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Mini Review

Research Progress on Modification of Hydroxypropyl Cellulose

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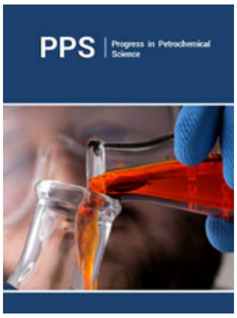

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Abstract

Hydroxypropyl cellulose, a semi-synthetic organic compound, is classified into high substitution and low substitution variants. Both display distinct physical and chemical traits, making them prevalent in a plethora of industries, including the pharmaceutical, daily chemical, construction, food and many others. For most efficient use of hydroxypropyl cellulose, it is crucial to comprehend and enhance its properties. For this reason, research in the field of hydroxypropyl cellulose modification has become a focal point. This paper provides a comprehensive review of the modification methods of hydroxypropyl cellulose and presents the current state of research in the field of hydroxypropyl cellulose modification, which has important reference value for practical application.

Keywords: Hydroxypropyl cellulose; Grafting modification; Crosslinking modification

Introduction

Hydroxypropyl cellulose is an outstanding non-ionic cellulose ether, prepared by reacting pure cellulose with propylene oxide and a small amount of sodium hydroxide [1]. The introduction of hydroxypropyl group significantly weakens the intramolecular and intermolecular hydrogen bonding force of cellulose, thus enhancing its solubility in solution and endowing it with excellent water solubility [2]. Moreover, through continuous research and development, it has been found that hydroxypropyl cellulose has superior edible, thermoplasticity [3], biocompatibility [4] and degradability [5]. As a result, hydroxypropyl cellulose is extensively used as a food additive [6], binder, thickener [7] and stabilizer [8] in numerous fields such as food, environment, daily chemical, textile and others, making significant contributions to the development of these industries. Hydroxypropyl cellulose, although possessing a significant number of hydroxyl groups that could be utilized as reaction groups, it lacks specific functional groups. This necessitates graft modification, which can produce a novel type of hydroxypropyl cellulose with enhanced functions. This significantly broadens its application field and as such, it presents a considerably broader development prospect.

Modification by Grafting

Grafting modification is an efficient technique often employed to enhance the properties of compounds by adapting polar or functional side groups on the polymer chain through free radical polymerization [9]. Consequently, the resulting product displays the advantageous characteristics of both molecules. By utilizing hydroxypropyl cellulose as a raw material, specific functional groups or monomers can be grafted onto it, thereby modifying or augmenting its properties and thereby expanding its scope of application.

Acetoacetyl group graft

Acetoacetyl groups are potent acylation agents capable of converting functional groups such as hydroxyl and amine groups into corresponding acetylation products, which usually enhance the relevant properties of the original compound [10]. Guo M et al. [11] synthesized hydroxypropyl cellulose acetoacetylation graft polymers by grafting acetoacetyl groups from hydroxypropyl cellulose and tested their thermal properties [11]. The research determined that the acetoacetyl groups added altered the crystallization properties of the hydroxypropyl cellulose, increased the heat capacity and boosted the ability to moderate heat effect. This demonstrated the successful grafting and enhancement of the thermoplasticity of the product. Future research can further optimize the reaction conditions to develop more efficient hydroxypropyl cellulose polymers with improved thermoplasticity.

Organosilicone antibacterial agent graft

Hydroxypropyl cellulose exhibits an excellent water absorption property, which is an advantage in some cases, but it also allows for an overgrowth of bacteria, resulting in reduced performance and service life [12]. Thus, it becomes necessary to modify this compound to enhance its antibacterial functionality. Zhang Q et al. [13] obtained Hydroxypropyl Cellulose (m-HPC) with antibacterial properties by grafting a self-made organosilicon antibacterial agent with hydroxypropyl cellulose [13]. It has good antibacterial property and can be used in food, cosmetics and other fields in the future. However, it is worth mentioning that the thermogravimetric experiment shows that the modified hydroxypropyl cellulose has reduced thermal stability. Therefore, enhancing the thermal stability of this novel material is a critical challenge to ensure its enhanced performance in various applications.

Methyl methacrylate and butyl methacrylate graft

Both methyl methacrylate and butyl methacrylate are multifunctional compounds, widely used in many fields such as medical, construction, automotive and electronics [14]. One of their most notable features is its potential to serve as a versatile monomer in the synthesis of polymers or copolymers [15]. This feature allows it to copolymerize with other monomer compounds to create robust chemical bonds and significantly enhance their properties [16]. Guo M et al. [17] prepared hydroxypropyl cellulose grafted polybutyl methacrylate copolymers by emulsion grafting copolymerization [17]. This process significantly improved the thermoplastic characteristics and added resistance to acid and organic reagent corrosion. The outcomes of this study can serve as a useful reference for future research exploring novel, environmentally friendly materials. Moreover, Tan JJ et al. [18] have successfully synthesized a novel copolymer of methyl methacrylate and hydroxypropyl cellulose through emulsion grafting reaction [18]. This copolymer demonstrates excellent resistance to various acid and alkali solutions as well as to organic solvents, but it is shown to have inferior thermal stability, which might be a result of the intense oxidation that takes place within the reaction process. In the future, it is crucial to optimize the preparation methods, such as temperature, PH, etc., to minimize the impact of the grafting reaction on the characteristics of the compounds.

Acrylamide graft

Acrylamide, the most important and simplest acrylamide compound, has a wide range of applications including water treatment flocculants, soil amendments, paper filler adjuvant, chemical grouting agent and fiber modifiers [19]. Shen YC et al. [20] utilized hydroxypropyl cellulose as the backbone and properly grafted polyacrylamide onto it [20]. The resultant polymer displayed excellent water retention and water resistance and therefore is anticipated to prove to be an ideal choice for sand fixation agents. When appropriately applied, it has the potential to assist with the control of land desertification, thereby contributing to the preservation of the environment.

Modification by Crosslinking

Crosslinking modification is the procedure wherein linear or branched polymer chains are connected into network or branched polymer via covalent bonds, leading to a boost in the strength and stability of materials [21]. This characteristic has made it widely concerned in pharmaceutical, food, environmental governance, catalysis and other fields. Shinya Y et al. [22] modified hydroxypropyl cellulose with cinnamoyl through photo crosslinking technology, and the obtained cinnamylated hydroxypropyl cellulose was found to have good thermal stability and good biocompatibility by thermal analysis and cell proliferation experiments [22]. This indicates that cinnamoyl not only enhances the thermal properties of hydroxypropyl cellulose, but also increases the biocompatibility, making its application range more extensive and providing theoretical basis for its application in medical devices and medical drugs in the future.

Other Chemical Modifications

In addition to grafting modification and cross-linking modification, hydroxypropyl cellulose is also modified by introducing some specific groups to it. Zhang YY et al. [23] introduced xanthogenated groups and the sulfur group on hydroxypropyl cellulose and the resulting HCX can be used as an adsorbent for water treatment to adsorb heavy metal ions in water, such as Cu^{2+}, Ni^{2+} and so on [23]. It is an ideal adsorbent for the purification of industrial wastewater. Because of its non-toxicity and pollution-free, it can be widely developed and utilized in the future.

Conclusion

The development of hydroxypropyl cellulose modification technology is an important strategy to enhance the characteristics of hydroxypropyl cellulose. Through a range of methods including grafting, cross-linking and general chemical modifications, the thermal stability, corrosion resistance and biocompatibility of hydroxypropyl cellulose can be significantly enhanced. Although significant progress has been made, the hydroxypropyl cellulose modification market still has considerable room for growth. Moreover, the application of various modification methods in combination has not been comprehensively explored. Looking into the future, with further improvements in hydroxypropyl cellulose modification technology, it is anticipated that hydroxypropyl cellulose will have a broader range of applications and bring more convenience to our daily lives.

References

1. Lavanya D, Kulkarni PK, Dixit M, Raavi PK, Krishna LN (2011) Sources of cellulose and their applications-a review. International Journal of Drug Formulation and Research 2(6): 19-38.
2. Nau M, Trosien S, Seelinger D, Boehm AK, Biesalski M (2019) Spatially resolved crosslinking of hydroxypropyl cellulose esters for the generation of functional surface-attached organogels. Frontiers in Chemistry 7: 367.
3. Wallmeier M, Hauptmann M, Majschak JP (2015) New methods for quality analysis of deep-drawn packaging components from paperboard. Packaging Technology and Science 28(2): 91-100.
4. Godinho MH, Gray DG, Pieranski P (2017) Revisiting (hydroxypropyl) cellulose (HPC)/water liquid crystalline system. Liquid Crystals 44(12-13): 2108-2120.
5. Weis SE, Braunschweig B (2019) Hydroxypropyl cellulose as a green polymer for thermo-responsive aqueous foams. Soft Matter 15(13): 2876-2883.
6. Leminen V, Ovaska SS, Tanninen P, Varis J (2015) Convertability and oil resistance of paperboard with hydroxypropyl-cellulose-based dispersion barrier coatings. Journal of Applied Packaging Research 7(3): 6.
7. Hassanpour S, Azhar FF, Bagheri M (2019) Novel nanogels based on hydroxypropyl cellulose-poly (itaconic acid) for adsorption of methylene blue from aqueous solution: Process modeling and optimization using response surface methodology. Polymer Bulletin 76(2): 933-952.
8. Nwanonenyi SC, Ogbobe O, Madufor IC, Oguzie EE (2016) Inhibitive performance of hydroxypropyl cellulose and potassium iodide on the corrosion of mild steel in sulphuric acid environment. Chemical Science International Journal 16(2): 1-12.
9. Raj V, Shim JJ, Lee J (2020) Grafting modification of okra mucilage: Recent findings, applications and future directions. Carbohydrate Polymers 246: 116653.
10. Pawar SN, Edgar KJ (2012) Alginate derivatization: A review of chemistry, properties and applications. Biomaterials 33(11): 3279-3305.
11. Guo M, Zhang LY, Wang P, Yu J (2012) Preparation and characterization of acetyl acetylation of hydroxypropyl cellulose. Journal of Zhejiang Forestry College 27(4):595-600.
12. Lin CM, Chang YC, Cheng LC, Liu CH, Chang SC, et al. (2020) Preparation of graphene-embedded hydroxypropyl cellulose/chitosan/polyethylene oxide nanofiber membranes as wound dressings with enhanced antibacterial properties. Cellulose 27: 2651-2667.
13. Zhang Q, Wang JT, Jiang S, Wei B, Chen SG, et al. (2010) Study on antibacterial modification of hydroxypropyl cellulose graft. Chinese Journal of Colloid & Polymer 28(4): 171-173+180.
14. Koshut WJ, Arnold AM, Smith ZC, Wright ZM, Sydlik SA (2019) Teaching polymer theory through the living polymerization and characterization of poly (methyl methacrylate) and poly (butyl methacrylate) homo-and copolymers. Journal of Chemical Education 96(5): 895-904.
15. Nuyken O (2004) Polymers of acrylic acid, methacrylic acid, maleic acid and their derivatives. Handbook of Polymer Synthesis. (2nd edn), CRC Press, pp. 92.
16. Zhu XX, Moskova M, Denike JK (1996) Preparation and characterization of copolymers of new monomers from bile acid derivatives with methacrylic monomers and selective hydrolysis of the homopolymers. Polymer 37(3): 493-498.
17. Guo M, Song CH, Lu D, Wang H, Sun LP (2011) Hydroxypropyl cellulose grafted with poly butyl methacrylate. Journal of Zhejiang A & F University 28(1): 132-138.
18. Tan JJ, Sun YM (2008) The graft copolymer of propyl cellulose and methyl methacrylate was synthesized and characterized. Anhui Provincial Association for Science and Technology, Anhui Provincial Department of Health, Anhui Provincial Food and Drug Administration, Theory and application of traditional Chinese medicine-proceedings of Anhui TCM inheritance and Innovation Doctoral Science and Technology Forum, College of Pharmacy, Anhui University of Traditional Chinese Medicine; School of Chemistry and Materials Science, Anhui Normal University, pp. 363-366.
19. Friedman M (2003) Chemistry, biochemistry and safety of acrylamide. A review. Journal of Agricultural and Food Chemistry 51(16): 4504-4526.
20. Shen YC, Yang XQ, Wang FH, Zhu H (2018) Preparation of acrylamide modified hydroxypropyl cellulose sand fixing agent. Technology Innovation and Application (26): 45-46.
21. Zhang M, Choi W, Kim M, Choi J, Zang XR, et al (2024) Recent advances in environmentally friendly dual-crosslinking polymer networks. Angewandte Chemie International Edition e202318035.
22. Yano S, Iwase T, Teramoto N, Shimasaki T, Shibata M (2018) Synthesis, thermal properties and cell-compatibility of photocrosslinked cinnamoyl-modified hydroxypropyl cellulose. Carbohydrate Polymers 184: 418-426.
23. Zhang YY, Luo CC, Wang H, Han L, Wang CQ, et al. (2016) Modified adsorbent hydroxypropyl cellulose xanthate for removal of Cu^{2+} and Ni^{2+} from aqueous solution. Desalination and Water Treatment 57(56): 27419-27431.