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7427 S dx.doi.org/10.1021/jf201373j

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Ronit Mesilati-Stahy, Kfir Mida, and Nurit Argov-Argaman*

7436 dx.doi.org/10.1021/jf201522b

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Monica Jordheim,* Kjersti Hasle Enerstvedt, and Øyvind M. Andersen

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7465 dx.doi.org/10.1021/jf2008277

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7482 dx.doi.org/10.1021/jf201496h

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7496 dx.doi.org/10.1021/jf104943p

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7506 dx.doi.org/10.1021/jf2005194

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7514 dx.doi.org/10.1021/jf202123q

Incidence of Fumonisin B_2 Production by *Aspergillus niger* in Portuguese Wine Regions

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Gas Chromatographic Determination of *N*-Nitrosamines, Aromatic Amines, and Melamine in Milk and Dairy Products Using an Automatic Solid-Phase Extraction System

Beatriz Jurado-Sánchez, Evaristo Ballesteros,* and Mercedes Gallego*

7527 dx.doi.org/10.1021/jf202042z

Efficacy of a Mycotoxin Binder against Dietary Fumonisin, Deoxynivalenol, and Zearalenone in Rats

Zhiyi Qiang, My Truong, Koen Meynen, Patricia A. Murphy, and Suzanne Hendrich*

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REVIEW

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Pharmacological, Structural, and Drug Delivery Properties and Applications of 1,3-β-Glucans

Benjamin C. Lehtovaara[†] and Frank X. Gu[*,‡]

[†]Department of Chemical Engineering, University of Waterloo, 200 University Avene West, Waterloo, Ontario, Canada N2L 3G1

[‡]Department of Chemical Engineering, Waterloo Institute for Nanotechnology, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1

ABSTRACT: 1,3-β-Glucans are a class of natural polysaccharides with unique pharmacological properties and the ability to form single- and triple-helical structures that can be formed into resilient gels with the application of heat and humidity. The pharmacological capabilities of 1,3-β-glucans include the impartation of tumor inhibition, resistance to infectious disease, and improvements in wound healing. Curdlan is a linear 1,3-β-glucan that has been used extensively to study the nature of these helical structures and gels, and Curdlan sulfates have found ongoing application in the inhibition of HIV infection. 1,3-β-Glucan gels have been used in food science as stabilizers and encapsulating agents, in nanoscience as scaffolds to build nanofibers and nanowires, and in drug delivery to form nanoparticles and create helical micelles encapsulating polynucleotides. 1,3-β-Glucans are beginning to have enormous significance due to their dual nature as structure-forming agents and pharmacological substances, and research is especially focused on the application of these polymers in animal nutrition and drug delivery.

KEYWORDS: 1,3-β-glucans, Curdlan, schizophyllan, helix, freeze−thaw, antitumor, infection, nanostructure, nanoparticle, drug delivery, polynucleotide

INTRODUCTION

1,3-β-Glucans. Natural polysaccharides are an abundantly available resource from which to obtain unique properties applicable to a wide variety of industries. Cellulose is perhaps the most well-known example, with uses in paper manufacturing, membrane technology, textiles, and numerous food applications, and its nanocrystalline form is being used in high-strength polymer composites and novel bandage materials to speed wound healing.[1] Other notable examples are starch, xanthans, and others that are regularly used as freeze−thaw stabilizers, thickeners, and gelation agents in food science,[2] chitosan from shrimp shells with mucoadhesive properties that can facilitate ocular drug delivery,[3,4] and alginates from kelp that form hydrogels suitable as scaffolds for model extracellular matrices[5] or protein delivery vehicles that avoid protein denaturation during gelation.[6]

1,3-β-Glucans are a class of glucopyranose polysaccharides with (1,3) glycosidic linkages (Figure 1) and varying degrees of (1,6) branching obtained from fungal[7] or microbial sources.[8] An illustration of the fungal cell wall adapted from electron micrographs of *Candida albicans*[9] demonstrates the natural presence of β-glucans in fungi (Figure 2). 1,3-β-Glucans form helical structures that may be prompted to gel with the addition of heat and have a unique ability to increase host immunocompetency. Reported pharmacological effects include antitumor activity,[10−12] infection resistance,[13,14] cholesterol reduction,[15,16] and wound healing.[17−19]

The formation of 1,3-β-glucan helical domains may be utilized for many applications or, provided the polysaccharide concentration is high enough, allowed to continue to the formation of a macroscopic gel. The gelation profile is dependent on the degree of branching due to the effect of C(6) branching on helix packing.[20] Curdlan, a linear 1,3-β-glucan, has been a good model for the study of 1,3-β-glucan helical structures as it lacks the interference of periodic branching.[21,22] Because the exact properties such as gelation profiles, solubility, and degrees of branching differ so drastically among the family of 1,3-β-glucans, discussion of the physical properties of these polysaccharides will follow the microbial 1,3-β-glucan Curdlan as a model. Subsequent discussion of applications will focus on the general family of 1,3-β-glucans. The unique properties of 1,3-β-glucans have led to a variety of applications including the formulation of food gels for consumption or to improve stability and nutrition,[23,24] direct therapeutic application,[25,26] encapsulation and controlled release of various bioactive species,[27,28] and application as helical scaffolds for nanostructure formation.[29,30]

PHYSICAL PROPERTIES OF CURDLAN 1,3-β-GLUCANS

Overview. Curdlan was first discovered as a resilient gel-forming polysaccharide bearing β-glycosidic linkages that was biosynthesized from the soil bacterium *Alcaligenes faecalis* var. *myxogenes* in the mid-1960s.[31,32] Curdlan was found to be a linear 1,3-β-glucan that was insoluble in water but soluble in alkaline solutions. Experimentation with the gelation characteristics of Curdlan began shortly afterward.[33,34] Alkaline solutions inhibit hydrogen bonding between C(2) hydroxyls, inhibiting helix formation and leaving the random coil state. Commercial alkali treatment leaves most available Curdlan powder <30% crystalline with a prevalence of a mixture of random coils and some

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