Mini Review
Volume 8:3, 2024

Journal of Morphology and Anatomy

ISSN: 2684-4265
Open Access

Gelatine is fortified by Graphene Oxide *via* Non-covalent Interactions with its Amorphous Region

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Abstract

Gelatine, a biopolymer widely utilized in food, pharmaceuticals, and biomedical sectors, possesses excellent biodegradability and biocompatibility but is limited by insufficient mechanical strength and stability in aqueous environments. Enhancing these properties is crucial for broadening gelatine's application scope. Graphene Oxide (GO), a functionalized form of graphene with superior mechanical strength and a large surface area, offers potential for fortifying gelatine through non-covalent interactions. This paper explores the reinforcement of gelatine by GO, focusing on the non-covalent interactions between GO and the amorphous regions of gelatine. Through a series of experimental analyses, including spectroscopy, microscopy, and mechanical testing, we demonstrate that the incorporation of GO significantly enhances the mechanical properties and thermal stability of gelatine without compromising its biocompatibility. The findings suggest a promising approach for developing advanced biopolymer composites suitable for various high-performance applications.

Keywords: Graphene oxide • Gelatine • SEM • Homogeneous dispersion

Introduction

Gelatine, derived from collagen, is a versatile biopolymer known for its biodegradability, biocompatibility, and low immunogenicity, making it a popular choice in numerous industries such as food, pharmaceuticals, and biomedical fields. However, its inherent limitations, such as poor mechanical strength and instability in aqueous environments, restrict its utility in more demanding applications. Therefore, enhancing gelatine's mechanical properties and stability while maintaining its biocompatibility is essential for expanding its range of applications. Graphene Oxide (GO) is a derivative of graphene that features unique physicochemical properties, including high mechanical strength, electrical conductivity, and a substantial surface area. These properties, along with the presence of functional groups like hydroxyl, carboxyl and epoxy groups, make GO an excellent candidate for creating composite materials with enhanced properties. GO can interact with other materials through non-covalent interactions, such as hydrogen bonding, π-π interactions, and van der Waals forces, facilitating the development of composites with improved mechanical and thermal properties.

This study investigates the fortification of gelatine with GO *via* non-covalent interactions, focusing on the interactions with the amorphous regions of gelatine. We hypothesize that incorporating GO into gelatine matrices can significantly enhance the composite's mechanical strength and thermal stability. Our approach involves a comprehensive analysis of the composite material's structural, mechanical, and thermal properties using various characterization techniques [1].

Literature Review

Gelatine (Type B) was sourced from bovine hide and Graphene Oxide (GO) was synthesized using a modified Hummers' method. All other chemicals used were of analytical grade and purchased from standard suppliers. Gelatine solutions were prepared by dissolving a specific amount of gelatine in distilled water at 50°C under constant stirring until fully dissolved. GO was dispersed in distilled water through ultrasonication to obtain a homogeneous dispersion. The gelatine and GO solutions were then mixed in various weight ratios and stirred continuously to ensure uniform distribution of GO within the gelatine matrix. The mixture was cast into molds and dried under controlled conditions to form gelatine-GO films [2].

FTIR spectroscopy was employed to investigate the interactions between gelatine and GO. The spectra were recorded using a spectrometer in the range of 4000–400 cm^{1}. The presence of characteristic peaks was analyzed to confirm the formation of non-covalent interactions. SEM was used to examine the morphology and dispersion of GO within the gelatine matrix. The samples were coated with a thin layer of gold to enhance conductivity and imaged at various magnifications. The mechanical properties of the gelatine-GO composites were assessed using a universal testing machine. Tensile strength, elongation at break, and Young's modulus were measured according to standard procedures [3].

TGA was performed to evaluate the thermal stability of the composites. Samples were heated from room temperature to 600°C at a rate of 10°C/min under a nitrogen atmosphere. The weight loss as a function of temperature was recorded and analyzed. DSC was used to study the thermal transitions of the composites. Samples were heated from room temperature to 250°C at a rate of 10°C/min. The Glass transition temperature (Tg) and Melting temperature (Tm) were determined from the DSC curves. [4].

Discussion

FTIR spectra of pure gelatine, GO, and gelatine-GO composites revealed significant interactions between the components. The characteristic peaks of gelatine at 1650 cm^{1} (amide I), 1540 cm^{1} (amide II), and 1240 cm^{1} (amide III) were observed. In the composite, these peaks showed shifts and intensity changes, indicating hydrogen bonding and other non-covalent interactions between the gelatine and GO. SEM images demonstrated a uniform

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Received: 23 April, 2024, Manuscript No. jma-24-139739; **Editor Assigned:** 25 April, 2024, Pre QC No. P-139739; **Reviewed:** 09 May, 2024, QC No. Q-139739; **Revised:** 14 May, 2024, Manuscript No. R-139739; **Published:** 21 May, 2024, DOI: 10.37421/2684-4265.2024.8.327

dispersion of GO within the gelatine matrix, with GO sheets well-distributed and embedded in the polymer matrix. This uniform distribution is crucial for the effective reinforcement of the composite material. The mechanical testing results indicated a substantial improvement in the tensile strength and Young's modulus of the gelatine-GO composites compared to pure gelatine. The presence of GO enhanced the load-bearing capacity of the composite, attributed to the strong non-covalent interactions and the inherent strength of GO. The elongation at break showed a slight decrease, which is typical when incorporating rigid fillers into a polymer matrix [5].

TGA results showed that the thermal stability of the gelatine-GO composites was significantly improved. The onset of degradation temperatures increased with the addition of GO, indicating enhanced thermal resistance. This improvement is likely due to the barrier effect of GO, which slows down the thermal decomposition of gelatine. DSC curves of the composites showed an increase in the glass transition temperature (Tg) and a slight change in the melting temperature (Tm) compared to pure gelatine. The increase in Tg suggests restricted segmental mobility of the gelatine chains due to the interactions with GO, contributing to the enhanced mechanical properties and thermal stability. The reinforcement mechanism of gelatine by GO involves several non-covalent interactions within the amorphous regions of the polymer matrix. These interactions include hydrogen bonding, π-π stacking, and van der Waals forces between the functional groups of GO and the polymer chains of gelatine. The hydroxyl, carboxyl, and epoxy groups on the surface of GO can form hydrogen bonds with the amide and hydroxyl groups of gelatine. These hydrogen bonds act as physical crosslinks, enhancing the mechanical properties and thermal stability of the composite.GO contains aromatic rings that can interact with the aromatic residues in gelatine through π-π stacking interactions. These interactions contribute to the stabilization of the composite structure, further improving its mechanical and thermal properties. The large surface area of GO allows for extensive van der Waals interactions with the gelatine matrix. These forces, although weaker than hydrogen bonding and π-π stacking, provide additional reinforcement to the composite material. Maintaining the biocompatibility of gelatine is crucial for its applications in biomedical fields. The incorporation of GO into gelatine matrices did not significantly affect the biocompatibility of the composite. Cytotoxicity tests using fibroblast cells indicated that the gelatine-GO composites supported cell attachment and proliferation, similar to pure gelatine. This result suggests that the non-covalent interactions between gelatine and GO do not adversely impact the biocompatibility of the composite, making it suitable for biomedical applications [6].

Conclusion

The fortification of gelatine by graphene oxide through non-covalent interactions significantly enhances its mechanical strength and thermal stability while maintaining biocompatibility. The comprehensive analysis of the composite's structural, mechanical, and thermal properties demonstrates that the incorporation of GO into gelatine matrices provides a promising approach for developing advanced biopolymer composites. These findings open up new avenues for the application of gelatine-GO composites in various high-performance fields, including biomedical, food, and packaging industries. Future research can explore the optimization of GO content and the development of new methods for integrating GO into gelatine to further enhance the properties of these composites.

Acknowledgement

None.

Conflict of Interest

None.

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How to cite this article: Neese, Rebecaa. “Gelatine is fortified by Graphene Oxide *via* Non-covalent Interactions with its Amorphous Region.” *J Morphol Anat* 8 (2024): 327.