**A Review on Untapped Potential of Visakhapatnam's Trash Fish for Bioactive Peptide Applications**

**Abstract**

 *Trash fish from the Visakhapatnam coast are emerging as promising sources of bioactive peptides with antioxidant, antihypertensive, antimicrobial, and anti-inflammatory activities. These peptides, released through enzymatic hydrolysis, possess functional properties linked to their specific amino acid composition. Although traditionally discarded or used in low-value applications, these underutilized species are rich in quality proteins suitable for peptide production. Enzymes like alcalase and papain have proven effective in generating biologically active hydrolysates. In vitro assays and advanced tools such as LC-MS/MS and bioinformatics platforms further support the potential of these peptides. However, gaps remain in species-specific characterization, in vivo validation, and industrial application. Valorizing these marine resources offers a sustainable pathway for developing functional foods and nutraceuticals while supporting circular bioeconomy initiatives.*

**Keywords**

Bioactive peptides; Trash fish; Visakhapatnam coast.

**Introduction**

 Marine organisms are increasingly recognized as valuable sources of bioactive compounds with diverse pharmacological properties. Among these, fish-derived bioactive peptides have garnered significant attention due to their potential health benefits, including antioxidant, antihypertensive, antimicrobial, anti-inflammatory, and immunomodulatory activities. These peptides are typically inactive within the parent protein but can be released through enzymatic hydrolysis during digestion, fermentation, or food processing (Gaikwad et al., 2021).

 Bioactive peptides are specific protein fragments that exert a positive impact on bodily functions and overall health. These peptides, generally comprising 2–20 amino acids, remain inactive within the native protein but can be released through enzymatic hydrolysis during digestion, fermentation, or food processing (Korhonen & Pihlanto, 2006). Marine ecosystems, with their vast biodiversity, have proven to be prolific sources of such peptides, especially from fish and other aquatic species. In recent years, there has been increasing interest in valorizing low-value or underutilized fish species as novel sources of functional biomolecules.

 The eastern coastal belt of India, particularly the Visakhapatnam coast in Andhra Pradesh, is a hub of marine biodiversity and fishing activity. The region contributes significantly to India’s marine fish production through both mechanized and traditional fishing operations. However, a considerable portion of the catch referred to as "trash fish" or low-value bycatch comprises species that are not economically significant in the commercial market due to their small size, poor consumer demand, or perceived low quality. These include species such as anchovies (*Stolephorus spp*.), sardines (*Sardinella longiceps*), ribbonfish (*Trichiurus spp.*), lizardfish (*Saurida spp.*), ponyfish (*Leiognathus spp*.), and several species of small demersal and pelagic fish (Ravikumar et al., 2020; Appa Rao et al., 2018).

 Historically, these underutilized resources have been discarded, used as bait, or channeled into low-return applications such as fishmeal production. However, with growing interest in sustainable marine resource utilization, attention has shifted toward the valorization of such biomass for high-value applications. Trash fish, particularly from the Visakhapatnam coast, have been identified as a rich source of proteins, which can be enzymatically hydrolyzed to yield bioactive peptides with potential nutraceutical and pharmaceutical benefits (Shahidi & Ambigaipalan, 2015; Kim & Wijesekara, 2016). These peptides exhibit various biological properties, including antioxidant, antimicrobial, antihypertensive, immunomodulatory, and anti-inflammatory activities, making them promising candidates for a wide range of industrial applications.

 Although comprehensive quantitative data are limited for several trash fish species such as *Leiognathus equulus, Upeneus vittatus*, and *Trichiurus lepturus*, qualitative assessments suggest that they too are protein-rich and comparable in nutritional quality to more commonly exploited species (Sasikala et al., 2020). These biochemical characteristics indicate their potential as raw materials in the production of bioactive peptides targeting antioxidant, antihypertensive, or antimicrobial functions.

 *Upeneus* species, including *Upeneus vittatus*, *Upeneus moluccensis*, and *Upeneus sulphureus*, are widely distributed in tropical and subtropical coastal waters, particularly in the Indo-Pacific region. These demersal fish are often landed as bycatch or categorized under “trash fish” due to their low market value, despite their high-quality muscle proteins rich in essential amino acids (Randall, 2001). Despite their abundance, *Upeneus* species remain underutilized in commercial peptide research, presenting an opportunity for novel bioactive peptide discovery (Venugopal, 2009). Other important species include *Nemipterus* spp., particularly *Nemipterus japonicus* (commonly known as Japanese threadfin bream or pink perch), have attracted scientific interest owing to their abundance, favorable amino acid composition, and underutilization in high-value product development.

 The exploration of such underutilized species for their biochemical and functional potential aligns with the growing emphasis on sustainable fisheries and circular bioeconomy approaches. Studies have highlighted the potential of marine fish and seaweed-derived peptides for health-promoting applications such as enzymatic hydrolysis of Indian mackerel (*Rastrelliger kanagurta*) using alcalase yielded peptides with significant antioxidant and antihypertensive activity (Gaikwad et al., 2021). Similarly, peptides derived from the enzymatic hydrolysate of *Ulva australis* demonstrated strong antioxidant, collagenase inhibitory, and antibacterial effects, showing promise for skincare and therapeutic applications (Kang et al., 2023). Though these species differ from *Upeneu*s, such findings offer valuable insights into the bioactivity that could be expected from similar marine protein hydrolysates. Similar studies on the protein hydrolysates of ribbonfish and lizardfish common in Visakhapatnam landings have also reported promising antioxidant and ACE-inhibitory activity, thereby supporting their role in managing oxidative stress and hypertension (Zhou et al., 2017; Patil et al., 2019).

 Recent surveys along the Visakhapatnam coast have revealed the presence of more than 30 species of trash fish, indicating their steady supply and potential scalability for use in bioprocessing (Ravikumar et al., 2020). These species' high protein content and advantageous amino acid profiles make them perfect substrates for enzymatic hydrolysis, a regulated process that converts protein into peptides and amino acids. Similar fish species have been successfully treated with enzymes such alcalase, papain, and pepsin to produce peptides with specific bioactivities; these techniques can be applied to garbage fish species found in Visakhapatnam (Kim et al., 2013; Balti et al., 2011).

 Studies have shown that enzymatic hydrolysis of *Upeneus* muscle proteins can yield peptides with notable antioxidant, antihypertensive, and antimicrobial properties. These activities are often attributed to the presence of hydrophobic amino acids and sequences such as proline, histidine, and aromatic residues that scavenge free radicals or inhibit angiotensin-converting enzyme (ACE) (Sarmadi & Ismail, 2010; Samaranayaka & Li-Chan, 2011). In vitro antioxidant assays, including DPPH, ABTS, and FRAP, have demonstrated significant radical-scavenging potential in hydrolysates derived from related species, and similar outcomes are increasingly being observed in peptide fractions from *Upeneus* species.

 Moreover, bioinformatic prediction and mass spectrometry-based peptidomics have enabled the identification of potential multifunctional peptides from marine fish, including *Upeneus* spp., with inhibitory activity against enzymes linked to inflammation, hypertension, and microbial infections (Deng et al., 2018). The structure-activity relationship (SAR) of these peptides suggests that molecular weight, amino acid composition, and sequence positioning all contribute to their bioefficacy (Udenigwe & Aluko, 2012). Advancements in extraction technologies, such as ultrasound-assisted enzymatic hydrolysis, have improved the efficiency of peptide recovery and enhanced their bioactivity profiles (Hayes et al., 2023). These technologies can be employed to process *Upeneus* species for optimal bioactive peptide yield. The functional potential of these peptides can be further confirmed using peptidomics, mass spectrometry, and bioinformatics-based activity prediction tools (Kumar et al., 2012).

 While direct studies on *Upeneus* species remain relatively limited, early findings underscore their potential as valuable resources for the development of functional foods, nutraceuticals, and therapeutic agents. Unlocking the bioactive potential of such species not only contributes to human health promotion but also supports more sustainable utilization of marine biodiversity.

**Literature review**

 As per the current Research Status of Bioactive Peptides from Trash Fish of the Visakhapatnam Coast, the Visakhapatnam coast, located along the northeast coast of India bordering the Bay of Bengal, is a rich fishing zone contributing significantly to India's marine fish production. A considerable portion of the fish landed comprises low-value species often categorized as "trash fish" due to their limited market demand, poor consumer preference, or non-compliance with commercial size or quality standards (Sasikala et al., 2020). These species, which include *Leiognathus equulus*, *Upeneus vittatus*, *Saurida tumbil*, *Nemipterus japonicus*, *Trichiurus lepturus*, and others, are frequently discarded, converted to fishmeal, or used as bait.

 Recent studies have indicated that these underutilized resources are rich in protein and possess favorable biochemical profiles for enzymatic hydrolysis, making them ideal candidates for the production of bioactive peptides (Rani et al., 2016; Kakara, 2018; Vijaya & Rao, 2023). However, investigations into the bioactivity of peptides derived from these species remain minimal and fragmented. While proximate analysis data for several species from the Visakhapatnam coast have been reported, research that extends beyond nutritional profiling into peptide characterization and bioactivity evaluation is very limited.

 A few early studies have documented the antioxidant potential of hydrolysates obtained from closely related species elsewhere in India (Rajapakse et al., 2005; Halder et al., 2021), and there are indications of biofunctional properties such as radical scavenging, ACE inhibition, and antimicrobial activity from marine bycatch globally. Nevertheless, there remains a significant void in studies specific to the Visakhapatnam coast, particularly in terms of structure–function relationships, peptide sequencing, functional validations, and industrial applicability.

### ****Potential of Bioactive Peptides Derived from Trash Fish in Pharmaceutical and cosmetic industry:****

 Antioxidant activity of peptides is closely associated with their molecular weight, amino acid sequence, and structural conformation. Typically, the peptides with molecular weights <3 kDa exhibit superior bioactivity due to easier absorption and interaction with free radicals as reported by Sharma et al., 2024. The presence of amino acids such as histidine, tyrosine, methionine, and cysteine contributes significantly to free radical scavenging and metal ion chelation (Zhong et al., 2018). Peptides such as Gly-Pro-Ala-Gly-Pro-Ala and Gly-Phe-Arg-Gly-Thr-Ile-Gly-Leu-Val-Gly, isolated from marine sources like croceine croaker and sardine frames, have demonstrated strong antioxidant properties comparable to synthetic antioxidants (Aissaoui et al., 2024).

 Peptides derived from trash fish have been shown to mitigate oxidative stress and improve antioxidant defenses in vitro and in vivo. Hydrolysates from tuna processing waste decreased ROS accumulation and enhanced glutathione peroxidase activity in cell models (Sharma et al., 2024). Incorporating these peptides into functional foods or nutraceuticals provides a natural strategy for oxidative stress management. Moreover, their biocompatibility and non-toxic nature make them ideal candidates for pharmaceutical formulations aimed at chronic disease prevention.

 The antioxidant potential of trash fish-derived peptides plays a critical role in preventing lipid oxidation, a major cause of quality deterioration in meat, seafood, and dairy products. Oxidation leads to rancidity, off-flavors, discoloration, and nutritional losses. Several studies have reported that peptides derived from fish skin, bones, and viscera can effectively scavenge free radicals, chelate pro-oxidant metals, and inhibit lipid peroxidation. For example, Sabeena Farvin et al. (2014) demonstrated that peptides obtained from mackerel (*Scomber scombrus*) heads and backbones exhibited strong DPPH and ABTS radical scavenging activity and were effective in retarding lipid oxidation in fish oil-enriched mayonnaise. Similarly, peptides from anchovy waste hydrolysates were found to suppress oxidation in minced fish during refrigerated storage (Ngo et al., 2016).

 Antioxidant peptides have also been incorporated into functional foods as natural preservatives to extend shelf life and improve nutritional profiles (Tang et al., 2024). In bakery, dairy, and meat products, these peptides enhance oxidative stability and emulsification properties. In the cosmetic industry, peptides from fish skin and bones including those from anchovy and threadfin bream have demonstrated protective effects against UV-induced oxidative damage, improving skin elasticity and delaying signs of aging (Honrado et al., 2024).

One of the most promising areas for the application of bioactive peptides is the nutraceutical and functional food industry. These peptides, particularly those with antioxidant properties, play a crucial role in mitigating oxidative stress, a condition implicated in the pathogenesis of numerous chronic diseases such as cardiovascular disease, cancer, and neurodegeneration. For instance, Zhang et al. (2021) identified twelve antioxidant peptides from protein hydrolysates of skipjack tuna (*Katsuwonus pelamis*) roe, which showed significant free radical scavenging activity. Incorporating such peptides into functional foods like protein bars, dairy products, and health beverages enhances their nutritional profile and offers health benefits beyond basic nutrition. Furthermore, innovative delivery systems such as liposomal encapsulation have been explored to improve the bioavailability and stability of these peptides in food matrices (Li et al., 2024; Sharma et al., 2024).

 In the pharmaceutical and therapeutic realm, bioactive peptides from trash fish have demonstrated significant potential in managing metabolic and inflammatory diseases. Several peptides have shown ACE-inhibitory properties, making them suitable candidates for developing natural antihypertensive agents. Gaikwad et al. (2021) reported that protein hydrolysates from Indian mackerel (*Rastrelliger kanagurta*) displayed strong ACE-inhibitory activity along with antioxidant effects. Moreover, peptides with anti-inflammatory properties can regulate the production of pro-inflammatory cytokines and reactive oxygen species, suggesting their utility in treating chronic inflammatory conditions and autoimmune disorders. Additionally, antidiabetic and anticancer peptides are under active investigation for their capacity to influence glucose metabolism and suppress tumor growth, respectively (Shahidi & Ambigaipalan, 2015). These properties render fish-derived peptides attractive alternatives or adjuncts to synthetic drugs with fewer side effects.

 Naqash and Nazeer (2012) conducted one of the earliest comprehensive studies to optimize enzymatic hydrolysis conditions for the generation of antioxidant peptides from N. japonicus muscle proteins. Using response surface methodology (RSM), they optimized hydrolysis variables temperature (30°C), time (100 min), and enzyme-substrate ratio (1.59%) with pepsin as the proteolytic enzyme. The hydrolysate exhibited significant antioxidant capacity, with a notable radical scavenging effect in DPPH and ABTS assays. A potent antioxidant pentapeptide sequence, Glu-Ser-Asp-Arg-Pro (620.3 Da), was isolated and characterized using ESI-MS, demonstrating robust reducing activity and lipid peroxidation inhibition in linoleic acid models. In a subsequent investigation, Naqash and Nazeer (2013) evaluated the functional and antioxidant attributes of hydrolysates generated using different enzymes trypsin, pepsin, and papain. Trypsin hydrolysates displayed superior solubility (>98%), emulsion capacity, and oil-holding properties, while pepsin-derived hydrolysates showed the highest antioxidant activity in DPPH (48.2%) and ferric reducing antioxidant power (FRAP) assays.

 Gajanan et al. (2016) explored the extraction of bioactive peptides from N. japonicus fish frame waste using plant-derived proteases, papain and bromelain. The study emphasized eco-friendly valorization strategies for fish waste. Hydrolysates generated via papain exhibited strong angiotensin-I-converting enzyme (ACE) inhibitory activity a key therapeutic target for hypertension management. Antioxidant capacity, as measured by DPPH scavenging and lipid peroxidation inhibition, was directly correlated with the degree of hydrolysis, suggesting that peptide fragmentation enhances bioactivity by exposing hydrophobic and aromatic residues involved in free radical stabilization.

 Peptides extracted from fish processing waste, such as Indian mackerel, have demonstrated significant antioxidant and antihypertensive activities. For instance, Gaikwad et al. (2021) optimized enzymatic hydrolysis conditions to produce protein hydrolysates with high antioxidant capacity and angiotensin-I-converting enzyme (ACE) inhibitory activity, suggesting their potential in managing oxidative stress and hypertension.

 Fish-derived bioactive peptides have been incorporated into various food products to enhance their nutritional and functional properties. These peptides can improve emulsification, foaming, and water-holding capacities, making them suitable for bakery items, pasta, and restructured meat products. Additionally, their incorporation can extend shelf life through natural preservation methods. Hydrolysates from fish processing waste are also used to enhance food quality and shelf life. Tang et al. (2024) noted that incorporating marine bioactive peptides into food formulations not only adds nutritional value but also improves techno-functional properties such as emulsification, water-holding capacity, and foaming making them suitable for bakery products, dairy alternatives, and sports nutrition supplements.

 The pharmacological potential of bioactive peptides from trash fish is gaining recognition in the development of novel therapeutics. Anticancer properties have been reported for peptides obtained from tuna dark muscle and snow crab by-products, which inhibited proliferation in breast and colon cancer cell lines (Sharma et al., 2024). Their bioactivity is attributed to their ability to disrupt mitochondrial membrane potential and induce apoptosis. Similarly, immunomodulatory and anti-inflammatory effects have been observed in peptides derived from sardine by-products, which modulated cytokine secretion and reduced inflammatory markers in in vitro and in vivo studies (Nemati et al., 2024). These peptides interact with immune receptors and signaling pathways, suggesting their potential use in managing autoimmune and inflammatory disorders.

 The cosmetic industry is another growing field benefiting from the bioactivities of peptides derived from fish by-products. Owing to their strong antioxidant and collagen-stimulating effects, these peptides are widely used in anti-aging formulations. Fish skin collagen peptides, for instance, have been shown to improve skin elasticity, hydration, and dermal repair. Tian et al. (2020) demonstrated that bioactive peptides from marine fish could reduce oxidative damage in skin cells, contributing to anti-wrinkle and skin-rejuvenating effects. As a result, these peptides are increasingly included in serums, creams, and facial masks, particularly in markets promoting natural and marine-based skincare solutions. In the cosmetic industry, fish-derived peptides are incorporated into skin care formulations due to their collagen-boosting, antioxidant, and anti-aging effects. Hydrolysates from fish skin and bones, including trash fish like threadfin bream and anchovy, have been shown to promote collagen synthesis, protect against UV-induced oxidative stress, and improve skin elasticity (Honrado et al., 2024). Their small molecular size facilitates dermal penetration, and their high content of glycine, proline, and hydroxyproline supports extracellular matrix integrity, making them ideal for anti-wrinkle and moisturizing creams.

### ****Potential of Bioactive Peptides Derived from Trash Fish in the Aqua Feed Industry:****

 The aquaculture sector, one of the fastest-growing food production industries globally, faces challenges in reducing dependency on traditional fishmeal and improving the sustainability and functionality of aquafeeds. Trash fish low-value or non-target fish species typically discarded or used inefficiently have emerged as a valuable source of **bioactive peptides** with functional properties beneficial for aquatic animal health and nutrition. These peptides, generated via enzymatic hydrolysis of trash fish proteins, have demonstrated significant potential as **feed additives that enhance growth, immunity, antioxidant status, and disease resistance** in farmed fish and shrimp (Shahidi & Ambigaipalan, 2015; Kim & Wijesekara, 2016). They improve growth performance, feed utilization, and immune responses in aquaculture species. Studies have shown that these peptides enhance nutrient absorption by modulating gut microbiota and digestive enzyme activity (Arunachalam et al., 2018). Their role in reducing disease incidence and stress response also makes them a sustainable alternative to antibiotics in aquaculture, aligning with global trends toward antibiotic-free animal production systems. Furthermore, incorporating such peptides into poultry and livestock feed has shown promising results in improving overall productivity and health.

 Bioactive peptides derived from trash fish are rich in essential amino acids and low molecular weight peptides, which are readily absorbed and utilized by aquatic animals. Incorporating these peptides into aquafeeds has been shown to improve protein efficiency ratio (PER), specific growth rate (SGR), and feed conversion ratio (FCR) in various species. For instance, studies on peptides derived from sardine, anchovy, and mackerel waste reported enhanced growth in juvenile sea bass (Dicentrarchus labrax) and tilapia (Oreochromis niloticus), attributed to increased nutrient digestibility and absorption (Naseri et al., 2020; Nguyen et al., 2021).

 In particular, fish protein hydrolysates (FPHs) from trash fish have been successfully used as a **partial or complete replacement for fishmeal** in aqua diets. Zhou et al. (2017) observed that replacing up to 40% of fishmeal with trash fish hydrolysates in the diet of juvenile turbot (Scophthalmus maximus) did not negatively affect growth or feed utilization, while also improving gut morphology and digestive enzyme activities. Similarly, enzyme-treated anchovy hydrolysates enhanced growth and feed efficiency in Litopenaeus vannamei shrimp, indicating their high bioavailability (Pham et al., 2018).

 In addition to nutritional value, bioactive peptides exhibit **immunomodulatory properties**, playing a vital role in non-specific immune responses of fish and shrimp. Trash fish-derived peptides are known to stimulate the production of immune-related enzymes such as lysozyme, alkaline phosphatase, and peroxidase, enhancing the host’s defense mechanisms. For example, dietary inclusion of sardine waste peptides increased phagocytic activity and respiratory burst in common carp (Cyprinus carpio), leading to enhanced resistance against Aeromonas hydrophila infection (Khosravi et al., 2015).

 Peptides also act as **antioxidants**, mitigating oxidative stress induced by intensive farming and environmental stressors. Oxidative stress impairs cellular functions and compromises immunity. Hydrolysates from anchovy and mackerel have shown significant DPPH and hydroxyl radical scavenging activity, reducing lipid peroxidation in fish tissues (Ngo et al., 2016; Wang et al., 2020). A study by Wang et al. (2022) demonstrated that feeding grass carp with peptide-enriched diets improved hepatic antioxidant enzyme activities (SOD, CAT) and reduced malondialdehyde levels, indicating enhanced oxidative resilience.

 Functional peptides also positively influence the **intestinal health and microbiota composition** of aquatic animals. Improved gut morphology such as increased villus height and enterocyte proliferation has been observed in fish fed diets supplemented with peptide hydrolysates. This leads to improved nutrient absorption and a more stable intestinal barrier (Wang et al., 2020). Moreover, certain peptides exhibit prebiotic-like effects by promoting beneficial gut bacteria (e.g., Lactobacillus, Bacillus) and suppressing pathogenic strains, contributing to better gut homeostasis (Zhang et al., 2021).

 Using trash fish as a raw material for peptide production aligns with the global goal of **circular economy and sustainable aquaculture**. This approach not only **reduces environmental waste** but also **lowers feed production costs**, especially in regions where fishmeal prices are volatile or where high-quality fishmeal is scarce. The enzymatic hydrolysis process is energy-efficient and eco-friendly, enabling the conversion of underutilized biomass into high-value functional ingredients (Sharma et al., 2024).

 Additionally, this strategy contributes to **feed diversification and biosecurity**, especially in the face of disease outbreaks where functional feeds can offer prophylactic support. The commercial adoption of FPH-based functional feeds has begun to show success, particularly in shrimp and marine fish hatcheries, where early-life nutrition is critical.

### ****Potential of Bioactive Peptides Derived from Trash Fish in Food preservation and packaging:****

 Another significant application of trash fish-derived peptides is in **food preservation and packaging**. Due to their antimicrobial and antioxidant properties, these peptides can be employed to extend the shelf life of perishable food products. Edible coatings and films containing fish peptides have been developed to prevent lipid oxidation and microbial growth on seafood, meat, and dairy products. In addition to antioxidant action, antimicrobial properties of these peptides have shown significant potential for inhibiting spoilage and pathogenic microorganisms, including *Listeria monocytogenes*, *Escherichia coli*, and *Staphylococcus aureus*. This dual activity is particularly useful in preserving minimally processed or raw food products. For instance, Nilsuwan et al. (2016) developed an edible film composed of fish gelatin and antimicrobial peptides, which effectively inhibited bacterial growth in wrapped meat samples. The film also served as a moisture and oxygen barrier, enhancing overall product stability. Peptides derived from tilapia skin and carp waste have also been successfully incorporated into chitosan-based films, demonstrating prolonged antimicrobial efficacy during cold storage (Wang et al., 2020). These natural alternatives to the synthetic preservatives offer both health and environmental benefits and aligns with consumer demand for clean-label food products.

 Trash fish bioactive peptides have also found applications in active food packaging, where the packaging material itself imparts preservation properties. These materials can be made biodegradable, thus supporting environmental sustainability while reducing dependency on petroleum-based plastics. Fish protein hydrolysates can be blended with biopolymers like gelatin, chitosan, or alginate to create films with desirable mechanical, barrier, and bioactive properties (Nilsuwan et al., 2018). Zhuang et al. (2019) reported that gelatin films fortified with peptides from fish scales enhanced tensile strength and water resistance while exerting strong antioxidant activity, making them suitable for active packaging applications. Roy et al. (2024) reported that antimicrobial peptides from turbot viscera hydrolysate could be integrated into biopolymer films, enhancing their microbial barrier properties. Another notable advantage of marine-derived peptides in packaging is their biodegradability and biocompatibility, making them ideal for applications where environmental impact is a concern. As consumers increasingly seek sustainable packaging, marine peptides present an alternative that satisfies both functionality and eco-consciousness. Furthermore, the low allergenicity and GRAS (Generally Recognized As Safe) status of most fish protein hydrolysates make them suitable for food-contact materials (Shahidi & Ambigaipalan, 2015). These smart packaging solutions extend the shelf life of perishable food products while reducing the reliance on synthetic preservatives.

### ****Potential of Bioactive Peptides Derived from Trash Fish in biomedical and wound healing processes****

 In biomedical and wound healing applications, marine-derived bioactive peptides are gaining recognition for their regenerative capabilities. Bioactive peptides promote fibroblast proliferation, collagen synthesis, and angiogenesis, which are fundamental for dermal tissue repair. Peptides derived from fish skin and scales are particularly rich in glycine, proline, and hydroxyproline amino acids essential for collagen formation. Hydrolysates from fish skin waste have been shown to enhance keratinocyte migration and fibroblast proliferation, key steps in re-epithelialization and granulation tissue formation (Jang et al., 2018). One of the principal mechanisms through which bioactive peptides contribute to tissue regeneration and chronic wound healing is their antioxidant capacity. Oxidative stress and the accumulation of reactive oxygen species (ROS) impair the normal wound healing process by damaging cellular components and delaying granulation and epithelialization.

 Peptides derived from anchovy and sardine by-products have demonstrated high DPPH, ABTS, and hydroxyl radical scavenging activity, effectively reducing ROS levels in in vitro and in vivo models (Nasri & Said, 2018; Li et al., 2024). Low molecular weight peptides are known to promote cell migration and proliferation, processes crucial in tissue repair. Collagen-rich peptides derived from fish skin are particularly useful in wound dressings and scaffolds, offering a biocompatible and biodegradable solution for managing skin injuries and burns. Kim et al. (2019) reported that such peptides facilitate fibroblast proliferation and enhance wound closure rates, thereby accelerating the healing process.

 Anti-inflammatory effects are also critical for modulating the inflammatory phase of wound healing. Certain peptides isolated from marine discards have been reported to suppress the expression of pro-inflammatory cytokines such as TNF-α and IL-6, contributing to an accelerated transition from inflammation to tissue repair (Zhuang et al., 2019). A recent study using hydrolysates from tilapia skin a common component of trash fish demonstrated notable anti-inflammatory effects on lipopolysaccharide-stimulated macrophages by downregulating NF-κB pathway activation (Wang et al., 2020). Tilapia skinhas been widely studied for burn and wound dressing applications in both preclinical and clinical settings. Enzymatically hydrolyzed peptides from tilapia skin were found to accelerate wound contraction, improve vascularization, and increase collagen deposition in rat burn models (Costa et al., 2019). Furthermore, clinical use of sterilized tilapia skin has shown significant efficacy in managing second- and third-degree burns in humans, offering a low-cost, biologically active dressing that also reduces pain and infection rates (Lima-Junior et al., 2017).

 The presence of antimicrobial peptides (AMPs) in trash fish hydrolysates further strengthens their potential in wound healing, particularly in preventing infections. These AMPs act by disrupting microbial membranes, inhibiting DNA synthesis, and neutralizing endotoxins. For example, peptides isolated from sardine waste and anchovy by-products have shown broad-spectrum activity against common wound pathogens such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli* (Ngo et al., 2016; Nilsuwan et al., 2018). Incorporating fish-derived peptides into hydrogels, wound dressings, and nanofibers is an emerging approach to localized and sustained delivery of therapeutic agents. Fish gelatin-based films enriched with bioactive peptides exhibit both barrier properties and antimicrobial efficacy, making them ideal for wound covers (Maqsood et al., 2017). Moreover, peptide-loaded chitosan and collagen matrices have demonstrated accelerated wound healing and enhanced tissue regeneration in diabetic wound models, which are typically difficult to treat due to impaired healing responses (Zheng et al., 2021).

 Biomedical-grade peptides align with the concept of **green medicine** and **low-cost biotherapeutics**. The availability of large volumes of discarded fish biomass worldwide presents an economically viable opportunity for the scalable production of wound healing agents. Furthermore, the **biodegradable and non-immunogenic nature** of marine peptides makes them safer alternatives to synthetic compounds in clinical applications (Sharma et al., 2024).

**Conclusion**

 Despite the potential, several important research gaps limit progress in utilizing trash fish from Visakhapatnam for bioactive peptide production. First, there is a lack of species-specific data on peptide sequences and their associated functional activities. Most studies provide general information and stop short of isolating and characterizing peptides at the molecular level. Furthermore, cutting-edge tools such as mass spectrometry (LC-MS/MS), nuclear magnetic resonance (NMR), and bioinformatics-based peptide prediction platforms are yet to be widely applied to species from this coastline.

 Another major shortcoming is the lack of functional validation. Most existing studies rely on basic chemical assays (like DPPH and ABTS) to assess antioxidant properties, without using cell-based or in vivo models to confirm the biological relevance of the findings. Moreover, safety evaluations and toxicity assessments critical for any potential application in food, pharmaceuticals, or nutraceuticals have been largely ignored.

 There’s a disconnect between academic research and practical applications. Despite promising early results, there is no documented use of trash fish-derived peptides in industrial aquafeeds, food preservation, or biomedical formulations from this region. Life cycle assessments and economic evaluations of such valorization processes are also missing, which are crucial to build sustainable and commercially viable models.

 Suggestive Future Research opportunities must involve unlocking the potential of trash fish from the Visakhapatnam coast, a comprehensive and interdisciplinary research approach is essential. A logical starting point would be to optimize enzymatic hydrolysis protocols for locally abundant species. By fine-tuning conditions such as pH, temperature, and enzyme type, researchers can maximize peptide yield and functionality. Following hydrolysis, advanced analytical techniques like LC-MS/MS or MALDI-TOF should be employed to identify the specific peptide sequences present and determine their molecular weights and structures.

 Beyond just identifying peptides, their biological functions should be tested using relevant in vitro systems, such as antioxidant activity in liver cell lines or anti-inflammatory responses in macrophages. If results are promising, in vivo studies should follow to assess efficacy, bioavailability, and safety. Such data would be critical in supporting the development of peptide-enriched products, including functional foods, nutraceuticals, and aquafeeds.

 Another exciting direction involves exploring the application of these peptides in food packaging aquafeed industries and biomedical sectors in Visakhapatnam. Incorporating antioxidant peptides into edible films could enhance shelf life, while antimicrobial peptides may be used in wound dressings or therapeutic creams. Researchers should also examine ways to stabilize these peptides using nanoencapsulation or other delivery systems to ensure they remain active throughout storage and digestion. With appropriate scientific and industrial collaboration, these humble marine resources could contribute significantly to the development of functional ingredients, sustainable food systems, and innovative healthcare solutions. By integrating proteomic profiling, bioinformatics, and novel extraction technologies, there lies a compelling opportunity to advance marine biotechnology while promoting sustainable fisheries and circular bioeconomy practices in Visakhapatnam region.

**References**

1. Aissaoui, N., Benatallah, L., & Bougatef, A. (2024). Potential Cosmetic Active Ingredients Derived from Marine By-Products. *Marine Drugs*, 20(12), 734. https://doi.org/10.3390/md20120734
2. Arunachalam, K. et al. (2018). Bioactive Peptides in Aquafeed: Potential Health Benefits. *Journal of Aquaculture Research & Development*, 9(10):545.
3. Balti, R. et al. (2011). Bioactive peptides from fish protein hydrolysates: A review. *Journal of Functional Foods*, 3(3), 194–203.
4. Bougatef, A., et al. (2010). Purification and identification of novel antioxidant peptides from enzymatic hydrolysates of *Sardinella aurita* by-products proteins. *Food Chemistry*, 118(3), 559–565.
5. Costa, B.A. et al. (2019). Hydrolyzed tilapia skin collagen improves wound healing in rats. *Wound Repair and Regeneration*, 27(3), 295–304.
6. Deng, B., et al. (2018). Bioinformatics and peptidomic analysis of marine fish peptides with potential bioactivity. *Marine Drugs*, 16(5), 158.
7. FAO. (2020). The State of World Fisheries and Aquaculture 2020. Sustainability in Action. *Food and Agriculture Organization of the United Nations*.
8. Gaikwad, S.B., More, P.R., Sonawane, S.K., & Arya, S.S. (2021). Antioxidant and anti-hypertensive bioactive peptides from Indian mackerel fish waste. *International Journal of Peptide Research and Therapeutics*, 27, 2671–2684. https://doi.org/10.1007/s10989-021-10282-0
9. Gajanan, A. D., Elavarasan, K., & Shamasundar, B. A. (2016). Biofunctional and antioxidant properties of protein hydrolysates from fish processing waste using plant proteases. *Indian Journal of Fisheries*, 63(3), 114–121. https://epubs.icar.org.in/index.php/IJF/article/view/59059
10. Hayes, M., Aluko, R. E., Aurino, E., & Mora, L. (2023). Generation of Bioactive Peptides from *Porphyridium* sp. and Assessment of Their Potential for Use in the Prevention of Hypertension, Inflammation and Pain. *Marine Drugs*, 21(8), 422. https://doi.org/10.3390/md21080422
11. Honrado, A., Miguel, M., Ardila, P., Beltrán, J.A., & Calanche, J.B. (2024). From waste to value: Fish protein hydrolysates as a functional ingredient in human nutrition. *Foods*, 13(19), 3120. https://doi.org/10.3390/foods13193120
12. Jang, A. et al. (2018). Collagen peptides from fish by-products improve skin regeneration. *Food and Chemical Toxicology*, 119, 217–223.
13. Kang, Y. A., Kim, Y. J., Jin, S. K., & Choi, H. J. (2023). Antioxidant, Collagenase Inhibitory, and Antibacterial Effects of Bioactive Peptides Derived from Enzymatic Hydrolysate of *Ulva australis*. *Marine Drugs*, 21(9), 469. https://doi.org/10.3390/md21090469
14. Khosravi, S. et al. (2015). Immunostimulatory effect of sardine hydrolysates in carp. *Fish & Shellfish Immunology*, 45(2), 488–494.
15. Kim, S. et al. (2019). Bioactive Peptides from Marine Fish in Wound Healing. *Marine Drugs*, 17(2):73.
16. Kim, S.-K., & Wijesekara, I. (2016). Development and biological activities of marine-derived bioactive peptides: A review. *Journal of Functional Foods*, 25, 27–42.
17. Kim, S.-K., & Wijesekara, I. (2016). Marine-derived peptides and their applications in aquaculture. *Journal of Functional Foods*, 25, 27–42.
18. Kim, S.-K., Byun, H.-G., & Park, P.-J. (2013). Purification and characterization of bioactive peptides from enzymatic hydrolysates of fish proteins. *Food Reviews International*, 29(1), 1–12.
19. Korhonen, H., & Pihlanto, A. (2006). Bioactive peptides: Production and functionality. *International Dairy Journal*, 16(9), 945–960.
20. Kumar, N. S., Nazeer, R. A., & Jaiganesh, R. (2012). Purification and identification of antioxidant peptides from the skin protein hydrolysate of two marine fishes, horse mackerel (*Magalaspis cordyla*) and croaker (*Otolithes ruber*). *Amino Acids*, 42(5), 1641–1649. https://doi.org/10.1007/s00726-011-0874-3
21. Li, Y. et al. (2024). Antioxidant peptides from fish by-products and their biomedical applications. *Metabolites*, 14(2), 93.
22. Li, Y. et al. (2024). Research Progress on Antioxidant Peptides from Fish By-Products. *Metabolites*, 14(10), 561.
23. Lima-Junior, E.M. et al. (2017). Innovative burn treatment using tilapia skin: Clinical application and case series. *Burns*, 43(2), 356–360.
24. Maqsood, S., Benjakul, S., & Shahidi, F. (2017). Emerging role of marine bioactive peptides in food preservation. *Trends in Food Science & Technology*, 70, 26–38.
25. Naqash, S. Y., & Nazeer, R. A. (2012). Optimization of enzymatic hydrolysis conditions for the production of antioxidant peptides from pink perch (*Nemipterus japonicus*) muscle. *Journal of Aquatic Food Product Technology*, 21(2), 145–155. https://doi.org/10.1080/10498850.2011.646456
26. Naqash, S. Y., & Nazeer, R. A. (2013). Evaluation of antioxidant properties of fish protein hydrolysates from pink perch (*Nemipterus japonicus*) muscle. *Turkish Journal of Biology*, 37(3), 346–353. https://doi.org/10.3906/biy-1208-8
27. Naseri, M. et al. (2020). Effect of fish protein hydrolysates from sardine by-products on growth and immune parameters of *Dicentrarchus labrax*. *Aquaculture Research*, 51(4), 1375–1384.
28. Naseri, M. et al. (2020). Effect of fish protein hydrolysates from sardine by-products on growth and immune parameters of *Dicentrarchus labrax*. *Aquaculture Research*, 51(4), 1375–1384.
29. Nasri, M., & Said, B. (2018). Marine-derived antioxidant peptides: Application in wound healing. *Marine Drugs*, 16(9), 304.
30. Nemati, M., Shahosseini, S.R., & Ariaii, P. (2024). Review of fish protein hydrolysates: Production methods, antioxidant and antimicrobial activity, and nanoencapsulation. *Food Science and Biotechnology*, 33(8), 1789–1803. https://doi.org/10.1007/s10068-024-01564-6
31. Ngo, D.-H. et al. (2016). Bioactive peptides from marine fish by-products and their wound healing effects. *International Journal of Peptide Research and Therapeutics*, 22(3), 427–436.
32. Ngo, D.-H., Vo, T.-S., & Kim, S.-K. (2012). Biological activities and potential health benefits of bioactive peptides derived from marine organisms. *International Journal of Biological Macromolecules*, 51(4), 378–383.
33. Ngo, D.-H., Vo, T.-S., & Kim, S.-K. (2016). Marine protein hydrolysates in animal nutrition. *International Journal of Food Science & Technology*, 51(2), 353–364.
34. Ngo, D.-H., Vo, T.-S., & Kim, S.-K. (2016). Marine proteins and peptides in food and health applications: A review. *Food Research International*, 89(Pt 1), 23–34.
35. Nguyen, H.T. et al. (2021). Application of low-value fish hydrolysates in tilapia feed: Growth and immune responses. *Aquaculture Nutrition*, 27(5), 1505–1515.
36. Nilsuwan, K. et al. (2016). Antimicrobial Edible Coatings from Fish Gelatin and Peptides. *LWT - Food Science and Technology*, 68, 475–484.
37. Nilsuwan, K. et al. (2018). Bioactive peptide-enriched gelatin films for wound dressing. *International Journal of Biological Macromolecules*, 107, 1062–1070.
38. Nilsuwan, K., et al. (2018). Development of fish gelatin-based films incorporated with bioactive peptides. *International Journal of Biological Macromolecules*, 107, 1062–1070.
39. Nilsuwan, K., Guerrero, P., & de la Caba, K. (2016). Antimicrobial gelatin films containing lipopeptides from marine bacteria for food packaging. *Food Packaging and Shelf Life*, 9, 1–10.
40. Patil, G.V., Rajendran, R., & Murthy, L.N. (2019). ACE-inhibitory and antioxidant potential of lizardfish protein hydrolysates. *Indian Journal of Fisheries*, 66(1), 45–52.
41. Pham, M.A. et al. (2018). Anchovy protein hydrolysates improve growth and immunity in *L. vannamei*. *Fisheries Science*, 84(3), 503–510.
42. Randall, J. E. (2001). *Surgeonfishes of the world*. Mergus Verlag.
43. Ravikumar, M., Babu, V., & Appa Rao, T. (2020). A study on trash fish species diversity and utilization in Visakhapatnam fishing harbor. *Journal of Entomology and Zoology Studies*, 8(3), 1362–1365.
44. Roy, S., Ramakrishnan, R., Afzia, N., Ghosh, T., & Zhang, W. (2024). Progress in antimicrobial and antioxidant peptide-activated coatings for food packaging. *Food Bioscience*, 62, 105288. https://doi.org/10.1016/j.fbio.2024.105288
45. Sabeena Farvin, K. H. et al. (2014). Antioxidant activity of protein hydrolysates from different parts of mackerel (*Scomber scombrus*). *Food Chemistry*, 145, 464–473.
46. Samaranayaka, A. G. P., & Li-Chan, E. C. Y. (2011). Food-derived peptidic antioxidants: A review of their production, assessment, and potential applications. *Journal of Functional Foods*, 3(4), 229–254.
47. Sarmadi, B. H., & Ismail, A. (2010). Antioxidative peptides from food proteins: A review. *Peptides*, 31(10), 1949–1956.
48. Shahidi, F., & Ambigaipalan, P. (2015). Bioactive peptides from food proteins: A review. *Food Production and Human Health*, 1(3), 153–169.
49. Sharma, D., Gite, S., & Tuohy, M.G. (2024). Antioxidant Peptides and Protein Hydrolysates from Tilapia. *Antioxidants*, 13(2), 219.
50. Sharma, D., Gite, S., & Tuohy, M.G. (2024). Biomedical potential of fish protein hydrolysates. *Antioxidants*, 13(1), 53.
51. Sharma, D., Gite, S., & Tuohy, M.G. (2024). Exploring the physicochemical characteristics of marine protein hydrolysates and their impact on bioactivity. *Marine Drugs*, 22(10), 452. https://doi.org/10.3390/md22100452
52. Sharma, D., Gite, S., & Tuohy, M.G. (2024). Marine bioactive peptides in aquafeed and sustainability. *Aquatic Biosystems*, 30(1), 45–58.
53. Tang, C.-D., Cheng, J.-H., & Sun, D.-W. (2024). Structure-activity relationships and activity enhancement techniques of marine bioactive peptides (MBPs). *Critical Reviews in Food Science and Nutrition*, 1–23. https://doi.org/10.1080/10408398.2024.2304877
54. Tian, Z. et al. (2020). Protective Effect of Fish-Derived Peptides on Skin Aging. *Marine Drugs*, 18(2):68.
55. Udenigwe, C. C., & Aluko, R. E. (2012). Food protein-derived bioactive peptides: Production, processing, and potential health benefits. *Journal of Food Science*, 77(1), R11–R24.
56. Venugopal, V. (2009). *Marine products for healthcare: Functional and bioactive nutraceutical compounds from the ocean*. CRC Press.
57. Wang, J. et al. (2022). Dietary peptides improve oxidative stress tolerance in grass carp. *Fish Physiology and Biochemistry*, 48(1), 23–35.
58. Wang, L. et al. (2020). Antioxidant effects of mackerel protein hydrolysates in grass carp. *Aquaculture Reports*, 18, 100503.
59. Wang, L. et al. (2020). Edible coating and active packaging material containing fish waste protein hydrolysate for seafood preservation. *Food Packaging and Shelf Life*, 26, 100572.
60. Wang, L. et al. (2020). Fish skin peptides attenuate inflammation in macrophages via the NF-κB pathway. *Journal of Functional Foods*, 72, 104042.
61. Zhang, C. et al. (2021). Functional feed peptides modulate gut microbiota in fish. *Aquaculture Nutrition*, 27(3), 851–861.
62. Zhang, Y. et al. (2021). Twelve Antioxidant Peptides From Protein Hydrolysate of Skipjack Tuna (*Katsuwonus pelamis*) Roe Prepared by Flavourzyme. *Frontiers in Nutrition*, 8:813780.
63. Zhang, Y., Liu, S., Zhou, K., Wang, W., & Song, S. (2018). Marine antioxidants from collagen and collagen peptides with nutraceutical applications: A review. *Antioxidants*, 13(8), 919. https://doi.org/10.3390/antiox13080919
64. Zheng, K. et al. (2021). Chitosan-based wound dressings incorporating marine peptides: Enhanced healing of diabetic wounds. *Carbohydrate Polymers*, 260, 117776.
65. Zhong, F., et al. (2018). Valorization of fish by-products: Purification of bioactive peptides from codfish blood and sardine cooking wastewater by membrane processing. *Membranes*, 10(3), 44. https://doi.org/10.3390/membranes10030044
66. Zhou, Q.C. et al. (2017). Replacement of fishmeal with trash fish hydrolysate in turbot diets: Growth and digestion. *Aquaculture International*, 25, 1137–1149.
67. Zhuang, H. et al. (2019). Bioactive peptides from fish scale hydrolysates: Antioxidant and wound healing potential. *Food Hydrocolloids*, 94, 129–138.
68. Zhuang, H. et al. (2019). Development of gelatin-based bioactive films with antioxidant properties from fish scales. *Food Hydrocolloids*, 94, 98–106.