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Fish scales : Waste processing as a potential source of bioactive compounds

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ABSTRACT

The rise of fish processing over the years has led to an upsurge of by-products like fish scales, bones and skin which are often considered as trash and discarded. Study on two most common carp fish in Indian freshwater, *Catla catla and Labeo rohita* revealed some valuable by- products from nonedible fish scales such as type I collagen, gelatin, hydroxyapatite, chitin and chitosan. The remarkable antioxidant effects of fish gelatin isolated from fish scale is of great pharmaceutical importance in addition to type I collagen which is utilized for implants to culture skin cells or as drug carrier for restoration of skin. Collagen has haemostatic characteristic and facilitate blood coagulation as well as tissue repair. A natural biocompatible component of fish scale that coexists with collagen protein is hydroxyapatite. Hydroxyapatite is also used in controlled drug release by pharmaceutical industry and hip replacement surgery. Currently chitosan obtained from chitin present in fish by-product is gaining popularity as a potential drug candidate and gene carrier for anticancer chemotherapy. Taken altogether, our study highlights the importance and method of extraction of different by-products of Indian fresh water fishes in health science.

Figures : 05 References : 32 Table : 01

KEY WORDS : Biomaterial; Chitosan; Collagen; Gelatin; Hydroxyapatite; Poly-unsaturated fatty acid.

Introduction

Over the previous decade, global shrimp and fish production has been gradually expanding, and this trend is projected to continue. Global fishery production was expected to have surpassed 178 million tonnes (MT) in the year 2018. Human consumption accounted for 156 million tonnes of the total, overall estimated at supply of 20.50 kilogrammes/capita yearly[9]. Rest 22 MT being allocated for non-dietary applications, mostly fish oil and fish-meal production. In past few decades, Global aquaculture industry has increased drastically across the world. From the year 1961-2017, worldwide edible fish consumption has hiked at an astonishing pace of 3.1% annually, a pace nearly twice of the global population expansion of 1.6% over the equivalent time period and greater than all other protein-rich foods originating from animals (meat, dairy) grew at a pace of 2.1% annually. The Consumption of fish has increased at a rate of around 1.5% each year, from 9.0 kg in the year 1961 to 20.5 kg in 2018[9]. Type I collagen, gelatin, hydroxyapatite, chitin and chitosan may be found in the scales of Indian big carp *Catla catla* and *Labeo rohita* which are highly advantageous and beneficial in the field of food Industries and medical healthcare.

Global Capture Fisheries Production: In the year 2018, worldwide capture fish production hit a new record of 96.4 MT, rising to 5.4% above the average of past three years. Maritime capture fish production climbed to 81.2 MT in the year 2017 to 84.4 MT in 2018, although falling short of all-time milestone of 86.4 MT in 1996. Inland water captures accounts for 12.5% of total catch fishery production globally. Both by geographically, and by country, inland water captures seem to be more concentrated than maritime catches. By-product utilisation has the ability to create more revenue while also lowering the disposal costs of materials[2].

Table -1 : Fish scales by-products

Collagen and Gelatin	Hydroxyapatite	Chitin and Chitosan
• Production of bioengineered tissue. • Highly crosslinked collagen and gelatin helps in prolong outflow of highly hydrophilic medicines. • Carriers for parenteral drug deliveries. • Collagen based microsphere are utilized for maintenance of IL-2 release. • Aids in blood coagulation, platelet adhesion and aggregation. • Implanted carrier for bone including protein like rhBMP-2. • Potential drug delivery during wound repair and tissue regeneration.	• Biocompatible substance with application as implant in dental and orthopaedics. • Chromatographic applications for removing colours and heavy metals from polluted water. • Employed as bone grafting material for high osteo-inductive characteristics. • Alternative for bone tissue engineering. • Biosensors for drug delivery. • Application as a catalyst in treatment of harmful gases. • Used as femoral plugs in hip replacement surgery. • Increase in osteo-integration, osteoblast adhesion and calcium mineral deposition on the surface of scaffold.	• In pharmaceutical and biomedical applications, because of its antibacterial and antioxidant properties • Application in nutraceutical industries for relief in inflammatory illness. • In drug delivery with the ability to boost drug target by improving absorption, stabilizing the drug component. • Low molecular weight chitosan leads to reduction in oxidative stress associated with uraemia. • Potential drug candidate and gene carrier for anti-cancer chemotherapy. • Liposome wrapped with low molecular weight chitosan are used for ophthalmic drug delivery.

Asia has dominated fish farming over the past 20 years, producing 89% of the world total in terms of volume. Outside of China, other leading producing countries (India, Bangladesh, Indonesia, Egypt, Chile, Norway and Vietnam) steadily increased their share of global aquaculture production during the last two decades[1]. Since the mid-2000s, Asia is constantly produced two third of worldwide inland water output, with Asia's top 6 producers accounting for 57% of overall inland water captures[9] (Fig.1).

Inland water captures – Indian scenario: India is among the largest global fish producers and second largest aquaculture country after China. The significance of Aquaculture and fishery sector was highlighted by blue

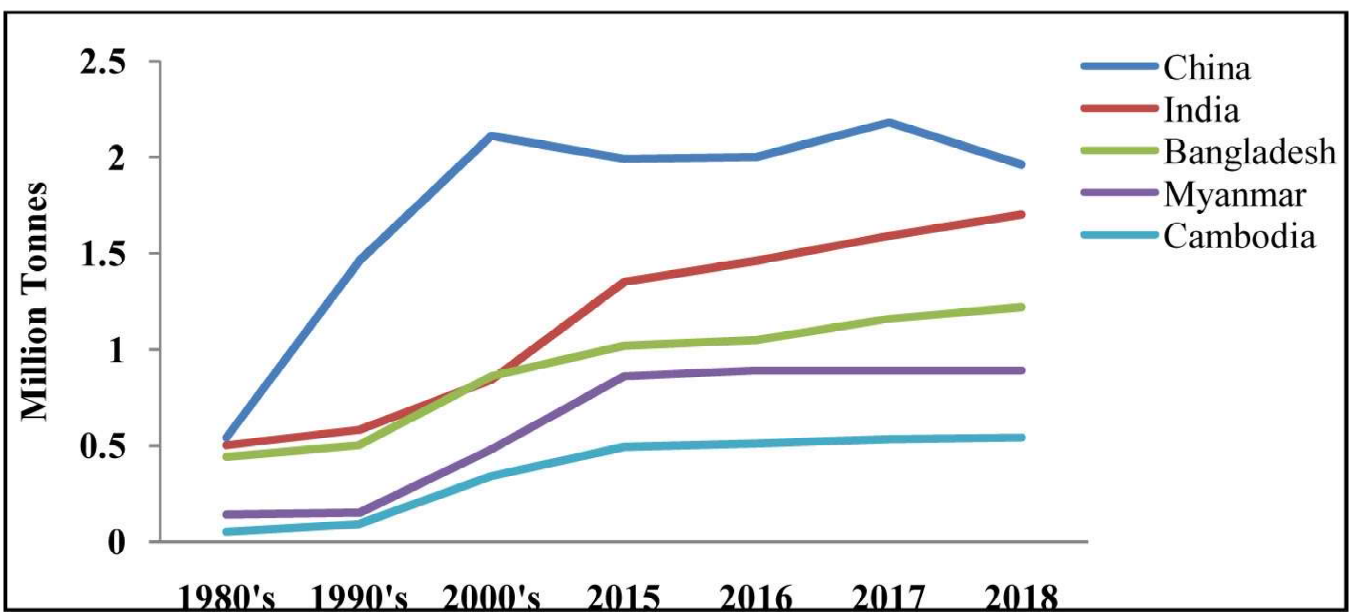

Fig. 1: Top five inland water capture producers in the world[9]

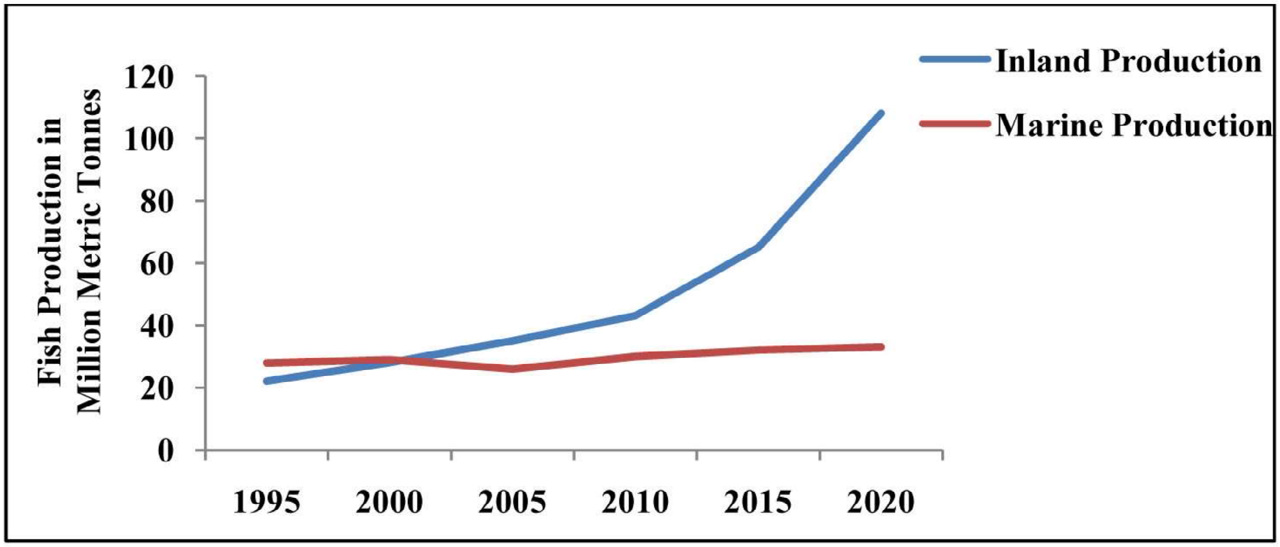

Fig. 2: Inland and marine production in India from last two decades[9]

revolution. The sector is now seen as sunrise sector, and it is expected to play a large part in the economic development of India in the not-too-distant future. India produces 7.58 percent of the world's production. India's extensive coastal territory provides tremendous prospects for fisheries, both in inland and marine waters, (Fig. 2) making aquaculture, one of the speediest growing businesses in India[1].

India has the 2nd largest share in worldwide aquaculture market, owing to its 2.36 million hectares of tanks and ponds, 7,500 km of coastline, and 1.1 million area of brackish water, all of which provide a suitable environment in fish farming. The fishing industry provides a source of income, for approximately 28 million individuals in India[1]. Freshwater aquaculture, which had a 34 percent share of inland fisheries in the mid-1980s, has risen to almost 80 percent over past few decades[6]. India's aquaculture production has been continuously expanding over the ages, reaching 5.77 million tonnes in 2015-2016. The two Indian major carps (IMCs), *Catla catla* and *Labeo rohita* account for majority of carp production in the country[16].

Andhra Pradesh, Chhattisgarh, Bihar, and West Bengal are the major aquaculture producers of freshwater fish. Andhra Pradesh, has a current production with approximately 15 lakh tonnes of freshwater fish, while 92 percent is delivered to different states. West Bengal, having current output of about 13 lakh tonnes fresh water fishes but still sourcing fishes primarily from Andhra Pradesh are country's two largest producers of freshwater fishery[15].

Major Indian Carps – *Labeo rohita* and *Catla catla*: *Catla catla and Labeo rohita* are the two most common carp fishes raised in India's freshwater aquaculture. Taking into account all the Indian main carps, *Catla* is a surface feeder, while Rohu is a column surface feeder[23]. In periphyton based polyculture system, workers[3] evaluated the production of two Indian main carps, *Labeo rohita* and *Catla catla*, and discovered that Rohu grazed on periphyton, but *catla* relied on planktonic food species[3].

Catla catla: In India, *catla* is a freshwater fish that can be found in abundance. *Catla's* greater growth rate and compatibility with other major carps, as well as its distinctive surface feeding habit and customer preference, have enhanced its appeal among fish farmers in Bangladesh, India, Pakistan, Laos, Myanmar, and Thailand in carp polyculture systems[9].

Labeo rohita: The Rui, Rohu, (*Labeo rohita*) is a carp-like fish that can be found in South Asian rivers. It's a huge omnivore with a lot of uses in aquaculture. The Rohu is a huge silvery fish with a prominently arched head that is typical of cyprinids. The Rohu may be found in rivers across much of Central, Eastern and Northern India as well as in Bangladesh, Vietnam, Pakistan, Myanmar and Nepal. It has also been found in certain rivers in Peninsular India and Sri Lanka[9].

Fish processing generates massive volumes of trash. After filleting, fish processing waste is estimated to account for about 75% of total weight of the fish, with scales, bones, and skins accounting for 30% of the trash[12]. The by-products usually composed of head (9-12 %), viscera (12-20 %), skin (1-4 %), bones (9–14 %), and scales (approx. 5-6%) are the most common by-products. Scales make up a large portion of fish by-catch and by-products, accounting for around 5-6% of the fish's body weight on average, and their handling as trash is problematic due to their poor biodegradability[11].

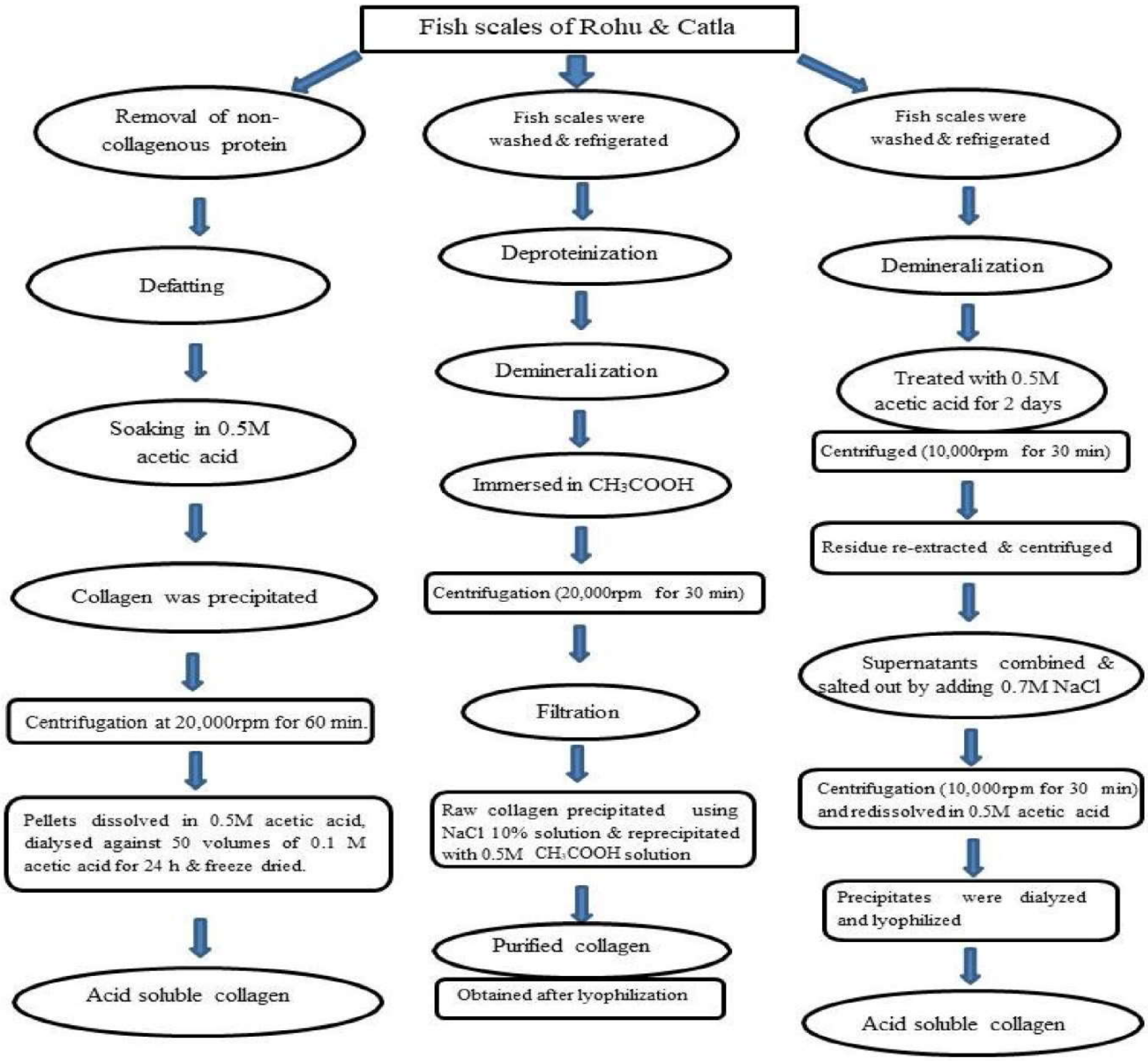

Fig. 3: Different methods of extraction of collagen from fish scales[5,10,22]

The use of fish processing waste helps to reduce detrimental environmental effects while also improving the quality of fish processing. Recycling these by-products into commercial items can be a bold way to control solid waste.

Extract of useful biomaterials from fish By-Products:

Collagen and Gelatin:

Collagen, which accounts for 30 percent of protein composition in fish bones, scales, and skin, is the most important structural protein[21]. Collagen is generic term for a protein superfamily that makes up about 30 percent of total content of protein in most vertebrates. It is the major element of extra-cellular matrix in connective tissue (tendon, scale, skin, ligament and ones). Collagen is divided into two classes based on structural characteristics; 2 classes found in fish (I and II) are suitable for both regenerative and cosmetic therapy (wound healing)[18]. Gelatin and collagen are the two unlike arrangements of the same macromolecule, with gelatin being a partially hydrolysed, denatured version of collagen. Gelatin is fibrous protein, made from collagen that has been thermally denatured[4].

Collagen can be isolated (Fig. 3) from fish scales and used in pharmaceutical applications and food products. It has properties comparable to gelatin extracted from pork and might be used as a replacement for mammalian gelatin in food items[18]. A significant advantage of adopting fish derivatives is that, unlike bovine derivatives, neither of these products poses a danger of spongiform encephalopathy transmission.

Hydroxyapatite:

The scales of *Catla catla* and *Labeo rohita* are made up of two layers: a surface layer with which hydroxyapatite (HAp) having bone ridges and collagens

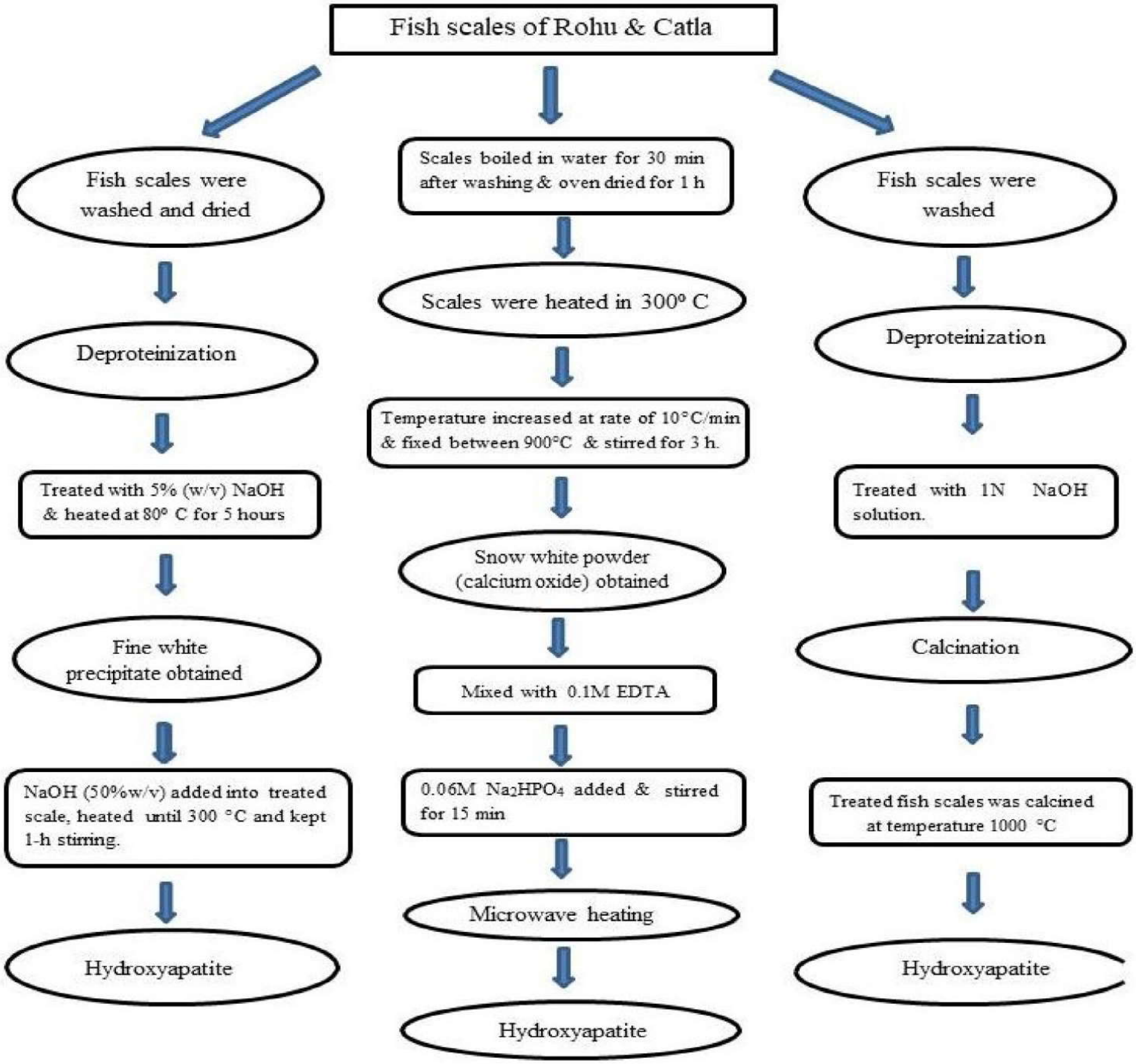

Fig. 4: Different methods of extraction of hydroxyapatite from fish scales

are mainly composed of an inner fibrous layer[29]. To minimise the complication, time commitment, and high expense of synthesised HAp, its generation from natural source is becoming increasingly important. Several researchers have investigated extractin on of Hydroxyapatite from animal teeth and bones, as well as from fish bones. Hydroxyapatite (HAp), on the contrary, is a natural component of fish scale that co-exists with collagen protein[29]. Since, the fish scales is a waste product, researchers have focused their efforts in the last decade on isolating (Fig. 4) and characterising its HAp[13,14,24,26]. Furthermore, fish scale Hydroxyapatite outperforms chemically generated HAp physiologically[28]. An additional benefit of employing fish scales might be that it would be a viable method of municipal solid waste management. The extraction along with purification of hydoxyapatite from maritime by-products using eco-friendly techniques integrate diverse microbiological, chemical, membrane, and enzymatic strategies and technologies which have been evaluated.

Chitin and Chitosan:

Chitin is one of the structural elements of fish scale, apart from crab shell and shrimps and squid pens[11]. Chitins from the marine source have been used to yield a extensive range of bioactive compounds featuring chito-oligomers, antioxidants, chitinase, chitosanase and anti-diabetic compounds and prodigiosin, a promising cancer therapy candidate[32]. Chitosan is manufactured primarily from chitin by the process of deacetylation method that involves alkaline solutions. Chitosan and chitin are ubiquitous saltwater

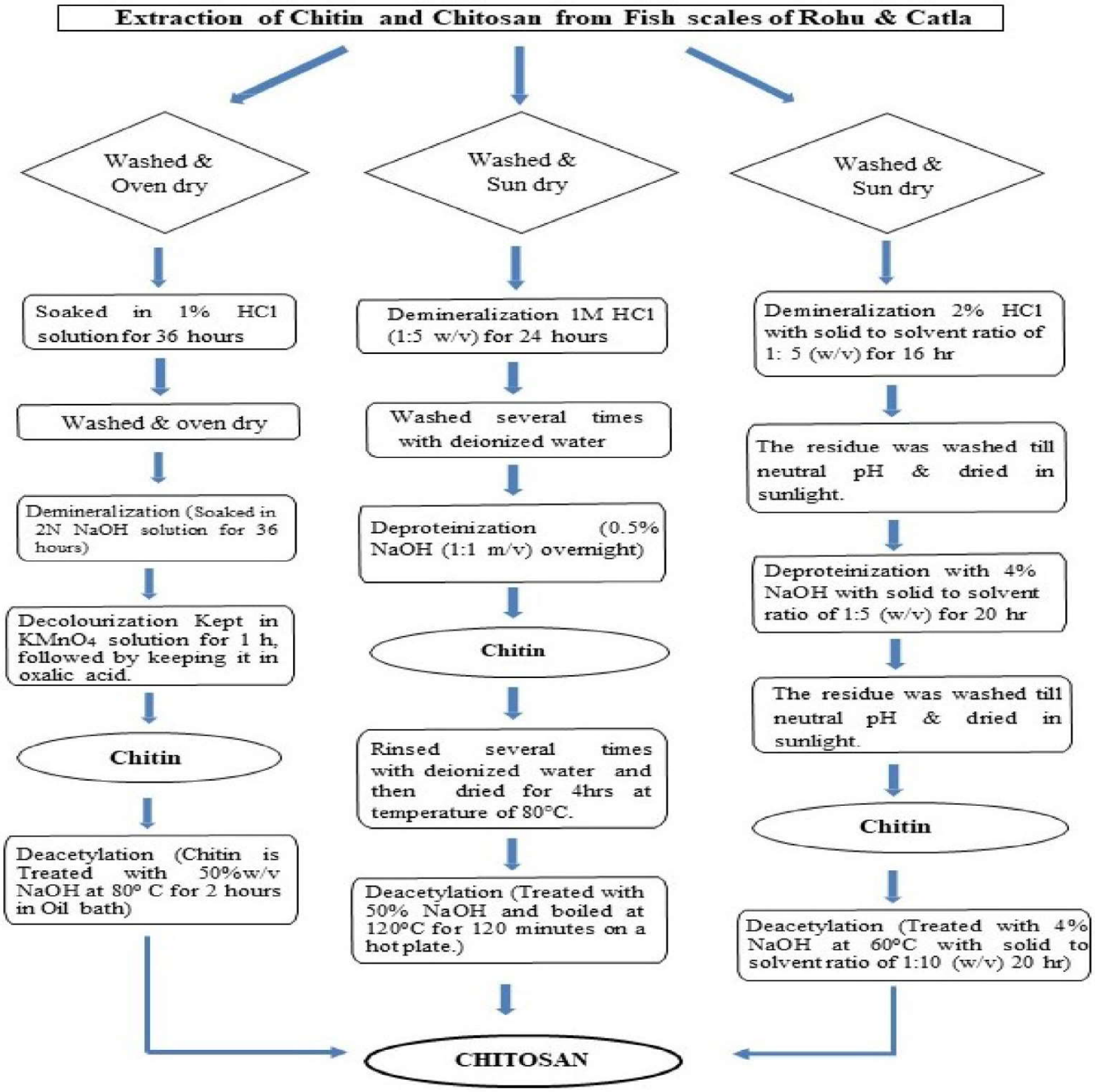

Fig. 5: Different methods of extraction of chitosan from fish scales[19]

polysaccharides that have earned a lot of attention in the food, pharmaceuticals, and healthcare industries owing to their unique physicochemical and biological characteristics[11]. The extraction (Fig. 5) and purification of chitin/chitosan, chondroitin sulphate, and hyaluronic acid from maritime by-products using eco-friendly techniques integrate diverse microbiological, chemical, membrane and enzymatic strategies and technologies have been evaluated[31].

Application of Biomaterials from By-Products in Healthcare System:

Biomaterials like Collagen and Gelatin, Hydroxyapatite, Chitin & Chitosan are multifunctional ingredients used in foods, pharmaceuticals, drug delivery, cosmetics, packaging and photographic films as a gelling agent, stabilizer, bone grafting, wound healing, gene carrier, biosensors, scaffolds, thickener, drug delivery, tissue regeneration, emulsifier, film former *etc*[7,8,14,17,20,21,24-28,30-32]. Biomaterials are mostly produced from pig skin, cattle hides and bones. Some alternative raw materials have recently gained attention from both researchers and the industry not just because they overcome religious concerns shared by Jews and Muslims but also because they provide, in some cases, technological advantages over mammalian gelatins. Fish by-products like skins, bones, scales from a number of fish species are among the other sources that have been comprehensively studied as sources for biomaterial production.

The diversified applications (Table-1) of different biomaterials from fisheries derived by-products are being summarized below.

Conclusion

Articles on Indian aquaculture marks the continuous increase in fish culture majorly *Catla catla* and *Labeo rohita.* In global market India ranks 4th in overall fishery production taken together inland water captures and marine water captures. The study provides useful information on different methods of extraction of by-products like collagen, hydroxyapatite and chitosan from fish scales. The recoveries of these by-products from fish waste are valuable, contributing to potential biomaterial for pharmaceutical use.

However, further technological developments are needed to optimize the production process and expand the volume of production. In future, there is a broad scope for by-products of fish processing industries in alternative biopolymer market and also in biomedical field. This alternative has an added advantage of being free from religious restrictions as mammalian derived by-products are mostly from skins and bones of bovine or pigs. The fish by-products can be used to meet the demands in pharmaceutical and biomedical industries. It solves the problem caused by disposal of by-products reducing the environmental pollution.

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