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Vikas Kumar
Scientist (FPT), TOT Division,
ICAR-CIPHET, Ludhiana,
Punjab, India

Dr. Armaan U Mujaddadi
Pr. Scientist, TOT Division,
ICAR-CIPHET, Ludhiana,
Punjab, India

Dr. VK Mishra
Subject Matter Specialist, KVK,
West Kameng, Dirang,
Arunachal Pradesh, India

Corresponding Author:
Vikas Kumar
Scientist (FPT), TOT Division,
ICAR-CIPHET, Ludhiana,
Punjab, India

Bioactive peptides from fishery by-products: A review

Vikas Kumar, Dr. Armaan U Mujaddadi and Dr. VK Mishra

Abstract
In recent years there is an increasing preference for bioactive peptides in food and pharmaceutical industries because of low toxicity, high specificity and less side-effects. The great demand of bioactive peptides for functional foods thereby offers the scope for the identification of novel bioactivities as well as new bioactive peptides from various bioresources. Among various bioresources one of the best bioresource is fish. Fish being nutritionally rich carries the potential of extraction of bioactive peptides from its muscle as well as by-products. Higher fish production globally leads to generation of significant quantum of non-edible tissues such as skin, fins, viscera, bones, scales, trimmings, etc. during post-harvest handling and processing. These by-products are traditionally used for low value fish manure, silage or fertilizer. However, these by-products being nutritionally rich can be used for extraction of high value nutraceuticals and bioactive peptides.

Keywords: Fishery, high specificity, less side-effects

Introduction

Total global fish production increased to 178.5 MMT in 2018 (SOFIA, 2020). Total contribution from capture fisheries was 96.4 MMT (12 MMT inland and 84.4 MMT marine) and from aquaculture 82.1 MMT (51.3 MMT inland and 30.8 MMT marine). In India a total fisheries potential estimated in 2018 was 22.31 MMT (17 MMT inland and 5.31 MMT marine; both from capture and culture resources (NFP, 2020) [4]. India produced a total of 13.42 MMT (provisional, FY 2018-19) fish contributed by inland fisheries (9.71 MMT) and marine fisheries (3.71MMT). This higher production also leads to the generation of a huge quantity of fishery by-products in the form of skin, head, viscera, trimmings, liver, frames, bones, and roes from finfishes during processing and handling to a tune of 20 MT globally.

The huge quantities of these wastes generated from fish processing impose a cost burden on the industry for its disposal and are a challenge for the fish processing industry as well as for environmental management. Therefore, traditionally fish wastes are converted to low value products like fish silage, fish meal and fish sauce. However, a considerable amount of protein, omega-3 fatty acids and valuable minerals with more health benefits, biologically active compounds having significant potential to provide novel and valuable food ingredients in these by-products are not fully utilized.

Fish and Fishery By-products

Fish is a broad term that includes any aquatic organisms harvested for commercial purposes, whether caught in wild fisheries or harvested from aquaculture or fish farming. The term fish (whether of freshwater, estuarine/ brackish water or marine/ salt water) include finfish, crustaceans (crayfish, crab, prawn/shrimp, lobster) and mollusks (bivalves such as mussel, oyster, scallop and univalves like abalone, snail, conch and cephalopods such as squid cuttlefish, octopus) (Sachindra and Mahendrakar, 2015) [10]. Seafood, synonymously used for marine fish, generally refers to a group of biologically diver-gent edible animals (excluding mammals) consisting not only of fish (finfish), whether of freshwater, estuarine, or marine habitats, but also of shellfish. Seafood includes a diverse range of aquatic animals and therefore the non-edible part generated varies greatly in compo-sition and amount (Suresh and Prabhu, 2012) [12]. SOFIA (2018) reported the contribution of fish for about 17 percent of animal protein, and 7 percent of all proteins, consumed by the global population. Fish provided about 3.2 billion people with almost 20 percent of their average per capita intake of animal protein. Globally fish and fish products provide an average of 34 calories per capita per day.

Fish has also significant dietary contribution in terms of high-quality, easily digested proteins especially in fighting micronutrient deficiencies.

Generally the yield calculated by the fish processing industry is based on a gutted fish with head-on, that is typically 40% on an average. Fish processing generates 35-40% edible meat and the remaining non-edible tissues are bones, skin/scales, swim bladders, intestines, roes, liver, blood etc. (Sachindra and Mahendrakar, 2015) [10]. The demand for RTE and other value added products that require skinless, boneless fillets further increases the amount of waste generated. Many species are inadvertently caught while harvesting fish and crustaceans and that are not processed for human consumption also adds to the waste. Processing of finfishes generates 10–50% of the total weight as non-edible parts, which includes head, gut (viscera), skin, bone, and flesh remaining on the bone. Shellfishes, especially crustaceans, generate up to 85% of raw material as non-ed-ible parts, which include head, shell (carapace), viscera, and append-ages (Suresh and Prabhu, 2012) [12]. Fish processing discards usually account for 3/4th of total weight of catch. Discards are generally dumped in-land or hauled into the ocean. Fish processing industry generates >60% by-products as waste in the form of skin, head viscera, trimmings, liver, frames, bones and roes (Chalamaiah, Hemalatha and Jyothirmayi, 2012) [1]. These by-products containing a significant quantity of protein are normally processed into low cost products like fish meal, animal feed, fertilizer, fish silage and sauce (Chalamaiah, Hemalatha and Jyothirmayi, 2012) [1]. Considerable amounts of these byproducts generated from fish processing impose a cost burden on the industry for its disposal (He, Franco and Zhang, 2013) [6].

Bioactive Peptide

Bioactive peptide is a specific amino acid sequence that promotes beneficial physiological effects to the consumers when ingested. It is usually a sequence of 2-20 amino acids. Different bioactive peptides have been identified from a range of foods such as milk, muscle foods (fish, chicken, beef, pork, etc.) and plants having different bioactivities such as anti-hypertensive, anti-oxidant, anti-thrombic, anti-adipogenic, anti-microbial and anti-inflammatory, etc. There are a number of bioactivities of peptides reported in literature (fig. 1). With the latest technological developments there is a great interest in the use of biologically active peptides in food and pharmaceutical industries because of specific characteristics like low toxicity and high specificity (Lafarge and Hayer, 2014, de Castro and Sato, 2015) [2]. Therefore, it is wiseful to extract such bioactive peptides having a very high value from the low value fish by-products.

Process of Obtaining Bioactive Peptide

There are different methods used to extract bioactive peptides from various protein sources. Based on the sources of protein, the bioactivity targeted and available facilities for extraction, methods are usually customized. However, a general process of major steps followed for obtaining bioactive peptide is given (fig. 2). Different bioassays are available to check the bioactivity of the peptides extracted based on the bioactivity under study. Scientific details of these assays are available in original research publications of many leading research journals.

Bioactive peptides from fish byproducts

Globally a number of fish species and their by-products have been studied by various researchers in search of bioactive peptides and novel bioactivities. Some of the studies tabulated (table 1) briefs the types of bioactivities studies carried out for different fish-byproducts of various fish species. For example: antihypertensive peptides extracted from both finfish (salmon, tilapia, tuna, mackerel, basa, etc) and shellfish (squid, shrimp) have been reported to lower the blood pressure usually mediated by Angiotensin Converting Enzyme-I (ACE-I) inhibition. There are many research publications available that show *in vitro* and *in vivo* efficacy of these peptides and mention Inhibitory Concentration (IC_{50}). IC_{50} is the concentration of peptide that inhibits 50% of maximum ACE activity. Similarly for other bioactive bioactivities peptides there are different assays based on its physiological role and chemical nature. Antioxidant peptides help reduce oxidation of consumers and thereby lower many of undesirable oxidative changes in the human body including ageing. Antimicrobial peptides vary in its activities against the types of microbes. A specific peptide showing bactericidal effect on a particular bacteria may not show its efficacy on other bacteria. Anti-prolific and anticancer peptides lowers the proliferation of tumor cells and thereby helps cancer patients. Other bioactive peptides also offer physiological advantages in one or other ways. These bioactive peptides can be used as an active ingredient in functional foods.

Table 1: Common bioactivities of peptides reported from fish byproducts

Bioactivity	Byproducts Used	Fish Species	References
Antihypertensive	Skin, head, viscera,bones scales, backbone	Salon, Pacific Cod Skin,, Tilapia, Ribbon Fish, Yellowfin sole, Sardine, Seabream, Tuna, Basa, Mackerel, Squid, Cape Hakem	Yatisha *et al*. (2019)
Antioxidant	Viscera, head, skin , backbones, frames, scale, fins; cepaholthorax, shells	Black Pomfret, Horse mackerel, Bluefin leatherjacket, Sardinelle,Tuna, Alaska pollock,Giant kingfish, Tilapia, Blue shark, Yellowfin sole, Silver Carp, Salmon, Shrimp Jumbo Squid	Sila, A., & Bougatef, A. (2016) [11]
Antimicrobial	Processing by-products, fermented fish sauce	African catfish *Clarias gariepinus* (*C. gariepinus*); Anchovy (Encrasicholina sp. and Stolephorus sp.); (Antimicrobial property against *Staphylococcus aureus, Aeromonas sobria, Aeromonas hydrophila, Escherichia coli*))	Wang, *et al*., 2015 [15]; Khositanon, *et al*, 2018
Anticancer	Fermented fish sauce	Oyster (*Saccostrea cucullata*) Anchovy (Encrasicholina sp. and Stolephorus sp.), Squid; Sea slug	Umayaparvath, *et al*., 2014 [14]; Khositanon, *et al*, 2018 [7]; Ngo *et al*, 2012
Antiproliferative	Backbone, shell	Squid, Cod, Plaice, Salmon, Tuna, Shrimp	Ngo *et al*, 2012 [9]
Antidiabetic	Skin-gelatin, Skin, Trimmings	Steelhead (*Oncorhyncus mykiss*) gelatin, Salmon	Cheung and Chang, 2017; Harnedy *et al*., 2018 [5]

Anti-coagulant	-	Yellowfin sole, Blue mussel, Echiuroid worm, Starfish,	Ngo *et al*, 2012 [9]
Calcium-binding	Frame, shell	Salmon, Pollack, Hoki frame, Shrimp	Ngo *et al*, 2012 [9]
Anti-coagulant	-	Yellowfin sole, Blue mussel, Starfish,	Ngo *et al*, 2012 [9]
Anti-HIV	-	Oyster, Marine sponge	Ngo *et al*, 2012 [9]

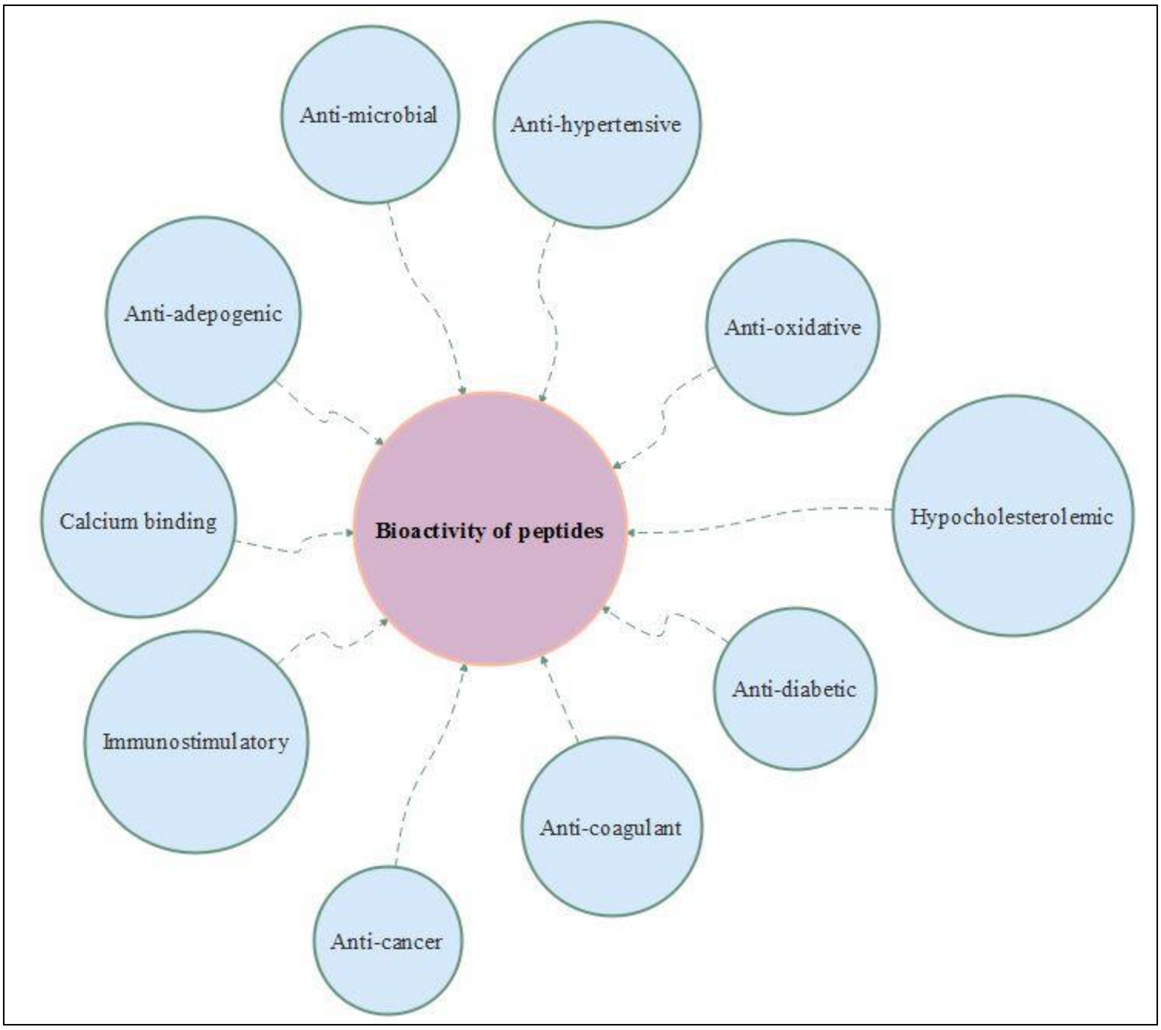

Fig 1: Common bioactivities of peptides reported from fish byproducts

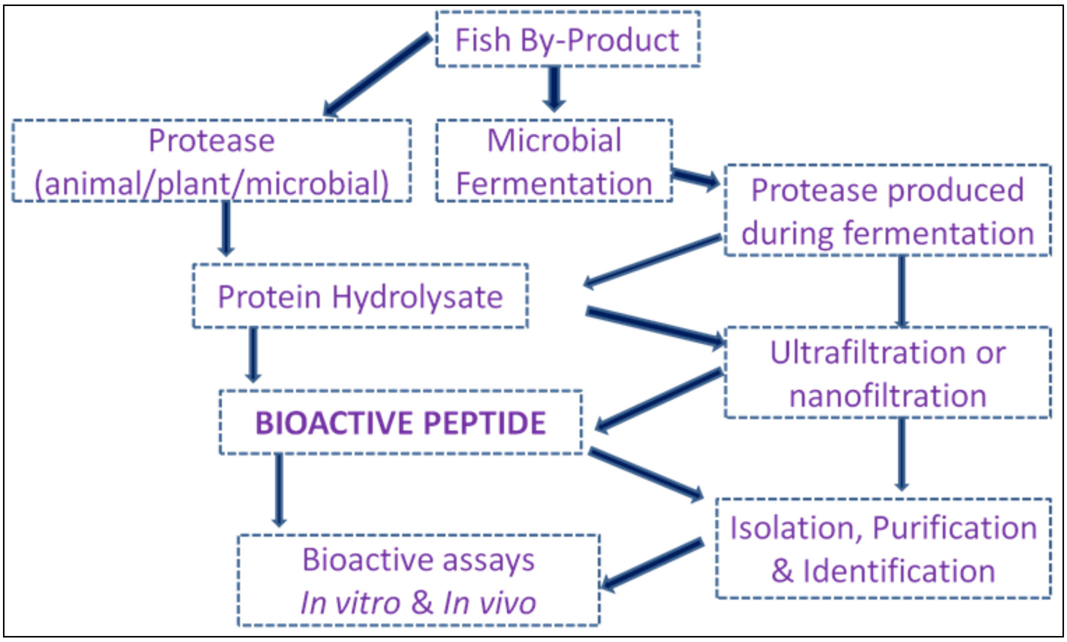

Fig 2: A general flow chart of major steps for obtaining bioactive peptides

Conclusion
Food and pharmaceutical industries prefer bioactive peptides because of low toxicity, high specificity and less side-effects. The great demand of bioactive peptides for functional foods thereby offers the scope for the identification of novel bioactivities as well as new bioactive peptides from various bioresources. Fish being nutritionally rich carries the potential of extraction of bioactive peptides even in its byproducts. An overview of available studies on the range of bio-activities peptides from fish byproducts has been discussed.

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