

Fish Collagen from Indian Major Carps: A Potential Biomaterial for Biomedical Research and Applications

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Abstract-- Collagen is one of the most important proteins in the extracellular matrix and has many uses in biomedical and tissue-engineering applications. Collagen is commonly obtained from bovine and porcine sources, but problems related to disease transmission, religious and ethical concerns, and environmental sustainability have increased the need for alternative sources. Fish-processing waste, especially skin and scales, has attracted attention as a useful and sustainable source of collagen. Indian major carps, such as *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*, are widely cultured in India and produce large quantities of processing by-products. Previous studies have reported that collagen obtained from catla and rohu skin and scales is mainly type I collagen and shows suitable structural and functional properties. Catla skin produced $63.40 \pm 1.26\%$ acid-soluble collagen and $69.53 \pm 0.92\%$ pepsin-soluble collagen, whereas rohu skin produced $46.13 \pm 1.27\%$ and $64.94 \pm 2.70\%$, respectively. The denaturation temperature of skin collagen was reported between 30.69 and 35.19 °C, while collagen from scales showed a denaturation temperature of about 36.5 °C. Carp collagen also has the ability to form fibrils, which makes it useful for developing materials that resemble the natural extracellular matrix. These properties suggest its possible use in wound dressings, tissue-engineering scaffolds, drug delivery systems, and regenerative medicine. However, some limitations, including thermal stability, mechanical properties, purification, sterilization, consistency of production, and limited clinical studies, still need attention. This review focuses on the extraction, characterization, properties, applications, and limitations of collagen obtained from Indian major carps and discusses its potential as a sustainable source of biomaterial.

Keywords-- Fish collagen; Indian major carp; *Catla catla*; *Labeo rohita*; *Cirrhinus mrigala*; type I collagen; tissue engineering; wound healing; biomaterials.

I. INTRODUCTION

Collagen is the most abundant structural protein in vertebrates and is found in many tissues, including skin, bone, cartilage, tendons, and ligaments. Type I collagen is especially important because it provides strength, can naturally break down in the body, and can interact with cells. Because of these properties, it is widely used in wound healing, tissue engineering, drug delivery, and regenerative medicine [1,2].

Bovine and porcine tissues are the main traditional sources of commercial collagen. However, concerns about disease transmission, ethical considerations, and religious or cultural restrictions have led researchers to look for alternative sources [3–5]. Fish-processing by-products such as skin, scales, and bones contain a considerable amount of collagen. These materials can be used to obtain useful biomaterials and, at the same time, help reduce waste from fish processing. Indian major carps, including *Catla catla*, *Labeo rohita*, and *Cirrhinus mrigala*, are important freshwater fish that are widely cultured and consumed in India. Their processing produces large amounts of skin and scales, which are often not fully utilized. Studies on catla and rohu have shown that their skin and scales can provide mainly type I collagen with useful structural, thermal, and fibril-forming properties [6,7].

This review focuses on the extraction, characterization, physicochemical properties, biomedical applications, limitations, and future prospects of collagen obtained from Indian major carps.

II. MATERIALS AND METHODS

A narrative literature review was carried out using scientific articles available through PubMed and ScienceDirect. The search used terms such as “fish collagen,” “Indian major carp collagen,” “*Catla catla* collagen,” “*Labeo rohita* collagen,” “fish skin collagen,” “fish scale collagen,” “acid-soluble collagen,” “pepsin-soluble collagen,” and “fish collagen biomedical applications.” Studies related to collagen extraction, characterization, physicochemical properties, fibril formation, and biomedical uses were mainly considered, with particular attention given to research on Indian major carps.

Fish collagen is mainly obtained from skin and scales using acid or pepsin-based extraction methods. In general, the skin is washed, cleaned of fat, and treated with a dilute organic acid to release the collagen. Fish scales usually need an additional demineralization step before collagen extraction [7]. The extracted collagen is commonly studied using techniques such as SDS-PAGE, FTIR, circular dichroism, DSC, SEM, amino-acid analysis, and fibril-formation tests to determine its structure and properties.

III. RESULTS AND DISCUSSION

1 Collagen yield and structural characteristics

The skin and scales of Indian major carps are promising sources of collagen. Pal et al. reported acid-soluble collagen (ASC) yields of $63.40 \pm 1.26\%$ from catla skin and $46.13 \pm 1.27\%$ from rohu skin, while pepsin-soluble collagen (PSC) yields were higher at $69.53 \pm 0.92\%$ and $64.94 \pm 2.70\%$, respectively [6]. These results suggest that pepsin treatment can improve collagen recovery by helping to dissolve collagen that may not be easily extracted using acid alone. However, these yields are based on specific experimental conditions and may vary depending on factors such as tissue type, fish age, pretreatment method, acid concentration, extraction time, temperature, enzyme concentration, and purification process [3–5]. SDS-PAGE and other structural studies have shown that collagen obtained from carp skin and scales is mainly type I collagen [6,7]. Type I collagen consists of three protein chains arranged in a triple-helix structure, which is important for maintaining its biological and functional properties.

2 Thermal properties and fibril formation

Thermal stability is an important property of collagen for biomedical applications. Pal et al. reported denaturation temperatures of about $30.69\text{--}35.19\text{ }^{\circ}\text{C}$ for collagen obtained from catla and rohu skin [6], while Pati et al. reported a denaturation temperature of about $36.5\text{ }^{\circ}\text{C}$ for collagen extracted from catla and rohu scales [7]. Although scale collagen showed relatively better thermal stability, some fish collagens are still less stable at higher temperatures than collagen obtained from mammals. Carp skin collagen has also shown good fibril-forming ability. Under the conditions used by Pal et al., rohu collagen showed about 78% fibril formation, compared with about 36% for catla collagen [6]. The formation of fibrils was also confirmed by SEM analysis. This property is important for biomedical applications because collagen fibrils are similar to the structure of the natural extracellular matrix and may help in developing tissue-engineering scaffolds.

3 Biomedical potential

The biological properties of collagen make fish-derived collagen useful for different biomedical applications. Collagen can be prepared in the form of membranes, sponges, and hydrogels, which provide a suitable environment for cell attachment, movement, and tissue repair. A systematic review of animal studies found that fish collagen membranes can support wound healing by improving wound closure, new skin formation, and collagen deposition [8].

Collagen can also be used to prepare porous scaffolds, hydrogels, membranes, and three-dimensional structures for tissue engineering. Its ability to interact with cells makes it useful for cell culture and regenerative medicine. In drug delivery, collagen-based materials can help carry therapeutic compounds and support their controlled or localized release [4,9]. For collagen obtained from Indian major carps, the presence of type I collagen and its ability to form fibrils indicate good potential for developing biomaterials. However, most of the available research is still limited to laboratory and animal studies, and more clinical studies are needed to confirm its safety and effectiveness in humans.

4 Advantages and limitations

One of the main advantages of collagen from Indian major carps is that their skin and scales are readily available as by-products of fish processing. Using these materials to produce collagen can help reduce waste and create a valuable product, supporting the idea of a circular bioeconomy [4]. Fish collagen may also be a suitable alternative to porcine collagen in applications where religious or cultural concerns need to be considered. However, some challenges still need to be addressed. The relatively low denaturation temperature of certain fish collagens may limit their use at body temperature. In addition, pure collagen materials may have low mechanical strength and can degrade quickly. These limitations can be reduced by cross-linking collagen or combining it with materials such as chitosan, gelatin, alginate, hydroxyapatite, or biodegradable synthetic polymers [4,5]. The purity and consistency of the extracted collagen are also important for biomedical use. Proper processing is needed to remove fats, pigments, minerals, non-collagen proteins, microorganisms, and leftover chemicals from extraction. The sterilization method should also be carefully selected because it can affect the structure and strength of collagen. Further studies are needed to evaluate cytotoxicity, immune reactions, endotoxin contamination, degradation behavior, and long-term tissue responses before Indian major carp collagen can be widely used in biomedical applications.

IV. FUTURE PROSPECTS

Future research should focus on developing simple, standardized, and scalable methods for extracting and purifying collagen from Indian major carps. Studies comparing the skin, scales, and bones of *C. catla*, *L. rohita*, and *C. mrigala* could help identify differences in collagen yield, structure, thermal stability, fibril formation, and degradation.

The properties of carp collagen may be improved by using methods such as cross-linking, combining it with other polymers, adding minerals or nanoparticles, and using three-dimensional bioprinting [4,5]. More laboratory and animal studies are also needed to evaluate cell compatibility, inflammation, degradation, tissue repair, and overall safety. Before clinical use, researchers should also consider sterilization, storage, consistent quality between batches, large-scale production, regulatory requirements, and production costs.

V. CONCLUSION

Indian major carps, especially *Catla catla* and *Labeo rohita*, are promising sources of type I collagen. Their skin and scales can be used to produce collagen through acid, enzyme-based, and demineralization methods. Studies have reported good collagen yields, a typical type I structure, fibril-forming ability, and useful thermal properties. Carp collagen may be used in wound dressings, tissue-engineering scaffolds, drug delivery, and regenerative medicine. Using skin and scales that are normally discarded can also help reduce fish-processing waste and provide economic benefits. However, some challenges remain, including low thermal stability in some preparations, poor mechanical strength, variation in extraction methods, and the need for effective purification and sterilization. In addition, more clinical studies are needed to confirm its safety and effectiveness. Future research should focus on improving extraction methods, modifying collagen-based materials, conducting biological and preclinical studies, and developing reliable large-scale production methods.

Overall, collagen from Indian major carps has good potential as a sustainable biomaterial for future biomedical applications.

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