SYNTHESIS, CHARACTERIZATION AND EVALUATION OF ELECTRICAL STIMULUS SENSITIVE BEHAVIOR OF Gt-cl-poly(AA) SUPERABSORBENT HYDROGEL

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Received: 6 Sep 2011, Revised and Accepted: 21 Nov 2011

ABSTRACT
In this research paper, synthesis of Gum tragacanth-acrylic acid based hydrogels using KPS-ascorbic acid and glutaraldehyde as an initiator-crosslinker via free radical polymerization technique was carried out. Morphological difference was observed using Scanning Electron Microscopy (SEM). Electrical stimulus studies on the swelling of candidate polymer using distilled water and artificial biological electrolytic system were carried out using 10V AC/DC source at 37°C.

Keywords: Gum tragacanth, SEM, Superabsorbent, Electrical stimulus sensitive

INTRODUCTION
Superabsorbent polymers have the property to absorb and retain extremely large amounts of a liquid relative to their own mass³. Cross-linked hydrogels³ undergoes hydrogen bonding with water molecules. This gives rise to swelling and holding of large amount of water while maintaining the physical dimension and structure³. Superabsorbent polymers can absorb 500 times its weight, when immersed in deionised /distilled water, but its absorbency decreases to 50 times when immersed in 0.9% saline solution. Some unique physical, chemical and biological properties of natural based polymers like non-toxicity, biocompatibility, renewability, equilibrium swelling and biodegradable give it an edge over the synthetic polymers. Dextrin, starch, psyllium and guar gum⁶-⁷ are among the natural polysaccharides being modified by various researchers. Biocompatible polymeric hydrogels are extensively used for biomedical and pharmaceutical applications such as sustained drug delivery⁸-⁹, pulsatile drug delivery¹⁰-¹¹, for controlling cell adhesion in tissue engineering¹²-¹³, for reconstruction or repair of soft tissues¹⁴, as biosensors¹⁵ and muscle actuators¹⁶. Physiological stimulus such as pH, ionic strength, temperature and electric field resulted in the phase transition of stimuli-responsive hydrogels. Yuk and Lee¹⁷ demonstrated the reversible bending of cross linked acrylamide gel induced by electric current in aqueous NaCl and proposed the mechanism for the bending phenomenon. Kim et al¹⁸ reported the bending behaviors of poly(acrylic acid)/poly acrylonitrile semi IPN hydrogels under various voltage conditions. They reported that as the applied voltage increases, the bending speed increases and further the deformation of the IPN hydrogels was reversible when the applied voltage was turned on and off. Osaka and Hasebe²⁰ reported the electrically activated artificial muscle system which contracted by the electrical stimulus under isothermal conditions. They reported that addition of NaCl increased the rate of water release whereas, addition of organic solvents such as ethanol, acetone reduces the rate of water release and the contraction resulted from the electrostatic interaction between charged macromolecules and the electrodes lead extensive dehydration of the gel. Ubi²¹ studied the use of electricity in bone healing and to treat scaphoid fractures. Sumano and Mateos²² reported forty-four patients were treated with electrical stimulation of the skin. Following electro-stimulation in all patients healing proceeded in a thoroughly organized manner, almost regardless of the severity of the type of wound or burn treated. Large volume change was observed in hydrogels under the influence of external stimuli²².

In this research paper, Gum tragacanth-acrylic acid based hydrogels was studied for electrical stimulus under AC/DC influence and its impact on swelling/deswelling behavior.

MATERIAL AND METHODS
Gum tragacanth (SD Fine Chemicals Pvt. Ltd.), ascorbic acid-potassium persulphate (SD Fine Chemicals Pvt Ltd.), glutaraldehyde (MERCK), acrylic acid (MERCK) and electrolytic powder (Cipla Pharmaceutical Ltd.) were used as received.

Instrumental Analysis
Scanning Electron Micrographs of the candidate polymers were taken on LEO-435VF, LEO Electron Microscopy Ltd. Thermal studies were carried-out on TGA/DTA 6300, SLL EXSTAR 6000 at a heating rate of 10 °C/min in air.

Synthesis of superabsorbent
25ml of distilled water and 1.0 g of Gum Tragacanth were taken in a reaction flask and 0.5 mol L⁻¹ of acrylic acid was added with constant stirring. This was followed by the addition of ascorbic acid-KPS in 1:1.25 molar ratios and 0.42 mol L⁻¹ of glutaraldehyde. The reaction was carried out at pH 7.0 for 90 min at 40 °C. The homopolymer was removed on completion of reaction by washing with hot water and gel was allowed to stand for about 10-12 hours undisturbed for gelling process to take place. The product obtained was dried in oven at 60°C till a constant weight was obtained. The percentage grafting (%G) and percentage swelling (%S) were calculated as per the following equation (1):

\[
\text{%S or % G} = \frac{FW - IW}{IW} \times 100 \tag{1}
\]

Where \(IW\) = initial weight, \(FW\) = final weight

Preparation of artificial biological fluid
Artificial biological fluid was prepared in the laboratory using electrolytic powder and distilled water (DW). 25gms of electrolytic powder was dissolved in 1000ml of distilled water to obtain the artificial biological fluid of 25000ppm.

Electrical stimulus sensitive studies using DC / AC source
Apparatus used for the electrical stimulus sensitive studies is shown in the Fig. 1. The system consists of an inner compartment \([20.5 cm (l) \times 15 cm (b) \times 0.2 cm (h)]\), a thermostat, thermometer and an outer compartment \([24.5 cm (l) \times 19 cm (b) \times 12 cm (h)]\) acting as a closed system. Distance between two copper electrodes was about 15.5 cm. Preoptimized and weighed dried hydrogel was immersed in artificial biological fluid at 37°C and 10V AC/DC source was applied. The polymer was found to show swelling behavior and was weighed after a regular time interval. Percentage swelling (Ps) was calculated by the formula:

\[
Ps = \frac{FW - IW}{IW} \times 100 \tag{2}
\]

Where \(IW\) = initial weight, \(FW\) = final weight

ISSN- 0975-1491
Vol 4, Issue 1, 2012
International Journal of Pharmacy and Pharmaceutical Sciences
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Int J Pharm Pharm Sci, Vol 4, Issue 1, 419-423

\[ Ps = \frac{W_s - W_d}{W_d} \times 100 \]

Where \( W_s \) and \( W_d \) are weights of swollen polymer and dry polymer, respectively.

Fig. 1: Apparatus for AC/DC stimuli studies

RESULTS AND DISCUSSION

Mechanism

Graft copolymerization of vinyl monomer onto the backbone takes place through \(-\text{OH} \) and \(-\text{CH}_2\) groups. Reaction mechanism for the grafting to take place can be summarized as below:
OH⁺ and SO₄⁻ radicals are produced which create the active sites both on backbone and monomer. Reaction between monomer and backbone propagate the chain further resulting in the formation of graft copolymer along with homopolymer. Reaction termination takes place on collision of two live chains or reaction of OH⁺ with the propagating chain.

**Scanning Electron Microscopy (SEM)**

A distinct morphological difference has been observed in case of SEMs of backbone and its graft copolymer with vinyl monomer. (Fig. 2)

**FTIR**

Broad peaks were obtained in the FTIR spectrum of *Gum tragacanth* at 3427.08 cm⁻¹ (O-H stretching bonded absorption of carbohydrates), 2934.78 cm⁻¹ (CH₂ asymmetric stretching), 1039.07 cm⁻¹ (C-O stretching region as complex bands, resulting from C-O and C-O-C stretching vibrations), 638 cm⁻¹ (Pyranose ring). On the other hand, FTIR spectrum of Gt-cl-poly(AA) showed peaks at 2854.31 cm⁻¹, 2659.42 cm⁻¹ and 2521.73 cm⁻¹ (O-H stretching of carboxylic acid), 1750.23 cm⁻¹ and 1613.40 cm⁻¹ (C=O stretching in carboxylic acid) was observed.

*Fig. 2: SEM (a) Gum tragacanth; (b) Gt-cl-poly(AA)*
Electrical stimulus sensitive studies using DC / AC source

Effect of AC source

From the Fig. 3 (a) it is evident that in both the media percentage swelling increases with time interval under the influence of AC source. In case of distilled water percentage swelling was found to increase for 24 hrs and attained maxima afterwards. However, in case of artificial biological fluid percentage swelling was found to increase until 19 hrs and became constant with further increase in time interval. Maximum swelling found in artificial biological fluid and distilled water was 344% and 361%, respectively. Under the influence of AC source, electrolysis takes place with the generation of H+ and OH- ions, which exerted ion screening effect. Due to electrostatic repulsions, the candidate polymer was found to exhibit swelling. Moreover, under the influence of AC source, lesser swelling was found in artificial biological fluid in comparison to distilled water. It is because of the fact that artificial biological fluid is a hypertonic solution and the polymer showed shrinking behavior in higher concentration solutions due to reverse osmosis24.

Effect of DC source

Percentage swelling was observed to increase with time interval under the influence of DC source (Fig. 3b). Maximum swelling in artificial biological fluid and distilled water was found to be 323% and 350%, respectively. It can be due to the fact that under the influence of DC source electrolysis takes place with the generation of H+ and OH- ions, which exerted ion screening effect and electrostatic repulsions took place. This resulted in increased swelling rate of crosslinked system. Moreover, under the influence of DC source, maximum swelling in artificial biological fluid was found to be lower in comparison to distilled water. This can be due to the fact that artificial biological fluid is a hypertonic solution and due to reverse osmosis polymer showed shrinking behavior under higher concentrations24.

CONCLUSION

The candidate polymer synthesized was found to show superabsorbent behavior both in distilled water and artificial biological fluid. Moreover, the product obtained showed AC/DC stimulus sensitive behavior which could be compared with the tissues in response to electrical stimulus in the body. Such smart electrical stimulus sensitive material could be used for the replacement of body organs like kidney, lung, muscles and heart valves and have got a great significance in tissue engineering.

REFERENCES