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Abstract

From Petrochemical to Photosynthetic: Algae-Derived Polymers for Sustainable Industrial Applications †

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† Presented at the 3rd International Online Conference on Polymer Science, 19–21 November 2025; Available online: https://sciforum.net/event/IOCPS2025.

Keywords: algae; algae-derived polymers; biodegradable; sustainability; bioplastics; circular economy; life cycle assessment

The global reliance on fossil-derived polymers continues to contribute to environmental degradation and climate change. As the world seeks sustainable alternatives, algae-derived polymers have emerged as a promising solution due to their renewable nature and compatibility with green chemistry and circular economy principles. Unlike traditional biomass sources, algae can be cultivated on non-arable land using saline or wastewater, reducing land-use conflict and freshwater consumption while simultaneously sequestering atmospheric CO_2. This review examines recent progress in the extraction, processing, and functionalization of algae-derived polymers, with a particular focus on polysaccharides such as alginate and carrageenan. A comparative analysis was conducted to evaluate their mechanical performance, biodegradability, and application scalability across various industries including sustainable packaging, biomedical devices, and textiles. The review draws on data from peer-reviewed publications within the past decade. The findings highlight that algal polysaccharides offer excellent film-forming capabilities, mechanical adaptability, and environmental biodegradability. Seaweed-derived polymers like carrageenan have shown strong potential in biomedical fields due to their gel-forming and biocompatible nature. Life-cycle assessments support the environmental benefits of algae-based bioplastics compared to conventional plastics. In conclusion, algae-derived polymers represent a rapidly advancing frontier in sustainable materials science. While their adoption in high-value sectors is accelerating, further interdisciplinary research is needed to overcome related cost, processing, and commercialization challenges.

Author Contributions: Conceptualization, A.H.M.A. and T.T.D.-A.; Investigation, T.T.D.-A.; Resources, A.H.M.A.; Data curation, T.T.D.-A.; Writing—Original Draft Preparation, T.T.D.-A.; Writing—Review and Editing, A.H.M.A.; Supervision, A.H.M.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Check for updates

Academic Editor: Valentina Siracusa

Published: 14 November 2025

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Conflicts of Interest: The authors declare no conflict of interest.

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https://doi.org/10.3390/proceedings2026136028