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Unlocking Chitin from Shells: Extraction, Properties and Applications

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Abstract

The abundant chitin biopolymers are the most promising and prevalent polysaccharides that exhibits in numerous roles because of their distinctive characteristics. It is applicable in various fields from biomedical sciences, agriculture, food, pharmaceuticals and waste management techniques. The shrimp shell waste is the promising sources for chitin polymers and this shrimp shell waste accounts for nearly 45-48% among total shrimp's waste. This waste consists of several substances such as chitin, proteins, calcium carbonates and some bioactive compounds and this holds a significant untapped potential to utilize it for various industrial applications. The extraction methods primarily involve chemicals that rely on harsh reagents, contributing for environmental pollution. However, biotechnological methods employ microorganisms or enzymes to ensure a sustainable extraction procedure. These biological methods face some challenges in terms of efficiency and time consumption. This hidden potential of shrimp shell waste can contribute to enhance economic growth, innovative biomedical applications and environment sustainability.

Keywords: Chitin, Processing waste, Shrimp biopolymer, Sustainable extraction methods

Introduction

The seafood consumption is growing globally, particularly shrimp which contribute to significant increase in shrimp export. India is the emerging leading shrimp exporter, contributing significantly to enhance country's economic growth and earn a good foreign exchange. Thus, the shrimp industry serves as the essential part for Indian marine economy, which generates employment and supports livelihoods mainly in coastal regions of the country. The total seafood export from India has touched high level earning during the financial year 2023-24 which was 17,81,602 MT worth for US$ 7.38 billion. Among this total export items, frozen shrimp contributed highest in terms of quantity and value worth ₹ 40,013.54 crores in 2023-24 and retained at top position and the shrimp export increases by 0.69% quantity wise (Anonymous, 2024).

However, this shrimp processing industries generates a huge quantity of waste which mainly consists of non-edible parts such as head, carapace and tail. In terms of quantity, shrimp processing waste accounts for 1.2-4.6 lakh tonnes and this waste alone can produce 6,712-27,453 tonnes of chitin. The shrimp waste often gets discarded or poorly managed and its quantity keeps on increasing as the export volume gets increases to meet global demand of seafood consumption.

The ways to manage this shrimp waste is by developing some value-added products from the secondary raw materials and convert them into high value end products. The products like chitin and their derivatives are the major value-added products that can be developed from the shrimp processing discards.

The chitin serves as the base material to synthesize other derivatives like chitosan, chito-oligosaccharides, glucosamine hydrochloride *etc*. Several other valuable compounds such as calcium carbonates (20-50%), proteins (20-40%) and also bioactive compounds can also be extracted from shell waste, which is an underutilized resource (Saini *et al.*, 2020). The

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products generated from the waste like chitin has numerous applications ranging from food industry, paper and textile, agriculture, pharmaceuticals, medicinal purposes, drug delivery *etc*. the products like calcium carbonates are widely used for production of plastics and paints. Despite having a huge potential, the waste still remains unexplored, improperly disposed and unutilized in India.

If this large amount of waste did not dispose properly, it is believed to pose a severe health issues and environmental hazards to both the communities *i.e.*, terrestrial and aquatic residents. It not only contributes to environmental pollution in coastal and aquatic regions, but also enhances the risk of landfills and burden on waste management systems.

To overcome such issues, there is emphasis development in field of sustainable waste management practices, strategies and innovative techniques in order to recycle and reuse the shrimp waste generated from the processing industries. In era of science and research, focus is given on the developments of eco-friendly products, biodegradable materials, fertilizers and animal feed, therefore contributing for economic growth.

Chitin

The chitin word was derived from the Greek word 'chiton' that means a coat of mail. The chitin is a linear polysaccharide consists of two subunits *i.e.*, major portion of N acetyl-D glucosamine and D-glucosamine as minor portion. These two subunits are linked together by β-1,4 glycosidic linkage. This is the second most prominent polysaccharide that exists in nature after cellulose. The crustaceans mainly arthropods like shrimp, crabs, lobsters, molluscs, insects, nematodes *etc*., contains chitin as major constituents of head, shell and carapace. Chitin produced by living organisms accounts for around 10^{12}-10^{14} tonnes annually, among which marine ecosystem contributes for 1.3×10^{12} kg year^{-1} and freshwater arthropods share around 2.8×10^{10} kg year^{-1}, as reported by Dhanabalan *et al.* (2021).

Chitin exists in three polymorphic forms namely, β, γ chitin (Figure 1). α-chitin consists of antiparallel chains and its is the most robust form among all other forms of chitin. β-chitin contains parallel chain arrangement whereas, γ chitin contains 1 antiparallel and 2 parallel layers and has similar strength and resistance like β-chitin.

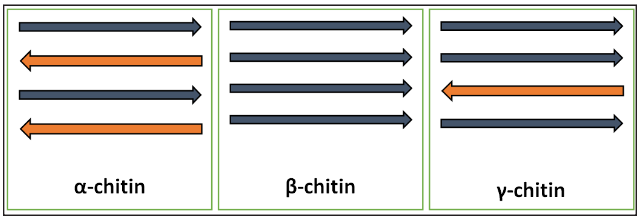

Figure 1: Different forms of chitin

Chitin polymer contains 6.5% of nitrogen on an average basis and the main derivatives of chitin like chitosan, in which hydrogen content reach up to 9.5%. In the process of conversion of chitin to chitosan, it undergoes a process of deacetylation, which eliminates 80% of acetyl groups and amino group remains. Antiparallel arrangement of microfibers in chitin favours hydrogen bonds which makes it a dense structure that results in greater hardness and crystallinity. The enzymes like chitinases help to degrade the chitin polymers and convert it to some chito-oligosaccharides or glucosamine. Chitin poses several properties like biodegradability, biocompatibility, antibacterial, antimicrobial, anticancerous activity, anticoagulant and non-toxicity.

Different Extraction Method for Chitin

Chemical Extraction

There are several methods suggested by literature in order to extract chitin, such as biological methods which involve the use of microbes and enzymes, chemicals and even the combination of both the methods to make the process of extraction more efficient and beneficial. All the methods have same aim: removal of pigments, proteins, minerals lipids and to obtain only the targeted material. At the moment, chemical method the most popular technique used in both laboratories as well as for industrial production and it is also the one that is most often mentioned in the literature. As previously stated, the goal of any extraction procedure is to remove the source material's whole organic and mineral composition. Deproteinization and demineralization are the two essential processes for obtaining chitin. The aim and chemicals employed in a process can alter the sequence in which these steps are performed. If required, a phase of depigmentation and deodorization can be added to the production process in addition to these two primary steps.

Deproteinization [Figure 2] is the process of removing the raw materials' protein content. Alkaline solutions, such as NaOH and KOH, are employed for this. NaOH solution is the most widely used and adopted for industrial manufacturing.

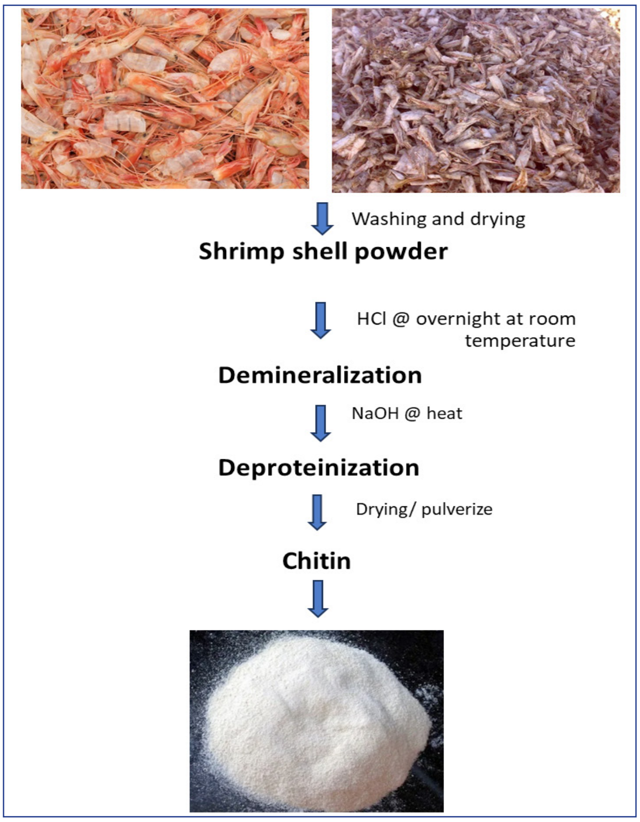

Figure 2: Flow chart for the manufacturing of chitin

The literature shows a wide range of production aspects. Gortari and Hours (2013) demonstrated that commercial chitin is deproteinized at an average temperature of 95 °C; however, they also point out that this range may cause the material to depolymerize and alter certain properties, such viscosity.

Demineralization is the process of removing calcium phosphate and calcium carbonate, two inorganic fillers, from raw material. Strong organic acids like HCOOH and CH_3COOH, as well as inorganic acids like H_2SO_4, HCl and HNO_3 and, are utilized. Because it is so effective at removing the minerals, HCl is the most often utilized acid in the manufacturing of commercial chitin. A reliable indicator of the material's impurity content is the discoloration. Chemicals like sodium hypochlorite, acetone, potassium permanganate and hydrogen peroxide, are used for carrying out the process of depigmentation.

The temperature during this acidic and basic treatment should be kept around 60-90 °C, to avoid the destruction of chitin structure. It is difficult to get pure white chitin powder because of the presence of various pigments in the shell waste, to prevent this bleaching agent like hydrogen peroxide is used to purify the chitin powder. The use of such chemicals for chitin extraction causes harmful impact on other aquatic animals when they leach out into the environment. Thus, alternative methods need to be developed.

Biotechnological Extraction

Chemical processes continue to be more efficient in the industrial sector, but the use of biotechnological methods offers a novel sustainable vision and new quality parameter, which offers a more suitable biomaterials for health care. The biotechnological process involves the combination of the chemical process with the use of biological methods, with the application of microorganisms to the system. Microorganisms have been used for the chitin extraction; they are used either in form of whole microorganism or in form of enzymes which are produced by such microorganism. Although this method is environment friendly, sustainable but is less efficient because of the main reason that is time consumption and less understanding about the linkages present between chitin and surrounding proteins. Indeed, the biological extraction method is much better than the chemical process. These microorganisms carried out the process of fermentation. Microbial and digestive enzymes are created and devour organic matter during fermentation. Proteases, or hydrolytic enzymes, are highly effective at deproteinizing proteins and can produce hydrolysed proteins as a high-value byproduct. Aranday-García *et al.* (2017) claimed that lactic acid produced by lactobacillus, offers superior outcomes and increased demineralization effectiveness. Each treated species is inoculated in a culture medium containing the required nutrients. Among other particular substances, this medium is mostly made up of carbohydrates, lipids, amino acids and supplies of calcium, iron and magnesium. The most popular medium for delivering balanced compositions is Agar, or commercial culture media, like MRS (Man Rogosa Sharpe).

Applications of Chitin

• Chitin polymer stimulates the immune system and also activates the immune cells to reduce inflammation.

• Chitin used to control the cholesterol levels and to reduce blood vessel inflammation and thus useful to cure cardiovascular diseases.

• It also used to boost immune functions and to prevent tumour growth to prevent development of cancer.

• The diseases like Alzheimer's can be aided by using chitin polymer and also investigated to use it for neural therapy.

• Chitin also helps to manage severe conditions like asthma by lowering the allergic reactions and inflammation because of its interaction with immunological mechanisms.

• It also promotes the proliferation and development of bacteria in gut microbiota those can enhance the digestive health.

• Chitin has antibacterial qualities and accelerates the tissue regeneration and help in wound healing.

• It enhances the therapeutic substances that can be delivered precisely and helps in drug delivery system.

• Age-induced oxidative stress: The antioxidant qualities of chitin assist reduce oxidative stress, which may slow down the aging process.

Conclusion and Future Perspectives

This review focuses on the different extraction methods involved in the production of chitin, properties and their applications. Chitin being the second most abundant polymer has versatile applications ranging from pharmaceuticals, biomedical, agriculture and waste management. It can be produced by using chemicals and biological method which involves the usage of various fermentative microorganisms or enzymes that act upon the shrimp shell waste. Still there is a demand for the innovation in field of extraction technique. Chitin has to be extracted in the purest form, so in order to apply it in various fields. So, it is advisable to implement research in field of biotechnological methods to make the extraction process faster and affordable.

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