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BIOMEDICAL EVALUATION OF HYDROGELS
MODIFIED BY GELATINBIOMEDYCZNA OCENA HYDROŻELI
MODYFIKOWANYCH ŻELATYNĄ

Abstract

In this study, a series of hydrogels was prepared by formation of crosslinked acrylic acid networks, modified by gelatine. The rate of swelling of prepared hydrogels in different distilled water was studied as a function of NMBA concentration on the polymeric matrix. Novel materials were characterized using in vitro investigation in SBF. Results showed that the pH value was affected by gelatine concentration in hydrogel.

Keywords: hydrogels, poly(vinyl alcohol), poly(acrylic acid)

Streszczenie

W przeprowadzonych badaniach otrzymano serie hydrożeli w wyniku usieciowania kwasu akrylowego oraz modyfikacji żelatyną. Określono zdolność pęcznienia hydrożeli w wodzie destylowanej dla różnej zawartości czynnik sieciującego w matrycy polimerowej. Nowe materiały zostały scharakteryzowane na podstawie badania in vitro w SBF. Wyniki pokazały, że na wartość pH wpływa zawartość żelatyny w hydrożelu.

Słowa kluczowe: hydrożele, poli(alcohol winylowy), poli(kwas akrylowy)

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1. Introduction

Polymer hydrogels have already been used for the fabrication of medical devices for several decades. Early examples include the work of Kolff to treat patients suffering from kidney failure by means of cellulose-based membranes and the pioneering studies of Wichterle and Lim to produce contact lenses from poly(hydroxyethyl methacrylate) [1].

Hydrogels represent a key means of controlled or sustained delivery. They consist of three-dimensional, insoluble (bio)polymeric networks capable of absorbing large amounts of water or biological fluids, and may be designed for stimuli-response release. Compared to other synthetic biomaterials, hydrogels closely mimic living tissues because of their similar chemical building blocks, thereby exhibiting a reduced incidence of toxicity and inflammation. The hydrophilic nature of biopolymers imparts water-binding properties whereas the presence of either physical or chemical cross-links results in the formation of a three-dimensional network that helps in retaining structural integrity when placed in an aqueous environment. Parameters used to characterize the suitability of a hydrogel for a particular application include: the polymer volume fraction in the swollen state, the average molecular weight of the polymer chain between two neighbouring cross-linking points, and the mesh/pore size between polymer chains. The preparation of hydrogels typically involves cross-linking functional groups (e.g. hydroxyl, amine, amide, ether, carboxylate and sulphonate) along the polymer chains to increase network rigidity [2–5].

2. Experimental

2.1. Materials

Acrylic acid (AA), ammonium persulphate (APS), potassium hydroxide (KOH) and gelatin were obtained from POCh Gliwice, Poland. N,N'-methylenebisacrylamide (NMBA) was acquired from Sigma Aldrich. All chemicals were of analytical grade and were used without further purification.

2.2. Preparation of PAA/gelatin hydrogel

PAA/gelatin hydrogels were synthesized under microwave irradiation in aqueous solutions. An appropriate amount of the AA monomer was added to the solution containing KOH. The mixture was then cooled slowly until the temperature dropped to 30°C and gelatin was added. Then an initiator (APS) and a crosslinker (NMBA) were added. The synthesis of hydrogel was carried out under microwave irradiation at 600 W for 5 min.

2.3. Swelling measurements

A 1.0 g polymer sample was dispersed in 500 ml distilled water for swelling equilibrium. After 1 h, the swollen sample was filtered. The water in the bag surface was removed, and then weighed. The swelling ratio (Q , g/g) was calculated as follows:

$$Q = \frac{w - w_0}{w_0}$$

where w was the weight of polymer after swelling, and w_0 was the weight of polymer before swelling [6].

2.4. Immersion in simulated body fluid (SBF)

The chemical stability and biological activity of hydrogels containing 2ml NMBA and different amounts of gelatin were evaluated on the basis of changes in the pH value. The SBF used for *in vitro* experiments was prepared by dissolving reagent grade chemicals of NaCl, NaHCO₃, KCl, K₂HPO₄·3H₂O, MgCl₂·6H₂O, CaCl₂·2H₂O, Na₂SO₄ and (CH₂OH)₃CNH₂ in distilled water and buffering with HCl to a pH of 7.4 at 37°C. It had ion concentrations that were nearly the same as those in human blood plasma, as shown in Table 1 [7].

Table 1

Ion concentrations of SBF and human blood (10⁻³molL⁻¹)

	Na ⁺	K ⁺	Mg ²⁺	Ca ²⁺	Cl ⁻	HCO ₃ ⁻	HPO ₄ ²⁻	SO ₄ ²⁻
SBF solution	142.0	5.0	1.5	2.5	147.8	4.2	1.0	0.5
Blood plasma	142.0	5.0	1.5	2.5	103.0	27.0	1.0	0.5

3. Results and Discussion

The influence of the crosslinking agent on the swelling ratio of PAA/gelatin hydrogel is shown in Fig. 1. Higher values of absorbency are obtained using a lower crosslinker concentration. In fact, with 1.5ml NMBA, a slimy gel was formed. The higher crosslinker concentration the lower the space between the polymer chains and, consequently, it results in a highly crosslinked rigid structure which cannot be expanded and hold a large quantity of water.

Hydrogels immersed in the SBF showed an insignificant tendency to change the pH value during the incubation time (Fig. 2). Further analyzed extracts showed a negligible tendency for decreasing the pH value with the incubation time, by about 1 pH value. The anionic polymer matrix which consisted of PAA hydrogels decreased the pH value. However, after incubation the samples containing 15% and 10% gelatin showed the pH value of about 7.4.

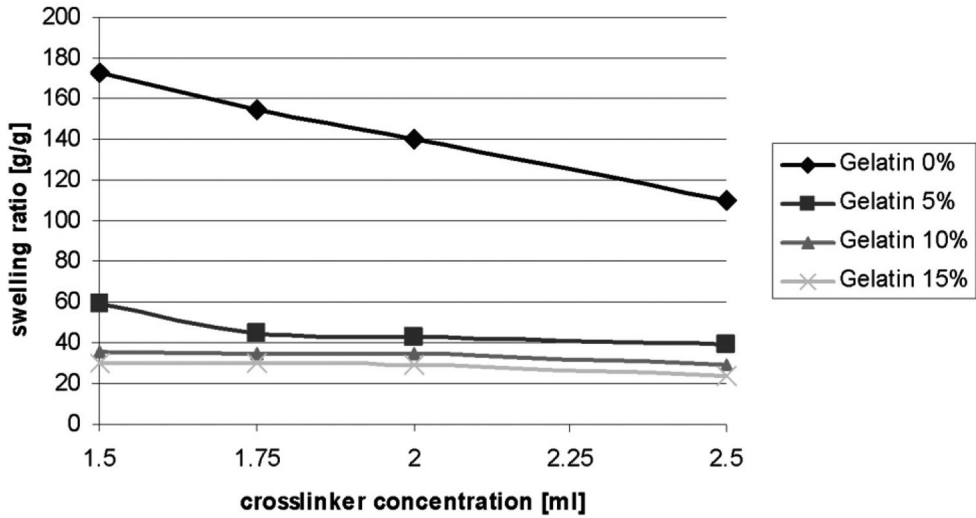


Fig. 1. Effect of crosslinker concentration on swelling ratio

Rys. 1. Wpływ stężenia czynnika sieciującego na zdolność pęcznienia

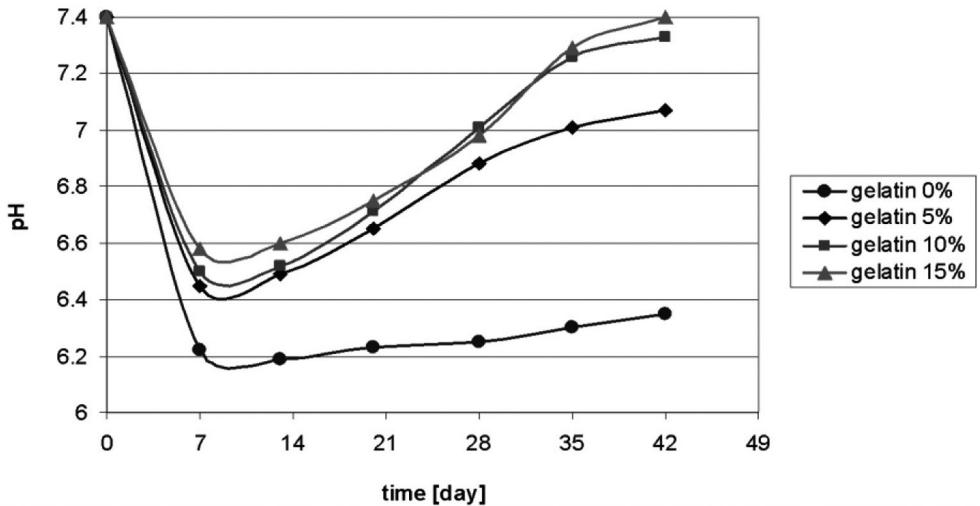


Fig. 2. Changes in SBF pH value

Rys. 2. Zmiany wartości pH SBF

4. Conclusions

The hydrogel, PAA/gelatin, was synthesized under microwave irradiation by graft gelatin onto acrylic acid in aqueous solutions. The effect of reaction variables such as the concentration of gelatin and NMBA were systematically optimized to achieve a hydrogel with the swelling capacity as high as possible. A higher crosslinker concentration decreased the space between the polymer chains and, consequently, it resulted in a highly crosslinked rigid structure which could not be expanded and hold a large quantity of water. After incubation the samples containing at least 10% gelatin showed the pH value similar to that of the pure SBF. PAA/gelatin hydrogels have the potential to be used as materials for biomedical applications.

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