Recent Advances in Marine Collagen: Extraction, Bioactivities, and Applications in Healthcare

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***Abstract*—Marine collagen, the first and foremost derived from fish byproducts, is rapidly evolving into a priceless and multifunctional bioresource with many applications in medicine. This review study reveals the diverse roles of marine collagen and their derivatives focusing mainly on the potential of these resources in green medical treatments. Besides exploring the improved patient wellbeing and therapy effectiveness that drug delivery systems made of marine collagen can bring, it also presents the highly biocompatible marine collagen evident in the skin care and cosmetics industry where collagen-based products have attracted great attention for their ability to boost skin moisture and elasticity, solve aging problems, and maintain healthy skin. On top of that, marine collagen's excellent properties still greatly benefit the cosmetics sector providing people with an effective and permanent method to enhance their physical appearance and self-confidence. At the same time, consideration should be given to sustainability when obtaining marine collagen. Besides waste reduction, using fishing industry byproducts promotes global efforts for more environmentally friendly practices. This article examines the impacts of such sustainable sourcing on the conservation and responsible usage of resources. Marine collagen and its derivatives are bioresources for healthcare applications that are both sustainable and adaptable. Apart from their numerous uses in regenerative medicine, pharmaceuticals, and cosmetics, as well as their environmentally friendly sourcing, they will really influence the future direction of healthcare.Marine collagen could be one of the most revolutionary factors of environmental and medical practices, Because of this, it deserves further study and development. By continuous unlocking the power of this exceptional material, we pave the way for a healthcare system that is not only more sustainable and environmentally friendly but also more effective.**

***Index Terms*—Marine collagens, Byproducts, Pharmaceutical and Bioresources**

I. INTRODUCTION

Fish collagen is sourced from the water-based surroundings on our planet and recently has become quite popular for its various applications and developments in industries and research fields. For example, fish collagen has been employed to manufacture sophisticated wound dressings and even drug delivery systems due to its remarkable capacity to accelerate wound healing. People think a single molecule of collagen measures approximately 2800 in length, carries a molecular weight of about 300 kDa, and has a diameter of about 1415 . Up till now, the researchers have identified 28 various types of collagen (Felician *et al*. 2018).Collagen, being a versatile protein with the high amount of water it can hold, biocompatibility strong, low immunogenicity biodegradable, porous structurally easy to process, able to pass lipid-free interfaces naturally able to blend with other materials like synthetic polymers related to few ethical and religious issues and having potential for large scale extraction. This set of properties makes collagen one of the main proteins essential in the biomedical pharmaceutical cosmetic and food sectors (Tylingo *et al*. 2016). The collagen obtained from mammals is largely used in transdermal and gene delivery systems as well as in the drug delivery methods such as protein-delivery mini pellets and tablets. Also, collagen-based wound sponges and cell culture system foundational matrices are employed (Subhan *et al*. 2015. It also plays a role in tissue engineering including skin replacement bone replacements and artificial blood vessels and valves. Fish collagen is seen as an ingredient that could be used broadly in food technology. As the use of fish collagen in the food sector increases it is a reflection of consumers preference for sustainability and natural food. And, its distinctive property of being a good emulsifier and gelling agent can be used to enhance the quality and taste of processed foods. Besides this, the health benefit of fish collagen - promoting joint as well as skin health - makes it even more desirable for health-conscious individuals (Smith *et al*. 2023. Fish processing waste can also be used by the fishing industry to produce inexpensive collagen. While only 25% of total fish weight is used by processing industries, the remaining 75% is discarded as waste (Srikanya *et al*. in 2017). Collagen-rich wastes such as skin bones and scales that make up about 30% of total fish waste can be converted into collagen. Apart from increasing the fish processing industry's profit, the resultant environmental benefits can also be a part of the solution for fish waste. Interestingly, the human body can utilize collagen derived from fish 15 times more efficiently than that from pigs and cows (Sripriya and Kumar 2015).

Current Update:
The global market for marine collagen powder is projected to increase from US$ 254.8 million in 2023 to US$ 401.4 million by 2033. It is forecasted that global sales of marine collagen powder will witness a compound annual growth rate (CAGR) of 4.6% over the next ten years (2023 to 2033). The benefits of marine collagen in comparison to terrestrial collagen are significant. Marine collagen is viewed as a reliable and attractive alternative to collagen sourced from land animals due to its low immunogenic potential, excellent biocompatibility, and reduced likelihood of transmitting diseases (Felician *et al*., 2018). The process of extracting collagen from marine invertebrates and vertebrates has become more popular, as it is more viable than sourcing it from terrestrial options. Collagen is typically sourced from marine invertebrates like cuttlefish, prawns, sea anemones, starfish, jellyfish, sea urchins, sponges, octopuses, mollusks, and squids (Salvatore *et al*., 2020). Furthermore, marine vertebrates, mainly fish and marine mammals such as whales, are also used to extract collagen (Felician *et al*., 2018). It is essential to recognize that numerous countries employ fish processing by-products for collagen extraction, thus meeting the growing demand for collagen while reducing environmental impact (Coelho *et al*., 2017).Studies recently showed a rising trend in the application of marine collagen in wound healing and tissue engineering fields. Collagen scaffolds of fish origin have not only proven to be highly biocompatible but they also encouraged cell growth, which is why such scaffolds are considered for use in skin regeneration and repair of cartilage (Diogo *et al*. 2021; Cruz *et al*. 2021). Technical progress in collagen extraction methods, such as enzyme-assisted and environmentally friendly extraction techniques, led to higher collagen recovery, better purity, and maintenance of the triple-helical collagen structure. These improvements have ramped up the potential of marine collagen for biomedical and pharmaceutical uses (Chen *et al*. 2022). Marine collagen is becoming a favorite of the public as a sustainable option over mammalian collagen due to its low immunogenicity, biodegradability, and environmentally leading sourcing from fish-processing by-products. The worldwide demand has gone up by leaps and bounds, Mostly in the nutraceutical and cosmetic sectors (Barzkar *et al*. 2023). Reports from scientists point at the successful deployment of marine collagen in regenerative medicine such as injectable hydrogels, modern wound dressings, and scaffolds for bone tissue engineering. Superior mechanical properties and enhanced bioactivities have led to a wider application of this material in clinical and biomedical research (Lin *et al*. 2024). Marine collagen has become a key biomaterial for 3D bioprinting and personalized medicine. 3D Marine collagen-based bioinks were effectively in the manufacture of biomimetic tissues and regenerative constructs, Because of this paving the way for new therapeutic applications (Zhang *et al*. 2025).

Structure of collagen
Collagen's setup is composed of different collagen types, namely I II III, V, and XI, which in concert form the collagen fibers. The core of a collagen molecule, its molecular architecture, comprises three intertwined chains. These three chains each contain about 1,000 amino acids sequenced in the -Gly-XY pattern. Proline is the third amino acid in the chain and really helps in connecting the three chains of the tropocollagen molecule. With proline, the other amino acid 4-hydroxyproline, found mainly in the X and Y positions, is also dependent on the presence of glycine in these chains. Collagen, Mainly type I, is widely considered the gold standard in tissue

engineering. (Table 1) displays information on the various collagen types and their tissue distributions (Zata *et al*. 2020). Being a complicated molecule, the picture of its structure has been changing as new findings are made. (Figure 1) illustrates that type IV collagen has a more flexible triple helix and it is limited to forming the basal membrane (D'souza *et al*. 2020). Collagen types VIII and X form hexagonal lattices while types XIII and XVII surround cell membranes.

They can be synthesized in two ways: by three identical chains (homotrimers) like collagen II III VII VIII X, etc. or by two or more different chains (heterotrimers) like collagen types I IV V VI IX-XI (Shigemura *et al*. 2011).

Collagen as Superior

Marine collagen is recognized as a safe and appealing substitute for land-based collagen because it triggers very little immune response, is highly compatible with the human body and carries a low risk of disease transmission (Felician *et al*. 2018).Also, the interest in marine invertebrates and vertebrates has increased because in many cases extracting collagen from these resources is much easier than from land ones. For example, collagen can be obtained from such various marine invertebrates as cuttlefish shrimp sea anemones starfish jellyfish, sea urchins sponges octopuses, mollusks, and squids.

II. TYPES OF COLLAGEN

Approximately 28 collagen types have been identified so far, made up of 46 different polypeptide chains.Each one has a distinctive triple helix structure, though there are differences in the length of the helix and the size and properties of the non-helical segments among various types (Miller, 1984).Type I collagen, which makes up 90 percent of collagen in the body, is the most abundant form and the one after that in order are types II and III.Type I collagen is widespread in nearly all connective tissues (Cheah, 1985).

Natural sources

Today, sourcing collagen from marine resources is regarded as the most secure way of obtaining the ingredient since nature has provided us with a wide supply of this raw material in the oceans. The notion that "life originated in the sea" underpins the willingness to accept this type of source. Whereas, collagen extraction from animal sources calls for a very complicated, costly and lengthy process. Besides, these sources give a smaller output of collagen with only 12 grams being produced per kilogram of raw material used (Perumal, 2013).

Marine origins

Collagen has been found in numerous marine organisms to date. The collagen obtained from marine sources is illustrated in (Table 2). A technical workflow for sourcing and producing soluble collagen is presented in (Figure 2). Marine collagen is extracted from a diverse array of both commercial and aquaculture fish species, along with non-fish species. This variety can be noted in the work of Han *et al*. (2021).

Additional sources

Other animal sources include chicken, kangaroo tails, rat tail tendons, duck feet, horse tendons, alligator bone and skin, bird feet, sheep (ovine source), frog skin, and occasionally even human skin (Wood *et al*. 2008). This is utilized because recombinant human collagen exhibits lower immunogenicity compared to collagen sourced from other animals. The pericardium of the adult horse is used for hernia repairs, skin and wound healing, and tendon reinforcement. Type I and type II collagen can be isolated from sources such as flexor tendons, articular cartilage, and equine skin. Types I, II, III, and V collagen, with type I being the most abundant, were obtained from the neck of chickens. Chicken feet are known to be an excellent source of collagen. Type IX can be found in the sternal cartilage of chicken embryos, along with types I, III, and IV sourced from the animal's muscle and epidermis, respectively. Additionally, type I collagen was extracted from the fallopian tube of a bullfrog (Wang *et al*. 2011), derived from the tissue of invertebrates.

General Properties

The yields and physicochemical properties of collagens extracted from marine organisms might vary given the extraction method. Actually, two of the frequently applied techniques for collagen extraction are pepsin-solubilized collagen (PSC) and acid-soluble collagen (ASC) (Chen *et al*. 2022). The ASC extraction method works by increasing the repulsion among tropocollagen molecules and disrupting the collagen helix crosslinks, So improving collagen extraction efficiency (Niu *et al*. 2016). PSC, usually referred to as atelocollagen, is the one treated with pepsin, which cleaves telopeptide regions and adjacent non-collagenous proteins, delivering a higher purity and lower antigenicity compared to ASC (at least that is what it is thought). Several researches have demonstrated that the application of pepsin and acids simultanously with enzymatic treatment can increase the collagen yield during extraction (Hadfi and Sarbon, 2019).

Structural Characteristics

Although the two types of collagen, marine collagen and mammalian collagen, differ slightly, the latter is characterized by a few cross-linking superstructures and amino acid compositions. The differences have a significant impact on the utility of marine collagen in the field of tissue engineering and regenerative medicine because the main features of it, such as cell attachment, cell growth, and extracellular matrix formation, are altered. The small structural variations affecting the cross-linking pattern and amino acid composition of marine collagen were recently explained by Smith *et al*. (2023).

Biological Activity

Marine collagen is prized for its distinct biologically active properties, including antioxidant and anti-inflammatory effects. The latest study by Chen and Li (2023) showed the possibility of marine collagen in facilitating wound healing by associating its bioactive peptides with lower inflammation and better wound recovery. These results open up new opportunities for the development of high-tech skin care products and wound dressings.

Extraction Techniques

Enzymatic and chemical hydrolysis are two approaches for extracting collagen. While enzymatic methods are considered to retain more nutrients, the chemical extraction process has gained popularity recently, making it important to explore alternative methods for collagen extraction (Sakib *et al*. 2021). Although enzymatic extraction is more expensive, it is also faster and produces less waste. The chemical method, which may vary in approach based on the source of the raw material, typically involves acidic or basic treatments for collagen extraction. To improve yields and remove non-collagenous materials, pretreatment methods can be utilized (Schmidt *et al*., 2016). Due to its solubility in neutral saline, acidic solutions, and acidic solutions supplemented with enzymes, these methods are the most common for collagen extraction (Schmidt *et al*., 2016). Various techniques can be utilized for the extraction of collagen.

Pre-treatment

Collagen that is a big part of animal connective tissues naturally have a very slow rate of degradation. This occurs even in the presence of hot water, as the collagen is cross-linked which hinders degradation. Schrieber and Gareis (2007) observed that a mild chemical treatment is required to open those cross-links for extraction. Later on, the partially hydrolyzed collagen was mixed with alkalis and diluted acids which helped keep the collagen strands intact while also opening the cross-links effectively. The acid treatment involves removing the acid-soluble components from the waste materials to reach the desired collagen. At the same time, when the solution at a certain temperature is applied, the skin expands to many folds of its size and non-covalent intramolecular linkages get broken. Fernandes de Almeida *et al*. (2012) have also stated that, for pretreatment, potassium hydroxide and sodium hydroxide are mostly used but the acid method is much more effective if you have less intensely packed collagen fiber containing raw materials such as fish skins and pig skins, while some are also hardly accessible for enzymatic hydrolysis. Sodium hydroxide and calcium hydroxide are mainly used in pretreatment. Yet, sodium hydroxide is more suitable as a pretreatment agent for skins as it greatly promotes swelling, which is a critical step in collagen extraction because it enables the mass transfer process within the tissue matrix (Liu *et al*. 2015).

Chemical hydrolysis

Acid hydrolysis is a process that can be used with both inorganic acids like hydrochloric acid and organic acids like citric, lactic, and acetic acids. Comparative evidence points to that organic acids may have a higher efficiency than inorganic ones

(Liu *et al*. 2015). Collagen is a plentiful protein during extraction, and it was shown that organic acids are very efficient in dissolving collagen cross-links and breaking interstrand cross-links. That's why, acetic acid is commonly employed in collagen extraction from acid solution. If acid-soluble collagen is the target product, the preparatory materials should be immersed in acetic acid with a concentration of 0-5 M. According to the source of raw material, the mixture would need to be stirred continuously at 4C for 24 to 72 hours (Liu *et al*. 2015). Following that, the derived collagen should be separated via filtration from the liquid supernatant that contains it. For precipitating the filtrate, sodium chloride is the main chemical used. After the extraction of collagen, one more filtration is necessary to pick up the supernatant in its liquid state. Collagen powder can be produced by finally precipitating the filtrate by using sodium chloride. The precipitate after being obtained by centrifugation, can be dissolved again in a small amount of 0.5M acetic acid, dialyzed in 0.1M acetic acid for 48 hours, and then distilled water is used for two days, with the solution being changed roughly every 12 hours (Schmidt *et al*. 2016).Acetic acid alone is not able to disrupt collagen because of the presence of very strong intermolecular covalent bonds in the telopeptide regions of its triple helix structure. Collagen solubility and the elimination of non-helical conformations are greatly enhanced when enzymes such as fish pepsin, mammalian trypsin papain alkaline protease, bromelain, and collagenase are used. Among these enzymes, pepsin has the largest share in marine collagen extraction (Ehrlich *et al*. 2010; Silva *et al*. 2014). Whole isolated collagen retains its triple helix structure, most A lot, type I collagen, which has an identical shape and amino acid composition. Each extracted molecule has the triple helix structure, amino acid profile, and appearance that correspond to type I collagen. The chemical characterisation reveals certain less compelling features such as the lack of specificity, the level of control over hydrolysis, minimal activity levels, and low salt concentrations in the resulting hydrolysate, In particular when compared with the spectral analysis of enzymatic assays.

Collagen acid extraction

Collagen acid extraction has been done as per the method of Hwang *et al*. (2007) with minor changes. Firstly, fish skin was cut to pieces. Then, in a very cold place (3-5C), 10 g of this material were weighed, blended with 10 volumes of 0.1 M NaOH, and mixed thoroughly for 24 h. When the liquid was thrown away, the residue was washed 3 times using distilled water. Then, the residue was mixed very well with 10 volumes of 0.5 M acetic acid overnight. After that, the extract was spun for 20 min at 10C at 10,000 speed. After the supernatant was dialyzed against distilled water for two days in the cold room, collagen extract was quantified, and the frozen collagen was called either wet weight or freeze-dried skin.

III. APPLICATION MARINE COLLAGEN

Additives of collagen

Collagen acid extraction was done based on the method of Hwang *et al*. (2007) with a few changes. The fish skin was cut into small pieces. In a chilled room (3-5C), 10 g of the material were weighed, then mixed with 10 times the volume of 0.1 M NaOH and agitated for 24 hours. After discarding the liquid, the rest of the residue was washed with distilled water three times. The washed residue was then stirred overnight with ten times volume of 0.5 M acetic acid. Next, the extract was centrifuged for 20 minutes at 10C and 10,000 speed. The supernatant was dialyzed against distilled water for two days in a cold room. Finally, the collagen extract was quantified, and the frozen collagen obtained is known as the wet weight or freeze-dried skin.

Wound healing

Collagen is an essential component of the dermis, making up about 70-80% of the skin, and it may play a very important role in the recovery of skin wounds. It acts as an extracellular matrix, providing a perfect environment for fibroblast cells to multiply and help in the healing process (Velnar *et al*. 2009). Collagen is necessary for wound healing in all stages from hemostasis and inflammation to proliferation and remodeling. New research points out the benefits of fish collagen Mainly in regard to wound healing. Fish collagen membranes, because of their porous and interconnected structure, ability to accommodate a high-density cell seeding, capability of facilitating the flux of nutrients and oxygen through the membrane, excellent biostability, and less immune response compared to other naturally sourced biomaterials, have a great potential for clinical applications (Chandika, 2015). Fish collagen has been identified by Pal *et al*. (2016) as a potential skin replacement for wound repair, which correlated with full thickness wounds. Collagen sponge not only induces the growth and proliferation of fibroblast and keratinocyte cells but also A lot enhances them. Collagen sponges, as Pal *et al*. (2016), could quicken the wound healing process in rat models.

Powder
Once collagen powder is ingested, absorption begins immediately, even before it reaches digestive system organs like the stomach and intestines. This way is much more effective. Besides being convenient, collagen powders can be added to coffee, water, or other drinks for simple consumption. Oral collagen intake also Quite a bit enhanced skin's elasticity, moisture, and collagen level, based on research (Choi *et al*. 2019).

Tablets
Collagen tablets have a lower concentration of hydrolyzed collagen compared to liquid and powder formats. Additionally, they require a longer time to break down and be absorbed in comparison to other types (Musayeva *et al*., 2022).

Cosmetics
Collagen is one of the main factors in the formulations of the beauty products that enhance skin moisture and skin aging fight. It can be used on lips, mucous membranes, and hair. One way to alter the collagen films for cosmetics use is by cross-linking collagens and merging with other proteins and polysaccharides. The recent studies detail increasing the denaturation temperature of the fish origin collagens for cosmetic applications. Collagen's influence on psychological and social health reveal its potential as a rejuvenating treatment for the elderly. Among various sources, marine collagen is a top choice as everyone knows by consumers. One way to source marine collagen sustainably is a fishery by-products and aquaculture, adherence to regulatory requirements, and application of efficient eco-friendly ways (Coelho *et al*. 2017). The collagen obtained from skins of salmon and codfish finds use as the main active ingredient in cosmetics. Actually, it has also been proved that the application of this component resulted in the effective retention of moisture, Because of this making it a good candidate for a hydrating agent. Besides, irritation and inflammation markers together with topical collagen exposure in the human dermis reconstruction did not reveal collagen-related skin reactions. So, fish skin collagen could be the source of eco-friendly and cost-effective cosmeceuticals development (Alves *et al*. 2017).

Food industry
Marine collagen protein (MCP) is one of the most commonly used food ingredients in the Asia Pacific region for a long time. Kumar *et al*. (2019) explained that MCP is a protein that can be further developed and manufactured as a dietary supplement. The addition of MCP apparently led to a significant decrease in the gelatinization viscosity and water-holding capacity, both the changes reflect its potential. MCP biscuits had antioxidant properties and at the same time contained fewer calories as per the authors. Collagen peptide cookies with improved nutrition were preferred during the sensory evaluation and could be a good product for geriatric nutrition (Kumar *et al*. 2019).

Pharmaceutical
Collagen is utilized in the pharmaceutical sector for purposes such as drug delivery, injectable dispersions, ophthalmological sponge shields, and microparticles. This substance is frequently used in the pharmaceutical and biomedical fields because of its low antigenicity, ability to facilitate cell attachment, biodegradability, and biocompatibility (Leitinger and Hohenester, 2007).

Tissue Engineering
Collagen type I is known for its outstanding biocompatibility and recognized as the most effective material for tissue engineering. The cell culture systems rely on this particular matrix. Collagen-based injectable matrices and scaffolds, which are commonly used for bone regeneration, are regularly employed in tissue engineering. These biomaterials mainly consist of collagen fibrils, i.e. types I II III, V, and XI. Due to its exceptional biocompatibility, collagen is an ideal material for tissue engineering, accompanied by other features like low

immunogenicity, high biodegradability, excellent mechanical properties, hemostatic ability, and strong cell adhesion (Dong and Lv, 2016). Nowadays, fish collagen scaffolds receiving more attention due to Truth is they can be easily obtained from fish skin wastes and bones, and they are highly biocompatible, which tends to reduce the risks tied to bovine collagen. A number of works have already explored the use of fish collagen scaffolds for tissue engineering purposes, which have led to promising results in the regenerative medicine area (Yamada *et al*. 2014).

Metabolism and Mechanism of Action

Due to its ability to stop bleeding, it is employed as a hemostatic agent or one of the coagulant components. Several medical uses of animal-derived natural collagen are known, while some drawbacks of animal-derived collagen include the potential for inflammation, heterogeneity between donors, and concerns for disease communicability. In the efforts to lower immune responses, some synthetic nanomaterials with similar features are engineered. That means, KODTM collagen was launched. KOD collagen as well as its blood-thinning elements can facilitate platelet activation and adhesion. It also interacts with the platelets that participate in clot formation, activates them, initiates the repair process, and reduces inflammation (Kumar *et al*. 2014).

Absorption, distribution, metabolization, and elimination

Research has shown that the initial effect observed after collagen hydrolysis is antioxidant activity, while the subsequent effect is biological activity (Tanaka *et al*., 2009). Studies indicate that collagen hydrolysates can be found in the portal vein and bloodstream after oral intake, with peptides being absorbed from the intestine as larger peptides in vivo. Some investigations suggest that peptides derived from collagen hydrolysis are absorbed from the gut after oral administration and can reach various tissues through systemic distribution. Several studies have been conducted on the absorption of compounds derived from collagen with respect to their structure. Due to its significantly lower average molecular weight compared to standard collagen peptides, collagen tripeptide has been shown to be readily absorbed into the bloodstream and transported to various tissues. The results of the study indicate that using collagen in the form of tripeptides enhances the absorption of functional peptides (Yamamoto *et al*., 2015).

IV. DISCUSSION

Marine collagen extracted from fish skin scales bones, and other marine by-products is becoming a hot topic because of its superior characteristics Biological compatibility, biodegradability, and low immunogenicity with a lower risk of disease transmission against mammalian collagen have made marine collagen a very appealing choice (Barzkar *et al*. 2023). With the evolution of extraction techniques including enzyme-assisted and green methods, collagen production has been enhanced while maintaining its biological function, thereby making it more suitable for biomedical uses. Scaffolds and hydrogels bases on marine collagen that are used marine collagen has been successfully applied in tissue engineering, wound healing, and cartilage regeneration as it promotes cell growth and extracellular matrix development (Diogo *et al*. 2021). Besides, the bioactive peptides produced from collagen have the ability to act as antioxidants and anti-inflammatory agents which helps in the quicker repair of tissues and maintenance of skin health. Clinical trials have also shown positive results in skin moisture, elasticity, and reduction of wrinkles by using oral marine collagen supplements (Han *et al*. 2021). Marine collagen continues to be an important element in regenerative medicine as shown by recent publications. For examples, advanced wound dressings, injectable hydrogels, and bone tissue engineering scaffolds having superior mechanical strength and biocompatibility were reported to be developed by marine collagen (Lin *et al*. 2024). By 2025, marine collagen will be widely recognized as a bioink for 3D bioprinting applications, thereby facilitating the production of biomimetic tissues and personalized regenerative constructs, the latter being a step towards clinical use (Zhang *et al*. 2025). There are still some disadvantages like the poor thermal resistance and the differences from one marine source to another. In total, the marine collagen is gaining momentum as a sustainable and valuable biomaterial with tremendous capabilities in the sectors of regenerative medicine pharmaceutical ,nutraceutical, and cosmetics industries.

V. CONCLUSION

Marine collagen and its different forms are considered to be sustainable bioproducts with a vast potential, in particular health related uses. This article mainly remodeled the versatility and sustainability of marine collagen, highlighting its fundamental impact on the future of healthcare innovations. Marine collagen is mainly derived from fish scales, skins and other products obtained from fish processing. Besides being highly compatible with the body it is also easily absorbed. Its low allergenic characteristics and structural similarity to human collagen make it an extraordinary resource in the fields of tissue engineering, regenerative medicine and wound healing. This is an attractive option for those who wish to go natural and sustainable for enhancing their beauty and general health. The significance of sustainability of marine collagen should definitely be a primary concern since it is not only a matter of protecting the environment but also about ethical sourcing and following the worldwide movement towards green practices. Marine collagen and its derivatives medical application is quite wide and in fact they constitute the backbone of the regenerative medicine pharmaceuticals cosmetics and skincare due to their versatility, bioclimatic and sustainability. With our understanding of marine collagen increasing and new researches coming about, there is a great potential for innovative medical applications. However, responsible sourcing of marine collagen supports the fishing industry's efforts to reduce waste and promote environmentally friendly practices. The introduction of marine collagen in healthcare can bring about a model shift offering long-lasting and efficacious solutions to a wide array of health issues.

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