探討混合鍵結葡聚醣之結構特性與應用

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一、　前言

二、　分子特性對混合鍵結葡聚醣凝膠之影響

三、　混合鍵結葡聚醣分子特性在材料中的應用

四、　結論

摘要

混合鍵結葡聚醣(Mixed-linkage glucans, MLGs)是由 β(1,3)與 β(1,4)鍵結組成的水溶性多醣，廣泛存在於穀類植物細胞壁中，具有獨特的凝膠行為與自組裝特性，因此本文目的為探討 MLGs 分子結構對凝膠形成的影響與其應用於奈米纖維複合材料之潛力。結果顯示，燕麥來源的 MLGs 具有較低的聚合度(degree of polymerization, DP) 3 和 4 的比值(1.8–1.9)，於 37 °C 即可形成穩定凝膠，其儲存模數 G'明顯高於損失模數 G''，呈現彈性凝膠特性；相較之下，大麥來源 MLGs 的 DP3:DP4 比值較高(2.4–2.8)，需加熱至 50 °C 以上才能形成明顯網絡結構，這可能和 DP3:DP4 比值較低的 MLGs 含有較多連續 β(1,4)鍵結片段有關，此結構易排列形成氫鍵網絡，使其凝膠溫度低且結構緊密，相較 β(1,3)鍵結比例高則破壞規則性，延緩凝膠形成。進一步透過 VvEG16 酵素水解後，分子量由 1.46×10^{6} g/mol 降至約 1.1×10^{5} g/mol，鏈長縮短並生成纖維狀與球狀顆粒，誘導分子間自組裝形成典型凝膠網絡。最後將其應用於纖維素奈米纖維(cellulose nanofibrils, CNFs)複合材料，原始大麥 β-葡聚醣(MLGB)其 DP3:DP4 為 2.9，能均勻包覆纖維表面，降低乾燥造成的角質化現象。乾燥後再分散樣品透光率由 20%提升至 35%，斷裂應變增加至 29.3%，拉伸強度達 92 MPa，顯示具良好韌性與結構穩定性。綜合上述文獻可得知，MLGs 的分子特性與酵素處理條件對凝膠形成與材料機械性能均具關鍵影響，為設計具可調性之多醣奈米複合材料提供新方向。

Structural characteristics and application of mixed-linkage glucans

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Outline

1. Introduction
2. Effect of molecular characteristics on gelation of mixed-linkage glucans
3. Applications of mixed-linkage glucan molecular characteristics in materials
4. Conclusion

Abstract

Mixed-linkage glucans (MLGs), composed of β(1,3) and β(1,4) linkages, are water-soluble polysaccharides abundant in cereal cell walls with unique gelation and self-assembly. This study explores the effect of MLG molecular structure on gelation and potential in nanofiber composites. Oat-derived MLGs with a lower ratio of degree of polymerization 3 to 4 (DP3:DP4) (1.8–1.9) form stable gels at 37 °C, with storage modulus (G′) exceeding loss modulus (G″), indicating elastic gels. Barley-derived MLGs with higher DP3:DP4 ratio (2.4–2.8) require heating above 50 °C to form a network. Lower DP3:DP4 ratios have more consecutive β(1,4) linkages, promoting hydrogen bonding and dense gels at lower temperatures; higher β(1,3) disrupt regularity, delaying gelation. VvEG16 enzymatic hydrolysis reduces molecular weight from 1.46×10^{6} to $\sim1.1\times10^{5}$ g/mol, producing shorter chains and fibrils/spherical particles that induce self-assembly into gel networks. Finally, it was applied to cellulose nanofibers (CNFs) composites. The native barley β-glucan (MLGB), with a DP3:DP4 ratio of 2.9, could uniformly coat the fiber surface and reduce hornification caused by drying. After drying and redispersion, light transmittance increases from 20% to 35%, fracture strain rises to 29.3%, and tensile strength reaches 92 MPa, showing good toughness and stability. Taken together, the above studies indicate that MLG molecular traits and enzymatic treatment crucially affect gelation and mechanics, offering new routes for tunable polysaccharide nanocomposites.

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