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Mini Review

Advances of Chitin Biomass Derived from Seafood Waste in Biomedical Applications

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Abstract

As the second abundant biomass in nature, chitin widely exists in crustaceans, insects, plankton, fungi and so on. Thus, extracting chitin from crustaceans' seafood waste and applying it and its derivatives in biomedicine represents the idea of turning waste into treasure. However, the poor solubility severely limits the application range and field of chitin. Thus, the chemical modification of chitin has always been a hot field in the research of such compounds, endowing chitin better solubility, pH-sensitive targeting, and drug delivery functions. In this review, the modification methods of chitin were summarized to improve the water solubility, pH sensitivity and targeting of chitin derivatives. At the same time, the application of chitin derivatives in many fields such as antibacterial, sustained release, targeting and drug delivery are introduced. This review offers a good reference for sustainable development.

Keywords: Chitin, Chemical modification, Antibacterial, Drug delivery

Introduction

The storage of chitin in nature is only lower than cellulose. Chitin is a renewable natural alkaline polysaccharide, non-toxic and without side effects, with good moisturizing and adsorption properties [1]. However, the poor solubility restricts chitin's application. Chitin derivatives from chemically modifying the active functional groups of chitin skeletons offer promising candidates. The -OH and -NH_2 active groups on chitin molecules are prone to chemical reactions. Compared with natural chitin, the modified chitin derivatives have better biocompatibility, physiological activity, better degradation and lower toxicity, while maintaining the original pharmacological effects such as bactericidal, antibacterial, anti-cancer and antiviral, including inducing red blood cell aggregation, promoting platelet activation, and activating complement system other than chitin [2]. Currently, chitin-based materials have been mainly applied to biomedicine as versatile functioning materials, including the preparation of nanomaterials, including nanoparticles, hydrogels, microsphere micelles, etc. It can also function as a targeted delivery vector for drugs and as a carrier for vaccines [3]. Therefore, chitin derivatives can be widely used and thus extend the application field of chitin. This review focuses on the literature in the past years, and it is hoped that this review will provide guidance for further expanding the application prospect of chitin.

Chemical Modifications of Chitin

The functional groups on chitin skeletons, like the glycosidic bond, are stable and difficult to break. The most reactive groups of chitin polymers are C_6-OH and C_2-NH_2. Focusing on these groups, the modification of chitin can be achieved by introducing other groups through molecular design [4]. Recent studies have witnessed the improvement of solubility in water, enhanced adhesivity and pH sensitivity of nature chitin via chemical modification, significantly broadening its application range [5].

Applications of Chitin Derivatives in Biomedicines

Antibacterial Application

Quaternary ammonium salts of chitin have demonstrated their great potential as anti-bacterial candidates [6]. Compared with chitin, quaternary ammonium chitin has greatly enhanced antimicrobial performance and is reported to be applied to anti-inflammatory nano-systems or in the form of filling fibers in wound dressings. The antibacterial mechanisms of chitin and N-trimethyl chitin are still unclear. Three kinds of mechanisms are speculated: electrostatic adsorption, interaction with large biomolecules such as protein and nucleic acid, decrease the absorption of essential elements. Pardeshi [7] demonstrated that the antibacterial mechanism of N,N,N-trimethyl chitin was achieved by chemically bonding to key components of bacteria and interfering regular functions, where the cations serve as the active sites of the polymer. Therefore, the antimicrobial behaviors of N,N,N-trimethyl chitin become prominent as positive charges increase. It is noteworthy that the functioning performance of N,N,N-trimethyl chitin decreased with decreasing pH, and lower pH values especially acidic environment would benefit the effect of antimicrobial.

Drug Delivery Application

Chitin derivative nanoparticles have good bio-adhesion as well as excellent permeability, greatly enhancing the application potential in drug transport and controlled release. Currently, chitin-derived materials are prominently employed in drug or molecules-controlled release and targeted drug carriers. Chitin-derived materials used in previous delivery carriers are mainly reported in the form of microspheres, nanoparticles, micelle [8], and the particle size is micrometer scale. Decrease the size to nanometer scale, it is reported in recent studies that smaller sizes provide chitin derivatives with great ability to overcome the low drug targeting efficacy due to the blockage of different biological barriers. Amphiphilic chitin has self-assembling micelles with greatly enhanced solubility, thus demonstrating good potential for targeted delivery of lipid-soluble molecules. Gels refer to a type of material capable of 3D spatial polymerization, containing large amounts of water in the micro-crosslinked skeleton configuration with tunable properties, including flexibility, dispersion or solubility, biodegradability, and functionality. The better adhesion and permeability of gels compared to nanoparticles, as well as the ability to transport small molecules, make chitin derivative nanomaterials promising in the biomedical field [9].

Perspective

The main raw material for industrial chitin is shrimp and crab shell. Merely in China, about 10 million tons of shrimp and crab shell wastes are produced every year, but the utilization degree of such waste is low at present, with around 90% buried or discarded [10]. The degradation process of shrimp and crab shell waste releases carbon dioxide and nitrogen oxides, causing serious environmental pollution. Therefore, promoting the utilization of chitin biomass can not only avoid the waste of such bulk marine renewable resources, but also benefit environmental protection and solid waste treatment. The major research area for making the best of chitin and its derivatives is targeted drug delivery, which is promising for clinical applications. The first concern regards the dispersion or solubility in aqueous solutions. Hydrophilicity of chitin-based materials requires strengthening via different treatment. The second concern is the controlled drug release, where the stability of loaded drugs and continuously drug release smartly responsive to the targeting microenvironment are key issues. The third concern relates to the degradation of chitin itself, as the decomposition of chitin may affect the drug release duration. Thus, multifunctional composite nanoparticles are needed to fabricate enhancing the stability of both drug molecules and chitin structures, elongating the drug administration durations.

The development of marine biomass resources, turning chitin-a key component of shell waste into high value-added drug molecules, drug delivery materials and anti-cancer disinfection virus, bacteria intelligent platform, to achieve the “waste into treasure”, will realize the successful green treatment of pollutants with low costs and good sustainability. Research in this direction will maximize the potential and value of marine biological resources in the biomedical field.

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Conflict of Interest

No conflict of interest.

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