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COPOLYMERIC HYDROGELS BASED ON POLY(ETHYLENE GLYCOL) ACRYLATE AND 2-HYDROXYETHYL METHACRYLATE OBTAINED BY GAMMA IRRADIATION

The hydrogels are one of the most promising materials for pharmaceutical and biomedical applications. Owing to their high water content, hydrogels usually show good biocompatibility in contact with blood, body fuids and tissues. Therefore, they are often used as contact lenses, wound dressings, artifcial cartilages or membranes as well as coatings for the materials applied in contact with the living organism, e.g., catheters, electrodes, and vascular prostheses. Because of their ability to swell as well as to release the trapped materials into the surrounding medium, hydrogels are used as drug delivery systems.

Poly(2–hydroxyethyl methacrylate) and related hydrogels have been considered for a variety of medical applications [1–4]. Its structure permits water contents similar to that of the living tissues. The poly(2–hydroxyethyl methacrylate) hydrogel is inert to normal biological processes, shows resistance to degradation, is permeable to metabolites, is not adsorbed by the body, withstands heat sterilization without damage, and can be prepared in a variety of shapes and forms.

Irradiation, especially because it is combined with the simultaneous sterilization of the product, is a very convenient method for the hydrogel synthesis.

Hydrogels based on 2–hydroxyethyl methacrylate, itaconic acid and poly(ethylene glycol) acrylate (Bisomer) have been prepared by gamma irradiation. Bisomer component and itaconic acid were used in order to improve the biocompatibility and to impart the pH sensitive behavior to 2–hydroxyethyl methacrylate, respectively.

Hydrogels were characterized in terms of swelling and dynamic mechanical analysis. The influence of the irradiation dose on swelling behavior and the mechanical properties of these hydrogels was investigated.

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MATERIALS AND METODS

Materials. 2–hydroxyethyl methacrylate (HEMA) (Fluka), itaconic acid (IA) (Aldrich), and poly(ethylene glycol) acrylate, i.e. short chains–Bisomer (BIS) (Laporte Chemical) were used as monomers. The structure of Bisomer is given in Figure 1. Distilled water was used as a solvent. All products were used without further purification.

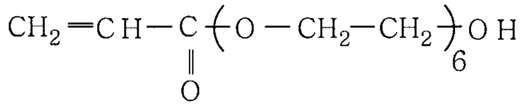

Figure 1. General formula of the Bisomer used

Preparation of hydrogels. Gels were prepared by γ – irradiation induced radical polymerization. Aqueous solutions of monomers were prepared in 10 mL of distilled water. HEMA/BIS/IA mass ratio was 50/48/2, respectively. Monomer solutions were placed between glas plates and irradiated to 10, 25 and 40 kGy in air at ambient temperature in Gammacell 220 type γ – irradiator at a fixed dose rate of 6 kGy/h.

Gel content. The gel content of the hydrogels was measured by extracting out the dissolvable portion in distilled water for 7 d and dried at room temperature for 3 d, until they reached constant weight. The gel percent was defined as follows: W0 is the weight of dried insoluble part remained after extraction with distilled water, and Wi is the initial weight of dried sample: Gel(%) = $(W_o/W_i) \cdot 100$.

Swelling studies. The xerogels discs were immersed in an excess of water, to obtain equilibrium swelling at 25°C. The progress of the swelling process was monitored gravimetrically. The swelling ratio (q) was calculated from the folowing equation: $q = W_t/W_o$, where Wo and W_t are the weights of xerogel at time 0 and swollen hydrogel at time t, respectively.

The equilibrium swelling degree was calculated as follows: $q_{eq} = W_e/W_o$, where W_{eq} is the weight of the hydrogel at equilibrium.

Dynamic mechanical analysis. Strain–frequency sweeps were performed on hydrogel discs, as synthesized and swollen to equilibrium, using a Rheometrics 605 mechanical spectrometer, with parallel plates geometry (25 mm in diameter). The complex shear moduli were measured as a function of frequency (ω), from 0.1 to 100 rad/s, at 28°C.

RESULTS AND DISCUSSION

Gel content. The gel percent is in the range of 75.0–94.7%. In Figure 2 the gel percent of all samples as a function of the irradiation dose is presented. The amount of gel increases with increasing the dose of irradiation from 10 to 25 kGy, and for 40 kGy it has practically the same value as for 25 kGy.

Swelling studies. The swelling curves in distilled water at 25°C of hydrogels are shown in Figure 3. The qeq values are in the range from 1458% for the hydrogel irradiated with 10 kGy, to 1130% and 1050% for hydrogels irradiated with 25 and 40 kGy, respectively. As expected, the swelling ratio decreases with increasing the irradiation dose.

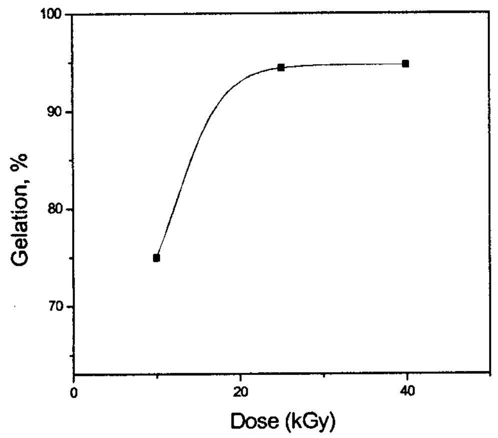

Figure 2. Gelation vs. irradiation dose

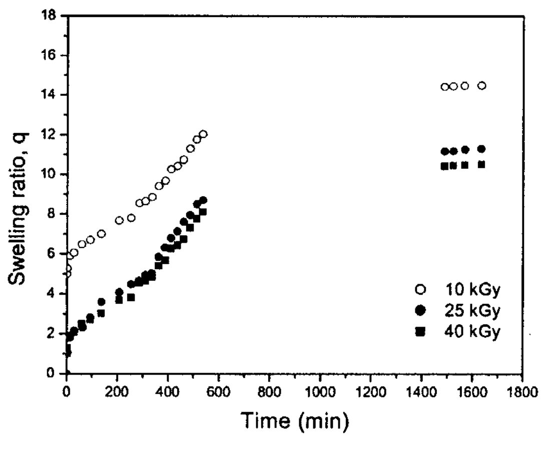

Figure 3. Swelling curves of hydrogels with different irradiation doses in water at 25°C.

Dynamic mechanical analysis. The network parameters depend on many factors, such as: feed composition, solvent, temperature, irradiation rate, irradiation dose and other factors.

The complex shear moduli, obtained from the dynamic mechanical analysis, were used to calculate the network parameters from the equation:

$$G = RT\upsilon_e\Phi_2^{1/3}(V_u/V_f)^{1/3} \qquad (1)$$

where V_u is the volume of dried, unstrained gel and V_f is the volume of network at formation, and R and T have their usual meaning.

The polymer/solvent interaction parameter, χ, was calculated from the following relation [5]:

$$\ln(1-\Phi_2) + \Phi_2 + \chi\Phi_2^2 + \upsilon_e V_1(\Phi_2^{1/3} - 2\Phi_2 f^{-1}) = 0 \qquad (2)$$

where $\Phi_2 = (D_0/D)^3$ (D_0 and D are the diameters of the dry and swollen disc), V_1 is the molar volume of water and f is the mean functionality of the monomers.

The network parameters calculated are presented in Table 1 and Table 2.

Table 1. The shear modulus (G), polymer volume fraction (Φ_2) and polymer–water interaction parameter (χ) of hydrogels

Sample	G (Pa)	Φ_2	χ
40	2500	0.0703	0.52
25	2250	0.0640	0.51
10	1990	0.0582	0.50

The molecular mass between cross-links (M_c) was calculated from:

$$M_c = \rho_2/\upsilon_e \qquad (3)$$

where ρ_2 is the density of the xerogel. The densities of the xerogels were determined from their weights and volumes, the latter being obtained micrometrically.

Table 2. The network parameters for hydrogels at formation

Sample	M_c (kg/mol)	υ_e (mol/dm^3)	Effective crosslinking
40	141.2	0.0095	0.08482
25	142.5	0.0073	0.07232
10	185.5	0.0069	0.06819

The polymer/water interaction parameter, χ, increases with increasing the irradiation dose. It turns out that irradiation doses higher than 25 kGy lead to a reduction in the polymer/water interactions (Table 1). Thus, as the solvent becomes poorer, hydrophobic interactions assume more importance. The decrease in χ means an increase in the thermodynamic goodness of the solvent. This phenomenon is caused in part by hydrogen bonding between polymer and solvent, which enhances the water absorption capacity.

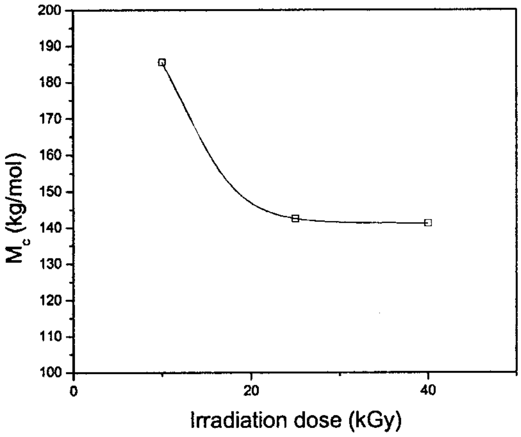

Figure 4. M_c vs. irradiation dose

The level of the irradiation dose plays an important role in determining mechanical properties of our samples. The complex shear moduli range from 1990 to 2500 Pa in good accordance with the level of the irradiation dose; hydrogels obtained at doses higher than 25 kGy have better mechanical properties. Analysing influences of the irradiation dose on M_c it can be seen that highly crosslinked hydrogels were obtained with higher doses, as expected (Figure 4).

The shear moduli values and network parameters are of the same order of magnitude as the values obtained for other similar systems [6].

CONCLUSION

In this work new hydrogels based on 2-hydroxyethyl methacrylate, itaconic acid and poly(ethylene glycol) acrylate were synthesized using gamma irradiation.

These polymers swell in water to yield homogenous transparent hydrogels. The swelling and mechanical behavior were influenced by the level of the irradiation dose. Hydrogels obtained at doses over 25 kGy have good swelling and mechanical properties.

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