

Preparation of a Cyclomaltoheptaose (β -cyclodextrin) Cross-linked Chitosan Derivative *via* Glyoxal or Glutaraldehyde

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Abstract: A cyclomaltoheptaose- β -cyclodextrin (β -CD) crosslinked chitosan derivative *via* glyoxal or glutaraldehyde was prepared. The structures of β -CD crosslined chitosan with glyoxal or glutaraldehyde were characterized by IR spectra. The surface morphology of the β -CD crosslinked chitosan particles was examined using a scanning electron microscope. The immobilization capacity of β -CD on chitosan was affected on the weight ratio of β -CD/chitosan, the utilization amount of crosslinking agent, the acidity of the reaction system and the temperature. The adsorption for nicotine indicated that the chitosan- β -CD was a good adsorbent.

Keywords: Chitosan- β -cyclodextrin, adsorbent, preparation.

Chitosan has been regarded as a multifunctional polymer applicable to various purposes¹. The potential of the material in medical applications, particularly in drug-delivery formulations has been demonstrated^{2, 3}. Recently, a crosslinked chitosan with various crosslinking agents was prepared as adsorbents⁴⁻⁷.

A β -cyclodextrin (β -CD) has been subjected to numerous studies, particular in terms of its complexing ability with a variety of components^{8, 9}. The complexing ability of β -CD has been well exploited in pharmaceutical industry. Chitosan derivatives bearing pendent cyclodextrin cavities have been prepared as a new efficient sorbent, inclusion complexes and drug-delivery formulations. For example, β -cyclodextrin was coupled to chitosan by the intermediate of its monochlorotriazinyl derivative or with 2-O-formylmethyl- β -CD to obtain the chitosan derivatives bearing β -CD. The crosslinked cyclodextrin derivatives were evaluated as dye sorbents for use in decontamination of waters from textile dyeing¹⁰⁻¹². The cyclodextrin-pendent chitosan derivatives were water-insoluble and highly porous beads. They had an ability to form inclusion complexes with various organic compounds^{13, 14}.

The use of β -CD as an adsorbent for the selective removal of bilirubin from aqueous fluids was, however, limited due to its inherent water solubility. Furusaki has reported the condensation of chitosan with average molecular weight of 7300 and carboxymethylated β -CD¹⁵. However, application to chitosan with higher molecular weight failed due to its extreme low solubility in water under the neutral or alkaline conditions which are necessary for the condensation reaction. In this paper we preliminarily reported

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preparation of the β -CD crosslinked chitosan derivative *via* glutaraldehyde or glyoxal in acidic solution. We presume that the product of crosslinking β -CD onto chitosan would improve its complexing ability and specificity. The factors affecting the preparation of chitosan- β -cyclodextrin are also reported in this paper.

Experimental

Chitosan from Ausin's Chitin Co. (China) was used as received. The viscosity-average molecular weight of the sample was found to be 2.1×10^5 , and the extent of deacetylation was 96.2%. β -CD from Suzhou Weijin Co. (China) was used after recrystallization with water. Glutaraldehyde (25% aq solution) and glyoxal (40% aq solution) were purchased. The surface morphology of the β -CD crosslinked chitosan particles was examined using a scanning electron microscope (Hitachi, model H-80).

Preparation of β -CD crosslinked chitosan

Chitosan and β -CD (weight ratio 1:5) were wetted in 1 mol/L hydrochloric acid, and then the mixture was stirred at room temperature until it was dissolved. The crosslinking agent glutaraldehyde or glyoxal (molar ratio of aldehyde and β -CD, 3:1) was added dropwise to the resulting solution for 1-2 h at 80°C. After the reaction, the solution was adjusted pH to 7-8 with 1 mol/L NaOH, and allowed to stir for 0.5 h. Thereafter, the mixture was cooled and filtered. The precipitate was washed several times with water to pH 7, and then washed three times with acetone. The β -CD crosslinked chitosan was finally freeze-dried. The amount of the immobilized β -CD was determined as described in the literature¹⁶. The determination of the immobilized β -CD was not interfered with the absorption peak of chitosan at 490 nm.

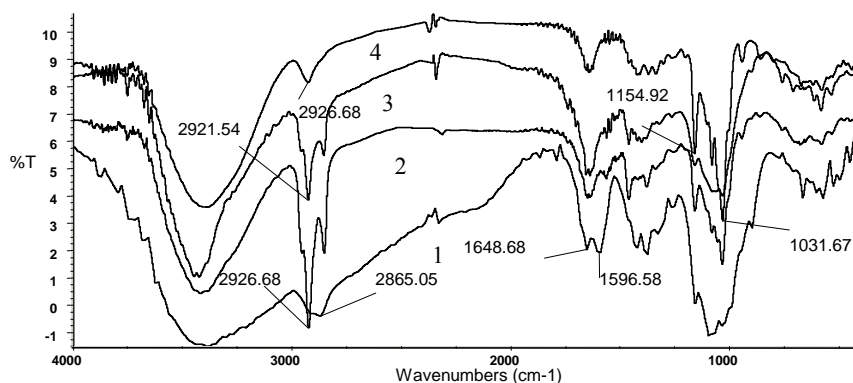
Results and Discussion

The structures of the β -CD-crosslinked chitosans with glyoxal or glutaraldehyde were characterized by IR spectroscopy. The IR spectrum of chitosan-glyoxal- β -CD **I** or Chitosan-glutaraldehyde- β -CD **II** in comparison with the spectrum of chitosan or β -CD was shown in **Figure 1**.

It showed that the peak of chitosan at 1596 cm^{-1} (N-H band) disappears obviously in **I** or **II**, but the characteristic peak of the O-H bending on β -CD appears at 1648 cm^{-1} for **I** or **II**. The spectrum of modified chitosan showed more resemblance to the spectrum of β -CD. The characteristic peak of the carbonyl group of **I** or **II** did not appear; this indicated that the carbonyl group on dialdehyde participated in the coupling reaction.

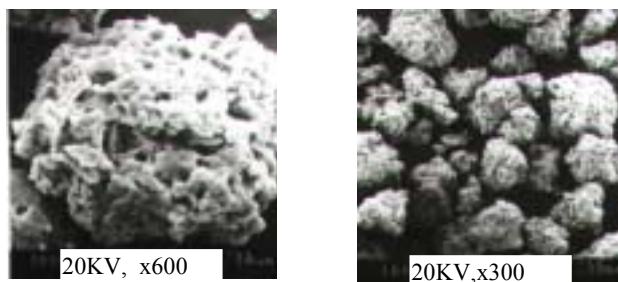
The microspheres of glutaraldehyde-crosslinked chitosan were spherical and have a smooth outer structure¹³; however, in the case of the incorporation of β -CD the outer structure of microspheres altered to a rough and multiporous surface (**Figure 2**). Masahiko¹¹ and Nobuo¹⁴ believed also that the water-insoluble chitosan-linked cyclodextrin beads have highly porous structure.

Figure 1 The spectrum of I or II in comparison with the spectrum of chitosan or β -CD

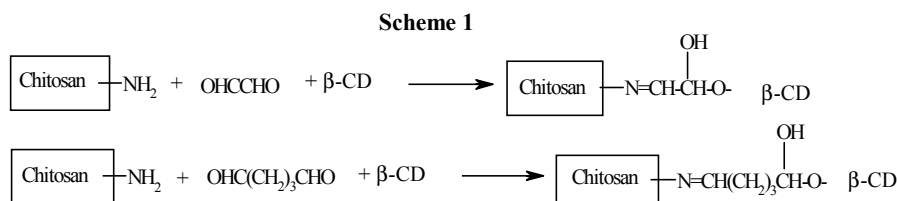


1: Chitosan; 2: Chitosan-glyoxal- β -CD I; 3: Chitosan-glutaraldehyde- β -CD II; 4: β -CD

Figure 2 SEM micrograph of Chitosan-glutaraldehyde- β -CD II



The reaction of β -CD-crosslined chitosan with glyoxal or glutaraldehyde was follow as **Scheme 1**.



In the reaction of a β -CD crosslinked chitosan *via* glyoxal or glutaraldehyde, the immobilization capacity of β -CD on chitosan depended on the weight ratio of β -CD/chitosan, the utilization amount of crosslinking agent, the acidity of reaction system and the temperature.

For example, according to our experiment, weak acidity was favorable for crosslinking reaction in water solution and the optimum temperature was about 80-90°C.

Insoluble β -CD crosslinked chitosan was a novel adsorbent for small organic molecule, such as nicotine (being continued).

These results fit well with those reported in the literatures^{17, 18}. The present study points out the feasibility of converting naturally occurring entities, like chitosan, into useful sorbents, which may have varied and far-reaching applications.

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