

Aquaculture Extracted Collagen Hydrolysate: Applications and Beneficial Effects

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Abstract

Aquaculture-extracted collagen hydrolysates gained lots of attention owing to their utility and positive impact in different categories ranging from nutritional to cosmetic usage. Sourced from the by-products of fish, these hydrolysates can be used as a renewable source of collagen, containing a host of collagen-derived bioactive peptides possessing healthful benefits. In the nutraceutical industry, they are well-known for improving joint support, skin flexibility, and bone density. These hydrolyzed peptides have been shown to promote cartilage repair, and increase skin moisture, skin tone, and wrinkle recovery so it is effective as active ingredients in cosmetic formulations. Collagen synthesis within the body is supported well by glycine, proline, and hydroxyproline. Besides, cosmetic and therapeutic effects, they improve the integrity of the intestinal barrier and promote the healing of the gut lining. It also plays an important role in improving cardiovascular health and building muscle mass. When the world continues to demand marine-related products, they offer an environmentally friendly and potent source of collagen compared to other forms with residual negative impacts on the health of human beings and the environment.

Keywords: Collagen-Hydrolysate, Aquaculture-derived collagen, Aquaculture by-products, Fish processing waste, Bioplastic production

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Introduction

Population growth has also led to a rise in demand for food production hence increased use of natural resources and in return production of organic wastes. The sharp increase in the food share which is consumed targets fish products. Over the last decades herring products have been considered as the priority in eating habits and facing a healthy diet (Coppola et al., 2021). Fish consumption remains the principal driver of production, world food fish consumption surged at an average annual growth rate of 3.1% between 1961 and 2017 as estimated by FAO. Compared to other animal protein foods (meat, pork, poultry, dairy) the annual consumption rate is at 2.1% per year. These increases in fish food production produce more waste. Fish is a very fragile food chain global weight of fish waste is said to be 9.1 million tons. The fish processing waste consists mainly of fins, skin, head, and viscera since the by-products are eliminated for the increasing of fish quality and nutritional value of fish, as well as to minimize contamination. Another rather obvious characteristic of fish processing waste is that its cost is high, it makes up 36% of the total weight. This weight percentage is considered as a possible source of other added by-products: proteins, amino-acids, collagen and many other valuable substances found in them (Bourdon et al., 2021). Extraction of ingredients has proved to be beneficial in fishery industry area (Jamil et al., 2024). For instance, fish such as omega 3 found on the fish head and viscera, and collagen which is obtained from fish skin, bone, cartilage as well as the scales. Collagen hydrolysate obtained from aquaculture sources has gained considerable attention for its several beneficial uses. It has the highest added value and significant development potential because the production cost of this product is relatively low and has multiple functions cosmetics and food industry (Correa et al., 2022). It is made up of three alpha polypeptide chains of more than one thousand amino acids linked in one triple helix structure for several uses in various fields. Aquaculture collagen has more advantages than the mammalian obtained collagen, such as pigs and cattle, due to some religious beliefs, immunogenic, or inflammatory sickness that can be transferred from the terrestrial animals (Ahmed et al., 2020). Collagen hydrolysates is extracted from seafood wastes such as fish skin, scales, and bones and has shown to be a useful component in a variety of different industries. The processing of seafood wastes can be environmentally friendly option which reduce the marine pollution. Collagens are proteins that have antioxidative and anti-hypersensitive properties that are effective against cancer, aging, cardiovascular diseases, diabetes and strengthen the connective tissues and it accounts for around 30% of the total protein (Jafari et al., 2020). The collagens is necessary for wound healing and tissue regeneration. Its widespread utilization is due to its exceptional bioavailability, sustainability, and the numerous benefits it provides to human health and well-being (Dai et al., 2013).

3. Sources of Aquaculture Extracted Collagen

Aquatic organisms are the source of collagen. Aquaculture collagen is derived from a wide range of fish species, as well as non-fish species (Han et al., 2021). Most common sources are ray-finned fishes and Chondrichthyes.

4. Extraction of Aquaculture Collagen

Extraction of collagen from aquaculture organisms with different methods and under different conditions involves different yields as well as physiochemical characteristic of the extracted collagen. Two techniques reported are acid soluble collagen (ASC) extraction and pepsin soluble collagen (PSC) extraction (Diogo et al., 2020). The reaction of acid -collagen used in ASC extraction ensures it extracts the collagen more effectively due the disruption of the crosslinks on the collagen helix chain and enhanced repulsion of tropo-collagen molecules (Niu et al., 2016). Though ASC is the most commonly used dermal filler, PSC which is also called as telo-collagen is free from antigens because of pepsin treatment, which eliminates telopeptide regions and other proteins which are not collagen (Kim et al., 2013). Papain in collaboration with the acids enhances extract yield of collagen (Niu et al., 2016). Extraction process of collagen from aquaculture sources is shown in Figure 1 (Venkatesan et al., 2017).

5. Aquaculture Collagen Hydrolysate

The hydrolyzed collagen is effective in nutrition, food, industry and medicine due to its biological activities (Ahmed et al., 2020). Also, that hydrolysate may be effective in the treatment of diabetes mellitus, hypertension, gastric ulceration, osteoporosis, skin moisture, and preservatives (Barzkar & Sohail, 2020). Collagen is gradually being included in drugs, foods, beverages, cosmetics, tissue engineering and health care products because of its diverse use across so many industrial outlets (Carvalho et al., 2020). This is the reason why collagen has application in medical and pharmacological industries due to its unique physiological characteristics such as, hemostatic ability, biodegradable, and have low in the reaction to antigens (Gilan et al., 2016).

5.1. Nutritional Benefits

Aquaculture collagen hydrolysates have garnered considerable interest because of their nutritional advantages. These peptides derived from hydrolysates of collagen in fish skins, bones and other waste materials are well absorbed and have many health benefits (Barzideh et al., 2013). Collagen hydrolysate contains a high amount of other essential amino acid including glycine, proline and hydroxyproline. These amino acids needed for skin elasticity and connective tissue, joints, and tissue repair (Liu et al., 2009). Collagen hydrolysate is also uniquely characterized by its comparatively low solubility, which is adjusted for those whose diet is intended to be enriched with natural products without using artificial additives. Compared to other products this form of protein is highly bioavailable for easy absorption into the body as well as stimulating the production of native collagen (Bilek & Bayram, 2015). Daily use may help improve skin's moisture and elasticity, thus promoting healthy skin ageing as it helps to replenish collagen that reduces with age. Also, its function in addressing tissue injury points to its value in the body structure, for sedentary as well as physically active persons, regardless of age (Santos et al., 2012).

Another advantage is that fish collagen hydrolysates might help in the management of congestive heart failure, as well as, enhance blood circulation and elasticity. It can be particularly helpful in avoiding the process of arterial wall becoming rigid as one age. The amino acids in collagen are beneficial in muscle mass maintenance especially during the old age and therefore makes it a good supplement to take (Liu et al., 2009).

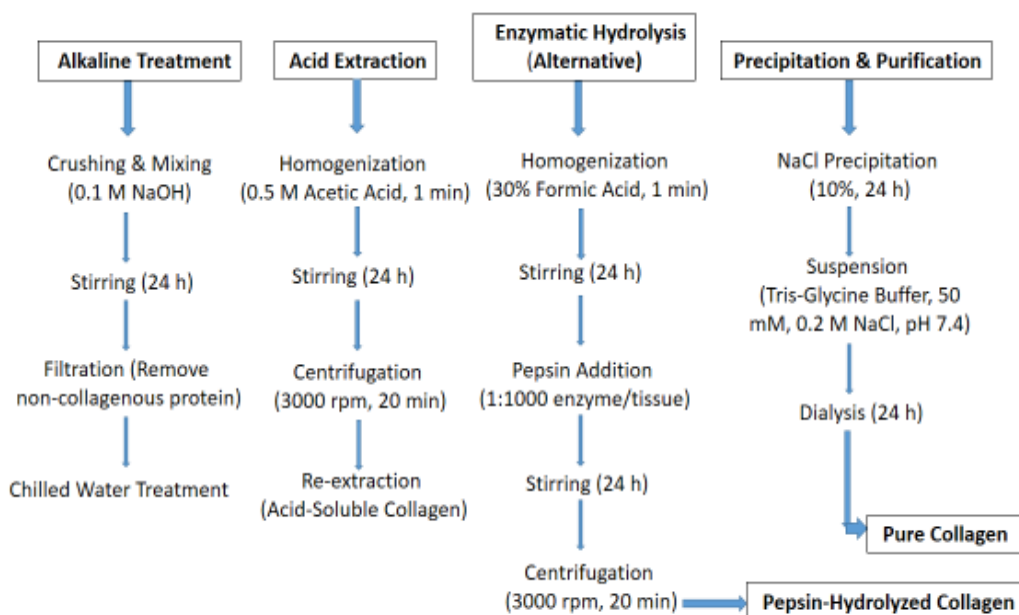


Fig. 1: Flow diagram of collagen extraction from aquaculture sources

5.2. Medical Applications

Collagen hydrolysate extracted from aquaculture is medically important with high bioactivity which makes them potential in wound healing, increase joint space and skin remodeling. Thus, Collagen an organic fibrous structure protein is irreplaceable in skin treatment and osteoarthritis, as it is needed as a cell repair and regeneration element. The hydrolyzed form of collagen particularly the fish origin has enhanced bioavailability than the bovine or porcine collagen because of the molecular size. collagen hydrolysates are also used in formulation of topical

cream and wound healing dressing (Kim et al., 2013). They help in the reproduction of skin tissues, inhibit the development of scars and facilitate quicker healing of wounds, severe burns and sores. This is especially necessary for treating chronic ulcers where the normal body healing mechanism may be somehow compromised collagen supplementation has been used to enhance skin flexibility, moisture, and erase fine lines making it an ingredient in products meant for erasing aging signs collagen hydrolysate is beneficial in the reduction of joint pain, increased joint flexibility, and the building of overall cartilage structure (Liu et al. 2018). It is also useful in the management of wounds due to its ability of regeneration of the tissue. Some works indicate that collagen has chondrogenic properties that can promote the synthesis of collagen in cartilage, helpful for osteoarthritic patients, for example Parasuraman et al mentioned that collagen extracted from aquaculture sources has been shown to possess good potential as functional ingredients for nutraceuticals and health foods due to its proprieties extracted simply and cheaply. The use of fibroblast proliferation and improvement of the extracellular matrix, support its role in tissue repair. Also, its biocompatibility makes it a viable candidate for biomedical applications such as biomaterials and sophisticated medical devices including bioengineered scaffolds and dressings (Brunt & Burgess, 2017).

5.2.1. Beneficial role of Collagen Hydrolysate in gut Health

Collagen hydrolysate which originates from aquaculture by-products is then needed in order to promote gut health. These components include Glycine, proline and hydroxyproline and these peptides help in maintaining the integrity of intestinal barrier and decrease inflammation (Hadfi & Sarbon, 2019). Collagen peptides improve the balance of gut microbiota, which means improving the overall state of the digestive system (Liu et al. 2018). Collagen hydrolysate has been seen to have anti-inflammatory effect on the gastrointestinal conditions. Mucosal healing and repair of injured intestinal tissues also add on therapeutic property of the compound (Bilek & Bayram, 2015). Another advantage of taking collagen hydrolysate supplement is that it helps maintain nutrient intake through the integrity of gut. The minors improve the health of metabolism and prevent chronic diseases such as obesity, diabetes and cardiovascular disease resulting from gut dysbiosis (Xu et al., 2021).

5.2.2. Role in Skincare

Collagens are highly popular in industries such as cosmetics, pharmaceuticals and medicine, due to its high biocompatibility, biodegradability, non-toxicity, and moisture retaining ability. Since the cosmetic industry is highly competitive and constantly searching for new and efficient products, the source of collagen is emerging topic in research. Aquaculture collagen has its prospect to young from about 70 years ago while doing research in marine sponges. The work has advanced the understanding of structural and physicochemical properties of collagen derived from the aquatic environment (Hu et al., 2021). Skin is a body tissue that primarily consists of collagen, type I, III and V. The most abundant subclass of collagen in the skin is type I. It has been reported that this type of collagen is essentially the same with aquaculture collagen (Xu et al., 2021). Aquaculture collagen is the most sought-after collagen source in the beauty industry of cosmetics and cosmetic products. Research on collagen obtained from fish skin such as tilapia skin revealed that the characteristics of collagen are commonly associated to type I collagen, in addition to ASC and PSC. The dissociation temperature of ASC is 36.1°C and the dissociation temperature of PSC is 34.4°C. Furthermore, ASC derived from skin of silver carp includes type I collagen (Hadfi & Sarbon, 2019).

Cosmetic products containing collagen meet various needs of people have concerning their skin, including lines, skin laxity and diminished elasticity. Collagen based products supports the major skin benefits with positive changes in skin elasticity and skin dryness. These inputs are backed by the development of new methods in the field of peptide technology that work to increase the loading of collagen in skin therapeutic formulations and topical applications for complete dermal rehabilitation (Dhatchayani et al., 2020). Natural immature collagen is required for cosmetic and biomedical products. although, fish collagen is relatively characterized by low-temperature gel, there is drawback in using heat-water and oil for emulsion. Aquaculture based collagen is utilized in numerous cosmetic products since, it can form an emulsion at high temperature, but has all the moisturizing factor of collagen (Das et al., 2021).

5.3. Application in Food and Beverages Industries

The application of collagen hydrolysate in food and beverages is one of its strengths. The use of collagen in enhancing raw material for meat, supplying animal protein, utilizing eco-friendly processes, and high biological qualities (Bourdon et al., 2021). Currently, collagen-based meat products with various effects on the digestive process are being produced. Collagen's ability to bind many toxins is useful while using collagen raw materials for deep processing with target component separation, theoretical and efficient solutions are still lacking. The most significant issue within the food industry is not only to feed all segments affordably but to ensure that these products have the greatest number of functionalities possible. In this regard, functional foods should be capable of capturing and/or blocking noxious environmental influences on the human body by entrapment and subsequent discharge of same. The most powerful adverse factor is the heavy metal ions and radionuclides factor the most aggressive negative factor (Ferrario et al., 2020).

Low impact proteins characterize many functional foods made for health conscious population and this extract is useful in foods created for this market for its protein and health improving content. Muscle recovery is one of the most important aspects that athletes and people who work out regularly understand this. Preferably, overt packaging for drinks, fortified protein bars and dietary supplements containing collagen peptides have become popular as they provide an easy way to enhance joint, skin and overall body health (Li et al., 2019).

5.4. Role in Drug Delivery Industry

Due to its biocompatibility and biodegradability, collagen hydrolysate extracted from aquaculture has a vast prospect in drug delivery systems as well as stimuli-sensitive hydrogels for encapsulation of multitudinous bioactive bourgeons. As a biopolymer the collagen can interact with cell membranes and influence the porosity and uptake of drugs by the cell. Because collagen mimics the ECM, it is possible to produce sophisticated drug delivery systems for controlled release with emphasis in therapy agents that address wound healing, cancer, and tissue

engineering (Bourdon et al., 2021).

The advantage of collagen hydrolysate application in drugs is its capacity to form stable hydro-gel structures. Such structures can be used to load hydrophilic and lipophilic drugs within the nanoparticles and provide stability and a sustained release characteristic for an adequate time duration. For example, collagen-based hydrogels have been used in the delivery of proteins, peptides and small molecules herein, thereby lowering the dosage and side effects. Such targeted drug delivery is most useful in oncological treatments where collagen-based systems have been depicted to enhance the concentration of the cancer therapies at the affected sites (Hu et al., 2021).

Furthermore, since collagen provides support to cells through cell signaling, its application in regenerative medicine is vital because it also encourages drug delivery for tissue repair and regeneration. Collagen hydrolysates while used in combination with growth factors or stem cells enhance tissue repair at the site of injury and can be an effective therapeutic solution in chronic ulcers, burns, and degenerative diseases (Ahmed et al., 2020). The ability they offer in managing drug release characteristics is also useful in diseases where the body requires consistent and accurate doses of drugs such as diabetes or rheumatoid arthritis. Therefore, collagen hydrolysate derived from aquaculture is a nutrient prospective into modern medicine innovative drug delivery systems with diverse therapeutic applications (Coppola et al., 2020). In the current world, new studies carried revealed opportunity of collagen-based hydrogels for anticancer drug delivery for tumor mass.

6. Environmental Significance of Aquaculture Collagen Hydrolysate

Fish processing waste such as skin, scales, bones and others contribute high amount of waste production in aquaculture sector. These residues if not well managed are not Eco friendly, causing pollution of soil, water, and emissions of greenhouse gases from decomposition of wastes stored in the landfill (Barzkar, 2020). However, getting collagen hydrolysate from these by-products is an environmentally friendly process because it makes optimum use of waste products instead of adding to environmental degradation. The extraction of collagen is one crucial way in a circular bioeconomy system since fish muscle waste products are used to generate valuable products. This approach is consistent with the global sustainability practices like the United Nations Sustainable Development Goals (UNSDGs) for example the UNSDGs 12 which focus on Sustainable Consumption and Production (Kim et al., 2013). Various industries which are involved in producing aquaculture by-products can benefit from reusing such products to lower waste, and to promote some measures of nature preservation.

Usually, the process of reconditioned collagen hydrolysate involves preliminary purification of impurities, and enzymatic hydrolysis, which decomposes collagen into peptides with beneficial characteristics. There are also advances ultrafiltration, freeze-drying and other enzymatic techniques advanced the method of collagen extraction as well as the recuperation yields accompanied by the functional proficiency of the product (Caruso et al., 2020). These methods lower the dependency on dangerous chemicals typically applied in the extraction of collagen, which can be disastrous to the environment. Besides that, collagen extraction also has the economic effects among the environmental issues. Through the production of collagen hydrolysate there are fresh income sources identified from the aquaculture operations due to availability of raw materials in pharmaceuticals and cosmetic industries (Coppola et al., 2020).

7. Advances in Collagen Hydrolysate-based Bioplastics

As consumers' awareness of the need to use environment friendly products rather than plastics increases, there has been an increase in the search for bioplastic production from collagen hydrolysate. A good source of biodegradable films and coatings, collagen peptides are derived from aquaculture by products (Bourdon et al., 2021). Such bioplastics possess considerable mechanical properties; elasticity and permeability to water vapor the minimum requirement for many applications. Fused bioactive peptides and bioplastics increases its antimicrobial and antioxidant capacity for protecting food products once used as packaging materials (Xu et al., 2021). In addition, collagen bioplastic is biodegradable hence lowers environmental pollution unlike the plastics derived from petroleum. Advanced fabrication methods like electrospinning and crosslinking enhance the thermal stability and degradation property of collagen derived bioplastics for use across various sectors like health and farming (Li et al., 2019). This progress also lends strong support for using aquaculture-derived collagen hydrolysate to support such developments.

Conclusion

With aquaculture sources, collagen hydrolysate exhibits the best interface of sustainability and creativity. The versatility of the sun depicting its Health applications, Cosmetics and Environmental Conservation makes it an important tool for change. Because this compound makes use of by-products and fosters circular economies, it effectively solves essential problems in waste management while supplying substantial value to industries of all types. Further development and investigation will surely extend the potential uses of resulting in improvements in medicine, skincare, and much more. Collagen hydrolysate incorporation into multiple segments like production of bioplastics is evidence of a progressive concept toward sustainable utilization of resources.

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