Review Article

Utilization and development of products from marine collagen in Asia Pacific region - Current status

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Abstract

Marine collagen has gained a prodigious attention as a bio resource with reference for its use in various disciplines including medicine, food cosmetics and many other industrial applications. The advancements in biotechnology in European countries has created an open market for marine collagen and its products. However, despite the availability and abundance of marine genetic resources in the Asia Pacific region, these resources remain largely underutilized. Further, there is an excess number of by-products generated from the fish processing industry which have created ample opportunities to develop collagen-based value-added products. The present review aims at identification of possible resources for marine collagen, extraction, and physiochemical characterization, while addressing the possibilities related to their uses in different industrial and research applications. Special attention will be given to identify the future perspectives with respect to marine collagen industry in Asia- Pacific region.

***Keywords**:* Food industry, Asia pacific region, marine collagen

Introduction

Being the most abundant fibrous protein found in multicellular organisms, Collagen represents nearly 30% of the total proteins in animals (Coelho et al., 2017). It provides the support and maintenance for structural integrity, shape, texture and resilience, while having regulated the development of tissues as well (Coelho et al., 2017).

Collagen has been isolated from various animals and even from plants. The main source of collagen is mammalian tissues. Collagen derived from human placenta and skin is also available in the market as commercial products, at a higher cost (Avila Rodríguez et al., 2018). In addition, collagen I homotrimer helices are produced using transgenic plants such as maize (*Zea mays*) and tobacco (*Nicotiana tabacum*) (Perret et al., 2001), whereas cartilage-specific human type II collagen is obtained using silkworm larvae (Felician et al., 2018). For many years, industrially, bones and skins from cattle and pigs are used for large scale production of collagen. However, the risk of contaminating with highly infectious and contagious diseases such as Transmissible Spongiform Encephalopathy (TSE), Bovine Spongiform Encephalopathy (BSE- Mad Cow Disease), and Foot and Mouth Disease (FMD) together with religious barriers for the use of collagen from pigs and cattle have created concern among public (Felician et al., 2018).

Marine-based collagen is identified as a safe and attractive alternative to terrestrial collagen, with weak immunogenicity, high biocompatibility, and low risk of transmissible diseases (Felician et al., 2018). Therein marine invertebrates and vertebrates have gained the interest to be utilized for the extraction of collagen with fewer problems than that of terrestrial counterparts.

Commonly marine invertebrates such as cuttlefish, prawn, sea anemone, starfish, jellyfish, sea urchin, sponges, octopus, mollusks, and squids are used to extract collagen (Salvatore et al., 2020). Marine vertebrates, especially fish and marine mammals (ex: whales) too, are used for the collagen extraction (Felician et al., 2018). The use of waste produced in fish processing to extract collagen, cannot be disregarded, as this is practiced in many countries as a solution for the inclining collagen demand in the market and also a solution for environment pollution (Coelho et al., 2017).

A continuous growth in research, related to marine collagen extractions can be identified over the years is given in the figure below. A considerable number of research has been

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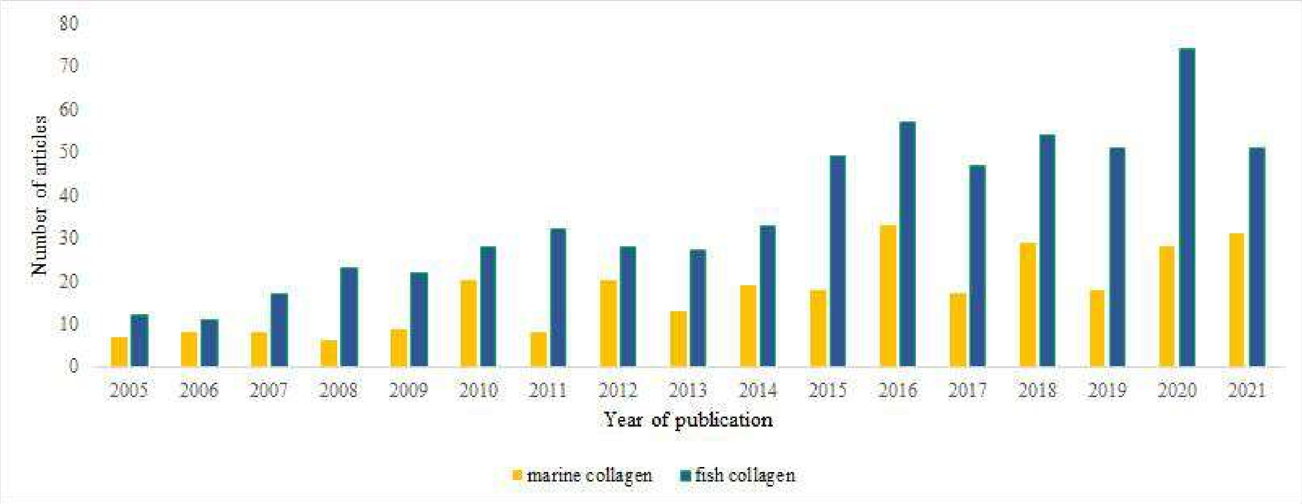

Figure 1. Number of research publications based on marine derived collagen; articles indexed in Science Direct journals published from 2005 to 2021 (last accessed on September 10th, 2021).

published related to marine based collagen, reflecting the growing concern among the scientists on marine collagen extraction and its uses.

Extraction of marine collagen: Methods and improvements

The extraction of marine collagen for human consumption holds a significant place in the current industrial world. Extracting collagen can be performed by chemical treatments and enzymatic treatments. Industrially, the more common method is chemical hydrolysis with acetic acid as it produces collagen with high nutritional value. Even though enzymatic extraction with pepsin has low waste and reduced processing duration, it can be identified as a high cost process (Ran and Wang, 2014).

Studies are reported on focusing the extraction of marine collagens using Acid Soluble Collagen extraction (ASC) method and Pepsin Soluble Collagen (PSC) extraction method. The table below, shows different species, different parts of the species, different extraction method result in a variety of yields in the collagen extraction process.

Marine collagen: Sources and possibilities

Production of marine collagen derived products rely on the marine fishing industry for a sustainable portion, in most of the European countries (FAO, 2021). Currently, the world fish catch has been reached for 132 million tons. Nearly 40% of marine activities are located in Asia-Pacific region while they produce 31.8 million tons of marine catch per year while, 12 million tons of fish catch is produced in East and West Indian oceans (FAO, 2021). Despite the high production of fish in this region, world marine fisheries are predicted to produce 28.7 million mt of by catch and 27.0 million mt of discard annually (FAO, 2021). This excludes the invertebrate fisheries, recreational fisheries, and subsistence fisheries. Further, fisheries in the Northwest Pacific account for more than a third of overall discards (FAO, 2021). Many countries are encouraged to develop principles of social, economic, and environmental sustainability in fishing industry, due to these losses and wastes.

Therefore, raw materials like collagen, gelatin, and collagen hydrolysates are focused in different industries including food industry, cosmeceutical industry, biomedical and other industries. These can be successfully utilized from marine biological resources, especially from fish waste.

Recent applications of marine collagen

Applications of marine collagen in food industry: General overview

Collagen has a variety of uses in the food industry, mainly as a food additive or packaging. Marine collagen peptide (MCP) is a functional component that can be extracted from scales/skin of fish. Collagen-based membranes are used to make films and coatings that are edible in order to increase the shelf life of different food products. While operating as a barrier against the migration of pathogens, moisture, oxygen and solutes, the membrane provides structural stability and vapor permeability to the food product (Neklyudov et al., 2003). Collagen casings are used to wrap around meat batter, sausages and other meat-based products. Animal collagen is also used as food additives to improve the rheological properties and reduce the fat consumption of sausages and frankfurters and also to ensure that enough levels of animal nutritional fibers are present (Neklyudov et al., 2003).

Table 1. Extraction of collagen from different marine resources

Source	Common Name	Species Name	Source tissue	Extraction Method	Yield %	References
Squid	Antarctic Squid	*Kondakovia longimana*	Skin	PSC	1.18%	Coelho et al., 2017
				ASC	0.94%	
			Muscle	PSC	0.88%	
				ASC	1.05%	
	Sub-Antarctic Squid	*Illex argentines*	Skin	PSC	3.26%	
				ASC	0.81%	
Jellyfish		*Rhizostoma pulmo*	Umbrella	PSC	0.315%	Addad et al., 2011
			Oral arms	PSC	1.03%	
		Cotylorhiza tuberculata	Umbrella	PSC	0.0453%	
			Oral arms	PSC	0.194%	
Sponge		*Chondrosia reniformis Nardo*	Whole	ASC	30%	Addad et al., 2011
Fish	Japanese Sea-Bass	*Lateolabrax japonicus*	Skin	ASC	51.40%	Nagai and Suzuki, 2000
			Bone	ASC	40.70%	
			Fin	ASC	36.40%	
	Chub Mackerel	*Scomber japonicus*	Skin	ASC	49.80%	
	Bullhead Shark	*Heterodontus japonicus*	Skin	ASC	50.10%	
	Skipjack Tuna	*Katsuwonus pelamis*	Bone	ASC	42.30%	
	Ayu	*Plecoglossus altivelis*	Bone	ASC	53.60%	
	Yellow Sea Bream	*Dentex tumifrons*	Bone	ASC	40.10%	
	Horse Mackerel	*Trachurus japonicus*	Bone	ASC	43.50%	
	Tilapia	*Oreochromis niloticus*	Skin	ASC	27.20%	Chen et al., 2016
			Scales	ASC	3.20%	
	Sailfin Catfish	*Pterygoplichthys disjunctivus*	Skin	ASC	26.20%	Herath et al., 2020
			Flesh	ASC	10.66%	
			Bone	ASC	3.40%	
			Fin	ASC	3.19%	
	Shark	*Prionace glauca*	Cartilage	ASC	0.15%	Seixas et al., 2020
				PSC	3.50%	
	Ray	*Zeachara chilensis*	Cartilage	ASC	0.92%	
				PSC	0.50%	
	Spotted Golden Goatfish	*Parupeneus heptacanthus*	Scales	PSC	1.20%	Matmaroh et al., 2011
				PSC	0.46%	

Collagen-based edible films and coatings receive special attention that functions to safeguard, maintain, and increase the shelf life of different food products. It also prevents fat oxidation, discoloration, and microbial growth while maintaining sensory properties. Marine collagens are being studied to develop edible films and coatings due to certain barriers of using bovine, porcine, ovine and duck feet collagen. As an example, Pepsin soluble collagen (PSC) was isolated from blue shark (*Prionace glauca*) skin and was used to coat fresh red porgy (*Pagrus major*) fillet compositing with collagen and evaluate coating effects on fresh red porgy (*Pagrus major*) fillet quality during storage at 4°C. According to the test results of the study, 1% of chitosan solution containing 0.8% of PSC was suggested as the best coating formulation to produce edible collagen and chitosan coating which have required qualities such as biodegradability, biocompatibility, cost effectivenes, and maintaining food quality in storage duration (Liu et al., 2020). Further, chemical nature of food, controlled release mechanisms, food organoleptic characteristics and additive toxicity are considerations that should be considered when designing a food packaging. According to recent studies, fish skin gelatin films incorporated with peppermint oil, cinnamon oil, sunflower oil, and citronella oils have been studied and as a result, active films against food poisoning microorganisms have been developed (Liu et al., 2020). Specially, food products including fish, meat, fruits and vegetables can be coated with gelatin-based films. According to Wang et al. (2021) fish skin collagen/sodium alginate blend has been developed successfully into an edible film with suitable rheological property.

The demand for collagen peptides/collagen hydrolysate obtained from seafood has surged as an antioxidant. As an instance, scales of *Pseudosciaena crocea* (croceine croaker fish) and *Chanos chanos* (milkfish) derived collagens exhibit high DPPH scavenging activity, ABTS and superoxide radicals scavenging activity together with higher effectively in lipid peroxidation system (Ahmed et al., 2014). Moreover, high antioxidant activity was resulted from collagen obtained from Nile tilapia in the direction of linoleic acid peroxidation and DPPH radical scavenging activity (Liang et al., 2014). According to Jeevithan et al. (2014), antioxidant activities were also found from low molecular weight polypeptide of collagen extracted from whale shark (*Rhincodon typhus*) cartilage (Ahmed et al., 2014). Big eye tuna skin and Spanish mackerel skins have a prospective potential source of mammalian collagen. Further, they can be put to use as antioxidant compounds in food applications (Devita et al., 2021).

It was identified that a very low number of research papers have been produced in most of the regions in the world related to applications of marine collagen in food industry. Mussel byssus, a by-product of mussel production, has recently been discovered to be a possible source of edible collagen (Rodríguez et al., 2017). Further, Bovine collagens are being used as a clarifying agent in alcoholic beverages. Similarly, fish collagen also has been reported to show efficient refining properties in beer and yeast production (Walker et al., 2017). Moreover, there are many available marine collagen products in the European market that were suggested for applications in dietary supplements, functional foods, confectionery and desserts.

Application of collagen in the food industry: **Asia pacific region**

Use of marine collagen protein (MCP) in various in food industries has been practiced in Asia pacific region for many years. According to (Kumar et al., 2019) MCP has a potential in developing into dietary supplement. In this study, MCP has been added (0–10%) in the biscuit flour and assessed its physical, textural and sensorial, functional effects of MCP-flour mix. Exhibiting promising features, water holding capacity and gelatinization-viscosity were decreased significantly by the addition of MCP. Upon supplementation, biscuits were shown to have anti oxidative properties as well as a slight reduction in calorie content. Sensorial preference was noted for nutritionally improved collagen peptide biscuits and it can be served as a potential geriatric nutrition option (Kumar et al., 2019). MCP obtained through enzymatic digestion of fish skins known to have beneficial effect on treating metabolic diseases and bone repair. In the aspect of sustainable use of fish waste during fish processing, bone, skin and skeleton can be used as main factors that promote health providing collagen and calcium. Bhagwat and Dandge (Bhagwat et al., 2006) have developed a milk-based food product (paneer) that contain collagen from buffalo milk. Moreover, composed paneer has been widely recognized and have good texture and sensorial qualities (Jeevithan et al., 2014). This research has an improved isolation process with a high denaturation temperature to isolate collagen and gelatin from silver tip shark cartilage. They identified that, silvertip shark cartilage type II collagens and type II gelatin have solubility, susceptibility to proteolytic enzymes, high denaturation temperature and efficient antioxidant activities which are promising characteristics. Type-II collagenous polypeptide from whale shark cartilage with a low molecular weight was also an excellent antioxidant source that can be incorporated into food industry (Jeevithan et al., 2014).

Application of marine collagen in biomedical science: General overview

Mammalian collagen mainly derived from pigskin, cowhide, and other mammals is a multifactorial biomaterial that has gone a long way in advanced biomedical science. Application of mammalian collagen has a pathological risk for transmitted zoonotic diseases and religious constraints. Due to these challenges, marine collagens have attracted the interest in the industry as a beneficial biomaterial that replaces marine collagen. However, characterization and biomedical applications of marine collagen are still in the early stages of development and yet to be discovered.

According to the current literature, a trend can be identified where focuses to blends collagen with other natural polymers. Although this combination of materials has piqued academic curiosity, it is still attracting industry interest. Blends of collagen with other polymers have been investigated in the biomedical area in recent years for the development of novel materials. Many studies related to biomedical applications of marine collagens are being conducted around the world other than Asian pacific region according to the statistics. As a result of this, opportunities for marine collagen in commercial market is increasing daily.

Especially, global market is focusing to valorization of marine by-products based on isolation of bio compounds and evaluation of biomedical applicability. Number of research were conducted in many regions, to upgrade the quality of biomedicine with biomaterials. The potential of blue shark skin collagen (*Prionace glauca*) to induce chondrogenic differentiation of human adipose stem cells was recently investigated, and this work highlighted the importance of using blue shark collagen biopolymer as a building block to produce highly effective temporary matrices for cartilage applications (Diogo et al., 2022).

Jellyfish collagen has been identified as a promising material, owing to its wide availability and ease of usage. Structural differences of jellyfish collagen a promising feature that influence the adhesion mechanisms of vertebrate cells mediated by integrin. Jelly fish collagen from *R. esculentum* has been extracted and it's a potential material for cartilage tissue engineering (Sewing et al., 2017). Porous scaffolds has been developed from fibrillated jellyfish collagen and alginate hydrogel which are mimicking both of the main tissue components of cartilage following hybrid technology, being a promising approach for chondrogenic differentiation of human mesenchymal stem cells (Pustlauk et al., 2016). Cannonball jellyfish also contain high collagen content, which has substantial potential as a raw medium for developing novel ingredients biomedical science. Chiarelli identified that Microencapsulation of *Lactobacillus rhamnosus* using collagen extracted from cannonball jellyfish improves survival during a 28-day shelf-life study to ~8 log CFU/g (Chiarelli). According to Alkildani et al. (2021), *R. pulmo* jellyfish can be used instead of collagen from mammals. In the case of the jellyfish 3D scaffolds, fibroblast viability was comparable and pre-osteoblast viability significantly higher than the medium control. These cells can be used in research of (bone) tissue regeneration because they showed positive healthy behavior on this marine collagen (Alkildani et al., 2021).

Consequently, several research have focused on the collagen extraction and characterization from skins of different fish, such as small-spotted cat shark (*Scyliorhinus canicula*), rabbit fish (*Chimaera monstruosa*), lantern shark (*Etmopterus* spp.), cat shark (*Galeus* spp.), cuckoo ray (*Leucoraja naevus*), common Atlantic grenadier (*Nezumia aequalis*), cod (*Gadus morhua*), and the scales and fins of *Catla catla* and *Cirrhinus mrigala* (Jafari et al., 2020). In relevant to marine fishes, by-products of sea bream marine fish species (*Spondyliosoma cantharus*) were used to extract collagen and evaluated as skin protectant agents against skin pathogens such as *C. albicans* and *S. aureus* through the actions as antimicrobials of same pathogens. Parallelly, Collagen-Nanochitosan-Henna Extract Composites of the same species was used to accelerate the wound healing process expressing biochemical and histological value (Tayel et al., 2021).

Another promising marine collagen source is sponges. In a recent study, demosponges: *A. cannabina* and *S. carnosus* have been observed and insoluble, intercellular, and spongin-like collagens were isolated from *A. cannabina* and *S. carnosus* (Tziveleka et al., 2017). Collagen extracted from sea urchin food waste is too considered as promising biomaterial for skin wound healing in a "blue biotechnologies" perspective for animals which have a veterinary interest (Tziveleka et al., 2017). Besides, sea urchins are well known delicacy in many countries and cultures around the world. The sea urchin is a widely used experimental model in both basic and applied biology. *P. lividus* is also an edible sea urchin that is favored for the delicacy of its gonads. All non-edible body parts can be recycled to make low-cost collagen substrates. Due to high resistance to mechanical stress and elasticity sea urchin might be suitable for specific tissue engineering applications; tendon or skin regeneration. They could also be used as highly resistant dermal stitches for surgical purposes or as skin tape for topical applications (lacerations or burns) (Benedetto et al., 201).

Application of marine collagen in biomedical science: Asian pacific region

Within recent years, large number of studies related to applications of marine collagen in biomedicine can be observed in Asian pacific region. In particular, tissue engineering and regenerative medicine have a great impact due to the emerging trend of using marine collagen. The potency of using marine collagen in bone tissue engineering was shown in a study that was conducted by Elango et al. (2018) recently. The biochemical and osteogenic properties of pepsin soluble and acid soluble collagen extracted from blue shark (*Prionace glauca*) skin was studied. Accordingly, the collagens from blue shark skin was identified with excellent biochemical and osteogenic properties that directs for therapeutic application in bones (Elango et al., 2018). It could be an opportunity for regenerating cartilage, bone, periodontal tissue, and the cornea by using fish collagen.

According to Oh et al. (2021), three-dimensional (3 D) printing is a powerful technology that has demonstrated significant promise in tissue regeneration. They have conducted a study, to develop tissue-engineered bone using fish collagen and the osteogenic abalone intestine gastro-intestinal digests from *Haliotis discus hannai*. This has been successfully studies in *in vitro* and *in vivo* models (Oh et al., 2021).

Collagen dressing technology encourages autolytic debridement, angiogenesis, and epithelialization while stimulating new tissue growth. Acute wounds with full thickness require a longer healing period that increases the risk of infection. Severe infection, on the other hand, can cause wound ulceration, necrosis, and even life-threatening complications. In current collagen dressing technology, collagen derived from marine fish scales are using to improve the healing of full-thickness wounds due to low immunogenicity and high biocompatibility (Feng et al., 2022). Another studyshowed that porous collagen sponges that were prepared using fish scales (*Lates calcarifer*) and extracts of *Macrotyloma uniflorum* has great antimicrobial activity. Based on the findings, it could be used as a burn/wound dressing material. Further, the fish scale collagen extracted from same marine species, *L. calcarifer* has been observed for some special characteristics: optically clear with sufficient strength in order to try as a potential candidate for corneal transplantation (Krishnan et al., 2012).

Type I collagen was extracted from the bones of two different marine fishes; *Magalaspis cordyla* and *Otolithes ruber* and subjected to *in vivo* testing to study the efficacy in healing the excision wounds. It demonstrated that it has exceptional medicinal value and revealed that it's a possible way to turn this waste into a useful source of medicine. Another important source of collagen is yellow fin tuna bones which is a promising candidate for development as an antibacterial agent (Natsir et al., 2021). Except wound healing property and anti-inflammatory property, some marine collagens can be used to drug delivery and various other biomedical applications: injectable collagen solutions, biomimetic scaffolds for 3D cell culture. As an instance, fish scale-derived collagen (snake head fish), in the methylated form is a promising potential scaffolding material for all the above applications (Wang et al., 2017).

Applications of marine collagen in cosmeceutical industry: Global overview

Collagen is a popular ingredient in cosmetics; to increase skin hydration and prevent skin ageing. It can be used for either hair care, oral care or mucous membrane care. Furthermore, collagen films used in the cosmetic industry can be modified through collagen cross-linking and/or collagen blending with other proteins and polysaccharides.

Current research direction state that collagen application for cosmetic purposes is focused on increasing the denaturation temperature of several types of collagens derived from fish species. Additionally, collagen will be used without a doubt for effective rejuvenating treatments in ageing population since it directly effects on psychological and social well-being of people. In light of this, marine collagen has become more popular due to high acceptance rate of consumers. However, sourcing of marine collagen should take several aspects into account such as sustainable sourcing, use of fishery and aquaculture by-products, legislative requirements efficient and environmentally friendly processes (Coelho et al., 2017).

Several countries including European region, American region have a growing interest on marine collagen based cosmeceutical products owing to specific qualities over synthetic components. Consumer acceptance on natural products takes a high rate in the path towards long healthy life without premature aging.

Deep sea fish sources from other regions of the word also have been studied for natural marine products. A significant component of this is the development and research of nutraceuticals based on marine collagen peptides. Though marine collagen peptides have specific qualities, some studies show a risk of arising an oxidative stress by marine collagen peptides-stimulated phagocytes. To avoid this, *Pollachius virens*, *Hippoglossus hippoglossus*, and *Pleuronectes platessa*, originated in the North Sea coast of France were used in clinical-laboratory studies; marine collagen peptides from fish combined with plant-derived skin-targeting antioxidants (coenzyme Q_{10} + grape-skin extract + luteolin + selenium) and it was administered to volunteers (De Luca et al., 2016). Ultrasonic markers (epidermal/dermal thickness and acoustic density) and skin parameters (moisture, flexibility, sebum production, and biological age) were measured three times (2 months before treatment and before and after cessation of 2-month oral intake). The supplementation remarkably improved skin elasticity, sebum production, and dermal ultrasonic markers. A supplement containing a combination of marine collagen peptides and skin-targeting antioxidants could be an efficient and safe way to improve skin qualities while avoiding oxidative harm (De Luca et al., 2016).

Collagen extracted from salmon and codfish skins is used as a targeted ingredient in cosmetic formulations. This application further reveals a high capacity to hold water, making it appropriate for use as a moisturizer on the skin. Besides, topical collagen exposure in a human reconstructed dermis, as well as molecular markers for irritation and inflammation, revealed no irritating potential. Thus, the isolation of collagen from fish skins may be a constitute in sustainable and low-cost cosmeceutical products (Alves et al., 2017).

Application of marine collagen in the cosmeceutical industry: Asian pacific region

Collagen market in Asian pacific region is expected to reach to the global market in light of sustainable use of marine natural resources. As stated by Sinaga (2021), untreated waste created from 61% of total fish biomass in the form of fish scales and skins may pose a threat if not utilized effectively. Mullet (Mugilidae) or *belanak* scales are one of the potential wastes as sources of collagen, which are popular in the cosmetics industry today. A recent study aimed to develop a facial wash (anti-acne) supplemented with collagen extracted from mullet scales in order to prepare valuable product from fish waste. It had excellent characteristics such as pH of 5.28, higher percentage of foam stability (93.33%), viscosity of 3.7396 CPS (Sinaga et al., 2021). Another study has been carried out by (Nakchum et al., 2016) with squid skin, a processing waste product. Collagen hydrolysate was observed as a valuable material that has many bifunctional activities such as anti-hyaluronidase inhibitory activity, copper chelating ability, ferrous chelating ability, hydroxyl radical scavenging activity which has a potential to be used as a nutraceutical or cosmeceutical agent (Nakchum et al., 2016).

Asterias pectinifera is also a nontoxic and environmentally friendly source of highly water-soluble, low-molecular-weight collagen peptides. It reduces ultraviolet radiation-induced photoaging when it combines with elastic nanoliposomes. Therefore, the combination of *Asterias pectinifera*-derived low-molecular-weight collagen peptides and elastic nanoliposomes could be a potential formulation for anti-aging cosmetics as an environmentally safe source of materials (Han et al., 2021).

Sea cucumbers are very promising source of collagen, and this is already used as a natural raw material for moisturizing cosmetics. Sea cucumber *Holothuria cinerascens* collagen has small molecular weight (80~90 kDa) that exhibit better moisture-retention and moisture-absorption capacity than glycerol. Due to this, it has the potential to be used in cosmetic formulas (Li et al., 2020). Fan et al. (2020) has studied the antiphotoaging activity of Jelly fish collagen extracted from jellyfish umbrella and hydrolyzed to prepare jellyfish collagen hydrolysate. The effects of these compounds on UV-induced skin damage of mice were evaluated by the skin moisture, microscopic analyses of skin and immunity indexes. Both compounds boosted the ability of UV-induced mouse skin to retain moisture, according to skin moisture studies. The immunity indexes showed that Jelly fish collagen and Jelly fish collagen hydrolysate play a role in increasing immunity of photoaging mice in vivo. Depending on this jelly fish collagen derived products can be identified as a potential novel antiphotoaging agent from natural resources (Fan et al., 2020).

Collagen polypeptides made from cod skin have been shown to exhibit moisture absorption and retention capabilities at various relative humidity. Furthermore, the preventive effects of collagen polypeptide against UV-induced skin damage in mice were investigated. The action mechanisms of collagen polypeptide mainly engage in enhancing immunity, reducing the loss of moisture and lipid, promoting anti-oxidative properties, reducing the increase of glycosaminoglycans, repairing the endogenous collagen and elastin protein fibers, and maintaining the ratio of type III to type I collagen (Hou et al., 2012). Further, gelatin hydrolysate from pacific cod (*Gadus macrocephalus*) skin has been investigated to observe the effect on UV irradiation-induced inflammation and collagen reduction of photoaging mouse skin. The findings revealed that oral administration of collagen hydrolysate reduced UV irradiation-induced skin damage by limiting the depletion of endogenous antioxidant enzyme activity, and by suppressing the expression of NF-κB as well as NF-κB-mediated proinflammatory cytokines expression. Based on these results, it may be potentially effective for protecting skin from UV irradiation-induced photodamages and prevention of photoaging (Chen and Hou, 2016). In another study, Hydrolyzed collagen from the defatted Asian sea bass (*Lates calcarifer*) was evaluated for bioactivities and toxicity. No cytotoxicity recorded at any concentrations (25–1000 μg/mL), but exhibited wound healing ability, significant ABTS radical scavenging activity, oxygen radical absorbance capacity. Thus, hydrolyzed collagen from the defatted Asian sea bass (Lates calcarifer) could be applied as antioxidant, skin nourishment and wound healing agents for food/drink fortification (Chotphruethipong et al., 2021).

Challenges

Although marine collagen secures its identity as a good raw material for various products in different industries, yet there are a number of challenges which must be addressed if it is to realize its full potential. The marine resource for collagen should be sustainably supplied without any short-comings. There should be a clear understanding of the marine species used in the extraction, including their taxonomic identification, biology and behavioral patterns etc. The policy initiatives should also favorable to boost economic development based on biotechnology. Proper policies are essential to build a strong collaboration between industry and research, to bring these biotechnological outputs to the market.

Conclusion

Extraction of collagen from marine resources and their bio prospecting is highly practiced in many European countries. Despite the abundance, species richness and high diversity of marine resources, the collagen extraction and utilization are still at its infancy in Asia Pacific region. This review discusses the possibilities of applying marine collagen in different industries such as healthcare, food and cosmeceutical. Sustainable utilization of marine collagen will directs to lowering the safety risks, cultural or religious concerns while uplifting economic viability as well as the quality of the products in this region.

List of Abbreviations

TSE - Transmissible Spongiform Encephalopathy

BSE - Bovine Spongiform Encephalopathy

FMD - Foot and Mouth Disease

ASC - Acid Soluble Collagen extraction

PSC - Pepsin Soluble Collagen

MCP - Marine collagen peptide

DPPH - 2,2-Diphenyl-1-picrylhydrazyl

ABTS - 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)

Competing interest

The authors declare that they have no conflict of interest.

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