey Agar (MCA) were identified to be *Klebsiella*spp*.* The findings from this present study also agree with the descriptions of Davin-Regli *et al.* (2019).

Biochemical and sugar fermentation test of bacterial isolates for fish samples (UCSDTF, CFCSDTF, MFCSDTF and WFCSDTF)

The biochemical and sugar fermentation tests of bacterial isolates from Tilapia fish coated with edible coating materials are presented in Table 3. The biochemical and sugar fermentation tests were used to identify the specific bacterial isolates. Using the biochemical and sugar fermentation tests, five specific bacterial isolates were identified, and they include *Micrococcus luteus, Enterococcus faecalis, Bacillus subtilis, Bacillus cereus and Staphylococcus aureus.* These specific bacteria were identified by observing their ability and inability to ferment selected sugars such as sucrose, lactose, maltose, mannitol and glucose. And also identified by their ability and inability to utilise and produce certain compounds and gases using biochemical tests.

It was observed that none of the isolates identified was able to break down tryptophan (indole test) or possess the cytochrome oxidase enzyme (oxidase test) or have the

Table 4. Colonial and microscopic characteristics of fungal isolates from samples (UCSDTF, CFCSDTF, MFCSDTF and WFCSDTF)

Colonial morphology	Microscopic characteristics	Identity of isolates
Cream butyrous colonies	Large Gram positive ellipsoidal budding cells	*Saccharomyces ellipsoideus*
Small moist and shiny cream colonies	Gram positive oval and spherical budding cells	*Saccharomyces cerevisiae*
Short white hyphae	Hyphae non septate, sporangiospores enclosed in sporangium	*Mucor*spp
Lemon green powdery spores attached an short mycelia	Septate hyphae, conidia arranged on a sterigma	*Aspergillusflavus*
Dirty green spores surrounded by white mycelia	Hyphae septate. Conidia mop-like head	*Penicilliumnotatum*
Green spores	Septate hyphae. Conidia arranged like mop head	*Penicilliumcryseogenum*

Codes: UCSDTF = Uncoated smoke-dried tilapia fish; CFCSDTF = Cassava flour coated smoke-dried tilapia fish; MFCSDTF = Maize flour coated smoke-dried tilapia fish; WFCSDTF = Wheat flour coated smoke-dried tilapia fish.

ability to produce hydrogen sulfide (hydrogen sulfide production). This showed that bacteria such as *Escherichia coli we*re not present in the Tilapia fish samples analysed. The trend of the results obtained in this present study agreed with the report of Zhang (2025) on the effect of edible coating on the quality of smoked fish. It was observed that *Micrococcus luteus* was unable to ferment all the sugars tested during the sugar fermentation test, while *Staphylococcus aureus* was found to be able to ferment all the sugars tested during the sugar fermentation test.

Colonial and microscopic characteristics of fungal isolates from fish samples (UCSDTF, CFCSDTF, MFCSDTF and WFCSDTF)

The colonial and microscopic characteristics of fungal isolates from Tilapia fish coated with edible coating materials is presented in Table 2. These organisms were identified by comparing their colonial and microscopic characteristics with standard reference organisms as presented in Table 4. The texture, colour, and forms of the colony are characteristics of each species and therefore useful in identification of fungi. The colonial and microscopic characteristics of fungal isolates also depend largely on morphological characteristics such as the type and arrangement of the spores produced as well as mycelia types, in addition to DNA sequencing (Shamsudin *et al*., 2025). A total of six different fungal isolates were identified from the Tilapia fish samples analysed. The isolates identified were *Saccharomyces ellipsoideus, Saccharomyces cerevisiae, Mucor* spp*., Aspergillus flavus, Penicillium notatus* and *Penicillium cryseogenum*. Fungal isolates identified from the Tilapia fish samples in this study were found to be similar to those reported by Sissoko *et al*. (2025) for spoilage microorganisms involved in fish smoking processes. Large Gram-positive ellipsoidal budding cells with cream butyrous colonies were identified as *Saccharomyces ellipsoideus. Saccharomyces ellipsoideus* is known for its large ellipsoidal budding and is used mostly for winemaking (Azadalifeva, 2019). Gram-positive, oval and spherical budding cells with small, moist and cream colonies were identified as *Saccharomyces cerevisiae.*

Distribution of isolates from different samples (UCSDTF, CFCSDTF, MFCSDTF and WFCSDTF)

The data in Table 3 and 4 show six genera of bacteria and six genera of fungi isolated from the fish samples. The bacterial isolates identified were *Bacillus* spp*., Micrococcus* spp*., Enterococcus* spp*., Staphylococcus aureus, Enterobacter* spp*.* and *Klebsiella* spp. These organisms were identified by comparing their morphological and biochemical characteristics with standard reference organisms. The fungal isolates identified were *Saccharomyces ellipsoideus, Saccharomyces cerevisiae, Mucor* spp*., Aspergillus flavus, Penicillium notatum,* and *Penicillium cryseogenum. Staphylococcus aureus was* the most occurrent bacteria isolated from the smoked-dried tilapia fish samples, while *Saccharomyces cerevisiae was* the most occurring fungi isolated. The presence of these organisms could partly come from the raw materials for production and subsequent handling, poor hygienic production, handlers, and from processing equipment/ utensils. Similar results were reported by Tahiluddin *et al*. (2022), who detected *Aspergillus, Staphylococcus aureus, Micrococcus* spp*., Bacillus* spp. etc, as some microorganisms in fresh and aquatic products. Also, this work is in agreement with the report by Reynadi *et al.* (2019) on the microbial quality of panti fillets and fish balls coated with cassava starch-based edible coating and gelatin-based edible coating, respectively. The presence of *Bacillus* spp*.* in the smoked- dried tilapia fish samples may be due to contamination from aerial spores carried in the air. The detectable presence of *Micrococcus spp*. and *Enterococcus* spp*.* was an indicator of improper handling. They occur in a wide range of environments, including water, dust and soil. *Staphylococcus aureus* is ubiquitous

and has been isolated from the nasal tract of 50% of healthy individuals, and it has also been found to be inhibited by edible coatings in correspondence with the present study (Cruz-Guzma *et al*., 2025). *Staphylococci* exist on food equipment, environmental surfaces, humans, and animals. Smoked- dried tilapia fish samples can easily be contaminated by hands, where the organism multiplies to an extremely high population and produces entero-toxins. The level of presence of coliforms as an indicator organism has been described as an index of food hygiene. *Klebsiella* spp. has also been discovered in fishes where it was implicated in bacterial pneumonia cases (Kusunur *et al*., 2026). *Saccharomyces cerevisiae* was isolated from all the fish samples analysed; this could be attributed to the ubiquitous nature of their spores. *Saccharomyces cerevisiae* is a species of yeast. Saccharomyces cerevisiae is a unicellular eukaryotic fungus, possessing several immune-stimulating compounds such as β-glucan, nucleic acids, chitin, oligosaccharides and other components (Said *et al*., 2023).

Aspergillus flavus was isolated from sample UCSDTF (Uncoated tilapia fish sample) alone. This implies that the edible coatings used on the smoke-dried tilapia fish samples helped to prevent the contamination of the fish samples with the pathogen. *A. flavus* principally produces the mycotoxin aflatoxin, which causes serious health issues for humans and animals that consume it. This fungus exists on an extremely large range of agricultural hosts, including various fruits, tree nuts, cereals, and mainly stored grains such as maize (Ventura-Aguilar, 2022). The presence of the identified organisms in the fish samples depicts a deplorable state of poor hygienic and sanitary practices employed in the processing and packaging of the samples. Most of the organisms found in this study are those commonly found in soil and water. But the edible coatings in this study proved effective in keeping the microbes at a safe limit in line with the findings of Faisal *et al*. (2025).

Conclusion

The study establishes the obvious impact of edible coating materials on the microbial quality of smoke-dried tilapia fish samples. The genera identified were *Bacillus spp., Micrococcus spp., Enterococcus spp., Staphylococcus spp., Enterobacter spp.* and *Klebsiella spp.* Also, the *fungi isolates identified* were *Saccharomyces ellipsoideus, Saccharomyces cerevisiae, Mucor spp., Aspergillus flavus, Penicillium notatus* and *Penicillium cryseogenum*. The use of cassava, wheat and corn flour coatings reduced the proliferation of micro-organisms on the tilapia fish samples within the period of study and is therefore recommended since the microbial load was found to be in the range considered safe for human consumption. Their application should be made known to both peasant and commercial fish processors.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Amadi-Wali, O., Amadi-Wali, C., & Njigwum, A. S. (2020). Isolation of diarrhea causing organisms (Salmonella and Shigella) from selected seafood. *International Journal of Tropical Disease and Health*, *41*(17), 1-8. https://doi.org/10.9734/ijtdh/2020/v41i1730369

Azadalifeva, S. F. (2019). The influence of initial acidity (pH) on the production of silver nanoparticles by *Saccharomyces ellipsoideus* bdu – xr1.*Azerbayjan National Academy of Sciences, 17*(1), 55-57.

Cruz-Guzmán, J. A., Garzón-García, A. M., Ruíz-Cruz, S., Márquez-Ríos, E., Valdez-Hurtado, S., Paredes-Quijada, G. T., ... & Jiménez-Ruíz, E. I. (2025). The effect of muicle–chitosan edible coatings on the physical, chemical, and microbiological quality of cazon fish (Mustelus lunulatus) fillets stored in ice. *Foods*, *14*(9), 1619. https://doi.org/10.3390/foods14091619

Davin-Regli, A., Lavigne, J. P., & Pagès, J. M. (2019). Enterobacter spp.: update on taxonomy, clinical aspects, and emerging antimicrobial resistance. *Clinical microbiology reviews*, *32*(4), 32(4), e00002-19. https://doi.org/10.1128/CMR.00002-19.

Faisal, M., Mansur, D., Desvita, H., & Heriansyah, M. B. (2025). Liquid smoke-infused edible coatings: Antimicrobial agents for preserving cherry tomatoes. *Case Studies in Chemical and Environmental Engineering*, *11*, 101091. https://doi.org/10.1016/j.cscee.2024.101091

Hasan, M. R., Suleiman, M., Ilagan, E., Crouch, N., Lopez, A. P., Thomas, E., & Tang, P. (2019). Growth of clinically important Gram-negative bacteria on MacConkey agar under aerobic versus CO2-enriched environment. *Journal of Clinical Microbiology*, *57*(12), 10-1128.https://doi.org/10.1128/jcm.01441-19

International Commission on Microbiological Specifications for Foods (ICMSF) (1986). *Microorganisms in foods 2. Sampling for microbiological analysis, principles and specific applications,* (2nd Edition), Toronto, Canada: University of Toronto Press, pp. 22.

Issa-Zacharia, A., Msangi, R., & Mboya, G. (2025). Revisiting chemical and microbiological quality and safety of fish and fish products. *International Journal of Microbiology and Biotechnology*, *10*(3), 73-90. https://doi.org/10.11648/j.ijmb.20251003.12

Kusunur, A. B., Medidi, P. K., Kumar, S. D., Nakka, A., Chigilipalli, H., Gattu, R., Sivam, V., Rangasamy, A., Vaiyapuri, M., & Badireddy, M. R. (2026). Edible Fish as a Source of Klebsiella pneumoniae: Incidence, Virulence, Biofilm Formation, Antimicrobial Resistance and Control Strategies. *Journal of AOAC International*, qsag087. https://doi.org/10.1093/jaoacint/qsag087.

Lestari, D., Haliza, E. N., & Setiawan, H. (2024). Effect of pH variations in Eosin Methylene Blue Agar (EMBA) medium on E. coli growth. *Jurnal Info Kesehatan*, *22*(1), 82-89. https://doi.org/10.31965/infokes

Li, X., Li, F., Zhang, X., Tang, W., Huang, M., Huang, Q., & Tu, Z. (2024). Interaction mechanisms of edible film ingredients and their effects on food quality. *Current Research in Food*

Science, *8*, 100696. ISSN 2665-9271, https://doi.org/10.1016/j.crfs.2024.100696.

Lou, X., Zhai, D., & Yang, H. (2021). Changes of metabolite profiles of fish models inoculated with Shewanella baltica during spoilage. *Food Control*, *123*, 107697.doi: 10.1016/j.foodcont.2020.107697

McMullan, J. E., Yeates, A. J., Allsopp, P. J., Mulhern, M. S., Strain, J. J., van Wijngaarden, E., ... & McSorley, E. M. (2023). Fish consumption and its lipid modifying effects–A review of intervention studies. *Neurotoxicology*, *99*, 82-96. https://doi.org/10.1016/j.37820771

Mondo, B. C., Akoll, P., Masette, M., & Mulinda, S. (2022). Effect of smoking technologies on nutritional values and concentration levels of polycyclic aromatic hydrocarbons in smoked fish (Mormyrus caschive and Oreochromis niloticus) of Terekeka, South Sudan. *African Journal of Food Science*, *15*(1), 1-9. https://doi.org/10.5897/AJFS2021.2155

Moshtaq, T. A. (2016). Morphology and classification of bacteria. Microbiology Module. Pp. 1-19. Retrieved from https://www.researchgate.net/publication/315803754

Obande, I. U., Aliyu, A. A., & Ed-Idoko, J. O. (2025). A review on the effects of smoked fish on the health of its consumers. *Asian Journal of Fisheries and Aquatic Research*, *27*(8), 156-160. https://doi.org/10.9734/ajfar/2025/v27i8986

Reynaldi, A., Rostini, I., Afrianto, E., & Rochima, E. (2019). The effect of garlic extract addition on tilapia skin gelatin based edible coating towards antimicrobial properties and fish meatball's shelf life. *World Scientific News*, *134*(2), 74-85.

Said, A. F., Al-Taee, N. T. T., & Al-Taee, S. K. E. (2023, April). Impact of Saccharomyces cerevisiae on Growth Performance of Carp Fish Exposed to CuSo4. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1158, No. 5, p. 052008). IOP Publishing. https://doi.org/10.1088/1755-1315/1158/5/052008.

Shamsudin, N. A., Seelan, J. S. S., Gansau, J. A., & Rusdi, N. A. (2025). Morphological and molecular identification of endophytic fungi from roots of epiphyte orchid Aerides odorata Lour in Sabah. *Scientific Reports*, *15*(1), 33908. doi: 10.1038/s41598-025-07189-x

Sheng, L., & Wang, L. (2021). The microbial safety of fish and fish products: Recent advances in understanding its significance, contamination sources, and control strategies. *Comprehensive Reviews in Food Science and Food Safety*, *20*(1), 738-786.https://doi.org/10.1111/1541-4337.12671.

Sissoko, A., Maiga, B. M. D. A., Samaké, S., Samaké, F., & Konaré, M. A. (2025). Spoilage microorganisms involved in fish smoking processes in West Africa: Implication for food quality. *International Journal of Fisheries and Aquatic Studies*, *13*(3), 206-209. https://www.doi.org/10.22271/fish.2025.v13.i3c.3090

Tahiluddin, A. B., Maribao, I. P., Amlani, M. Q., & Sarri, J. H. (2022). A review on spoilage microorganisms in fresh and processed aquatic food products. *Food Bulletin*, *1*(1), 21-36. https://doi.org/10.29329/foodb.2022.495.05

Rosniawati, T., Rahayu, W. P., Kusumaningrum, H. D., Indrotristanto, N., & Nikastri, E. (2020). Prevalence and level of *Salmonella* spp. Contamination on selected pathways of preparation and cooking of fried chicken at the household level Food Science and Technology, *41*(suppl 1),41-46. https://doi.org/10.1590/fst.10120

Ventura-Aguilar, R. I., Gónzalez-Andrade, C., Hernández-López, M., Correa-Pacheco, Z. N., Teksür, P. K., Ramos-García, M. D. L., & Bautista-Baños, S. (2022). Effect of biodegradable coatings on the growth of Aspergillus flavus in vitro, on maize grains, and on the quality of tortillas during storage. *Molecules*, *27*(14), 4545. https://doi.org/10.3390/molecules27144545

Wang, X., & Zheng, Z. (2025). Mechanistic insights into fish spoilage and integrated preservation technologies. *Applied Sciences*, *15*(14), 7639. https://doi.org/10.3390/app15147639

Wu, Y., Feng, Y., Xue, M., Xiao, Z., Jin, L., Gao, R., ... & Zhou, Y. (2023). Isolation and identification of Staphylococcus saprophyticus from diseased hybrid sturgeon. *Fishes*, *8*(5), 250. https://doi.org/10.3390/fishes8050250

Zhang, P., You, X., Liu, R., & Xie, D. (2025). Advances in the Application of Edible Antimicrobial Coatings and Films for Fish Preservation. *Journal of Food Science*, *90*(12), e70729.https://doi.org/10.1111/1750-3841.70729.

Zhang, X. R., & Xu, K. (2022). Research progress on edible coating preservation technology of perishable food. *The Food Industry*, *43*(9), 244-248.