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Self-assembly Cellulose-based Biomedical Materials

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Abstract

Cellulose is the most abundant biopolymer and the fundamental structural component of plants. It is a natural linear polysaccharide based on repeating units of (1⟶4) linked D-glucose (33% of vegetal material). It combines biocompatibility, strong biodegradability (certain ruminants, termites, and fungus have glycoside hydrolases and cellulase enzymes), and no toxicity with adequate esterification reactivity.

Keyword: Cellulose • Biopolymer • Biomedical materials

Introduction

Several cellulose esters show proper aqueous solubility or can produce stable aqueous nanoparticulate or micelle dispersions following further functionalization, even when cellulose itself is not soluble in water. In this context, water-soluble cellulose esters such as methyl cellulose (MC), hydroxyethyl cellulose (HEC), and (hydroxypropyl) methyl cellulose (HPMC) are widely utilised in the food and pharmaceutical industries, and are viewed as promising materials for novel smart medications [1].

Because of the polymer matrix biocompatibility and swelling qualities when in contact with biological fluids, HPMC-based drug delivery devices are well established in medical applications. For various medicinal uses, cellulose-based micro/nanoparticles, hydrogels, fibres, films, and composites have been proposed (e.g. antibiotic and anticancer drug delivery). Antimicrobial behaviour seen after cationization or when manufactured as composites or other formulations against L. monocytogenes and *E. coli* [1], as well as reduced cytotoxicity, are two advantages of cellulose-based systems. Self-assembly of stimuli-responsive amphiphilic celluloses as nanoparticulate systems for prolonged release of various medicines, on the other hand, is a hot research topic [2,3].

However, instead of delivering the covalently grafted molecule, these self-assembled devices are primarily focused on releasing loaded hydrophobic medicines. Furthermore, information on the development of agrochemical controlled delivery systems is not as common as reports on medical research. Our research builds on prior work in the field of polymer-based methods for long-term release of brassinosteroids in agriculture. Diosgenin ((25R)-spirost-5-en-3-ol) is a steroidal sapogenin derived mostly from the basic hydrolysis of dioscin, the most abundant steroidal saponin. Both dioscin and its derivative diosgenin have antioxidant, anti-inflammatory, estrogenic, and cytotoxic properties in certain cancer cell lines. Due to the presence of the necessary backbone and stereochemistry in diosgenin, it is the primary substrate in the chemical synthesis of certain steroids [3]. In this way, diosgenin is the predecessor of two Cuban brassinosteroids analogues (DI31 and S7) that have been employed as commercial agrochemicals for the past two decades (Biobras-16). Once applied, Biobras-16 regulates plant growth and protects crops from biotic and abiotic stress, resulting in yield increases of 5–25%. However, because exogenous brassinosteroids are rapidly metabolised, the projected agrochemical effects are not fully realised in plants.

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Biomedical Materials

One of the most promising ways for producing micelles from amphiphilic polymers is self-assembly. Amphiphilic block copolymers in solution can self-assemble into a range of nanoscale structures, including micelles and vesicles, despite the presence of both hydrophilic and hydrophobic groups in the backbone of the molecular chain. Polymer micelles also have a wide range of potential applications in biomedicine, including medication or gene delivery, biosensors, and bioimaging. Many synthetic block polymers, on the other hand, are limited in their use on a broad scale due to their high costs and probable biotoxicity [4].

As a result, there has been an increasing interest in producing amphiphilic polymers from natural polysaccharies, due to their numerous advantages, including their abundance, low cost, safety, non-toxicity, biocompatibility, and biodegradability. Cellulose is a type of polysaccharide that may be extracted from trees, cotton, straw, and other higher plant cell walls since it is produced by photosynthesis [5]. It is one of the most abundant natural polymer organic molecules on the planet, consisting of -(1-4)-linked anhydroglucose repeating units (($C_6H_{10}O_5$) n, n=10000 to 15000, depending on the cellulose parent material) cellulose acetate (CA), methylcellulose (MC), ethylcellulose (EC), hydroxyethylcellulose (HEC), hydroxypropylcellulose (HPC), sodium carboxymethylcellulose (CMC), and other cellulose derivatives are commonly utilised.

Cellulose

Furthermore, cellulose and its derivatives have been shown to be harmless in both animals and humans, making it a suitable biomedical material. Meanwhile, the abundance of functional groups in the cellulose molecule allows for modification of cellulose and its derivatives to produce a self-assembling product. Self-assembly as a practical and successful technique for manufacturing cellulose-based materials has recently been extensively investigated, as evidenced by a growing number of papers. Molecules associate into well-defined, functional geometries during the self-assembly of cellulose-based materials through simple interactions with one another. The self-assembly of cellulose and its derivatives is similar to that of many other biological molecules, such as DNA and proteins, which might produce materials in the aqueous phase under normal conditions. We looked at how self-assembled cellulose materials have progressed in biomedicine recently. We first looked at cellulose and its derivatives dissolution and modification. Meanwhile, the self-assembly of cellulose-based polymers was succinctly explained. Following that, cellulose-based materials with various stimuliresponsive properties, such as temperature, pH, light, and redox, were highlighted [6]. Finally, we talked about how self-assembled cellulose materials can be used in biomedicine for drug/gene delivery, bioimaging, biosensors,

and other applications. We hope that by presenting self-assembled cellulose materials from theory to application, this review will provide a comprehensive overview of this intriguing new biomedical material [7].

As a result, up to two or three foliar spray administrations are typically applied to crops, increasing the Biobras-16 application's economic cost. Furthermore, the hydrophobicity of brassinosteroids DI31 and S7 limits their bioavailability to plants, and the commercial Biobras-16 formulation contains a significant amount of ethanol as well as certain environmentally undesirable chemicals (i.e. N, N-dimethylformamide, surfactants). The synthesis of novel biodegradable conjugates of diosgenin, DI31, and S7, by conjugation to water soluble cellulose esters via hydrolysable ester linkages, is presented here to increase bioavailability and offer sustained release of the parent steroids over time.

Conclusion

In this study, we created steroid-cellulose conjugates that were functionalized with three different steroids that were coupled by an ester bond, and we measured their total reflectance. Dynamic light scattering, atomic force microscopy, scanning and transmission electron microscopy were used to assess self-assembly of these conjugates, as well as Fourier transform infrared (ATR-FTIR), proton nuclear magnetic resonance (1H NMR), and bi-dimensional nuclear magnetic resonance (2D-NMR) spectroscopies. In an acidic aqueous media, in vitro drug release of steroids from conjugates was studied. The produced cellulose nanoparticles were further tested in vitro for their agrochemical action against radish (Raphanus sativus). This is, to our knowledge, the first method for developing a cellulose self-assembled particulate-based system for the delivery of brassinosteroids as agrochemicals.

Conflict of Interest

The author has no conflict of interest towards the article.

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