

Unlocking Nature's Building Blocks: Emerging Advances in Chitin and Collagen Research

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1. Introduction

Chitin and collagen—two of nature's most abundant structural biopolymers—continue to inspire breakthrough innovations in materials science, biomedicine, food engineering, food packaging, and environmental sustainability. Their unique hierarchical architectures, intrinsic biocompatibility, and tunable physicochemical properties have cemented their role as key biomaterials for next-generation applications. This Special Issue of *Polysaccharides*, “Chitin and Collagen: Isolation, Purification, Characterization, and Applications, 2nd Edition,” brings together state-of-the-art research that advances our molecular understanding and technological utilization of these versatile biopolymers. In particular, emerging advances underscore their growing significance as sustainable, biodegradable alternatives for food packaging, addressing both performance and environmental challenges in this critical sector.

Building upon previous integrative reviews such as Rahman's Editorial on marine biopolymers [1], this Special Issue highlights important progress in extraction efficiency, structural analysis, functionalization strategies, and translational applications. Chitin and collagen research is rapidly evolving, driven by environmental pressures, climate change, circular-bioeconomy initiatives, and increasing demand for bio-derived functional materials [2–5], and value-chain trends for marine biopolymers have been characterized in recent global analyses [2].

2. Highlights from This Special Issue

2.1. Advances in Extraction and Purification Strategies

Several articles in this Special Issue present novel methods that improve the sustainability, scalability, and cost-effectiveness of isolating chitin and collagen from marine and terrestrial sources. These studies also advance the sustainable and efficient extraction of chitin and the preparation of chitosan-based functional materials. They reflect the growing emphasis on eco-friendly demineralization, enzyme-assisted extraction, and green chemistry approaches, echoing global trends in biopolymer valorization and sustainable extraction [6–9]. Selvoski et al. [10] provide a compelling demonstration of chitin extraction from marine biofouling organisms, *Jassa* amphipods and *Coryne* hydroids, showing that these understudied species provide chitin of comparable quality to commercial references. Their work (Figure 1) exemplifies how marine waste can be repositioned as a valuable biomaterial feedstock, supporting circular bioeconomy goals.

Privar et al. [11] investigate the gelation and cryogelation behavior of chitosan in the presence of diglycidyl ether crosslinkers, revealing the underlying causes of poor



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crosslinking efficiency in acidic media. Their mechanistic insights have direct implications for hydrogel design.

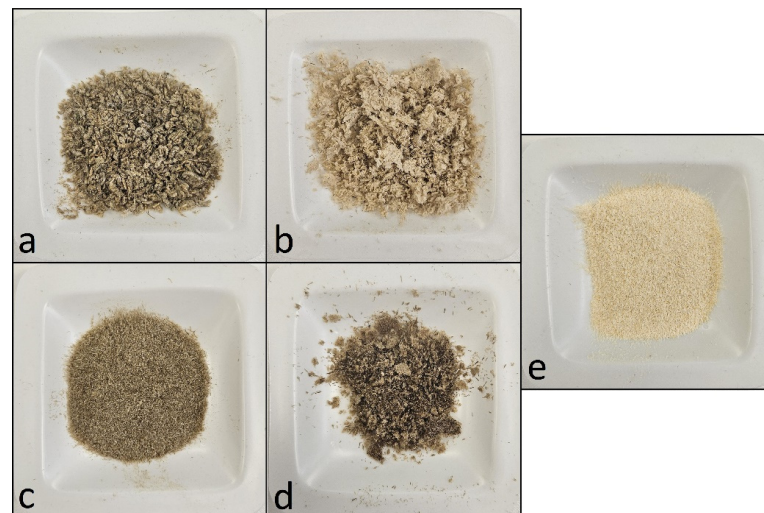


Figure 1. Chitin extracted from amphipods and hydroids. This figure illustrates the extraction of chitin from unconventional marine sources, with clear visual comparison to commercial chitin. (a) Powdered amphipods, (c) powdered hydroids, and their corresponding extracted chitin. (b) Chitin extracted from powdered amphipods, (d) chitin extracted from powdered hydroids, and the commercially purchased chitin. (e) Chitin derived from shrimp shells [10].

Boughanmi et al. [12] examine polyelectrolyte complex formation between chitosan and pectin or PEMA, highlighting how molecular weight and mixing speed govern complex stability—an important consideration for formulation science.

In parallel, Mourak et al. [13] optimize the TEMPO-mediated oxidation of chitosan, demonstrating enhanced antibacterial and antioxidant properties, positioning TEMPO-oxidized chitosan as a promising bioactive material.

Finally, Selvoski et al.'s extraction work [10] and the biological-response survey of Schröder et al. [14] (Figure 2), together, demonstrate how source variation and composition influence chitosan properties. These figures highlight two core advances emerging from the Special Issue: (i) expanding natural chitin sources through sustainable harvesting; and (ii) understanding how molecular architecture dictates biological and functional responses.

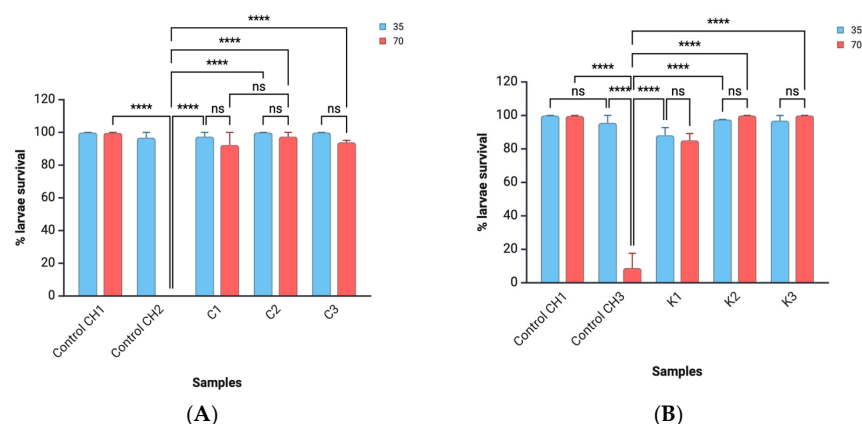


Figure 2. Biological and activity profiling of chitosan mixtures. The graphical summary of molecular-weight variants, deacetylation, mixed formulations, and the resulting antimicrobial/biological response helps highlight the tunability of chitosan-based materials. (A) Samples C1, C3, and C4 compared to control samples (CH1 and CH3); (B) samples K1, K2, and K3 compared to control samples (CH1, CH3), **** p -value < 0.0001 [14].

2.2. Structural Characterization and Functional Properties

The structural tuning of chitosan and chitin-based systems emerged as a consistent theme across this Special Issue.

Díaz Bukvic et al. [15] investigate how the 3D arrangement of polyhydroxylated crosslinkers affects the mechanical and physicochemical properties of chitosan hydrogels, demonstrating that crosslinker geometry is a powerful determinant of hydrogel stiffness, swelling, and microstructure.

Schröder et al. [14] provide a molecular-weight-resolved comparison of chitosan mixtures derived from marine sources, linking variations in deacetylation and MW distribution to antimicrobial activity and cytocompatibility (Figure 2).

Sarier et al. [16] advance thermoresponsive chitosan films designed for food packaging, showing that temperature-dependent swelling and mechanical properties can be exploited to create multifunctional, biodegradable packaging materials.

Hidaka and Sakai [17] report on photo and Schiff base crosslinkable chitosan/oxidized glucomannan hydrogels, demonstrating printability and crosslinking versatility ideal for 3D bioprinting applications.

Córdoba et al. [18] introduce self-healing injectable hydrogels derived from carboxymethyl chitosan and oxidized agarose, highlighting reversible bonding networks and shear-thinning behavior.

These contributions collectively reinforce that chitin/chitosan structural alterations—whether via oxidation, crosslinker geometry, or polymer blending—directly dictate macroscale behavior. This observation is consistent with earlier global insights into chitin and collagen structure–function relationships [19–21], and with their emerging roles as biomineralization templates [22].

2.3. Toward Applications: From Biomedicine to Environmental Remediation

A diverse set of applied studies illustrates the broad relevance of chitin-based materials. Krastev et al. [23] develop chitosan-coated electrospun PHB biohybrid mats capable of supporting growth and long-term storage of *Bacillus subtilis*—a promising platform for microbial preservation and agricultural biotechnology. Zanotti et al. [24] produce supercritical-dried chitosan-based aerogels with significant adsorption capacity for methyl orange dye, presenting a scalable approach for wastewater remediation. Chung et al. [25] compare the adsorption behaviors of graphene oxide–chitosan and graphene–chitosan hybrids, revealing that surface chemistry strongly influences dye uptake and sorption mechanisms.

In the realm of food and agriculture, de Gante-de la Maza et al. [26] investigate chitosan enriched with methanolic plant extracts, demonstrating antifungal activity while assessing phytotoxicity and acute toxicity for safe agricultural use.

Finally, Schröder et al. [14] and Selvoski et al. [10] underscore practical pathways for producing biologically responsive or sustainably sourced chitosan for future biomedical, packaging, and environmental applications.

Although this Special Issue was designed to encompass both chitin and collagen, the current group of submissions leans strongly toward chitin and chitosan. This trend reflects a global surge in interest in marine-derived polysaccharides, sustainable sourcing, and valorization of biomass—including invasive or biofouling species. Nonetheless, we anticipate that collagen-focused contributions will expand in future volumes as attention on marine collagen and hybrid chitin–collagen materials intensifies.

3. Outlook and Future Directions

As I reflect on the contributions gathered here, several prospective trajectories emerge for the field of chitin and collagen research:

1. **Food Packaging Applications:** Recent advances in chitosan-based films and composites, as highlighted by Sarier et al. [16], point to an exciting future for sustainable food packaging solutions. Thermoresponsive and biodegradable chitosan films offer the potential for smart packaging that adapts to environmental conditions, reduces plastic waste, and extends shelf life. Ongoing research should focus on optimizing barrier properties, mechanical strength, and food safety compliance, as well as scaling up production methods for industrial use. Integration of bioactive compounds, such as plant extracts or antimicrobial agents, could further enhance packaging functionality by preventing spoilage and improving food security. Collaboration with food scientists, packaging engineers, and regulatory agencies will be crucial to translating these laboratory innovations into commercial products that meet the diverse needs of Canadian and global consumers.
2. **Expanded Source Diversity and Circular Bioeconomy:** The successful use of biofouling organisms suggests a promising path toward waste valorization and sustainable sourcing. Future work could explore other underutilized biomasses (e.g., invasive species, algal–fungal composites, industrial by-products, etc.), potentially coupling chitin extraction with ecological remediation.
3. **Deeper Structure–Function Mapping:** Given the wide variation in degree of acetylation (DA), crystallinity, molecular weight (MW), and morphology, all shown to influence thermal, mechanical, and biological behavior, systematic studies correlating structure to function will be invaluable. This will facilitate the rational design of materials targeted for specific uses (biomedical implants, drug delivery, filtration, environmental remediation, food packaging, etc.).
4. **Collagen Resurgence—Especially Marine Collagens and Composite Materials:** While this issue saw mostly chitin/chitosan-based works, I anticipate renewed interest in collagen, especially marine-derived or otherwise non-traditional collagens, and their integration with polysaccharides (e.g., composites, hybrid scaffolds). Such efforts could leverage the complementary strengths of collagen (protein–ECM mimicry) and chitin/chitosan (biodegradable polysaccharide scaffolding).
5. **Toward Translation and Standardization:** As more labs contribute extraction protocols, physicochemical characterizations, and application demonstrations, there will be increasing demand for standardization: agreed methods for measuring DA, MW, crystallinity, bioactivity, and safety; benchmarks for biomedical and environmental applications; and guidelines for scalable, reproducible processing.

4. Conclusions

The collection of papers in this Special Issue reaffirms the extraordinary potential of chitin and its derivatives and underscores that even in 2025, we are far from exhausting their richness. By opening new resource streams (marine biofouling organisms), refining material design (chitosan mixture tuning), and pointing toward practical applications, the contributions assembled here represent both maturity and innovation in the field. As Guest Editor, I am grateful to all the authors, reviewers, and readers who embraced our broad and future-oriented vision for “Chitin and Collagen.” I hope this Special Issue serves not only as a compendium of current advances but also as a springboard for future breakthroughs across sustainability, biomedicine, materials science, food packaging, and beyond.

Conflicts of Interest: The author declares no conflicts of interest.

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