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[Perspective of chitosan hydrogel]

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[Abstract] Chitosan hydrogel are 3-D macromolecular networks cross-linked by deacetylation of chitin. It has several intrinsic characteristics, such as biocompatibility, biodegradability, bacteriostatic effects and adequate resources in nature.[1] This kind of biomaterial can be constructed with multi-layered structure without any auxiliary cross-linking agent, which possesses orientated strength and modulus. Moreover recent research shows that these special properties enable chitosan hydrogel to have biological and clinical potential: drug delivery, stem cell carrier, internal fracture fixation material and so on. All of these applications are tightly related to chitosan's unique abilities and convenience to achieve.

Introduction

Hydrogels are networks of polymer chains that are hydrophilic, sometimes found as a colloidal gel in which water is the dispersion medium. Hydrogels are formed with polymeric networks. They also have a degree of flexibility which is similar to natural tissue, due to their significant water content. Therefore, the application of hydrogels pervades daily life and advanced industry.[2]

Chitosan hydrogel is a special form of hydrogels usually achieved from chitin. It has arouse considerable attention due to its unique performance in the field of biomaterial.

In my selected literature, the researchers have found a method to construct orientation in the chitosan hydrogel, the gel could be applied with three layers with totally different morphology and mechanical properties.[10] The first layer is formed with relatively low modulus and porous structure. By diffusion of NaOH, the hydrogel seems more orientated due to the entanglement from the first molecule to the following one. When the NaOH concentration decreased to extremely low, the layer becomes compact rapidly, and the modulus of this layer is much higher than the porous one.

In this case, this special method could be utilized to create material with multi-layered structure, such as a rod with a hard-to-bend shell and a soft core. This structure is perfect as internal fracture fixation material.[3]By the way, the orientated structure could even serve as a modulate signal for cell activities like migration.[4]

Moreover, preparation of the hydrogel is very convenient and inexpensive. Chitosan and NaOH for regulation of the layers are all easy to get. And the sophisticated hydrogel can be produced simply from chitosan solution.

As far as I am concerned, I think they have done great job to achieve their goal, but it remain puzzles that why the hydrogel could not be prepared in other way, such as screw extruder. What's more, how chitosan hydrogels could be applied for practical use haven't been explained in details.

Recent Progress

Orientated hydrogel is not the only wonderful design from chitosan because some other breakthroughs spring up in the field of chitosan hydrogel recently, especially at the point of drug delivery. By the way, I finally got the chance to know the exact practical application of chitosan hydrogel. For instance, recently a kind of genipin-cross-linked catechol-chitosan mucoadhesive hydrogels has been developed for drug delivery[5]. Researchers have been studying mucoadhensive polymers like chitosan and its derivatives for a long time, to maintain an intimate contact with the mucosa lining in the wet conditions of oral cavity, because only the material with enough residence time can ensure drug release and absorption. Scientists now can attach catechol functional groups to the backbone of chitosan, and cross-linked the polymer with a non-toxic cross-linker genipin, to achieve a novel catechol-functionalized hydrogel. This kind of hydrogel can meet all the requirements for drug delivery, such as biocompatibility and slower degradation rate. The

experiments in vivo also worked well and showed promising future.

There are some even more exciting reports this year, a research group made it to produce a hydrogel from chitosan and silver nitrate by a special reaction of chitosan solution containing silver ions with tripolyphosphate to create chitosan beads loaded with silver nanoparticles of antimicrobial properties serving as a control drug release nanocomposite.[6] This is the first report of chitosan hydrogel with silver nitrate. Its antimicrobial property and other novel performance caused by nanosilver enable its broad range of applications in optics, electronics, biotechnology and medicine.[7]

Another aspect of recent progress is stem cell carrier. Brown adipose derived stem cells is a special cell capable of regenerating the myocardium after infarction, which means the ability to restore heart function. The proposed chitosan hydrogel could be injected into tissue as a stem cell carrier. Researchers have found that this hydrogel can ensure the survival of these stem cells and have explored the amazing mechanism of this process.[8] The loss of vessels from diseases could be specifically treated with another kind of stem cell, but we can still try chitosan hydrogel. The chitosan hydrogel could be fabricated with particular shape like microtubes[9],which showed high cell survival and minimal cytotoxicity in vitro. The chitosan-based hydrogel encapsulating various functional stem cells can serve as a novel platform for treating various cardiovascular diseases.

Discussion

The gelation process of aqueous solution of chitosan is very unique and interesting to investigate, its mechanisms involving many theories of chemical thermodynamics and macromolecular physics. The author says that the rate of gelation is controlled by NaOH diffusion,[10] the orientated hydrogel gelation process could be divided into three stages coordinated to the three layers. In the first stage macromolecules were static and rearrangement could not happen because of the high gelation rate (which caused by high concentration of NaOH), in contrast to such low chitosan concentrations that the interactions between macromolecules are too small to detect. In stage two, the interactions became stronger and the decreased NaOH concentration made the rate much lower than stage one, so that requirements for organized rearrangement and stacking were satisfied, if this is qualified, then the rearrangement will make the macromolecules in array which would certainly improve its strength and modulus. Finally, the original entanglement in the gap relaxed and restriction of macromolecules has been eliminated, and the structure became very compact. In this case, the mechanism indicates that correct NaOH fusion rate and diffusion direction is the key to propose a ideal orientated chitosan hydrogel, such as produce a bone-shaped rod.

Under this theoretical basis and the intrinstic charateristics of chitosan, the chitosan hydrogel have unimaginable potential for further research and application. Although the method is limited in solution, I think we would find more efficient way to produce chitosan hydrogel. Because sometimes the concentration would be restricted by the solubility due to different pH or temperature. If this problem could be solved, it would help make stronger hydrogel, in my opinion.

Anyway, we can believe with confidence that there will be more significant discovery in this field and more practical application in near future.

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