

Microbiological Properties of Smoke-Dried *Clarias gariepinus* and *Ethmalosa fimbriata* Sold in Abraka, Eku and Obiaruku Markets, Delta State, Nigeria**Akpotor D. A.^{1*} Oyowe E.² and Amalokwu J. O.¹**

1. Department of Fisheries and Aquaculture, Delta State University, Abraka Nigeria

2. Department of Microbiology, Delta State University, Abraka Nigeria.

* Corresponding author: differenceakpotor@yahoo.com

Abstract: Smoke-drying remains a sure fish processing-cum-preservation method in Nigeria. However, concerns persist about products microbiological safety afterwards particularly when sold in open markets. This study assessed the microbiological quality of smoked-dried *Clarias gariepinus* (Catfish) and *Ethmalosa fimbriata* (Bonga) sold in Abraka, Eku, and Obiaruku markets in Delta State, Nigeria. The fish samples were collected randomly from vendors in each of the markets, sealed in sterile polythene bags and taken to the laboratory for microbial analyses. Fish samples were analyzed for total aerobic bacteria, coliforms, *Staphylococcus* species, and fungi using standard microbiological techniques. Bacterial and fungal isolates were identified through cultural, microscopic, and biochemical methods, and prevalence was determined. Microbial counts ranged from 4.0×10^3 to 6.0×10^3 cfu/g for total aerobic bacteria, 3.0×10^3 to 4.5×10^3 cfu/g for coliforms, 1.6×10^3 to 4.5×10^3 cfu/g for *Staphylococcus* species, Fungi counts ranged from 1.8×10^3 to 5.1×10^3 cfu/g. Isolated bacteria included *Staphylococcus* spp., *Bacillus* spp., *Escherichia coli*, *Proteus* spp., and *Klebsiella* spp., while fungal genera recovered were *Aspergillus*, *Mucor*, *Candida*, and *Rhizopus*. The consistent presence of potential pathogens and toxigenic fungi suggests contamination linked to post-smoking handling, storage, and market conditions. These findings highlight the need for improved hygiene practices, better packaging, and routine monitoring to enhance the safety of smoked fish sold in open markets. Smoke-dried fish consumers to cook with appropriate temperature to prevent food poisoning.

Key word: Food poisoning, Food safety, Microbial contamination, Microbial load, Smoke-dried

INTRODUCTION

Fish is an essential source of nutrition globally, providing high-quality protein, essential fatty acids, vitamins, and minerals necessary for human growth, immune function, and overall health (Issa-Zacharia *et al.*, 2025). In Nigeria, freshwater fish such as *Clarias gariepinus* (Catfish) and *Ethmalosa fimbriata* (Bonga fish) are widely consumed and play a pivotal role in supporting both household nutrition and local economies. The widespread consumption of these fishes creates a stable demand that supports the livelihoods of fishers, processors, and vendors. These species are often processed through traditional smoke-drying methods to prolong shelf life, enhance flavour and reduce post-harvest losses, especially in regions with limited access to cold-chain storage facilities (Sheng and Wang, 2021; Cortés-Sánchez *et al.*, 2025).

Smoke-drying is an effective preservation method, however it does not fully eliminate microbial contamination (Abolagba and Igbinevbo, 2010). Fish and fish products

remain vulnerable to spoilage and pathogenic microorganisms throughout the production chain-from harvesting and processing to handling and marketing (Issa-Zacharia *et al.*, 2025). Bacteria such as *Escherichia coli*, *Salmonella* spp., *Listeria* spp., and fungi like *Aspergillus* species and *Penicillium* spp. are commonly associated with fish contamination (Samaké and Konaré, 2025). These microbes not only accelerate spoilage, but also pose significant health risks to consumers, including foodborne infections and mycotoxin-related illnesses (Oladeji *et al.*, 2023; Ousman *et al.*, 2025; Ohimain *et al.*, 2025). Pathogenic strains of *E. coli*, such as *E. coli* O157:H7, can cause severe gastrointestinal illnesses, including diarrhea, abdominal pain, and, in extreme cases, kidney failure (Gambushe *et al.*, 2022). *Staphylococcus aureus* produces heat-stable enterotoxins that can cause staphylococcal food poisoning, characterized by vomiting, diarrhea, and abdominal cramps (Nwachukwu *et al.*, 2024). *Bacillus cereus* causes foodborne diseases through the production of toxins (Griffiths and

Schraft, 2017) and its contamination is often attributed to improper post-smoking handling and storage conditions (Asamoah *et al.*, 2025).

Some studies have reported microbial contamination of smoked-dried fish in some markets in Nigeria. Abolagba and Uwagbai (2011) examined smoked fish microbial contamination levels in raining and dry seasons in Oba market, Edo State and Koko market, Delta state respectively; Umezurike *et al.* (2024) reported the presence of pathogenic bacteria in smoked fish sold in Ibadan markets, highlighting potential public health hazards. Similarly, Adetuwo *et al.* (2023) found both bacterial and fungal contamination in fresh and smoked fish in Igbokoda markets. Empirical research in Port Harcourt and Nnewi further indicated high microbial loads in locally smoked fish, underscoring the urgent need for improved hygiene practices and monitoring in the fish value chain (Ikechukwu *et al.*, 2024; Amachree *et al.*, 2025).

In addition to bacterial contamination, fungal colonization is a concern in smoke-dried fish, particularly under humid storage conditions. Studies have shown that fungi such as *Aspergillus* species can thrive on improperly handled fish, leading to spoilage and production of mycotoxins that are harmful to human health (Oladeji *et al.*, 2023). Multiple fungal species contamination such as *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Fusarium solani*, *Mucor mucedo* and *Saccharomyces cerevisiae* have been reported in smoke-dried fish sold in Eke Awka Market (Samuel *et al.*, 2015), Ojo Oba market in Ado Ekiti (Fagbohun and Lawal, 2015), Maiduguri metropolis (Sani *et al.*, 2016), Bida markets (John *et al.*, 2020), Awka markets (Ikeh *et al.*, 2024), Uyo markets (Anosike *et al.*, 2025), Okitipupa market (Ogundipe *et al.*, 2025), in Nigeria. Adjovi *et al.* (2019) also reported mycotoxigenic fungi and mycotoxins in processed fish samples in Cotonou markets in Benin. These fungi belong to five genera: *Aspergillus flavus*, *Aspergillus fumigatus*,

Aspergillus niger, *Fusarium solani*, *Mucor mucedo* and *Saccharomyces cerevisiae* (Samuel *et al.*, 2015). These contaminants pose significant threat to health of smoke-dried fish consumers (Anosike *et al.*, 2025). The combined presence of bacteria and fungi in smoked fish demonstrates the complexity of microbial hazards in traditional fish products and the need for systematic assessment of their microbiological quality. Despite the high consumption of smoke-dried fish in Delta State, particularly in Abraka, Eku, and Obiaruku, recent data on their microbial quality are limited. Assessing the microbiological properties of *Clarias gariepinus* and *Ethmalosa fimbriata* in these markets is critical to understanding potential public health risks and guiding food safety interventions. The study investigated the microbiological quality of smoke-dried catfish and bonga fish sold in Abraka, Eku, and Obiaruku markets in Delta state, Nigeria.

MATERIALS AND METHODS

Sample Collection: Smoked fish, including *Clarias gariepinus* (Catfish) and *Ethmalosa fimbriata* (Bonga fish), were purchased from three major markets in Delta State, Nigeria: Abraka, Eku, and Obiaruku. Samples were handled carefully in sterile bags and transported to the laboratory, and analyzed immediately to prevent changes in microbial composition.

Total Aerobic Plate Counts (TAPCs): To estimate the total bacterial load, 1 gram of each fish sample was mixed with 9 ml of sterile 0.1% peptone water and homogenized as adapted from the slightly modified method of (Mitiku *et al.*, 2022). Ten-fold serial dilutions were prepared, and 0.1 ml of each dilution was spread onto nutrient agar plates in triplicate. The plates were incubated at 37°C for 24–48 hours, after which colonies were counted and expressed as colony-forming units per gram (cfu/g).

Total Coliform Counts: Coliform bacteria were assessed using MacConkey agar. Fish homogenates were diluted as above, and 0.1 ml of the appropriate dilution was spread

onto the agar. After incubation at 37°C for 24 hours, pink lactose-fermenting colonies were counted and reported as cfu/g (Onoja, *et al.*, 2024).

Total *Staphylococcus* Counts: *Staphylococcus* species were quantified following the slightly modified method described by Mitiku *et al.* (2022). Diluted fish samples (0.1 ml) were plated on Mannitol salt agar and incubated at 37°C for 24–48 hours. Colonies showing yellow colour and characteristic morphology were counted, providing an estimate of *Staphylococcus* load in cfu/g.

Bacterial Isolation and Identification from the Samples: Individual bacterial species were isolated and identified, following the method described by Onoja *et al.* (2024) using selective media: *E. coli* on Eosin Methylene Blue agar, *Bacillus* spp. on nutrient agar, *Proteus* spp. on MacConkey and blood agar, *Klebsiella* spp. on MacConkey agar, and *Staphylococcus* spp. on Mannitol salt agar. Distinct colonies were sub-cultured for purity. Identification relied on colony morphology, Gram staining, and standard biochemical tests, such as catalase, oxidase, coagulase, indole, citrate, urease, and motility. Presence or absence of each isolate was recorded, and prevalence (%) calculated relative to the total number of species tested.

Total Fungal Counts: Fungal populations were assessed using potato dextrose agar (PDA) supplemented with chloramphenicol to inhibit bacterial growth. Homogenized fish samples were serially diluted, and 0.1 ml aliquots of appropriate dilutions were spread onto the plates. Incubation was carried out at 28–30°C for 3–5 days. Colonies were counted and expressed as CFU/g.

Fungal Isolation and Identification: Fungal species were identified based on the appearance of colonies on the agar (colour, texture, and growth pattern) and microscopic characteristics using lactophenol cotton blue staining (Bachoon and Dustman, 2008). Species identified included *Aspergillus flavus*, *Aspergillus niger*, *Mucor* spp.,

Candida spp., and *Rhizopus* spp. Presence or absence was recorded, and prevalence (%) calculated as a proportion of positive isolates relative to total species tested.

RESULTS

The total aerobic plate counts of smoked fish samples obtained from Abraka, Eku, and Obiaruku markets ranged from 4.0×10^3 to 6.0×10^3 cfu/g (Table 1). *Ethmalosa fimbriata* showed the highest TAPC in Obiaruku (6.0×10^3 cfu/g), with Abraka and Eku recording similar counts (5.0×10^3 cfu/g). *Clarias gariepinus* had the highest TAPC in Eku (5.0×10^3 cfu/g), while Abraka and Obiaruku had similar counts (4.0×10^3 cfu/g).

The total coliform counts of smoked fish ranged from 3.0×10^3 to 4.5×10^3 cfu/g, reflecting a biologically reasonable proportion of total aerobic bacteria. *Ethmalosa fimbriata* from Obiaruku had the highest coliform counts (4.5×10^3 cfu/g), while Abraka and Eku were similar (3.1×10^3 cfu/g). *Clarias gariepinus* had similar counts across all markets (3.0×10^3 cfu/g).

Total *Staphylococcus* counts ranged from 1.6×10^3 to 4.5×10^3 cfu/g. *Ethmalosa fimbriata* had the highest count in Obiaruku (2.2×10^3 cfu/g), with Abraka and Eku similar (1.8×10^3 cfu/g). *Clarias gariepinus* from Obiaruku recorded a higher count (4.5×10^3 cfu/g) compared to Abraka and Eku (1.6×10^3 cfu/g). Bacterial isolates recovered included *Staphylococcus* spp., *Bacillus* spp., *E. coli*, *Proteus* spp., and *Klebsiella* spp., (Table 2) and are all known to cause foodborne illnesses. Presence/absence was recorded per sample, and prevalence (%) was calculated based on positive isolates relative to total species tested. Fungal counts ranged from 1.8×10^3 to 5.1×10^3 cfu/g (Table 3). *Ethmalosa fimbriata* from Obiaruku recorded slightly higher counts (2.0×10^3 cfu/g) compared to Abraka and Eku (1.8×10^3 cfu/g). *Clarias gariepinus* had the highest fungal counts in Abraka and Eku (5.1×10^3 cfu/g), slightly lower in Obiaruku (4.5×10^3 cfu/g). Species recovered included *Aspergillus flavus*,

Aspergillus niger, *Mucor* spp., *Candida* spp., and *Rhizopus* spp., (Table 4) which are known aflatoxin producers. Prevalence (%)

was calculated as the proportion of positive isolates relative to the total species tested.

Table 1: Microbial Counts of Smoked Fish Samples (cfu/g)

Market	<i>E. fimbriata</i> (TAPC)	<i>C. gariepinus</i> (TAPC)	<i>E. fimbriata</i> (Coliform)	<i>C. gariepinus</i> (Coliform)	<i>E. fimbriata</i> (Staphylococcus)	<i>C. gariepinus</i> (Staphylococcus)
Abraka	5.0×10^3	4.0×10^3	3.1×10^3	3.0×10^3	1.8×10^3	1.6×10^3
Eku	5.0×10^3	5.0×10^3	3.1×10^3	3.0×10^3	1.8×10^3	1.6×10^3
Obiaruku	6.0×10^3	4.0×10^3	4.5×10^3	3.0×10^3	2.2×10^3	4.5×10^3

Table 2: Occurrence and Prevalence of Bacterial Isolates in Smoked Fish Samples from Different Markets

Fish species/Market	<i>Staphylococcus</i> spp.	<i>Bacillus</i> spp.	<i>E. coli</i>	<i>Proteus</i> spp.	<i>Klebsiella</i> spp.	Prevalence (%)
<i>C. gariepinus</i> (Abraka)	+	+	+	+	+	100
<i>C. gariepinus</i> (Eku)	+	+	+	+	+	100
<i>C. gariepinus</i> (Obiaruku)	+	+	+	+	+	100
<i>E. fimbriata</i> (Abraka)	+	+	+	+	+	100
<i>E. fimbriata</i> (Eku)	+	+	+	+	+	100
<i>E. fimbriata</i> (Obiaruku)	+	+	+	+	+	100

Prevalence (%) reflects the proportion of positive isolates. The 100% prevalence may reflect the small sample size

Table 3: Total Fungal Counts of Smoked Fish Samples (cfu/g)

Market	<i>E. fimbriata</i>	<i>C. gariepinus</i>
Abraka	1.8×10^3	5.1×10^3
Eku	1.8×10^3	5.1×10^3
Obiaruku	2.0×10^3	4.5×10^3

Table 4: Percentage Occurrence of Fungal Isolates in Smoked Fish Samples

Fish species/Market	<i>Aspergillus</i> <i>flavus</i>	<i>Aspergillus</i> <i>niger</i>	<i>Mucor</i> spp.	<i>Candida</i> spp.	<i>Rhizopus</i> spp.	Prevalence (%)
<i>C. gariepinus</i> (Abraka)	+	–	–	+	+	60
<i>C. gariepinus</i> (Eku)	–	+	+	+	–	60
<i>C. gariepinus</i> (Obiaruku)	+	+	–	–	+	60
<i>E. fimbriata</i> (Abraka)	–	+	+	–	+	60
<i>E. fimbriata</i> (Eku)	+	–	+	+	–	60
<i>E. fimbriata</i> (Obiaruku)	+	+	–	+	+	80

Key + = Positive – Present, - = Negative –Absent

DISCUSSION

This study assessed the microbiological quality of smoked *Clarias gariepinus* and *Ethmalosa fimbriata* sold in selected open markets in Delta State, Nigeria. The findings revealed varying levels of bacterial and fungal contamination across markets and fish species, highlighting the influence of post-processing handling, vending environment, and storage conditions on the microbial safety of smoked fish.

The total aerobic plate counts (TAPC) of smoked fish from Abraka, Eku, and Obiaruku ranged from 4.0×10^3 to 6.0×10^3 cfu/g, reflecting moderate microbial loads. *Ethmalosa fimbriata* from Obiaruku recorded the highest TAPC (6.0×10^3 cfu/g) but *Clarias gariepinus* showed the highest counts in Eku (5.0×10^3 cfu/g). The lowest count (4.0×10^3 cfu/g) was observed in *Clarias gariepinus* samples from Abraka and Obiaruku. In Eku, both *Ethmalosa fimbriata*

and *Clarias gariepinus* showed similar counts (5.0×10^3 cfu/g). These findings are consistent with previous studies in Nigeria, which reported aerobic counts of smoked fish within 10^3 – 10^5 cfu/g, attributed to post-smoking handling and market exposure (Akinrotimi *et al.*, 2024; Ikechukwu *et al.*, 2024; Umezurike *et al.*, 2024). The slightly higher TAPC in Obiaruku samples may be due to prolonged exposure to ambient conditions and frequent handling, factors noted to influence microbial loads in smoked fish (Akomolede *et al.*, 2022; Kanki *et al.*, 2025). Total coliform counts ranged from 3.0×10^3 to 4.5×10^3 cfu/g, indicating a substantial proportion of the total aerobic population. Higher coliform levels in *E. fimbriata* from Obiaruku (4.5×10^3 cfu/g) suggest contamination via poor handling and environmental exposure, similar to patterns observed in other Nigerian market studies (Mitiku *et al.*, 2022). *Clarias gariepinus* exhibited more uniform coliform counts across all markets, which may reflect species-specific resistance to surface contamination due to thicker skin and larger size. *Staphylococcus* counts varied between 1.6×10^3 and 4.5×10^3 cfu/g, with the highest load in *C. gariepinus* from Obiaruku. These observations are consistent with earlier studies reporting *Staphylococcus* contamination in smoked fish as a result of handling and poor hygiene practices (Mitiku *et al.*, 2022; Obasi and Danladi, 2023). Although, below toxin-producing thresholds, the presence of *Staphylococcus* spp. indicates potential health risks if fish are stored under ambient conditions.

All samples yielded bacterial isolates including *Staphylococcus* spp., *Bacillus* spp., *E. coli*, *Proteus* spp., and *Klebsiella* spp., with 100% prevalence. This is consistent with earlier findings in smoked fish sold in Nigerian markets, where these organisms were isolated as indicators of faecal contamination and post-processing lapses (Akinrotimi *et al.*, 2024; Ikechukwu *et al.*, 2024; Umezurike *et al.*, 2024). The detection of *Bacillus* spp. further reflects the spore-forming capacity of these bacteria, allowing

survival through smoking and subsequent germination.

Fungal counts ranged from 1.8×10^3 to 5.1×10^3 cfu/g, with *C. gariepinus* generally showing higher loads than *E. fimbriata*. Isolated fungi included *Aspergillus flavus*, *Aspergillus niger*, *Mucor* spp., *Candida* spp., and *Rhizopus* spp., some of which are known for spoilage and mycotoxin production. The higher fungal prevalence in *E. fimbriata* from Obiaruku (80%) may reflect more favourable environmental conditions and poor handling. These findings corroborated previous observations of fungal contamination in smoked fish sold in tropical markets (Akomolede *et al.*, 2022; Kanki *et al.*, 2025).

Overall, the findings indicated that smoked fish from Abraka, Eku, and Obiaruku harbored moderate levels of bacteria and fungi, including potential foodborne pathogens and toxigenic species. However, smoking reduced microbial loads, post-processing contamination remained significant, highlighting the need for improved hygiene, packaging, and storage practices to ensure the safety of smoked fish in open markets.

CONCLUSION

Smoked *Clarias gariepinus* and *Ethmalosa fimbriata* sold in Abraka, Eku, and Obiaruku markets showed moderate levels of bacterial and fungal contamination despite smoke-drying. The detection of coliforms, *Staphylococcus* spp., and potentially toxigenic fungi suggests that post-smoking handling, storage, and market conditions are key contributors to microbial contamination rather than the smoking process itself. The variations in microbial loads among markets further reflect differences in environmental exposure and hygiene practices. Although, smoked fish remains a widely consumed and nutritionally important food, these findings highlight the need for improved hygiene, packaging, and routine microbial monitoring to reduce potential public health risks associated with traditionally processed fish products.

REFERENCES

- Adesomojo, A., Ekundayo, O., Oke, T., Eramo, T., Laaqsso, I. and Hiltunen, R. (1991). Volatile constituents of *Monodera tenuifolia* fruit oil. *Planta Med.* 393-394.
- Abolagba, O. J., and Igbinevbo, E. E. (2010). Microbial load of fresh and smoked fish marketed in Benin metropolis, Nigeria. *Research Journal of Fisheries and Hydrobiology*, 5(2):99-104.
- Abolagba, O. J., and Uwagbai, E. C. (2011). A comparative analysis of the microbial load of smoke-dried fishes (*Ethmalosa fimbriata* and *Pseudotolithus elongatus*) sold in Oba and Koko markets in Edo and Delta States, Nigeria at different seasons. *Australian Journal of basic and Applied Sciences*, 5(5):544-550.
- Adetuwo, O. J., Adegbehingbe, K. T., and Rachael, O. T. (2023). Safety concerns on microbes associated with fresh and smoked fish sold in Igbokoda Market, Nigeria. *Journal of Advances in Microbiology*, 23(10):72–82.
- Adjovi, Y. C. S., Tiko, G., Gnonlonfin, B. G., and Sanni, A. (2019). Morphologic and molecular characterization of *Aspergillus flavus* isolated from smoked, fermented and dried fishes sold in main markets of Cotonou (Benin). *Journal of Food and Industrial Microbiology*, 5(1):131.
- Akinrotimi, O. A., Onoja, C. R., Ikeogu, F. C., Ayaabu Cookey, I. K., and Amanze, S. C. (2024). Evaluation of microbial profiles of selected ready and non-ready to consume fish products vended in some open markets in Awka, Anambra State, Nigeria. *IJRDO Journal of Biotechnology*, 2(1):9–17.
- Akomolede, O. O., Balogun, A., and Christoper, M. S. (2022). Microbiological assessment of smoked fishes from various processing points in Ado Ekiti Metropolis. *Asian Journal of Fisheries and Aquatic Research*, 17(3):9–17.
- Amachree, D., Akinrotimi, O. A., Orokotan, O. O., and Ayaabu Cookey, I. K. (2025). Microbiological assessment of some smoked dried fish samples sold in Port Harcourt metropolis, Nigeria. *IJRDO Journal of Food Science and Quality Control*.
- Anosike, I. K., Abasiubong, V. N., Egbomuche, R. C., Ikon, G. M., Amadi, C. P., Ndubuisi, S. A., and Ehichoya, S. O. (2025). Prevalence of *Aspergillus* species in smoke-dried fish from selected markets in Uyo, Akwa Ibom State, Nigeria. *Researchers Journal of Science and Technology*, 5(8):1-17.
- Asamoah, E. K., Nunoo, F. K. E., Addo, S., Nyarko, J. O., Adjei, M. Y. B., Kunadu, A. P. H., and Hyldig, G. (2025). Comparison of the efficiency of improved and traditional fish smoking kilns and their effects on smoked fish quality in Ghana. *Journal of the Science of Food and Agriculture*, 105(5):2923-2930.
- Bachoon, D. S., and Dustman, W. A. (2008). Exercise 8: Selective and differential media for isolation. *Microbiological Laboratory Manual: Mason, OH, USA*.
- Beyer, D. S., Dustman, A., and Wendy, A. (2008). Exercise 8: Selective and differential media for isolation. In M. Stranz (Ed.), *Microbiology Laboratory Manual*. Mason, O.
- Cortés-Sánchez, A. D. J., Díaz-Ramírez, M., Salgado-Cruz, M. D. L. P., León-Espinosa, E. B., Arano-Varela, H., Arroyo-Maya, I. J., and Perea-Flores, M. D. J. (2025). Foodborne Illnesses and Microbiological Safety of Fish and Fish Products: A Brief Overview in Regard to Mexico. *Applied Sciences*, 15(21):11447.

- Fagbohun, E., and Lawal, O. (2015). Aflatoxins investigation and mycobiota of selected marketed smoked-dried fish samples in Ado-Ekiti, Nigeria and their environmental health implications. *British Microbiology Research Journal*, 7(3):126-132.
- Gambushe, S. M., Zishiri, O.T. and El Zowalaty, M. E. (2022). Review of *Escherichia coli* O157:H7 prevalence, pathogenicity, heavy metal and antimicrobial resistance, African perspective. *Infection and Drug Resistance*, 15:4645-4673. doi: 10.2147/IDR.S365269. PMID: 36039321; PMCID: PMC9420067.
- Griffiths, M.W and Schraft, H. (2017). *Bacillus cereus* food poisoning. In: *Foodborne diseases* (pp. 395-405). Academic Press.
- Ikechukwu, C. C., Akinrotimi, O. A., and Ayaobu Cookey, I. K. (2024). Evaluation of microbial load in some smoked marine fish products sold in Nnewi Metropolis, Anambra State, Nigeria. *IJRDO Journal of Veterinary and Animal Science*, 2(1):1-6.
- Ikeh, M. I., Ishar, C. O., Chiakwelu, P. C., Okeke, O. A., Okeke, C. J., Offor, V. O., ... and Benedict, A. G. (2024). Study of Fungal Organisms Associated With Smoked and Dried Fish Sold in Awka Markets, Anambra State. *African Journal of Agriculture and Food Science*, 7(4), 87-98.
- Issa-Zacharia, A., Msangi, R. S., & Mboya, G. R. (2025). Revisiting chemical and microbiological quality and safety of fish and fish products. *International Journal of Microbiology and Biotechnology*, 10(3):73-90.
- John, W. C., Buba, B. A., Ayisa, T. T., Oke, O., Ihum, T. A., and Ishaya, M. (2020). Mycological examination of smoke-dried fish sold in Bida major markets. *European Journal of Biology*, 5(1):28-40.
- Kanki, H., Omotosho, A. O., Adamu, S., Okekeaji, U., Akor, M. S., and Lemu, M. M. (2025). Microbial Contamination of Smoked Tilapia Fish Sold in Kure Market, Minna, Niger State, Nigeria. *International Journal of Pathogen Research*, 14(1), 76-83.
- Mitiku, B. A., Mitiku, M. A., Ayalew, G. G., Alemu, H. Y., Geremew, U. M., and Wubayehu, M. T. (2022). Microbiological quality assessment of fish-origin food along the production chain in Upper Blue Nile watershed, Ethiopia. *Food Science and Nutrition*, 11(2):1096-1103.
- Nwachukwu, P. C., Nwachukwu, M. O., Bamson, M., Azorji, J. N., Onyebuagu, P. C., and Ubah, V. C. S. (2024). Isolation, characterization and identification of bacteria associated with suya meat sold in Owerri City, Imo State, Nigeria. *FNAS Journal of Applied Biological Sciences*, 1(1):1-5.
- Obasi, B. C., and Danladi, G. (2023). Evaluation of microbiological quality and organoleptic properties of smoked dried fish sold in Wukari markets, Taraba State, Nigeria. *Magna Scientia Advanced Biology and Pharmacy*, 9(1):87-93.
- Ogundipe, O., Folounso, T. V., Adeshina, K., Abu, B., and Teniola, O. D. (2025). Fungal spoilage of smoked-dried fish in Okitipupa, Ondo State, Nigeria. *Direct Research Journal of Agriculture and Food Science*, 13(3):208-213.
- Ohimain, E. I., Oku, I. Y. and Charles, E. E. (2025). Potential health benefits and risks associated with the consumption of the giant African land snail: A review. *Journal of Food Safe and Hygiene*; 11 (1):1-12.
- Oladeji, F. O., Adebayo, O. J., and Tope, A. T. (2023). Fungi associated with the spoilage of smoke-dried fish in open

- market in Osogbo, Nigeria. *Asian Journal of Food Research and Nutrition*, 2(4):676–680.
- Onoja, C. R., Ikeogu, F. C., Akinrotimi, O. A., Ayaabu-Cookey, I. K., and Amanze, S. C. (2024). Evaluation of microbial profiles of selected ready and non-ready to consume fish products vended in some open markets in Awka, Anambra State, Nigeria. *IJRDO Journal of Biotechnology*, 2(1):9–18.
- Ousman, A. H., Boureima, K., and Edwige, S. T. R. (2025). Isolation and biochemical characterization of *Escherichia coli* and other Enterobacteriaceae from smoked and dried fish in Chad. *Microbiology Research Journal International*, 35(7):1–9.
- Samaké, F., and Konaré, M. A. (2025). Spoilage microorganisms involved in fish smoking processes in West Africa: Implication for food quality. *Marketing*, 6:7.
- Samuel, O., Ifeanyi, O., and Ugochukwu, O. (2015). Mycoflora of smoke-dried fish varieties sold in Eke Awka Market in Anambra State, Nigeria. *American Journal of Life Science Research*, 3(3):196-201.
- Sani, F. M., Nasir, I. A., and Torhile, G. (2016). Mycological evaluation of smoked-dried fish sold at Maiduguri Metropolis, Nigeria: Preliminary findings and potential health implications. *European Journal of Health Sciences*, 2:5-10.
- Sheng, L., and Wang, L. (2021). The microbial safety of fish and fish products: Recent advances. *Comprehensive Reviews in Food Science and Food Safety*, 20(1):738–786.
- Umezurike, E. T., Adegbehingbe, K. O., Abeeb, A. S., Sindiku, O., Effiong, A. P., Melle, V. A., Alimi, B. F., and Ajadi, S. T. (2024). Microbial profile of smoked fish sold in selected markets in Ibadan Metropolis, Oyo State, Nigeria. *Journal of Advances in Microbiology*, 24(12):128–138.