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Upcycling Fish Waste into Biopolymers Reducing Climate Change Effects through Sustainable Innovation: A Review

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Abstract

The increasing environmental concerns over plastic pollution have driven the search for sustainable alternatives, with biopolymers emerging as a promising solution. Biopolymers, derived from renewable resources, offer biodegradability and non-toxicity, making them environmentally friendly substitutes for conventional plastics. Among various sources of biopolymers, fish waste such as skin, scales, bones, and other by-products from the fishing industry has gained attention as an underutilized resource for biopolymer production. Fish waste is rich in valuable compounds like collagen, chitin, keratin, and gelatin, which can be processed into high-value biopolymers with applications in industries such as medicine, agriculture, food packaging, and cosmetics. This review explores the potential of local fish waste as a source of biopolymers, focusing on the extraction methods, properties, and applications of biopolymers derived from fish waste. It also discusses the environmental and economic benefits, such as waste valorization and reduction in plastic pollution, along with the challenges in scaling up production and commercialization. Ultimately, the review highlights the significant promise of fish waste-derived biopolymers in contributing to sustainable material development and advancing the circular economy.

Keywords: Biopolymers; Biodegradability; Commercialization; Conventional; Environmental; Economy.

1. Introduction

The rapid growth of plastic production and its consequent environmental burden have spurred global interest in sustainable alternatives to conventional petroleum-based plastics [1]. The plastic pollution crisis, particularly from single-use plastics, is increasingly affecting ecosystems and wildlife across the globe. Biopolymers polymers derived from renewable resources have emerged as promising replacements, offering biodegradability, non-toxicity, and reduced environmental footprints [2]. These bio-based polymers can replace harmful plastics in a variety of applications, from packaging materials to medical devices. Among the various sources of biopolymers, fish waste has gained significant attention due to its abundance and rich organic composition [3]. The global fishing and aquaculture industries generate vast quantities of fish waste, including parts such as skin, scales, bones, and internal organs, much of which is discarded or used for low-value products. Fish waste, however, is rich in valuable compounds like collagen, chitin, and keratin, which can be processed into high-value biopolymers [4]. These biopolymers derived from fish waste have found applications in various industries, including medical, agricultural, food packaging, and cosmetics [5]. This review explores the potential of fish waste as a source of biopolymers, focusing on the various types of biopolymers derived from fish waste, the extraction processes, their applications, and the environmental and economic implications [6]. Furthermore, it highlights the challenges in scaling up the production of fish waste-derived biopolymers and explores the future prospects of this innovative field [7]. Biopolymers are a class of polymers that are derived from renewable biological resources such as plants, animals, and microorganisms. Unlike conventional synthetic plastics, which are based on fossil fuels, biopolymers are biodegradable, reducing their long-term environmental impact. Biopolymers can be broadly classified into three categories: polysaccharides (e.g., cellulose, chitosan), proteins (e.g., collagen, gelatin), and lipids (e.g., polyhydroxyalkanoates). The primary advantage of biopolymers over traditional plastics lies in their biodegradability and non-toxicity [8]. While synthetic plastics can take hundreds of years to degrade, biopolymers break down naturally in the environment, reducing the accumulation of plastic waste. Furthermore, biopolymers are derived from renewable sources, which helps mitigate the depletion of fossil resources and promotes a circular economy model.

Biopolymers are used in a variety of industries, such as medicine (e.g., tissue engineering, wound healing), food packaging (e.g., biodegradable films and coatings), agriculture (e.g., natural pesticides and fertilizers), and cosmetics (e.g., anti-aging products and skin treatments). As research and technology advance, the applications of biopolymers continue to expand, providing a sustainable solution to plastic pollution [9]. The fishing industry produces millions of tons of fish annually, and with it, large quantities of fish waste. Fish waste includes fish skins, scales, bones, heads, and internal organs, which are often discarded or used for low-value purposes like animal feed or fertilizer [10]. However, fish waste contains valuable compounds such as collagen, chitin, keratin, and other proteins that can be processed into high-value biopolymers [11].

2. Review of Literature

The possibility of amino acids and glucosamine production from the treatment of shrimp shells in high-temperature and high-pressure water was investigated. Under the tested conditions, the highest number of amino acids (70 mg/g of dry shrimp shell) from hydrolysis of proteins was obtained at a reaction temperature of 523 K in 60 min. This amount was about 2.5 times the total amino acids obtained at 363 K, the temperature at which shrimp extracts for use in noodles soup are being prepared. The amount of simple amino acids such as glycine and alanine increased with increasing temperature up to 523 K and decreased thereafter. This behavior has also been observed from other seafood processing wastes such as fish entrails and scallop waste. Glucosamine was not detected presumably because of its deamination to produce glucose or cellulose (Quitain, A. T., Sato, N., Daimon, H., & Fujie, K., 2001) [12].

The term antimicrobial packaging encompasses any packaging technique(s) used to control microbial growth in a food product. These include packaging materials and edible films and coatings that contain antimicrobial agents and also techniques that modify the atmosphere within the package. In recent years, antimicrobial packaging has attracted much attention from the food industry because of the increase in consumer demand for minimally processed, preservative-free products. Reflecting this demand, the preservative agents must be applied to packaging in such a way that only low levels of preservatives come into contact with the food (Cha, D. S., & Chinnan, M. S., 2004) [13].

Plastics are not biodegradable and there is no concerted effort for plastic waste management. All this has promoted worldwide research to develop new biodegradable alternatives to plastics. Amidst the pro plastic arguments, there still is a strong need for the lookout for alternatives for synthetic plastics and to replace them steadily. Biodegradable polymers or bioplastics are important and interesting areas that are being looked out as alternatives for synthetic plastics. These are a new generation of materials able to significantly reduce the environmental impact in terms of energy consumption and greenhouse effect. Polyhydroxyalkanoates (PHA)are microbial polyesters. These polymers have properties similar to synthetic plastics and in addition are biodegradable and biocompatible (Kshama, L., 2004) [14].

The aim of this study was to extract collagen from fish skins and investigate the physical properties of the biodegradable films formed from the extracted fish collagen. Extraction of collagen using hydrogen peroxide or enzymatic methods proved to be unsuccessful. A white collagen substance was successfully extracted using a hydrochloric acid extraction method; however, it was unsuitable for the formation of edible films. An acetic acid extraction process successfully yielded a collagen substance, which could be used to form biodegradable collagen films. Differences in the mechanical film properties, tensile strength, Young's modulus, elongation and water vapor permeability were found between collagen films from different fish species. Films formed from collagen of New Zealand (NZ) hoki and NZ ling had greater elongation (%EL), tensile strength (TS) and elasticity in comparison with similar films from Irish (IRL) fish species (O'Sullivan, A., et al., 2006) [15].

Composite materials, especially “green composites,” fit well into this new paradigm shift. Simply stated, biobased materials include industrial products for durable goods applications, made from renewable agricultural and forestry feed stocks, including wood, agricultural waste, grasses and natural plant fibers composed of carbohydrates such as sugars and starch, lignin and cellulose, as well as vegetable oils and proteins. Producing chemical products and new materials from renewable resources is not a new idea. Most of the chemical products and materials came from renewable resources until the early part of the 20th century.1 The success and tremendous growth of the petrochemical industry in the 20th century, however, slowed the growth of biobased products.

Environmental as well as economic factors are now driving the trend toward greater utilization of biobased polymers and materials.2-5 The challenge to scientists and engineers is to develop the technology needed to make the biobased materials revolution a reality (Kshama, L., 2004) [16].

Concerns on environmental waste problems caused by non-biodegradable petrochemical-based plastic packaging materials as well as the consumer's demand for high quality food products has caused an increasing interest in developing biodegradable packaging materials using annually renewable natural biopolymers such as polysaccharides and proteins. Inherent shortcomings of natural polymer-based packaging materials such as low mechanical properties and low water resistance can be recovered by applying nanocomposite technology. Polymer nanocomposites, especially natural biopolymer-layered silicate nanocomposites, exhibit markedly improved packaging properties due to their nanometer size dispersion (Rhim, J. W., & Ng, P. K., 2007) [17].

Electrospinning is a fabrication technique, which can be used to create nanofibrous non‑wovens from a variety of starting materials. The structure, chemical and mechanical stability, functionality, and other properties of the mats can be modified to match end applications. In this review, an introduction to biopolymers and the electrospinning process, as well as an overview of applications of nanofibrous biopolymer mats created by the electrospinning process will be discussed. Biopolymers will include polysaccharides (cellulose, chitin, chitosan, dextrose), proteins (collagen, gelatin, silk, etc.), DNA, as well as some biopolymer derivatives and composites (Schiffman, J. D., & Schauer, C. L., 2008) [18].

Polysaccharides are widely used in foods as thickening, gelling, stabilizing, emulsifying, and water-binding agents. The majority of the polysaccharides currently employed in the food industry are derived from plants and seaweed. Recently, microbial polysaccharides have emerged as an important set of bio thickeners for foods. These biopolymers have overcome to a great extent the flaws associated with the plants and seaweeds polysaccharides. This relatively new class of biopolymers has unique rheological properties because of their potential of forming very viscous solutions at low concentrations and pseudoplastic nature.

This review deals with the current applications of these microbial biopolymers in the food industry with a special focus on the commonly used important exopolysaccharides in this area (Cha, D. S., & Chinnan, M. S. 2004) [19].

Chitosan, pectin and chitosan–pectin pellets were studied as adsorbents for Cd2+ from acidic aqueous solutions at selected conditions. Several adsorption sites were considered and adsorption mechanisms for the biopolymers–metal interactions are proposed taking into account theoretical and experimental results. Langmuir adsorption isotherms for Hg, Pb and Cd on pellets gave KL values of 796, 1551 and 7265 L mequiv.−1; their Memax (mequiv./g) being 0.027 (2.71 mg/g), 0.1075 (11.2 mg/g) and 0.022 (1.23 mg/g), respectively. Chitosan adsorption of Hg achieved 85–100% and 70–75% for Pb and Cd, respectively. Ci (initial concentration) was 47,045.4 μg/g chitosan for Pb, 6863.6 μg/g chitosan for Hg and 5.4436 μg/g chitosan for Cd (Debbaudt, A. L., Ferreira, M. L., & Gschaider, M. E. 2004) [20].

The very properties that made polymers commercially viable are posing great environmental problems for our future generations. Also, the starting material for most of the commercial polymers is crude oil. Thus, environmental issues coupled with decreasing crude oil reserves have forced the polymer industry to find new sources. These problems having been taken into consideration, biopolymers have emerged as a promising field. This paper takes into consideration the sources of renewable materials, such as starch, lignocellulosic biomass, vegetable oils, proteins, etc.; the synthesis of polymers such as polylactic acid and monomers such as furfural, ethane, propanediol, etc., from renewable materials; and the recent developments in this field (Flaris, V., & Singh, G. 2009) [21].

The growing reliance on synthetic polymers has raised a number of environmental and human health concerns. Most plastic materials are derived from nonrenewable resources and not biodegradable. Their distinguishing properties like durability and strength also ensure their persistence in the environment and complicate their disposal. Replacing synthetic polymers with biopolymers offers advantages in terms of biodegradability and biocompatibility, however, still suffers from high production costs. Therefore, most research has shifted towards the development of cost-effective ways of producing these biopolymers. Levan is a homopolymer of fructose with many outstanding properties like high solubility in oil and water, strong adhesivity, good biocompatibility and film-forming ability.

However, its industrial use has long been hampered by costly production processes which rely on mesophilic bacteria and plants. Halomonas sp. AAD6 halophilic bacteria were found to be the only extremophilic species producing levan at high titers and hence considerable research effort has been directed to combine the advantages of osmoadaptation and halophilicity to favor high yield levan production (Küçükaşık, M. F. 2010) [22].

In this study natural biopolymer “chitosan” was synthesized using locally available shrimp type of Penaeus monodon. Synthesis of chitosan involved four main stages: preconditioning, demineralization, deproteinization and deacetylation. The first stage, “preconditioning” process, is a new step introduced in this research. Effect of deacetylation conditions such as alkali concentration, number of times deacetylation was performed, and reaction temperature was investigated. Yields of chitin and chitosan from P. monodon were calculated. Chitosan was characterized by using Fourier Transform Infrared (FTIR) Spectroscopy and X-ray diffraction. The degree of deacetylation of synthesized powder was calculated using FTIR spectra. Both characterization techniques confirm the existence of chitosan (Sewvandi, G. A., & Adikary, S. U. 2012) [23].

After cellulose, chitin is the most widespread biopolymer available in nature. Chitin has economic value because of its biological activities, industrial and biomedical applications. There are three sources of chitin, namely crustaceans, insects and microorganisms. The commercial sources of chitin are shells of crustaceans such as shrimp, crabs, lobsters and krill. In the present study, chitin has been extracted from locally available fish in Rourkela. The obtained chitin was converted into the more useful chitosan. The obtained chitin and chitosan have been characterized by using different techniques like spectral analysis, X-ray diffraction, Elemental analysis, Fourier transforms infrared spectroscopy (FTIR), Scanning electron microscopy (SEM) and Differential scanning calorimetry (DSC). XRD analysis indicated the crystalline nature of the chitin and chitosan. The FTIR patterns displayed the bands corresponding to stretching and vibration of O-H, N-H and CO bonds and conformed to the formation of α-chitin. Degree of deacetylation (DD) value was calculated using elemental analysis, potentiometric titration and FTIR. Using FTIR analysis DD value was found to be 61% (Kumari, S., et.al., 2015) [24].

The main directions in food packaging research are targeted toward improvements in food quality and food safety. For this purpose, food packaging providing longer product shelf-life, as well as monitoring safety and quality based upon international standards, is desirable. New active packaging strategies represent a key area of development in new multifunctional materials where the use of natural additives and/or agricultural waste is getting increasing interest. The development of new materials, and particularly innovative biopolymer formulations, can help to address these requirements and also with other packaging functions such as: food protection and preservation, marketing and smart communication to consumers. The use of biocomposites for active food packaging is one of the most studied approaches in the last years on materials in contact with food (Valdés, A., et. al., 2014) [25].

The transition from a fossil fuel-based economy to a bio-based economy necessitates the exploitation of synergies, scientific innovations and breakthroughs, and step changes in the infrastructure of chemical industry. Sustainable production of chemicals and biopolymers should be dependent entirely on renewable carbon. White biotechnology could provide the necessary tools for the evolution of microbial bioconversion into a key unit operation in future biorefineries. Waste and by-product streams from existing industrial sectors (e.g., food industry, pulp and paper industry, biodiesel and bioethanol production) could be used as renewable resources for both biorefinery development and production of nutrient-complete fermentation feedstocks. This review focuses on the potential of utilizing waste and by-product streams from current industrial activities for the production of chemicals and biopolymers via microbial bioconversion (Koutinas, A. A., et.al., 2014) [26].

Processing of plant materials for food and feed production leads to a significant number of by-products and bio-wastes, which are potential sources of nutraceuticals, biopolymers, and biofuels. The waste produced during processing can be rich in oil, carbohydrates, proteins, and other nutritional components. Researchers are increasingly exploring the utilization of by-products, to prevent pollution and related adversities. In past decades, plant by-products have been established as a source of nutraceutical components, including dietary fibers, phenolics, and many other compounds. Scientists have also explored plant by-products and the wastewater of the food industry as the cheap feedstocks of a variety of biopolymers (Routray, W., & Orsat, V. 2017) [27].

This study revealed the potential of L. rohita scale as raw material for gelatin production, giving relatively high yield. Gelatin was characterized using UV-vis, FTIR, SEM and XRD methods. Morphological investigation showed that this polymer exhibits microporous morphology, FTIR spectrum indicates chemical bond formation of gelatin whereas XRD analysis revealed the crystalline structure of it. It also shows high protein content (90%) with low moisture (4.2%) and ash (1.4%) content. In brief, fish scale is a costeffective and environmentally friendly source of gelatin which can be used in various industrial applications (Das, M. P., et. al., 2017) [28].

Extraction of collagen consists of pretreatment to remove grease, hydrolysis to remove undesirable protein, and extraction to obtain acid-soluble collagen (ASC) by acetic acid. Biopolymer was synthesized by crosslinking collagen and cross- linking agent, sodium alginate (SA). Optimum concentration of collagen and SA is required. The different concentrations (1, 3, 5%) of SA were dissolved by sodium phosphate buffer. The extracted collagen was characterized by using Fourier Transform Infrared Spectroscopy (FTIR) to analyze functional groups. Biopolymer was characterized by functional groups, micrograph, and thermal stability. Results reveal, functional groups Amide A (3414 cm−1), Amide I (1637 cm−1), Amide II (1548 cm−1), Amide III (13338 cm−1) refers to collagen Type-I. ASC was successfully extracted from Channa striata and classified as Type-I collagen. Addition of SA for 3% has the best thermal stability (Issains, F. B., et. al., 2019, December) [29].

Chitosan, the de-acetylated chitin derivative, was evaluated for its ability to be used as a coagulant for Martapura groundwater treatment. This study is using chitosan derived from original fish scales of Kalimantan called Papuyu (Anabas testudineus) for the treatment of iron ion-containing Martapura groundwater throught coagulation-flocculation method. The reduction efficiency of iron ion removed by coagulation-flocculation processes using chitosan from Papuyu fish scales is the main evaluating parameter. The obtained chitosan have been characterized and analyzed by Fourier transforms infrared spectroscopy (FTIR) and Scanning electron microscopy (SEM). Using the chitosan from Papuyu fish scales as coagulant at neutral pH and room temperature led to decreasing the groundwater iron concentration become 3.43 mg/L (around 71% removal).

The result was then compared to the coagulation-flocculation treatment using the commercial chitosan from shrimps' shell (93% deacetylated). Moreover, it's found the coagulation-flocculation treatment using the chitosan from fish scales as coagulant more favor than the commercial one (Irawan, C., et. al., 2018, July) [30].

Chitin has been produced from different sea waste sources including molluscs (mussel and oyster shell), crustacean (prawn and crab) and fish scale (pang and silver scales) using deproteinization and demineralization as chemical methods. The conditions of chemical extraction determine the quality of chitin. The results revealed that about 1 and 10% HCl and NaOH were adequate concentrations for deproteinization and demineralization process respectively. Chitin from oyster and crab shell waste had the highest yield of 69.65 and 60.00% while prawn, mussel shell, pang and silver scales had the lowest yield of 40.89, 35.03, 35.07 and 31.11% respectively. Chitin solubility is controlled by the quantity of protonated acetyl groups within the polymeric chain of the chitin backbone, thus on the percentage of acetylated and non-acetylated D-glucos-acetamide unit. Good solubility results were obtained in mussel, oyster and crab shells respectively. The chitin molecular weight characteristics and activity are controlled by the degree of acetylation (DA) and the distribution of acetyl group extending in the polymer chain. DA is determined by acid-based titration methods and molecular weight determined by Brookfield viscometry. Both methods are found to be effective (Alabaraoye, E., Achilonu, M., & Hester, R. 2018) [31].

Biopolymers comprise a large variety of molecules with diverse chemical structures involving from polysaccharides to proteins, bioplastics, polyamides, polyesters, among others. Also, biopolymers are very abundant in nature and one major waste of industrial and agricultural activities contributing to environmental pollution. On the other side, the recent advances in micro- and nanotechnologies in the biomedical field open a new window for their use in drug delivery, tissue engineering and many health-associated technologies. The production and physicochemical properties of the main biopolymers used in biomedical applications reported in the literature are reviewed in this chapter (Bayón, B., Berti, I. R., Gagneten, A. M., & Castro, G. R. 2018) [32].

Seafood, a delight for many people, is sold in the market as a wide variety of products. However, seafood industries produce many by-products; for example, during the processing, the heads and shells of shellfish are generated as waste. This results in the generation of a large amount of shell waste that is accumulated over time, inducing a major environmental concern. Effective solutions for recycling shell waste should be taken into consideration, and the extraction of commercially useful substances like chitin and its derivates, such as chitosan, could be a valid solution for reducing the seafood waste's environmental impact. Thus, during this work, we propose the use of chitosan as biowaste, to induce the formation of solid films useful for decontaminating water from emerging pollutants. In particular, ketoprofen was used as a model contaminant, and a high percentage of removal, at least 90%, was obtained in a short time under our experimental conditions. Thus, a comprehensive investigation into the adsorption of ketoprofen onto chitosan film was performed, detailing the nature of the adsorption by studying the effects of pH, temperature changes, and electrolyte presence in the solutions containing the pollutant. The process was found to be pH-dependent, involving meanly electrostatic interactions between the pollutant molecules and chitosan (Das, M. P., et. al., 2017) [33].

In the last decades biopolymers produced from renewable resources have attracted great interest in both the scientific and industrial fields. Composites based on biopolymers are being increasingly recognized as better alternatives to traditional nonbiodegradable materials due to their ability to get degraded by environmental agents. The bio nanocomposites based on biopolymers attracted special attention because they form a fascinating interdisciplinary area that brings together materials science, biology, and nanotechnology. Biopolymer-based sensors are less expensive, and their production techniques are quite simple. The combination of polymers with carbon nanomaterials for the preparation of chemical sensors opens up inspiring areas of research due to their excellent biocompatibility, sensitivity, and selectivity. This chapter gives a general introduction to biopolymers and describes briefly the importance of biopolymer composites and recent developments in biopolymer-based chemical sensors (Abhilash, M., & Thomas, D. 2017) [34].

In this study we provide an overview of the latest developments in the extraction, production, modification and applications of fruit residues and by-products in the formation of protein-based biopolymers, in particular for the formulation of edible films. Our aim was mainly to demonstrate the highly transdisciplinary character of these topics by giving an overview of the main developments and research topics in the chemistry and engineering aspects of protein-based biopolymers. These innovative raw materials have been evaluated for the production of biomaterials to be used in some key sectors, such as food packaging (Burgos, N., Valdés, A., & Jiménez, A. 2016) [35].

In this study, an antioxidant peptide fraction with a molecular mass < 30 kDa (PF30) isolated from rainbow trout (Oncorhynchus mykiss) skin gelatin hydrolysates was encapsulated in chitosan-coated nanoliposomes. The mean particle size of liposomal nanovesicles containing PF30 was found to be in the range 163.4–234 nm with a low polydispersity index (PDI < 0.5); furthermore, the ζ-potential changed from +3.9 mV in uncoated liposomes to +45.5 mV in biopolymer-coated liposomes. FTIR spectra showed electrostatic interactions as well as hydrogen bonding between phospholipid head groups and amine groups of chitosan. The entrapment efficiency of PF30 (2 mg/ml) was found to be highest in nanoliposomes coated with 0.4% (w/v) chitosan. Biopolymer-coated liposomes demonstrated more sustained peptide release behavior in vitro. Moreover, the chitosan-coated nanoliposomes maintained the antioxidant activity of the PF30 and could be considered a potential candidate for efficient delivery of bioactive compounds in nutraceutical and functional foods (Ramezanzade, L., Hosseini, S. F., & Nikkhah, M. 2017) [36].

Fish waste is attracting growing interest as a new raw material for biopolymer production in different fields, mainly in food packaging, with significant economic and environmental advantages. This review paper summarizes the recent advances in the valorization of fish waste for the preparation of biopolymers for food packaging applications. The issues related to fishery industry waste and fish by-catch and the potential for re-using these by-products in a circular economic approach have been presented in detail. Then, all the biopolymer typologies derived from fish waste with potential applications in food packaging, such as muscle proteins, collagen, gelatin, chitin/chitosan, have been described. For each of them, the recent applications in food packaging, in the last five years, have been overviewed with an emphasis on smart packaging applications.

Despite the huge industrial potential of fish industry by-products, most of the reviewed applications are still at lab-scale. Therefore, the technological challenges for reliable exploitation and recovery of several potentially valuable molecules and the strategies to improve the barrier, mechanical and thermal performance of each kind of biopolymer have been analyzed (Issains, F. B., et. al., 2019, December) [37].

In order to achieve this, effective filtration systems are required to ensure that the water quality is satisfactory for the cultivation of aquatic organisms. Chitosan, an industrial waste material derived from crustacean farming, is a renewable natural material that is biodegradable and possesses adsorbent characteristics. In this work, chitosan foam was incorporated in filters and was evaluated as an adsorbent of aquaculture pollutants, adding value to the material and at the same time providing a use for industrial waste. The foam was characterized by scanning electron microscopy and energy dispersive spectroscopy, apparent density, and water absorption capacity. It was used to remove ammonia, nitrite, orthophosphate, and turbidity from aquaculture effluents. The foam consisted of a bilayer with smooth and porous sides, which presented low density, flexibility, and high-water absorption capacity. The best proportion of the foam, in terms of the mass of foam per volume of solution (% m v^{-1}), was 0.10, which resulted in removal of 32.8, 57.2, 89.5, and 99.9% of ammonia, nitrite, orthophosphate, and turbidity, respectively. This biopolymer produced is biodegradable, and when saturated with organic compounds from aquaculture, and no longer suitable for reuse as a filter material, it can be employed as a fertilizer, hence closing the sustainability cycle of the aquaculture production chain (Zadinelo, I. V., et. al., 2018) [38].

Fishery residues are abundant raw materials that also provide numerous metabolites with high added value. Their classic valorization includes energy recovery, composting, animal feed, and direct deposits in landfills or oceans along with the environmental impacts that this entails. However, through extraction processes, they can be transformed into new compounds with high added value, offering a more sustainable solution. The aim of this study was to optimize the extraction process of chitosan and fish gelatin from fishery waste and their revalorization as active biopolymers.

We successfully optimized the chitosan extraction process, achieving a yield of 20.45% and a deacetylation degree of 69.25%. For the fish gelatin extraction process, yields of 11.82% for the skin and 2.31% for the bone residues were achieved. In addition, it was demonstrated that simple purification steps using activated carbon improve the gelatin's quality significantly. In view of the low technological transfer and the lack of information about the revalorization of fishery waste, this work offers extraction conditions with good yields that can be easily implemented in the existing industrial fabric, reducing costs and supporting the economic development of the fish processing sector and the creation of value from its waste (Rocha-Pimienta, J., et. al., 2023) [39].

Scale, skin, internal organs, viscera, trimmings, bone, tails, and fins are common fish wastes that are difficult to dispose of. Discarded fish waste has become a global environmental concern. The conversion of fish waste into valuable materials, on the other hand, is currently in high demand around the world. This brief review summarizes recent works on tilapia wastes utilization in three areas: biomedical applications such as wound dressing treatment, synthesis of hydroxyapatite and gelatin extraction, wastewater treatment, and biofuel. The recovery of valuable materials from tilapia biowaste helps to reduce the environmental problems caused by discarded tilapia waste (Zadinelo, I. V., et. al., 2018) [40].

Plastic materials obtained from oil are used in the food industry. These polymers are cheap and available. They have good mechanical properties, good barriers for oxygen and vaporizable aromatic substances, and they can be hot welded. However, the main disadvantage is that biopolymers are not biodegradable, and certainly not environmentally friendly. Nanocomposites will be applied for food packaging in the future. Nanoscale research, including detection of a pathogen, active packaging, antimicrobial packaging, and the formation of barriers, will improve food packaging. It may be possible to use particles that are not organic to introduce diverse components such as colors and odors. They also may be used as tanks for the controlled release of drugs or fungicides (Grujic, R., Vukic, M., & Gojkovic, V., 2017) [41].

Chitin and chitosan are biopolymers with excellent bioactive properties, such as biodegradability, non-toxicity, biocompatibility, haemostatic activity and antimicrobial activity. A wide variety of biomedical applications for chitin and chitin derivatives have been reported, including wound-healing applications. They are reported to promote rapid dermal regeneration and accelerate wound healing. A number of dressing materials based on chitin and chitosan have been developed for the treatment of wounds. Chitin and chitosan with beneficial intrinsic properties and high potential for wound healing are attractive biopolymers for wound management. This review presents an overview of properties, biomedical applications and the role of these biopolymers in wound care (Singh, R., Shitiz, K., & Singh, A., 2017) [42].

3. Conclusion

The escalating environmental challenges posed by plastic pollution, especially from single-use plastics, have underscored the urgent need for sustainable alternatives to petroleum-based plastics. Biopolymers, derived from renewable biological resources, present an eco-friendly solution to this global issue, offering biodegradability, non-toxicity, and a reduced environmental footprint. As industries continue to seek environmentally viable materials, biopolymers stand out for their potential to replace traditional plastics in numerous applications, ranging from packaging to medical devices. Among the various sources of biopolymers, fish waste has garnered increasing attention due to its abundance and rich organic composition. The global fishing and aquaculture industries generate substantial amounts of fish waste, which, while often discarded or used for low value purposes, contains valuable biopolymer precursors such as collagen, chitin, and keratin. These compounds can be extracted and processed into high-value biopolymers with diverse applications, including medicine, food packaging, agriculture, and cosmetics. For instance, fish-derived collagen is highly sought after in biomedical fields, chitosan finds use in agriculture and food packaging, while keratin offers possibilities in textiles and personal care. As research in this field progresses, the prospects for fish waste-derived biopolymers look promising. The integration of these biopolymers into global supply chains could help address some of the most pressing environmental issues while opening up new economic opportunities, particularly for communities involved in the fishing industry.

Declaration of Conflicting Interests

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