

with the derivative of chitin prior to placing the material between the vital tissues.

The invention will now be described in further detail with reference being made to the following examples. It should, however, be recognized that the examples are given as being illustrative of the present invention and are not intended to define the spirit and scope thereof.

EXAMPLE 1

A. One gram of medical grade chitosan (free amine), such as Protan, Inc.'s Protosan LV Chitosan acetate, was added to 44 ml of a 2% acetic acid solution and shaken, stirred or mixed until dissolved. Any insoluble matter was removed. The viscosity of the solution was greater than 250 cps as measured by a Brookfield viscometer. The solution was then poured and allowed to dry to make clear films.

B. Films were ionically cross-linked by placing the film of a measured thickness into dilute solutions of sulfuric acid, or sodium sulfate. It was necessary to use stronger concentrations of SO_4^- ions to cross-link thin films. The cross-linking or insolubilizing reaction had to occur before the soluble chitosan film had a chance to dissolve.

Films of thicknesses ≥ 0.04 mm cross-linked easily when placed in 0.024 M sulfuric acid and became elastic and flexible.

Films of thicknesses ≤ 0.04 mm cross-linked in 0.24 M sulfuric acid and became elastic and flexible.

EXAMPLE 2

The same procedure was used to make films as in Example I A. However, instead of using dilute sulfuric acid solutions, sodium sulfate, sodium phosphate or sodium borate solutions at a pH of less than or equal to 6 were used to cross-link the dry chitosan acetate films.

The concentration of sodium sulfate solutions used was 0.5 M for films between 0.024–0.1 mm thick. Similarly, 0.5 M sodium phosphate, phosphoric acid (10%) and monohydrogen orthophosphate, were used to cross-link films of these thicknesses as was sodium borate, $\text{Na}_2\text{B}_2\text{O}_7$, at less than 0.4 M concentration.

The elastic moduli of the films ranged between 13–31 pascals when wet.

EXAMPLE 3

2.0 grams of chitosan (medical grade) was dissolved in 100 ml of 0.17 M acetic acid. Any insoluble material was removed. The viscosity of the solution was >250 cps. The solution was poured into a mold and allowed to dry.

Films of thicknesses ranging from 0.04–0.1 mm were cross-linked or insolubilized with 1% H_2SO_4 (0.24 M). The thicker films took less time to react than the thin films. The films could be boiled in water for one hour without insolubilizing.

EXAMPLE 4

1 g of N,O CM-chitosan was mixed with 100 ml of deionized water. Films were made by pouring this solution onto a flat surface and allowing it to evaporate. The dry films were then placed in a saturated solution of glutamic acid at room temperature to cross-link them.

Thin (≤ 0.5 mm thick) films readily cross-linked ionically to form thin slightly elastic films. Thick films (0.8 mm in thickness or more) formed a cross-linked outer surface with gelatinous material in the interior.

EXAMPLE 5

The same types of films were made by adding the films to a saturated solution of aspartic acid rather than glutamic acid as in the above example. The properties of the materials made with aspartic acid rather than glutamic acid did not differ noticeably.

EXAMPLE 6

2 grams of N,O CM-chitosan were added to 100 ml of water. The solution was mixed well. The solution was poured and dried into a small mold to make a thick N, O, CM-chitosan film and then cross-linked using saturated solutions of aspartic acid, glutamic acid or a combination thereof. These acids were negatively charged at a pH of 6 ie. were acidic amino acids which contain a carboxylic acid group in the R group end of the amino acid and therefore ionize to become an anion at $\text{pH} \geq 6$. The sample formed a pillow structure having an outer film or membrane. The membrane formed because only the outside of the film had cross-linked and the inside remained visco-elastic. When the pillow structure was placed in boiling water, the structure of the film resorbed into a thick visco-elastic substance. The total percentage of CM-chitosan in the solution was less than 0.25%.

EXAMPLE 7

2 grams of chitosan acetate were added to 0.9% NaCl and mixed. After heat sterilization in the absence of oxygen, the material was then ready to be injected into place.

EXAMPLE 8

A 2% N,O CM-chitosan was added to 900 ml of 0.9% NaCl. The solution could be used as a visco-elastic substance to inject at the site in order to prevent adhesions from forming.

While acetic acid was used to solubilize the chitin or derivatives thereof, other well known acids in concentrations capable of solubilizing the chitin may also be used.

While several examples of the present invention have been described, it is obvious that many changes and modifications may be made thereunto, without departing from the spirit and scope of the invention.

We claim:

1. A method of preventing adhesions between soft internal body tissues consisting essentially of the step of placing a material between the tissues, said material comprising biodegradable ionically cross-linked carboxy containing derivatives of chitin which are soluble in dilute acidic aqueous solutions.

2. The method as set forth in claim 1 wherein the derivative of chitin is N,O carboxyl methyl-chitosan.

3. The method as set forth in claim 1 wherein the derivative of chitin is chitosan.

4. The method as set forth in claim 1 wherein the derivative of chitin is N, carboxyl methyl-chitosan.

5. The method as set forth in claim 1 wherein the derivative of chitin is O, carboxyl methyl-chitosan.

6. The method as set forth in claim 1 wherein the derivative of chitin is sulfated N, carboxyl methyl-chitosan.

7. The method as set forth in claim 1 wherein the derivative of chitin is carboxyl methyl-chitin.

8. The method as set forth in claim 1 wherein the aqueous solution contains acetic acid.