



Beyond a Physical Barrier: Fish Mucus as an Emerging Source of Bioactives

Khumujam Sapana Devi¹, Tincy Varghese*², Amrutha Gopan³, Sujata Sahoo¹

¹ICAR-Central Institute of Fisheries Education, Mumbai, India

²ICAR-Central Institute of Fisheries Technology, Kochi, India

³ICAR-Central Institute of Brackishwater Aquaculture, Navsari Centre, Navsari, India

Corresponding Author

Tincy Varghese

Email: 4tincy@gmail.com

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ABSTRACT

Fish mucus is often viewed as a physical barrier on the fish body separating it from the aqueous environment. However, it is actually a biologically active layer that plays an important role in protecting fish. It is rich in mucin proteins, antimicrobial peptides, enzymes, immune-related proteins, lipids, and other bioactive compounds. Mucus protects against pathogens and environmental challenges. Recent studies have also highlighted its antimicrobial, wound-healing, anti-inflammatory, and other potentially beneficial properties. In addition, microorganisms naturally associated with fish mucus may contribute to disease resistance and offer possibilities for probiotic applications in aquaculture. These findings are expanding our understanding of fish mucus from a protective barrier to a promising natural source of bioactive compounds. Further exploration of these molecules could open new avenues for their application in cosmetics, biotechnology, aquaculture and biomedicine.

KEYWORDS

Epidermal secretion; Marine Bioactives; Antimicrobial activity; Wound healing; Mucosal defence

Introduction

Fish live in an environment filled with microorganisms, parasites, pollutants, and other potential threats. Yet, before many of these hazards can reach the living tissues beneath the skin, they encounter a thin, slippery layer of mucus. Produced primarily by specialised mucus-secreting cells, fish epidermal mucus is much more than a simple coating on the body. It forms a dynamic interface between the fish and its aquatic surroundings and serves as one of the first lines of defence against biological and environmental challenges (Dash et al., 2018). The mucus layer is continuously produced and shed, helping to trap microorganisms and limit their attachment and colonisation on the skin. At the same time, its complex biochemical composition gives it functions that extend far beyond a physical barrier. Mucins, glycoproteins, antimicrobial peptides, enzymes, lipids, metabolites, and immune-related proteins work together to support pathogen defence and other protective processes (Reverter et al., 2018). Increasing evidence also suggests that some components of fish mucus may contribute to tissue protection and wound healing (Kwan and Ismail, 2018; Yuliana et al., 2025). Thus, this outer epidermal secretion represents a diverse natural reservoir of bioactive molecules with potential value not only for maintaining fish health but also for biomedical and biotechnological applications.

Protective role of fish mucus

Physical barrier

The protective function of fish mucus results from the combined action of its physical properties, bioactive molecules, and associated microbial community. Mucins give the mucus layer its viscous, slippery nature, helping trap microorganisms and interfere with their attachment and colonisation on the skin. The continuous production and shedding of mucus can further help remove trapped organisms and unwanted materials from the epidermal surface. In addition to protecting against abrasion, the mucus layer can act as an interface between the fish and potentially harmful environmental substances, including toxic compounds and

heavy metals (Reverter et al., 2018). The viscoelastic properties of mucus can also help limit the movement of motile microorganisms across the skin surface (Reverter et al., 2018). Importantly, mucus is not a static barrier. Its production and biochemical composition can change in response to environmental and biological conditions such as stress and pathogen exposure. Changes in mucus secretion and composition during pathogen challenge suggest that the mucus layer can actively respond to threats rather than simply forming a permanent covering over the skin (Reverter et al., 2018). This dynamic nature allows the fish to maintain a responsive protective surface while continuously interacting with its aquatic environment.

Antimicrobial properties

One of the most important protective properties of fish mucus is its antimicrobial activity. The mucus contains a diverse group of molecules, including antimicrobial peptides (AMPs), lysozyme, lectins, complement proteins, immunoglobulins, enzymes, and other antimicrobial proteins (Dash et al., 2018; Reverter et al., 2018). AMPs are particularly important components of innate mucosal defence and include molecules such as piscidins, defensins, pardaxin, cathelicidins, and histone-derived peptides (Reverter et al., 2018). These molecules can act rapidly against invading microorganisms. Some AMPs interact with microbial membranes and disrupt their integrity, while others act through different mechanisms. Lysozyme provides another important form of antibacterial defence by breaking bonds within the peptidoglycan structure of bacterial cell walls, thereby weakening the bacterial envelope (Dash et al., 2018). Other immune-related proteins, including C-reactive proteins, also contribute to innate defence at the mucosal surface. Transferrin provides a different protective mechanism by binding iron and reducing its availability to microorganisms, thereby limiting the resources needed for their growth (Dash et al., 2018). Histone-derived molecules found in fish mucus have also been reported to show antibacterial, antifungal, and

antiparasitic activities, illustrating the broad spectrum of chemical defence associated with the mucus layer (Reverter et al., 2018). Together, these different components allow mucus to defend the fish through multiple complementary mechanisms rather than relying on a single antimicrobial compound.

Protection can also involve the microorganisms that naturally inhabit the mucus. The mucus surface supports diverse microbial communities, some of which may contribute to host defence by producing substances that inhibit potential pathogens. For example, Lowrey et al. (2015) reported that bacterial isolates associated with rainbow trout skin mucus inhibited the growth of aquatic fungal pathogens. More recently, Leonora and Caipang (2025) reviewed bacterial isolates from fish mucosal surfaces that showed probiotic characteristics or antagonistic activity against pathogens, suggesting that these resident microorganisms may represent an additional component of mucosal defence and a potential resource for aquaculture applications.

The protective role of mucus also involves broader mucosal immune responses. Immunoglobulins, complement proteins, lectins, and other immune-related molecules present in mucus participate in immune recognition and defence (Dash et al., 2018; Reverter et al., 2018). Some fish mucus AMPs have also been reported to influence B-cell functions, suggesting that these peptides may contribute to mucosal immune responses in addition to their direct antimicrobial activity (Reverter et al., 2018). Evidence from zebrafish further suggests that mucus can have immunomodulatory functions. Adult zebrafish mucus has been reported to influence immune responses induced by dextran sulfate sodium (DSS) in larvae and has been proposed to contribute to maternal immune protection (Wang et al., 2024).

Mucus contains diverse lipid components, including saturated, monounsaturated, and polyunsaturated fatty acids, which may contribute to protection against pathogenic invasion (Dash et al., 2018).

Recent evidence also demonstrates species-specific antimicrobial activity. For example, mucus from *Cilus gilberti* has shown activity against *Vibrio* strains, which are important pathogens in aquaculture, further highlighting the protective potential of fish mucus (Alvarez et al., 2026). Some mucus components have more specialised protective functions.

Wound healing properties

The protective properties of mucus become particularly important when the skin is damaged. A wound disrupts the normal barrier of the skin and exposes underlying tissues to the surrounding environment, creating a need for both protection and tissue repair. The mucus layer can help protect the injured surface while its bioactive components may also support processes involved in wound healing.

Experimental evidence supports the wound-healing potential of fish mucus. Deo et al. (2016) investigated the crude mucus extract of the marine catfish *Osteogobius militaris* using both in vivo and in vitro models. Treatment with mucus extract enhanced wound contraction compared with the control. After seven days of treatment, wounds receiving mucus extract also showed higher hydroxyproline levels, a marker associated with collagen synthesis. In addition, lysyl oxidase activity increased with increasing mucus concentration, suggesting an association with processes involved in collagen maturation and tissue repair. The mucus extract also showed angiogenic activity in the chick chorioallantoic membrane model, with marked neovascularisation observed at the highest dose tested. Together, these findings provide experimental evidence that fish mucus contains components capable of supporting several processes associated with wound healing, including wound contraction, collagen-related tissue repair, and angiogenic activity (Deo et al., 2016).

More recently, Yuliana et al. (2025) reported that mucus from snakehead fish (*Channa striata*) accelerated wound healing and exhibited antibacterial activity against *Staphylococcus aureus*. The 15% mucus

formulation produced the strongest effects and showed wound-healing activity comparable to the positive control. The combination of antibacterial and wound-healing effects is particularly noteworthy because successful repair of an injured surface requires both protection from microbial invasion and restoration of damaged tissue. These findings suggest that fish mucus may contain a combination of bioactive components that contribute to both defence and repair, although the specific molecules responsible for these effects and their mechanisms of action remain to be established.

Anti-inflammatory and Antiarthritic Properties

Recent studies suggest that fish mucus contains bioactive compounds capable of regulating inflammatory responses. By reducing excessive inflammation, these compounds may help protect tissues from further damage and support the healing process. The anti-inflammatory activity of fish mucus has generated interest in its possible application for managing inflammatory disorders, including arthritis. Although research in this area is still limited, preliminary findings indicate that mucus-derived compounds could serve as potential candidates for the development of natural anti-inflammatory products.

Antihypertensive Properties

Fish mucus has also attracted attention as a source of bioactive peptides with antihypertensive activity. Some peptides isolated from aquatic organisms have been shown to inhibit angiotensin-converting enzyme (ACE), an enzyme involved in blood pressure regulation. By interfering with ACE activity, these compounds may help maintain normal blood pressure levels. Although research on fish mucus-derived antihypertensive compounds remains at an early stage, the available evidence suggests promising possibilities for future therapeutic applications.

Haemolytic Properties

Certain components of fish mucus exhibit haemolytic activity, meaning they can disrupt red blood cell membranes. These

compounds are believed to play a defensive role by protecting fish against predators, parasites, and invading microorganisms. Although haemolytic activity may contribute to the natural defence mechanisms of fish, it also highlights the need for careful evaluation of mucus-derived compounds before they are developed for biomedical applications. Understanding both the beneficial and potentially harmful effects of these compounds is essential for their safe utilisation.

Other protective roles

Protective functions of mucus also involve other bioactive components beyond antimicrobial peptides and immune-related proteins. Reef fish mucus, for instance, contains mycosporine-like amino acids (MAAs), which can protect against solar radiation (Braun et al., 2016). Together, these findings demonstrate that the protective properties of fish mucus arise from a diverse mixture of bioactive molecules with different functions, ranging from direct antimicrobial activity to protection from environmental stressors.

Potential Applications of Fish Mucus-Derived Bioactives

The diverse biological properties of fish mucus have attracted considerable interest in aquaculture, biotechnology, and medicine. The antimicrobial compounds present in mucus may provide environmentally friendly alternatives for disease control in aquaculture. Similarly, mucus-derived bioactive molecules with wound-healing, anti-inflammatory, and antihypertensive properties could contribute to the development of novel therapeutic products.

Advances in proteomics and biochemical analysis have revealed numerous proteins and peptides in fish mucus associated with immune defence and tissue repair. However, further research is required to identify the active compounds, understand their mechanisms of action, assess their safety, and evaluate their commercial potential.

Prospective species for mucus collection

A few fishes, such as murels, catfishes, eels, toadfishes, pufferfish, etc produce a high amount of mucus. Fish mucus is generally

collected by gently scraping the body surface using sterile equipment under controlled conditions.



Fig. Collection of Mucus from fish

Conclusion

Fish epidermal mucus is far more than a physical coating on the skin. Its complex mixture of mucins, antimicrobial peptides, enzymes, immune-related proteins, lipids, and other bioactive molecules protects against pathogens and environmental challenges. The microorganisms associated with the mucus may further contribute to this defence and represent a potential source of beneficial probiotics for aquaculture. Emerging experimental evidence also points to wound-healing potential, although many of the molecules involved remain to be identified and their specific functions require validation. Together, these findings highlight fish mucus as a promising natural reservoir of protective and healing bioactives with potential value in aquaculture and biomedicine.

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