



Research Paper

Mycoflora associated with dried *Labeo rohita* marketed in Jammu, Union Territory of Jammu and Kashmir, India

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How to Cite

Singh, Y.P., Devi, G., and Jyoti, M.K. (2026). Mycoflora associated with dried *Labeo rohita* marketed in Jammu, Union Territory of Jammu and Kashmir, India. *Journal of Fisheries and Zoological Sciences*, 1(2), 29-35. <https://doi.org/10.65385/JFZS0005>

ISSN: 3108-1991 (online)

Article History

Received 08 February 2026

Accepted 02 March 2026

First Online 14 March 2026

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Keywords

Dried fish

Labeo rohita

Fungal diversity

Seasonal variation

Mycotoxin

Food safety

Abstract

Dried fish is a widely consumed food product and is highly susceptible to fungal contamination during drying, storage, and marketing. The present study investigated the seasonal diversity and distribution of fungi associated with dried *Labeo rohita* marketed in Jammu, Union Territory of Jammu and Kashmir, India, over a one-year period (January–December). A total of 28 fungal species belonging to 12 genera were isolated and identified. *Aspergillus*, *Penicillium*, *Fusarium*, *Cladosporium*, *Mucor*, and *Rhizopus* were the dominant genera. Several species, including *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Aspergillus terreus*, *Penicillium chrysogenum*, *Penicillium expansum*, and *Fusarium moniliforme*, were detected throughout the year, indicating strong ecological adaptability. Pronounced seasonal variation in fungal diversity and abundance was observed, with the highest fungal load during summer and monsoon months and a marked decline during winter. Many of the dominant fungi are known producers of mycotoxins such as aflatoxins, ochratoxin A, fumonisins, and trichothecenes, indicating a potential food safety risk. Based on the findings of the present study, it is recommended that improved drying techniques and controlled storage conditions be implemented to minimize fungal contamination in dried *Labeo rohita*. Routine microbiological monitoring and adherence to hygienic handling practices are also essential to ensure product safety and quality.

1. Introduction

Fish is an important source of high-quality animal protein, essential amino acids, polyunsaturated fatty acids, vitamins, and minerals, contributing significantly to nutritional security, particularly in developing countries (FAO, 2020; 2022; Tilami & Sampels, 2018; Mohanty et al., 2019; Frontiers Editorial Team, 2021). Among freshwater fishes, *Labeo rohita* (Hamilton, 1822), an Indian major carp, is widely consumed owing to its nutritional value, consumer preference, and economic importance (Mohanty et al., 2017). Traditional preservation methods such as sun-drying are commonly employed to extend shelf life and facilitate storage and transportation, especially in regions with limited cold-chain facilities (Deng et al., 2021). Dried fish products are highly vulnerable to fungal colonization due to prolonged exposure to open environments during drying, handling, storage, and marketing. Environmental factors such as high relative humidity, suboptimal drying, and unhygienic storage conditions favor the establishment and proliferation of diverse mycoflora (Fagbohun et al., 2019; Thiyagarajan & Jamal, 2021). Fungal contamination not only causes deterioration in product quality but is also of serious concern from public health perspective, as several

fungal genera, particularly *Aspergillus*, *Penicillium*, and *Fusarium*, are known producers of mycotoxins (Deng et al., 2021; Nordin et al., 2022).

Previous studies have documented the occurrence of mycoflora in dried and smoked fish from various parts of India and other tropical regions; however, fungal diversity and dominance patterns differ considerably with respect to climatic conditions, processing practices, and market hygiene (Atapattu & Samarajeewa, 1990; Adebayo-Tayo et al., 2015; Thiyagarajan & Jamal, 2021). Reports from South and Southeast Asia frequently indicate the presence of toxigenic fungal species associated with dried fish products, emphasizing the potential risk of mycotoxin contamination (Deng et al., 2021; Fagbohun et al., 2019).

The Union Territory of Jammu and Kashmir exhibits distinct agro-climatic conditions and traditional fish marketing systems. Although fungal pathogens associated with freshwater fish have been reported from the Kashmir region (Magray et al., 2021), systematic studies on the mycoflora of dried fish products marketed in Jammu are limited. In particular, information on the diversity and seasonal occurrence of fungi associated with dried *Labeo rohita* from this region remains scarce.

The present investigation was undertaken to document the diversity and seasonal distribution of mycoflora associated with dried *Labeo rohita* marketed in Jammu (UT of Jammu & Kashmir). The study aimed to generate baseline mycological data and assess the potential occurrence of toxigenic fungal species, thereby contributing to food safety assessment and post-harvest quality management of dried fish products.

2. Materials and Methods

2.1 Study Area and sample collection

Dried fish samples of *Labeo rohita* were collected from major retail markets of Jammu city, Union Territory of Jammu and Kashmir, India, over a one-year period from January to December (2024-2025). Sampling was carried out monthly to assess seasonal variation in mycoflora. Freshly marketed dried fish samples were randomly collected from different vendors, packed in sterile polyethylene bags, labeled, and transported to the laboratory for mycological analysis. Samples were processed within 24 h of collection.

2.2 Isolation of mycoflora

Fungal isolation was performed using the standard dilution plate and direct plating techniques. For dilution plating, 10 g of dried fish tissue was aseptically homogenized in 90 mL of sterile distilled water and serially diluted up to 10^{-3} . Aliquots (1 mL) from appropriate dilutions were inoculated onto Potato Dextrose Agar (PDA) and Czapek Dox Agar (CDA) supplemented with chloramphenicol (50 mg L^{-1}) to inhibit bacterial growth. For direct plating, small surface-sterilized fragments of dried fish were placed directly onto the culture media. All plates were incubated at $28 \pm 2^\circ\text{C}$ for 5–7 days and observed daily for fungal growth.

2.3 Purification and maintenance of isolates

Emerging fungal colonies were sub cultured repeatedly onto fresh PDA plates to obtain pure cultures. Pure isolates were maintained on PDA slants at 4°C for further identification and analysis.

2.4 Identification of fungal isolates

Fungal isolates were identified based on macroscopic and microscopic characteristics following standard mycological keys and descriptions. Colony morphology, growth pattern, pigmentation, and sporulation were recorded. Microscopic features such as conidiophore structure, spore morphology, and reproductive structures were examined using lactophenol cotton blue staining. Identification was carried out with reference to standard taxonomic manuals (Raper & Fennell, 1965; Barron, 1972; Ellis, 1971; Gilman, 2001; Pitt, 1979; Sutton, 1980; Barnett & Hunter, 1998; Samson et al., 2014). Nomenclature was updated according to current taxonomic standards.

2.5 Seasonal distribution analysis

The occurrence and frequency of fungal species were recorded on a monthly basis and grouped into seasons based on local climatic conditions. Seasonal variation in fungal diversity was assessed by comparing the number of species recorded during different seasons of the year.

2.6 Assessment of toxigenic potential

The potential toxigenic nature of fungal isolates was inferred based on documented literature reports of mycotoxin production by the identified species, particularly aflatoxins, ochratoxin A, fumonisins, and trichothecenes.

3. Results

3.1 Mycospectrum and seasonal occurrence of fungi associated with dried *Labeo rohita*

The mycological analysis of dried *Labeo rohita* revealed a rich and diverse fungal community throughout the year (Table 1). A total of 28 fungal species belonging to 12 genera were isolated during the study period. The dominant genera included *Aspergillus*, *Penicillium*, *Fusarium*, *Cladosporium*, *Mucor*, and *Rhizopus*, indicating their strong adaptability to dried fish substrates.

Several fungal species such as *Alternaria alternata*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Aspergillus terreus*, *Cladosporium cladosporioides*, *Curvularia lunata*, *Fusarium moniliforme*, *Fusarium sporotrichioides*, *Geotrichum candidum*, *Mucor* sp., *Penicillium chrysogenum*, *Penicillium expansum*, and *Rhizopus stolonifer* were detected throughout all months, demonstrating year-round persistence. In contrast, species such as *Aspergillus glaucus*, *Aspergillus restrictus*, *Penicillium* sp., *Trichothecium roseum* and *Ulocladium* sp exhibited seasonal or sporadic occurrence, being largely confined to warmer and more humid months.

A clear seasonal trend was evident, with greater species richness during summer and monsoon months (April–September), while fungal occurrence declined during winter (December–February).

3.2 Seasonal abundance of fungal colonies

Quantitative analysis of fungal colonies (Table 2) further supported the seasonal variation in fungal contamination. The highest total number of colonies was recorded during the monsoon season (July–September; 987 colonies), followed by post-monsoon (October–December; 876 colonies) and summer (April–June; 840 colonies). The lowest fungal load occurred during winter (January–March; 642 colonies).

Table 1: Seasonal occurrence of fungal species associated with dried *Labeo rohita* marketed in Jammu, UT of Jammu & Kashmir

S. No.	Fungal species	Winter (Dec–Feb)	Summer (Mar–Jun)	Monsoon (Jul–Sep)	Post-monsoon (Oct–Nov)
1	<i>Alternaria alternata</i>	+	+	+	+
2	<i>Aspergillus flavus</i>	+	+	+	+
3	<i>Aspergillus fumigatus</i>	+	+	+	+
4	<i>Aspergillus glaucus</i>	–	+	+	–
5	<i>Aspergillus niger</i>	+	+	+	+
6	<i>Aspergillus ochraceus</i>	+	+	+	+
7	<i>Aspergillus restrictus</i>	–	+	+	–
8	<i>Aspergillus clavatus</i>	–	+	+	+
9	<i>Aspergillus terreus</i>	+	+	+	+
10	<i>Aspergillus sydowii</i>	–	+	+	+
11	<i>Aureobasidium</i> spp.	+	+	+	+
12	<i>Botrytis cinerea</i>	+	+	+	+
13	<i>Cladosporium cladosporioides</i>	+	+	+	+
14	<i>Cladosporium herbarum</i>	+	+	+	+
15	<i>Curvularia</i> sp.	+	+	+	+
16	<i>Emericella nidulans</i>	+	+	+	–
17	<i>Fusarium moniliforme</i>	+	+	+	+
18	<i>Fusarium oxysporum</i>	+	+	+	–
19	<i>Fusarium pallidoroseum</i>	+	+	+	–
20	<i>Fusarium sporotrichioides</i>	+	+	+	+
21	<i>Geotrichum candidum</i>	+	+	+	+
22	<i>Mucor</i> sp.	+	+	+	+
23	<i>Penicillium chrysogenum</i>	+	+	+	+
24	<i>Penicillium expansum</i>	+	+	+	+
25	<i>Penicillium</i> sp.	–	+	+	–
26	<i>Rhizopus stolonifer</i>	+	+	+	+
27	<i>Trichothecium roseum</i>	+	+	+	+
28	<i>Ulocladium</i> sp	–	+	+	–

Symbols: + = present in at least one month of the season; – = absent during the season.

Among individual taxa, *Aspergillus*, *Penicillium*, and *Fusarium* species contributed substantially to the total fungal population across all seasons. *Aspergillus niger*, *Aspergillus flavus*, *Penicillium expansum*, *Fusarium oxysporum*, *Fusarium pallidoroseum*, and *Rhizopus stolonifer* showed particularly high colony counts during the monsoon and post-monsoon periods, reflecting favorable environmental conditions for growth and sporulation.

3.3 Fungal diversity indices

Diversity analysis using Shannon–Wiener (H') and Simpson's ($1-D$) indices revealed consistently high fungal diversity across all seasons (Table 3). The highest diversity was observed during the monsoon season, with a Shannon–Wiener index of $H' = 3.29$ and a Simpson's index of $1-D = 0.962$, indicating greater species richness and evenness.

Winter, summer, and post-monsoon seasons exhibited

comparable diversity values, with Shannon–Wiener indices ranging from 3.26 to 3.27 and Simpson's indices between 0.959 and 0.960. The high Simpson's values (>0.95) across seasons suggest that no single fungal species dominated the community, although relative abundance varied seasonally.

3.4 Overall interpretation

The combined qualitative (Table 1), quantitative (Table 2), and diversity index (Table 3) analyses demonstrate that climatic factors—particularly temperature and humidity—play a critical role in shaping fungal diversity and abundance on dried *Labeo rohita*. Warm and humid conditions during summer and monsoon seasons favored higher fungal occurrence, colony density, and diversity, whereas cooler and drier winter conditions limited fungal proliferation. The persistent presence of several *mycotoxigenic* genera, notably *Aspergillus*, *Penicillium*, and *Fusarium*, throughout the year underscores the potential risk of mycotoxin contamination in dried fish and highlights the need for improved drying, storage, and monitoring practices.

Table 2: Seasonal occurrence and relative abundance of fungal colonies isolated from dried *Labeo rohita*

S. No.	Fungal species	Jan–Mar (No., %)	Apr–Jun (No., %)	Jul–Sep (No., %)	Oct–Dec (No., %)
1	<i>Alternaria alternata</i>	22 (3.4)	27 (3.2)	38 (3.9)	23 (2.6)
2	<i>Aspergillus clavatus</i>	11 (1.7)	16 (1.9)	20 (2.0)	11 (1.3)
3	<i>Aspergillus flavus</i>	29 (4.5)	44 (5.2)	34 (3.4)	53 (6.0)
4	<i>Aspergillus fumigatus</i>	30 (4.7)	23 (2.7)	53 (5.4)	32 (3.7)
5	<i>Aspergillus glaucus</i>	21 (3.3)	21 (2.5)	34 (3.4)	23 (2.6)
6	<i>Aspergillus niger</i>	43 (6.7)	53 (6.3)	22 (2.2)	43 (4.9)
7	<i>Aspergillus ochraceus</i>	23 (3.6)	37 (4.4)	32 (3.2)	21 (2.4)
8	<i>Aspergillus restrictus</i>	12 (1.9)	14 (1.7)	22 (2.2)	13 (1.5)
9	<i>Aspergillus sydowii</i>	11 (1.7)	21 (2.5)	31 (3.1)	26 (3.0)
10	<i>Aspergillus terreus</i>	21 (3.3)	32 (3.8)	42 (4.3)	43 (4.9)
11	<i>Aureobasidium</i> spp.	12 (1.9)	23 (2.7)	43 (4.4)	21 (2.4)
12	<i>Botrytis cinerea</i>	22 (3.4)	29 (3.5)	34 (3.4)	32 (3.7)
13	<i>Cladosporium cladosporioides</i>	32 (5.0)	54 (6.4)	32 (3.2)	21 (2.4)
14	<i>Cladosporium herbarum</i>	12 (1.9)	15 (1.8)	21 (2.1)	22 (2.5)
15	<i>Curvularia lunata</i>	22 (3.4)	32 (3.8)	22 (2.2)	42 (4.8)
16	<i>Emericella nidulans</i>	11 (1.7)	12 (1.4)	31 (3.1)	23 (2.6)
17	<i>Fusarium moniliforme</i>	24 (3.7)	20 (2.4)	34 (3.4)	43 (4.9)
18	<i>Fusarium oxysporum</i>	21 (3.3)	43 (5.1)	46 (4.7)	39 (4.5)
19	<i>Fusarium pallidoroseum</i>	21 (3.3)	34 (4.0)	52 (5.3)	24 (2.7)
20	<i>Fusarium sporotrichioides</i>	23 (3.6)	34 (4.0)	45 (4.6)	32 (3.7)
21	<i>Geotrichum candidum</i>	21 (3.3)	24 (2.9)	34 (3.4)	41 (4.7)
22	<i>Mucor</i> sp.	26 (4.0)	38 (4.5)	38 (3.9)	36 (4.1)
23	<i>Penicillium chrysogenum</i>	21 (3.3)	36 (4.3)	45 (4.6)	42 (4.8)
24	<i>Penicillium expansum</i>	35 (5.5)	48 (5.7)	48 (4.9)	45 (5.1)
25	<i>Penicillium purpurogenum</i>	35 (5.5)	23 (2.7)	24 (2.4)	31 (3.5)
26	<i>Rhizopus stolonifer</i>	27 (4.2)	35 (4.2)	42 (4.3)	46 (5.2)
27	<i>Trichothecium roseum</i>	42 (6.5)	32 (3.8)	46 (4.7)	36 (4.1)
28	<i>Ulocladium</i> sp.	12 (1.9)	20 (2.4)	22 (2.2)	12 (1.4)
	Total colonies	642	840	987	876

Table 3: Seasonal fungal diversity indices (Shannon–Wiener and Simpson) of fungi associated with dried *Labeo rohita*

Season (Months)	Total colonies (N)	Shannon–Wiener index (H')	Simpson's diversity index (1–D)
Winter (Jan–Mar)	642	3.26	0.959
Summer (Apr–Jun)	840	3.26	0.959
Monsoon (Jul–Sep)	987	3.29	0.962
Post-monsoon (Oct–Dec)	876	3.26	0.96

4. Discussion

4.1 Mycoflora associated with dried *Labeo rohita*

The present investigation provides a comprehensive data of the mycoflora associated with dried *Labeo rohita* marketed in Jammu, Union Territory of Jammu & Kashmir. A total of 28 fungal species belonging to 12 genera were recovered, indicating that dried fish serves as a highly favorable substrate for fungal colonization. Similar fungal assemblages on dried and smoked fish have been widely reported from different regions of India and other tropical and subtropical countries, emphasizing the susceptibility of dried fish products to fungal contamination under traditional processing and marketing practices (Fagbohun et al., 2019; Sahoo et al., 2020; Thiagarajan & Jamal, 2021; Magray et al., 2021; Nayak et al., 2022; Nordin et al., 2022).

4.2 Dominance of *Aspergillus*, *Penicillium*, and *Fusarium*

Species of *Aspergillus*, *Penicillium*, and *Fusarium* predominated throughout the year. These genera are well-known xerophilic and xerotolerant fungi capable of growth under low water activity conditions characteristic of dried fish products (Pitt & Hocking, 2009; Kumar et al., 2021; Bhat et al., 2023). The continuous occurrence of *Aspergillus flavus*, *Aspergillus niger*, *Aspergillus fumigatus*, *Aspergillus terreus*, *Penicillium chrysogenum*, *Penicillium expansum*, *Fusarium moniliforme* (syn. *Fusarium verticillioides*), and *Fusarium sporotrichioides* across all months suggests persistent contamination from drying surfaces, storage environments, and airborne sources.

Comparable dominance of these genera has been reported from dried fish markets in West Bengal (Kolkata, Digha), Tamil Nadu (Thoothukudi, Nagapattinam), Assam (Guwahati, Silchar), Odisha, Kerala, and Andhra Pradesh, where open sun-drying and high ambient humidity prevail (Adebayo-Tayo et al., 2015; Sahoo et al., 2020; Dutta et al., 2021; Magray et al., 2021; Nayak et al., 2022; Das et al., 2023). Similar fungal profiles have also been documented from Bangladesh and Sri Lanka, indicating regional uniformity in dried fish mycoflora across South Asia (Nordin et al., 2022; Rahman et al., 2023).

The occurrence of *Cladosporium*, *Alternaria*, *Curvularia*, and *Botrytis* species reflects airborne contamination, as these fungi are ubiquitous outdoor saprophytes commonly associated with dust and plant debris. Their presence highlights the influence of open drying and retail display systems on fungal deposition, a pattern also observed in dried fish markets in Assam, West Bengal, and coastal Odisha (Samson et al., 2010; Dutta et al., 2021; Nayak et al., 2022; Deng et al., 2021).

4.3 Seasonal variation in fungal occurrence and load

A distinct seasonal trend was observed, with maximum fungal load and species richness during the monsoon season (July–September), followed by summer and post-monsoon periods. Elevated temperature and relative humidity during these seasons favor rapid fungal growth, sporulation, and secondary metabolite production (Pitt & Hocking, 2009; Sahoo et al., 2020; Kumar et al., 2021; Deng et al., 2021; Bhat et al., 2023). The lowest fungal counts recorded during winter months may be attributed to reduced moisture availability and lower ambient temperatures that inhibit fungal activity.

Similar seasonal patterns have been reported from dried fish markets in Assam, West Bengal, Odisha, and coastal Tamil Nadu, where moisture absorption during monsoon months significantly enhances fungal infestation and spoilage (Magray et al., 2021; Nayak et al., 2022; Das et al., 2023).

4.4 Fungal diversity and community structure

High Shannon–Wiener and Simpson's diversity indices across all seasons indicate a species-rich and evenly distributed fungal community on dried *L. rohita*. The highest diversity during the monsoon season reflects favorable microclimatic conditions and increased microbial competition. Comparable diversity patterns have been documented in dried fish and other stored commodities from Odisha, Assam, and Kerala under tropical climatic conditions (Sahoo et al., 2020; Nayak et al., 2022; Nordin et al., 2022; Bhat et al., 2023). The absence of dominance by a single species suggests a complex and dynamic fungal ecosystem, increasing the likelihood of co-occurrence of toxigenic and allergenic fungi.

4.5 Implications for mycotoxin contamination

The frequent isolation of mycotoxigenic fungi such as *Aspergillus flavus*, *Aspergillus ochraceus*, *Penicillium expansum*, *Fusarium moniliforme*, and *F. sporotrichioides* indicates a significant risk of mycotoxin contamination in dried fish. These fungi are known producers of aflatoxins (AFB₁, AFB₂), ochratoxin A, fumonisins (FB₁, FB₂), and trichothecenes (T-2 and HT-2 toxins), which are associated with hepatotoxic, nephrotoxic, immunosuppressive, and carcinogenic effects (Pitt & Hocking, 2009; Kumar et al., 2021; Nayak et al., 2022; Deng et al., 2021; Nordin et al., 2022; EFSA, 2023).

Recent Indian studies have reported the presence of aflatoxins and ochratoxin A in dried and smoked fish from open markets in West Bengal, Odisha, Andhra Pradesh, and coastal Tamil Nadu, frequently exceeding permissible limits during monsoon months (Sahoo et al., 2020; Dutta et al., 2021; Das et al., 2023). Although mycotoxin analysis was not undertaken in the present

study, the persistent occurrence of toxigenic fungi suggests a substantial risk of mycotoxin accumulation in dried fish marketed in Jammu.

4.6 Allergenic and public health implications

Several isolated fungi, including *Aspergillus fumigatus*, *Aspergillus niger*, *Cladosporium*, and *Alternaria*, are recognized sources of fungal allergens. Exposure to their spores may result in allergic rhinitis, asthma, and occupational respiratory disorders among fish handlers and vendors, as reported from Indian coastal markets (Chakraborty et al., 2021; WHO, 2022; Chowdhary et al., 2023).

Overall, the findings highlight deficiencies in hygienic handling, drying efficiency, storage practices, and market sanitation. Traditional sun-drying on open platforms, exposure to dust and insects, and storage in moisture-permeable containers facilitate continuous fungal contamination. Similar concerns have been raised by Indian studies on dried fish value chains in Odisha, Assam, and Tamil Nadu (Sahoo et al., 2020; Nayak et al., 2022). Adoption of improved drying technologies, moisture-proof packaging, and regular monitoring of fungal and mycotoxin contamination is therefore essential to ensure food safety.

5. Conclusion

Dried *Labeo rohita* marketed in Jammu contains a diverse fungal population with clear seasonal variation. The frequent occurrence of mycotoxigenic genera such as *Aspergillus*, *Penicillium*, and *Fusarium* indicates potential food safety risks, particularly under warm and humid conditions during summer and monsoon seasons. These findings highlight the influence of climate on fungal proliferation. Therefore, improved drying methods, hygienic handling, moisture-proof storage, and regular monitoring of fungal and mycotoxin contamination are recommended to ensure product safety, maintain quality, and enhance marketability while protecting public health.

6. Statements and Declarations

Ethical Approval: This study did not involve live animal experimentation or human participants. Dried fish samples (*Labeo rohita*) were procured from retail markets for microbiological analysis. Therefore, formal ethical approval from an institutional animal ethics committee was not required.

Conflict of Interest: No conflict of interest was reported by the authors.

Funding statement: Not applicable

Acknowledgements: The authors acknowledge the support of the Department of Botany, Government Degree College Samba, University of Jammu, for providing laboratory facilities.

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