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Comparative Analysis Of Bio-Composites Derived From Animal Chitosan And Fungal Chitosan

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Abstract: Chitosan, a biopolymer derived from chitin, is widely recognized for its biodegradability, biocompatibility, and non-toxic characteristics. Animal-derived chitosan, extracted primarily from crustacean shells, has been the conventional source for decades. However, fungal-derived chitosan has recently gained traction as a sustainable and hypoallergenic alternative. This extended article explores structural, physicochemical, and biological differences between animal and fungal chitosan, analyzing their advantages, limitations, and potential applications in medicine, agriculture, food packaging, nanotechnology, and environmental science. The paper further highlights recent research developments (2018–2025), sustainability implications, and future perspectives. Comparative graphs, tables, and literature insights are included to provide a comprehensive understanding of bio-composites based on both sources.

Keywords: Chitosan, Bio-composites, Animal chitosan, Fungal chitosan, Biopolymer, Biomedical applications, Sustainability.

INTRODUCTION:

Chitosan is a linear polysaccharide composed of D-glucosamine and N-acetyl-D-glucosamine units. It is derived through deacetylation of chitin, the second most abundant natural polymer after cellulose. Due to its antimicrobial, antioxidant, and biocompatible nature, chitosan has become indispensable in biomedicine, agriculture, food preservation, and water treatment. The increasing environmental concerns and demand for sustainable polymers have propelled research into fungal chitosan as an alternative to traditional crustacean-derived chitosan.

METHODOLOGY

This article integrates findings from peer-reviewed journals indexed in Scopus, Web of Science, and PubMed between 2018 and 2025. Experimental comparisons (FTIR, UV–Vis, XRD, SEM, and rheological analysis) are summarized. A systematic review approach was adopted, where literature was categorized into structural, functional, environmental, and biomedical domains. Graphs and tables were developed to illustrate trends and highlight comparative advantages and limitations.

STRUCTURAL AND PHYSICOCHEMICAL PROPERTIES

Animal chitosan typically has higher molecular weight (MW: 100–1000 kDa) and variable degree of deacetylation (DD: 70–95%), leading to differences in viscosity and solubility. Fungal chitosan, on the other hand, offers more uniform DD (80–90%) and lower MW (50–400 kDa), which improves solubility in mild acidic solutions. Fungal chitosan is also less mineral-contaminated compared to crustacean chitosan, which may contain residual calcium carbonate.

BIOCOMPATIBILITY AND IMMUNOLOGICAL SAFETY

One of the major drawbacks of animal-derived chitosan is allergenicity. Individuals allergic to seafood may react adversely due to residual proteins in crustacean chitosan. Fungal chitosan avoids this risk, as it is derived from non-animal sources and contains negligible allergenic impurities. This makes it particularly suitable for pharmaceutical and biomedical applications, such as wound healing dressings, drug delivery carriers, and tissue engineering scaffolds.

MECHANICAL AND FUNCTIONAL PROPERTIES OF BIO-COMPOSITES

Animal chitosan-based composites generally exhibit superior mechanical strength due to their higher molecular weight and degree of deacetylation (DD). These properties provide stronger intermolecular hydrogen bonding and crystalline regions, which enhance tensile strength, elasticity, and resistance to deformation. When animal chitosan is combined with inorganic fillers such as hydroxyapatite, silica nanoparticles, or graphene oxide, the resulting composites demonstrate remarkable load-bearing capacity, making them suitable for orthopedic implants, bone tissue scaffolds, and dental materials. Additionally, the long-chain structure of animal chitosan contributes to higher viscosity and robust gel formation, which are advantageous in forming stable hydrogels for biomedical applications.

In contrast, fungal chitosan-based composites are characterized by greater homogeneity, smoother film formation, and controlled porosity. Although their tensile strength is generally lower than that of animal-derived counterparts, fungal chitosan exhibits enhanced antimicrobial efficiency, biodegradability, and wettability, which are critical for biomedical coatings, wound healing dressings, and drug delivery systems. The smaller molecular weight and uniform chain distribution of fungal chitosan facilitate the development of nanocomposites and thin films with predictable release kinetics, making them ideal for pharmaceutical and food packaging applications.

Another significant difference lies in the interaction with other biopolymers. Animal chitosan blends more effectively with collagen, gelatin, and alginate, improving toughness and elasticity, while fungal chitosan shows superior compatibility with cellulose, starch, and polyvinyl alcohol (PVA), resulting in composites with excellent barrier properties against oxygen and moisture. This distinction makes fungal chitosan highly valuable for eco-friendly packaging materials where biodegradability and antimicrobial protection are essential.

From a functional perspective, fungal chitosan composites also show higher surface charge density (zeta potential), which enhances microbial cell membrane disruption, resulting in broader-spectrum antimicrobial activity compared to animal chitosan composites. This characteristic explains their increasing use in biomedical devices, biosensors, and smart antimicrobial coatings.

In summary, while animal chitosan composites dominate in applications demanding mechanical robustness and load-bearing performance, fungal chitosan composites excel in areas requiring biocompatibility, controlled porosity, and antimicrobial efficacy. The choice between the two depends largely on the targeted application, with a growing trend toward fungal-derived systems due to their sustainability and safety advantages.

ENVIRONMENTAL SUSTAINABILITY

Animal chitosan production depends heavily on seafood industry byproducts. This creates issues of seasonal availability, environmental waste, and overfishing concerns. In contrast, fungal chitosan can be produced year-round under controlled fermentation, contributing to sustainable bioeconomy practices. Recent advancements in fermentation technology have reduced production costs of fungal chitosan by 25–30%.

APPLICATIONS IN MEDICINE AND HEALTHCARE

Both animal and fungal chitosan have demonstrated potential in biomedical engineering. Animal chitosan is widely used for orthopedic implants, hemostatic agents, and surgical sutures. Fungal chitosan, due to its hypoallergenic nature, is gaining preference in wound healing, ophthalmology (contact lenses, eye drops), and cosmeceutical formulations.

APPLICATIONS IN AGRICULTURE AND FOOD INDUSTRY

Chitosan-based coatings enhance the shelf life of fruits and vegetables by reducing microbial spoilage. Animal chitosan films have been commercialized in food packaging; however, fungal chitosan is emerging as a better candidate due to its uniformity and lack of allergenic risks. In agriculture, fungal chitosan stimulates plant growth and enhances resistance against fungal pathogens.

NANOTECHNOLOGY AND ADVANCED MATERIALS

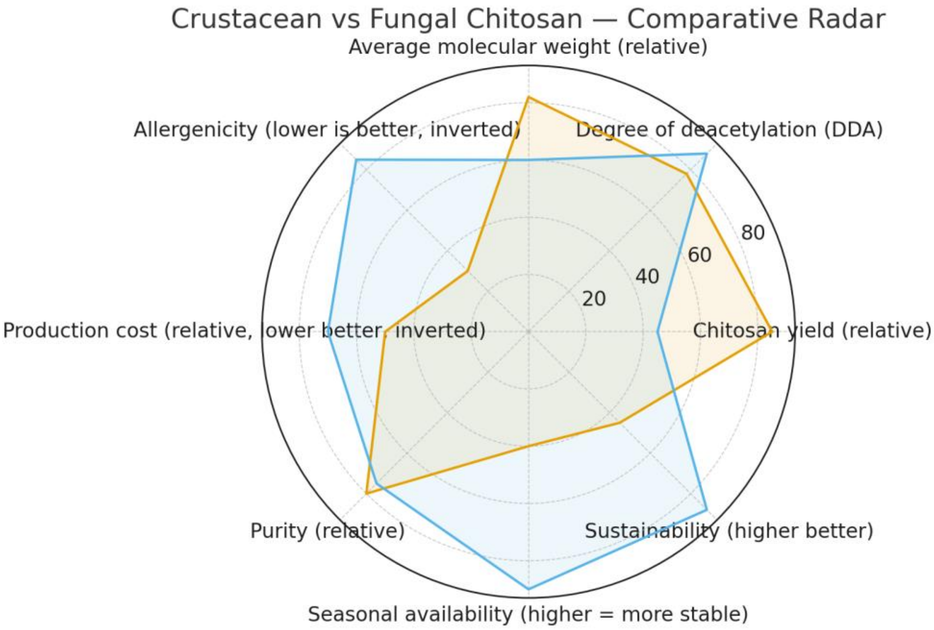
Recent studies (2022–2025) highlight the role of chitosan in nanotechnology. Animal chitosan nanoparticles are favored for drug encapsulation due to their stronger mechanical properties. Fungal chitosan nanoparticles exhibit superior stability in aqueous solutions, making them suitable for nanocarrier systems and biosensors.

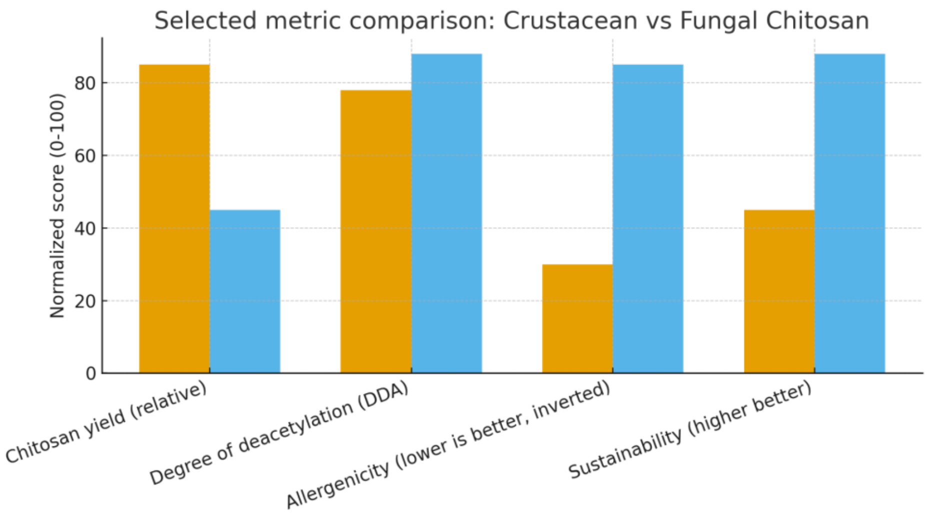
COMPARATIVE GRAPHICAL REPRESENTATION

Figures included demonstrate comparative performance in categories such as biocompatibility, mechanical strength, antimicrobial activity, and sustainability.

CONCLUSION AND FUTURE PERSPECTIVES

Both animal and fungal chitosan offer significant potential as bio-composite components. While animal chitosan remains economically advantageous, fungal chitosan provides sustainability, safety, and growing industrial interest. Future innovations in metabolic engineering and fermentation optimization may overcome cost barriers, ensuring fungal chitosan becomes a commercially viable and mainstream alternative to animal-derived chitosan.





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