Chapter 12
Chitosan as a Renewable Biopolymer:
Extraction, Modification, Properties, and Potential Applications

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ABSTRACT

Chitosan is widely recognized as a promising eco-friendly polymer due to its renewability, biocompatibility, biodegradability, non-toxicity, and ease of modification, offering numerous opportunities for development. As a cationic polysaccharide, chitosan exhibits distinctive physicochemical and biological properties that are influenced by factors such as its molecular weight and degree of deacetylation. Recently, there has been a surge of interest in chitosan derivatives, driven by the quest for improved efficiency and expanded applications. The versatility and distinctive properties of this polymer offer tremendous potential for advancements in diverse fields, ranging from healthcare to environmental remediation. This

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review presents an updated overview of chitosan's production sources and extraction methods, with a particular focus on its physicochemical properties. Furthermore, it highlights the benefits of chitosan derivatives and delves into various approaches for biopolymer modification.

INTRODUCTION

Chitosan is the most important and widely recognized derivative of chitin, the most abundant amino polysaccharide on Earth (Azmana, Mahmood, Nayeem, & Arifin, 2024). Chitin is the second most prevalent natural polysaccharide and can be found in a variety of renewable sources, including algae, mollusks, crustacean shells, insect exoskeletons, and fungal cell walls (Cohen & Poverenov, 2022; Junceda-Mena, García-Junceda, & Revuelta, 2023). Due to its ubiquitous presence, chitin has garnered significant attention from researchers over the past decade as one of the most important natural polysaccharides (Liu et al., 2023). Chitin is a linear homopolymer consisting of N-acetyl-D-glucosamine units connected by β (1–4) glycosidic bonds. Through chemical deacetylation, chitin is converted into a random copolymer made up of D-glucosamine and N-acetyl-D-glucosamine, which forms chitosan. The number of N-acetyl-D-glucosamine residues in the polymer determines its degree of acetylation (DA). To be classified as chitosan (CS), at least 50% of the polymer must be deacetylated. The physical, chemical, and biological properties of chitosan are largely determined by its degree of deacetylation (DD) (Elizalde-Cárdenas et al., 2024).

Chitosan contains three primary functional groups that contribute to its reactivity: an amino group (NH_2), an N-acetamide group, and hydroxyl groups (OH) located at positions C_2, C_3, and C_6, respectively. The presence of the hydroxyl and amino groups enables structural modifications in the polymer backbone, allowing for adjustments to its properties and optimizing its applications (Gal, Rahmaninia, & Hubbe, 2023). Additionally, the glycosidic bonds and acetamide groups in its structure can also serve as reactive sites (Aranaz Corral et al., 2021). Crustacean shells, particularly those of crabs and shrimp, are the primary source of chitin. The processes of demineralization, deproteinization, and deacetylation can be carried out using either chemical or biological methods. To produce chitosan (CS), acetyl groups must be removed during the deacetylation process. The degree of deacetylation (DD) of chitosan is influenced by several factors, such as alkali concentration, temperature, treatment duration, and the number of alkali treatments. Chemically, chitin can be deacetylated using a 40–50% aqueous alkali solution at temperatures of 100–160°C over a period of a few hours (Pellis, Guebitz, & Nyanhongo, 2022). Chitosan (CS) is a polycationic polymer with positively charged amino groups (pK_a of 6.5), making it soluble in liquids ranging from acidic to neutral. Its solubility is influenced by several factors, including the pH of the solution, molecular weight, and degree of deacetylation (DD%). As the molecular weight of CS increases, its dissolution rate slows due to the formation of numerous intra- and intermolecular hydrogen bonds between the polymer chains. Additionally, as the degree of deacetylation increases, more amino groups in the chain become protonated, resulting in enhanced water solubility (Islam, Dmour, & Taha, 2019).

The purpose of this study is to conduct a comprehensive review of the scientific literature to provide relevant and useful information on chitosan. This analysis will not only cover the various extraction methods of this natural biopolymer but also its physicochemical properties and the potential modifications that can be made to enhance or tailor its characteristics. Finally, the study will highlight the diverse applications of chitosan in fields such as biomedicine, agriculture, and the food industry, emphasizing its potential as a multifunctional material.