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INFLUENCE OF MONOMER AND CROSSLINKER MOLAR RATIO ON THE SWELLING BEHAVIOUR OF THERMOSENSITIVE HYDROGELS

The synthesis of the poly(N-isopropylacrylamide-co-2-hydroxypropyl-methacrylate) hydrogel along with the analysis of the residual monomers content and influence of monomer and crosslinker molar ratios on the swelling behaviour was investigated. Synthesis of thermosensitive hydrogel based on N-isopropylacrylamide was carried out with the molar ratios of 5, 10, 15 and 20 mol% of monomer 2-hydroxypropyl-methacrylate, in the presence of ethylene glycol dimethacrylate as a crosslinker (1, 1.5, 2 and 3 mol%) and 2,2'-azobis(2-methylpropionitrile) as an initiator in acetone. The quantities of residual monomers in the synthesized copolymers were determined by HPLC method, ranging from 0.19 to 0.49% for N-isopropylacrylamide and from 0.13 to 0.63% for 2-hydroxypropyl-methacrylate, counting the amount of xerogel. The hydrogels swelling ratio depending on time at 20 and 40 °C was examined. It was found that the hydrogel with 5 mol% 2-hydroxypropyl-methacrylate and 1 mol% ethylene glycol dimethacrylate had the highest degree of swelling (α = 29.59) at 20 °C, and that the hydrogel with 20 mol% 2-hydroxypropyl-methacrylate and 3 mol% ethylene glycol dimethacrylate had the lowest swelling degree (α = 2.17) at 40 °C.

Keywords: thermosensitive hydrogel; residual monomers; swelling; N-isopropylacrylamide; 2-hydroxypropyl-methacrylate.

By definition, hydrogels are crosslinked polymer networks with hydrophilic properties. They are generally prepared based on hydrophilic monomers, but hydrophobic monomers are sometimes used in hydrogels preparation in order to regulate the properties for specific applications [1]. In general, the three integral parts of hydrogel synthesis are the monomer, initiator, and crosslinker. To control the heat of polymerization and the final hydrogels properties, solvents such as water or other aqueous solutions can be used. After the synthesis, the hydrogel mass needs to be washed to remove impurities left from the synthesis process. These include non-reacted monomers, initiators, crosslinkers, as well as unwanted products produced *via* side reactions. The hydrogel properties can be modulated by varying the factors related to reaction conditions, such as the reaction vessel, time, temperature, monomer type, type of crosslinker, crosslinker-to-monomer ratio, monomer concentration, and type and amount of initiator. Conventional methods for hydrogel synthesis include radical polymerization and copolymerization or, in some cases, polycondensation. There are many inventive approaches for obtaining hydrogels described in literature, like microwave synthesis, irradiation of gamma rays, etc. [2-7].

Stimuli sensitive hydrogels represent a special group of so-called intelligent or smart hydrogels which demonstrate large property changes in response to small physical or chemical stimuli (temperature, pH, ionic strength, electromagnetic radiation, etc.) [8]. In recent years there has been an expansion in the use of stimuli sensitive polymers to solve various biomedical problems. Stimuli sensitive hydrogels are used for the synthesis of those hydrogels which are used in controlled drug delivery, increasing the solubility of

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drugs and reduce the degradation and toxicity of drugs.

Temperature-sensitive hydrogels are probably the most studied class of stimuli sensitive hydrogels in drug delivery research. These hydrogels are able to swell or deswell as a result of change in the temperature of the surrounding fluid. When the temperature is raised above the lower critical solution temperature (LCST), the entropy term (hydrophobic interactions) dominates, leading to polymer contraction. The efficiency of the hydrogen bonding process has a negative temperature dependency and above the LCST, the hydrogen bonds between the monomer side-groups and water molecules will increasingly be disrupted with increasing temperature [9]. Representatives of temperature-sensitive polymers include poly(*N*-isopropylacrylamide), p(NIPAM), and its copolymers, in which a phase transition based on hydration-dehydration behavior is induced in response to temperature. Temperature-sensitive hydrogels are the most investigated, because these signals are easily controlled and have wide-ranging applicability in the fields of biotechnology, chemical processing, and medicine [10,11]. Properties of thermoresponsive p(NIPAM) hydrogels, poly(*N*-isopropylacrylamide-*co*-acrylamide) and poly(*N*-isopropylacrylamide-*co*-*N*-hydroxymethylacrylamide-co-hydroxyethylmethacrylate) prepared by redox polymerization were investigated [12,13]. Also, the behavior of water p(NIPAM), poly(*N*-isopropylacrylamide-*co*-2-hydroxyethylmethacrylate), poly(*N*-isopropylacrylamide-co-acrylamide) and poly(*N*-isopropylacrylamide-*co*-*N*,*N*-dimethylacrylamide) hydrogels, synthesized by radical polymerization were studied at large [14,15]. pH and temperature-sensitive hydrogels, based on NIPAM and itaconic acid, were investigated too, as well as their possible application in controlled release of drugs [16-18].

Synthesis of superapsorbent thermosensitive hydrogel with minimized residual monomer content is an essential prerequisite, particularly in their applications concerning hygienic, pharmaceutical and food packaging products. Residual contents of at least 0.5 and even 1.0% or more of free monomers are often found in polymers manufactured on an industrial scale. The variation of the hydrogel properties (*i.e.*, gel content, swelling capacity, and residual monomer content) *versus* the initiator system and concentration was investigated in many scientific works and patents [19-21].

Testing the biocompatibility of hydrogels is an important step in the development of systems for drug delivery and other biomedical applications. Frequently, toxicity caused by polymeric biomaterials is associated with residual monomer, initiator and solvents, and not with the polymer network itself. For this reason it is important to remove them from synthesized hydrogels using appropriate solvent and then to analyze them. To reduce the level of residual monomers inside the hydrogels, chemical and physical methods are used and determined using the two most common equipment High-Performance Liquid Chromatography (HPLC) and Gas Chromatography (GC) [22].

The kinetics of the polymerization of homopolymers and copolymers containing an active ester of acrylic acid by reversible addition fragmentation chain transfer (RAFT) was followed by withdrawing samples from the polymerization mixture at different intervals of time and analyzing the residual monomer concentrations by ^{1}H-NMR [23]. Ringsdorf and Simon have prepared hydrophobically-modified p(NIPAM) by free radical copolymerization. The absence of residual unattached chromophores was confirmed by the Gas Permeation Chromatography (GPC) traces [24]. Nguyen and collaborators have removed the solvent and residual monomer under vacuum and the samples were then analyzed using GPC [25]. Xia and collaborators have investigated thermal response of narrow-disperse p(NIPAM) prepared by atom transfer radical polymerization and determined monomer conversion gravimetrically and corrected for residual monomer using ^{1}H-NMR spectroscopy [26,27]. Virtanen and Tenhu have studied *N*-isopropylacrylamide and glycidyl methacrylate obtained by free-radical homopolymerization, and the copolymers were twice reprecipitated from acetone solutions with diethyl ether to remove and determined the residual monomers [28]. Benzyl and cumyl dithiocarbamates as chain transfer agents in the RAFT polymerization of NIPAM was investigated. The residues were dried under vacuum, whereby residual monomer was removed by sublimation. Even GC determination of the residual monomer was not reliable as the conversions determined for the same sample varied considerably due to sublimation of the monomer and evaporation of the internal standard (*n*-decane) [29].

HPMet was selected as a comonomer in the hydrogel polymerization because of its excellent performances for both soft and hard tissues. It was widely used in immunocytochemical processes. Hydrophilic polymer of HPMet has the excellent biocompatibility and the similarity of its physical and chemical properties with the living tissues, satisfactory chemical and hydrolytical stability and good tolerance by the cells [30-32]. The synthesis of hydrogels based on *N*-isopropylacrylamide and 2-hydroxypropyl methacrylate obtained by gamma irradiation, characteri-

zation and investigation of their properties as drug carrier were investigated [30].

There was no available literature related to the analysis of the residual monomers content for poly(*N*-isopropylacrylamide-*co*-2-hydroxypropyl-methacrylate) hydrogel (p(NIPAM-*co*-HPMet)). The aim of this paper is to investigate the swelling behaviour of p(NIPAM-*co*-HPMet) hydrogel and to analyze the residual monomers for possible pharmaceutical applications. Presented results are part of extensive research concerning the applicability of p(NIPAM-*co*-HPMet) hydrogels as potential carriers for controlled delivery of nonsteroidal anti-inflammatory drugs.

EXPERIMENTAL

Materials

N-isopropylacrylamide (NIPAM) 99%, Acros Organics, New Jersey, USA; 2-hydroxypropyl-methacrylate (HPMet) 96.5%, Acros Organics, New Jersey, US; ethylene glycol dimethacrylate (EGDM) 97%, Fluka, Chemical Corp., CH; 2,2'-azobis(2-methylpropionitrile) (AZDN) 98%, Acros Organics, New Jersey, US; aceton, Centrohem, Belgrade, RS, methanol, Unichem, Belgrade, RS.

Synthesis of p(NIPAM-*co*-HPMet) hydrogels

Copolymers of p(NIPAM-*co*-HPMet) from NIPAM monomer with 5, 10, 15 and 20 mol% of HPMet monomer were synthesized by radical polymerization. EGDM crosslinker (which concentration in the reaction mixture was in range from 1, 1.5, 2 and 3 mol%) and the initiator 2,2'-azobis(2-methylpropionitrile) in acetone were used at the same time in the reaction mixture.

Chemical structures of monomers NIPAM (a) and HPMet (b), the EGDM crosslinker (c) used in the synthesis and possible structure of the p(NIPAM-*co*-HPMet) hydrogel (d) are shown in Figure 1.

The reaction mixture was injected into glass tubes, which were then fused, and subjected to polymerization under the temperature range of 70 °C for 2 h, 80 °C for 1 h, and 85 °C for 0.5 h. After cooling, the crosslinked copolymers were separated from the glass tubes and the hydrogels obtained in long cylindrical shapes were sliced into small cylinders ($d \times l$ = = 4 mm×10 mm, where d is diameter, and l is length).

Analysis of residual monomers

Synthesized gels (0.5 g of dry gel) were extracted with 30 cm^3 methanol within 24 h in order to remove all the water insoluble compounds so that their subsequent analysis using HPLC method could be performed. Gels were then immersed in methanol/distilled water solution in ratios of 75/25, 50/50, 25/75 and 0/100% for one day to replace the methanol with water in the gel. Gradual substitution of methanol with water was carried out in the order to effect flushing of methanol from the hydrogel. The gels were then dried at 40 °C to pass into a stage of xerogel for further testing, such as their swelling behavior.

The methanol solution obtained via extraction of gels, was analyzed by HPLC chromatography. HPLC device: Agilent 1100 series, column: ZORBAX XDB-C18 250 mm×4.6 mm, 5 μm, eluent: methanol, flow rate: 1 cm^3/min, injected sample volume: 10 μl, temperature: 25 °C, detector: DAD Agilent 1200 series and detection wavelength: 220 nm.

Hydrogel swelling

The swelling behavior was monitored gravimetrically. Xerogels were immersed in distilled water at temperatures of 20 and 40 °C. The swelling ratio (α) was calculated by the following equation:

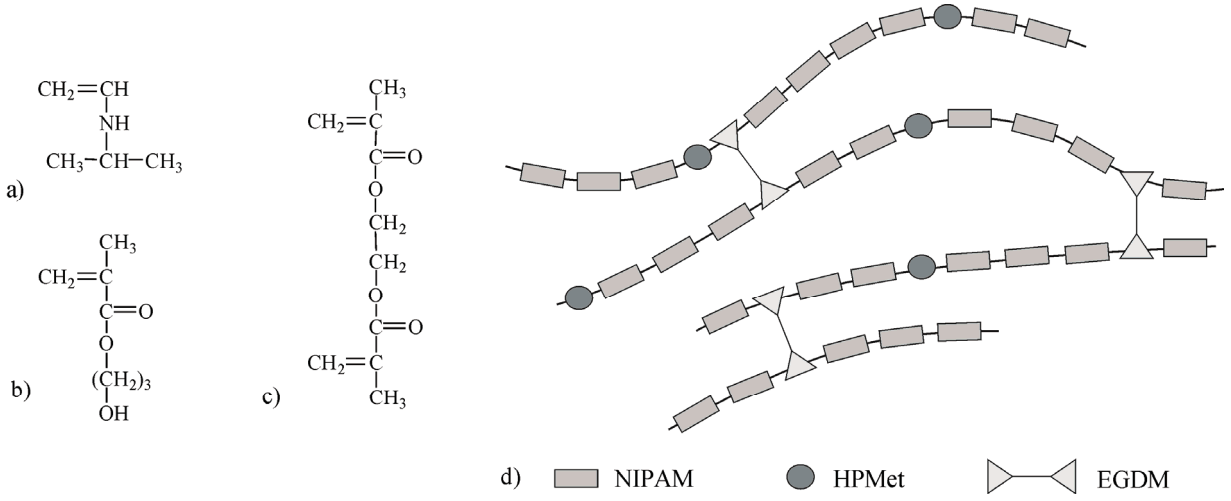

Figure 1. The chemical structures of: a) NIPAM, b) HPMet, c) EGDM, d) possible structure of the p(NIPAM-co-HPMet) hydrogel.

$$\alpha = \frac{m - m_0}{m_0} \quad (1)$$

where m_0 is dry gel mass, and m is mass of gel swollen after time t.

RESULTS AND DISCUSSION

Analysis of residual monomers

The HPLC chromatograms of NIPAM and HPMet monomers are shown in Figure 2. Retention time for the NIPAM is Rt = 2.597 min while for the HPMet is Rt = 2.316 min. It is very convenient that peaks arising from these monomers are well separated and there is no overlap so that the selected chromatographic conditions can be used to determine the residual monomer concentration in methanol extracts. As peak areas are proportional to the concentration of monomers, based on calibration curves monomer concentrations in methanol extract were determined.

The dependence of peak area on NIPAM concentration was linear for concentration range of 0.3 mg/cm^3, which for the following Eq. (2) applies:

$$c = \frac{A - 113.0}{26652.8} \quad (2)$$

where A (mAU*s) is peak area, and c (mg/cm^3) is concentration of NIPAM.

The dependence of peak area on HPMet concentration was linear for concentration range of 1 mg/cm^3, for which the following Eq. (3) applies:

$$c = \frac{A - 435.3}{10164.7} \quad (3)$$

The quantities of residual monomers obtained (NIPAM and HPMet) are presented in Tables 1 and 2. Table 1 shows the residual monomers masses calculated comparing to the total xerogels mass. Table 2 shows the quantities of unreacted monomers compared to their amount in the initial reaction mixture.

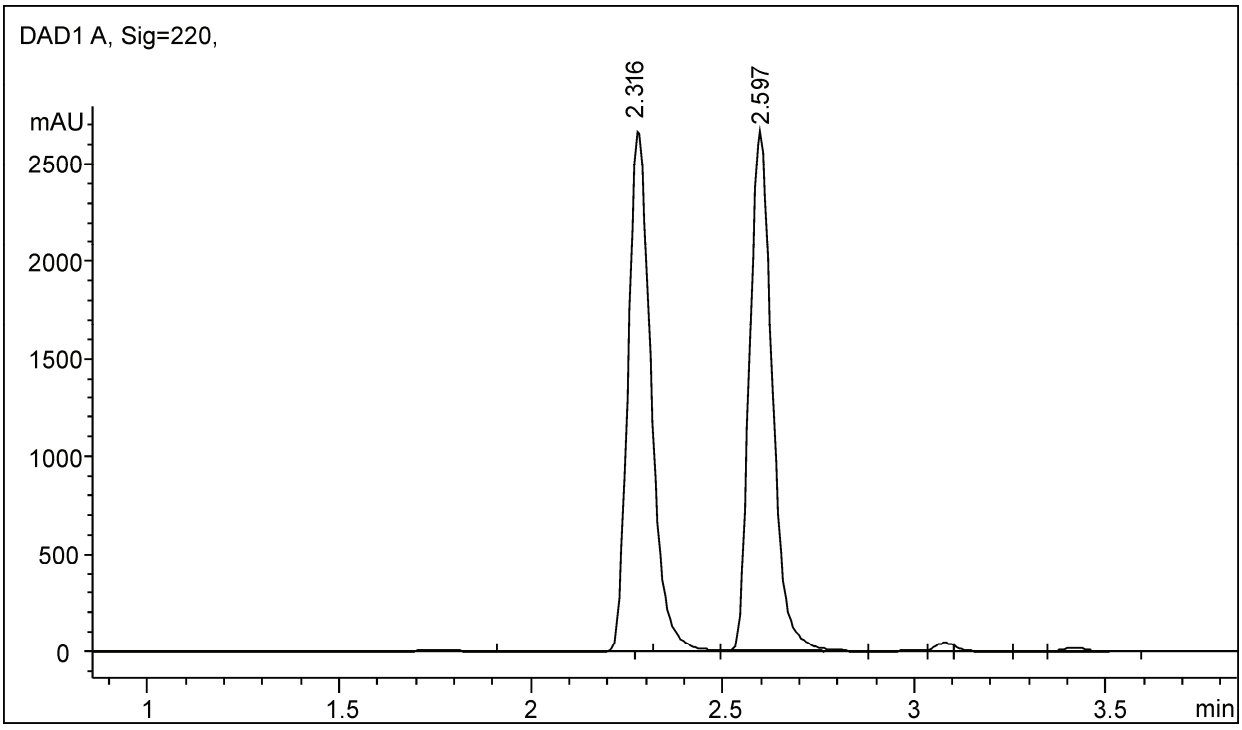

Figure 2. The HPLC chromatograms of monomers NIPAM (R_t = 2.597 min) and HPMet (R_t = 2.316 min).

Table 1. Masses of residual monomers to the total xerogel mass (mg/g)

EGDM, mol%	HPMet, mol%							
	5		10		15		20	
	NIPAM	HPMet	NIPAM	HPMet	NIPAM	HPMet	NIPAM	HPMet
1	2.61	0.27	3.29	0.77	3,08	0.58	3,65	0.60
1.5	2.19	0.19	3.23	0.48	2.91	0.66	1,72	0.40
2	2.23	0.14	2.21	0.53	3.22	0.46	3,13	0.52
3	1.79	0.09	2.40	0.50	2.80	0.67	1,36	0.32

Table 2. Quantities of unreacted monomers compared to the initial amount present in the reaction mixture

EGDM, mol%	HPMet, mol%							
	5		10		15		20	
	NIPAM	HPMet	NIPAM	HPMet	NIPAM	HPMet	NIPAM	HPMet
1	0.28	0.43	0.38	0.63	0.38	0.32	0.49	0.25
1.5	0.24	0.31	0.38	0.40	0.37	0.37	0.23	0.17
2	0.25	0.24	0.26	0.44	0.41	0.26	0.43	0.22
3	0.20	0.15	0.29	0.42	0.36	0.38	0.19	0.14

Quantities of unreacted monomers obtained after the polymerization varied from 0.19 to 0.49% for NIPAM, and from 0.13 to 0.63% for HPMet, counting the amount of xerogel. According to the amounts of residual monomers obtained, it can be concluded that their quantity is negligible and that the monomer conversion in the polymerization process is nearly complete.

Hydrogel swelling

Figures 3-6 show curves of swelling ratio in distilled water at 20 °C for p(NIPAM-*co*-HPMet) hydrogels with 5, 10, 15 and 20 mol% of HPMet, respectively, as a function of time and for different crosslinker contents of 1, 1.5, 2 and 3 mol% of EGDM.

From Figures 3-6 it can be observed that hydrogels with the lowest contents of HPMet and EGDM have the highest swelling ratio. Hydrogel with 5 mol% of HPMet and 1 mol% of EGDM reached the highest swelling ratio at 20 °C, so that 1 g of gel can absorb nearly 30 g of water. The lowest swelling ratio was obtained within hydrogel with the highest molar ratio of HPMet (20 mol%) and the highest content of EGDM (3 mol%), where 1 g of gel can absorb nearly 4 g of water at 20 °C.

For the synthesized hydrogels, the swelling ratio increases extensively during first 6 h. Gels with the highest crosslinker content (3 mol% EGDM) are the fastest to achieve equilibrium state, while achieving the equilibrium swelling ratio of hydrogels with the lowest crosslinker content (1 mol% EGDM) takes up to 2 days.

It can be noticed that along with the increase of crosslinker content swelling ratio decreases in all of the graphs. Hydrogels with higher crosslinking ratio swell less, compared to the hydrogels with the same monomer molar ratio but with minor crosslinking ratio. The reason for these occurrences is the formation of a denser network in the polymer gel due to the large amounts of crosslinker. The polymer chains are more

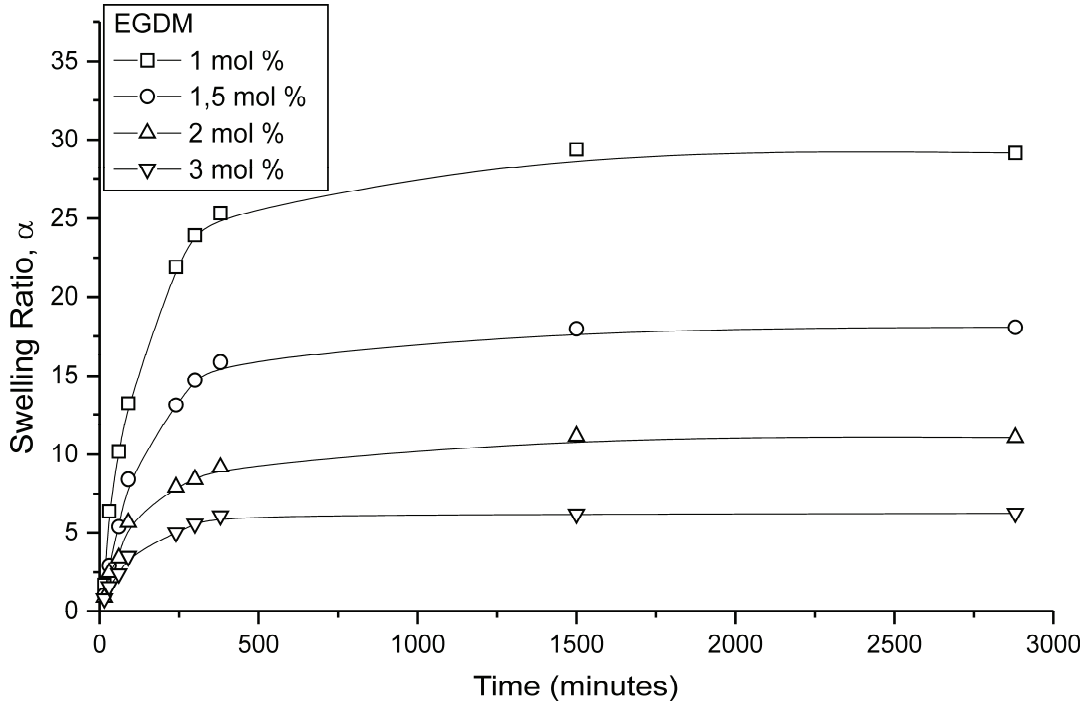

Figure 3. Swelling ratio (α) for p(NIPAM-co-HPMet) with 5 mol% of HPMet at 20 °C, depending on the time and content of EGDM.

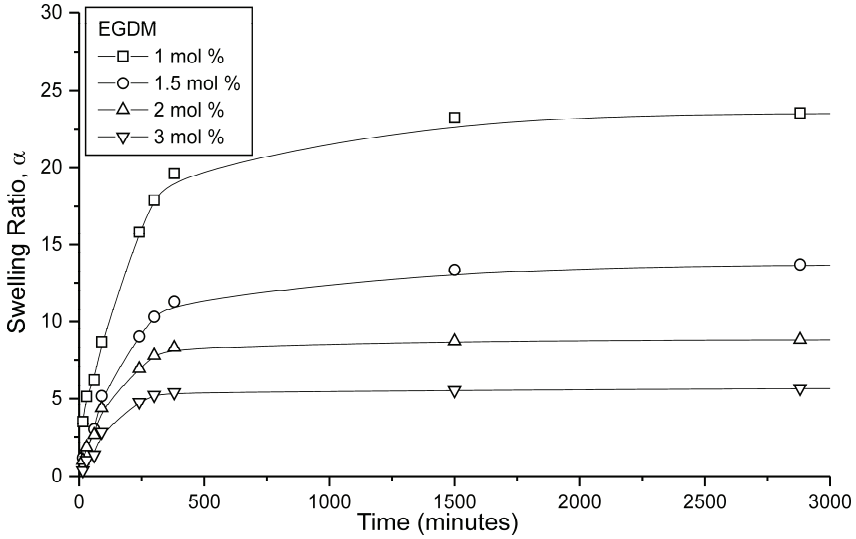

Figure 4. Swelling ratio (α) for p(NIPAM-co-HPMet) with 10 mol% of HPMet at 20 °C, depending on the time and content of EGDM.

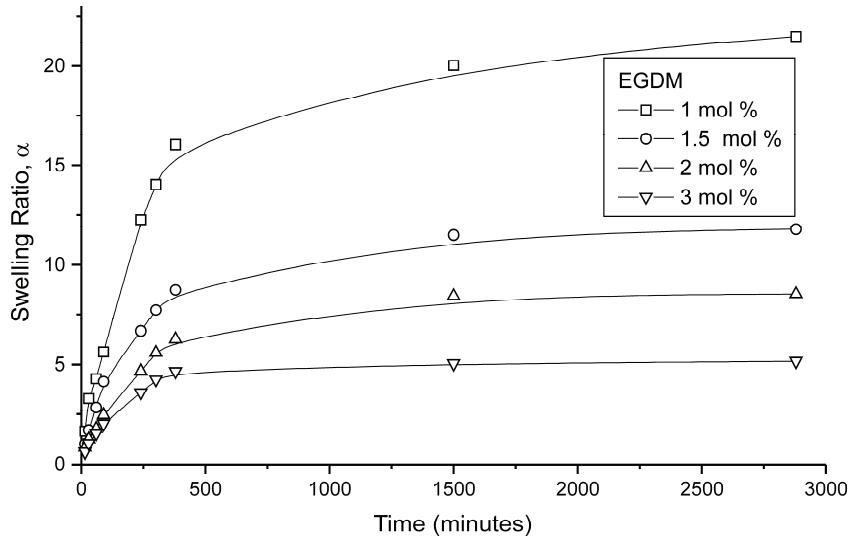

Figure 5. Swelling ratio (α) for p(NIPAM-co-HPMet) with 15 mol% of HPMet at 20 °C depending on the time and content of EGDM.

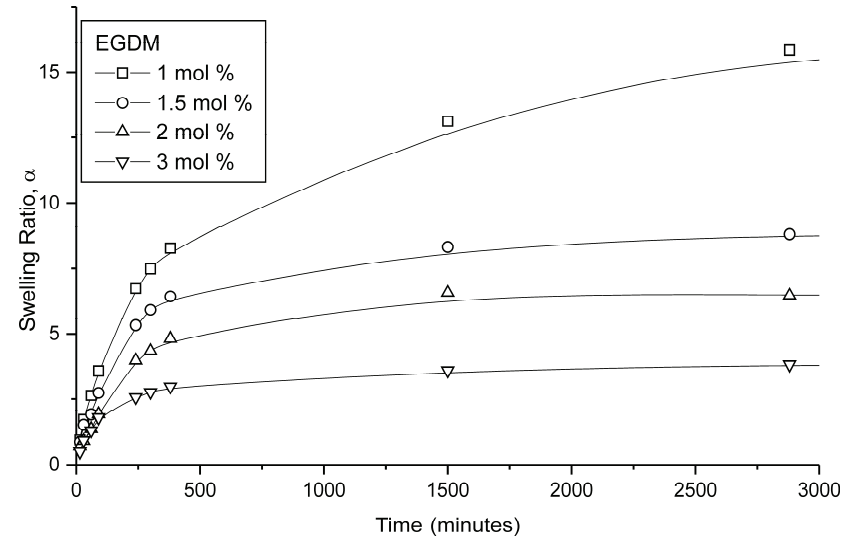

Figure 6. Swelling ratio (α) for p(NIPAM-co-HPMet) with 20 mol% of HPMet at 20 °C depending on the time and content of EGDM.

fixed and as a result appear less able to absorb water. In contrast, when a small quantity of crosslinker is present, the length of the polymer chains between two knots is larger, the network is able to expand and absorb a greater amount of water. Regulating the amount of crosslinker used in the gels synthesis can affect the internal free volume to be filled with the water molecules. Large internal free volume allows a large amount of solvent to be placed inside the gel, which increases the swelling. On the other hand, small internal free volume reduces the swelling of gels. With the increase of crosslinkers amount the speed of swelling and equilibrium swelling ratio decreases.

In all of the graphs with the increase of HPMet monomer content, the swelling ratio decreases. Hydrogels with 5 mol% of HPMet show the highest ratio of swelling, which reduces proportionally with the increase of comonomer content, so that hydrogels with 20 mol% HPMet have the lowest value of the swelling ratio. This occurrence is a consequence of higher NIPAM hydrophilicity compared to a lower hydrophilicity of monomer HPMet. Given that a number of hydrogen bonds in the hydrogel increases the collapse of the gel [9], the assumption is that the addition of HPMet might have come to a further increase in the number of hydrogen bonds in the hydrogel. They can further be built from the terminal OH group of HPMet with the electronegative O atom from the ester functional groups (HPMet and EGDM), or with N from NIPAM. The possibility of increasing the number of hydrogen bonds with the addition HPMet leads to increased collapse of hydrogel, which is consistent with the experimentally obtained results of equilibrium swelling degree (Table 3). These results are consistent with published literature data, but show a much higher swelling ratio values obtained by varying the composition of the appropriate reactants [30,31]. Thermo-sensitivity of the obtained p(NIPAM-*co*-HPMet) gels was confirmed by examining the swelling ratio at elevated temperature of 40 °C. A comparative review of the values of the equilibrium swelling ratio, α, depending on the content of EGDM and HPMet used in the gel synthesis, tested at temperatures of 20 and 40 °C is shown in Table 3.

Presented values of maximum equilibrium swelling ratio showed analogous dependence. Namely, the highest swelling ratio at 40 °C was obtained for hydrogel sample with 5 mol% of HPMet and 1 mol% of EGDM (α = 5.79) while the lowest swelling ratio was obtained for the sample with 3 mol% of EGDM (α = 2.17) with 20 mol% of HPMet. From Table 3 it can also be observed that at a temperature of 40 °C, as expected, the swelling ratio of hydrogels continuously decreases with increasing crosslinking ratio because higher crosslinkers content increases the network density, reducing the mobility of polymer chains and the elasticity of the network. While temperature increases, contraction of the network occurs and apart from the free diffusion of water molecules there is an active extrusion due to the swollen hydrogel collapse, as a result of phase transition phenomena [30,31].

The authors investigated the swelling behavior of the pure p(NIPAM) hydrogel and phase transition for p(NIPAM-*co*-HPMet) hydrogels with 5, 10, 15 and 20 mol% of HPMet depending on the temperature (from 10 to 50 °C). Results for series hydrogel with 2 mol% of EGDM are shown in the Figure 7.

Pure p(NIPAM) hydrogel reaches the highest swelling ratio compared to the p(NIPAM-*co*-HPMet) hydrogel in any of monomer ratios, which can be observed from Figure 7. Also, it is important to compare this swelling behavior of pure p(NIPAM) hydrogel with similar results found in literature [30,31].

The LCST is a very important factor for thermosensitive hydrogels. The NIPAM has a LCST around 32 °C. Based on the results from literature, the temperature dependence on the swelling ratio of p(NIPAM-*co*-HPMet) hydrogel, α, phase transition is observed at temperature around 34 °C [30,31]. LCST closer to physiological body temperature (36-38 °C) is achieved by copolymerization of thermosensitive NIPAM with HPMet. This is particularly important for the controlled release of nonsteroidal anti-inflammatory drugs.

The reason for the appearance of phase transition is the change of water uptake in the crosslinked polymer network, because of destruction of the hydrogen bonds in the hydrogel at higher temperatures. Hydrogel then reaches significantly lower swelling ra-

Table 3. Equilibrium swelling ratio (α) depending on the content of EGDM, molar ratio of HPMet and temperature

EGDM, mol%	HPMet, mol%							
	5		10		15		20	
	20 °C	40 °C	20 °C	40 °C	20 °C	40 °C	20 °C	40 °C
1	29.59	5.79	23.54	4.31	21.46	4.04	15.84	4.52
1.5	18.01	4.29	13.69	3.36	11.79	3.06	8.8	3.69
2	11.04	2.36	8.81	3.16	8.5	2.91	6.47	2.99
3	6.24	1.6	5.65	2.7	5.15	2.63	3.82	2.17

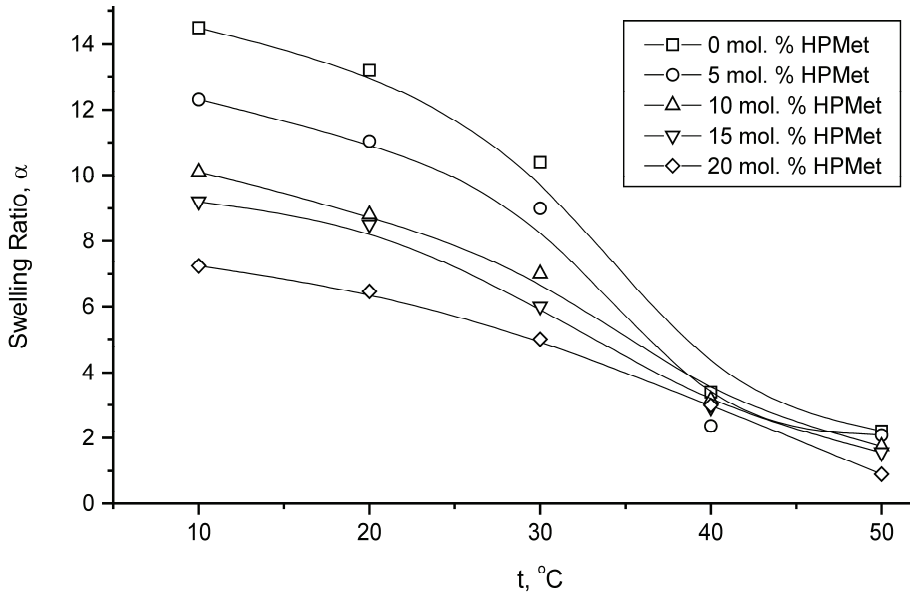

Figure 7. Swelling ratio for pure p(NIPAM) and p(NIPAM-co-HPMet) hydrogels with 5, 10, 15 and 20 mol% of HPMet with 2 mol% of EGDM depending on the temperature.

tio. The backbones of the polymer, the long chains of C–C bonds to which the side chains are attached are hydrophobic and tend to reduce their surface area exposed to the highly polar water molecules. They can do so by forming aggregates [9]. When hydrogen bonds between the side groups and the water are present, the aggregation of the backbone is prevented because the hydrogen bond interactions with the water molecules are stronger than the backbone interactions. When the hydrogen bonds are broken by increasing thermal agitation, aggregation takes place, resulting in shrinkage of the thermosensitive hydrogel with increasing temperature [33]. At temperature of 20 °C hydrogels are completely transparent, while at 40 °C or at the temperature of phase transition they become opaque, milky white.

The synthesized p(NIPAM-*co*-HPMet) hydrogels behave as "smart hydrogels" because they respond to temperature increase stimulus and can be used to absorb aqueous solutions of substances at lower temperatures, or to release them during temperature increase.

CONCLUSIONS

Poly(*N*-isopropylacrylamide-*co*-2-hydroxypropyl--methacrylate) hydrogels based on NIPAM copolymer with 5, 10, 15 i 20 mol% of HPMet, using different crosslinker concentrations of EGDM (1, 1.5, 2 i 3 mol%) were synthesized. The amount of residual NIPAM and HPMet values obtained, analyzed by HPLC method, shows almost complete conversion. The hydrogel with the lowest molar ratio of HPMet and EGDM reached the highest swelling ratio at 20 °C, while the lowest swelling ratio was obtained with the highest molar ratio of HPMet and EGDM. With an increase of crosslinker and HPMet content the swelling ratio decreases. Thermo-sensitivity of the obtained p(NIPAM--*co*-HPMet) gels was confirmed so that the increase in temperature decreases the swelling ratio, which was expected by the presence of phase transformation. By regulating the amount of crosslinkers used in the gels, synthesis can affect the water absorption ability, and hence the swelling ratio can be controlled.

Nomenclature

AZDN - 2,2'-Azobis(2-methylpropionitrile)
EGDM - Ethylene glycol dimethacrylate
HPMet - 2-Hydroxypropyl methacrylate
LCST - Lower critical solution temperature
NIPAM - *N*-Isopropylacrylamide
p(NIPAM) - Poly(*N*-isopropylacrylamide)
p(NIPAM-*co*-HPMet) - Poly(*N*-isopropylacrylamide-*co*--2-hydroxypropyl-methacrylate)

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NAUČNI RAD

UTICAJ MOLARNOG ODNOSA MONOMERA I UMREŽIVAČA NA KARAKTERISTIKE BUBRENJA TERMOOSETLJIVIH HIDROGELOVA

Predmet ovog rada je sinteza kopolimernog hidrogela poli(N-izopropilakrilamid-ko-2-hidroksipropilmetakrilata), analiza sadržaja rezidualnih monomera i ispitivanje uticaja molskog odnosa monomera i umreživača na karakteristike bubrenja. Sinteza termoosetljivog hidrogela na bazi N-izopropilakrilamida izvršena je sa molarnim udelom 5, 10, 15 i 20 mol% monomera 2-hidroksipropilmetakrilata, u prisustvu umreživača etilenglikoldimetakrilata (u koncentraciji: 1, 1,5 , 2 i 3 mol%) i inicijatora 2,2'-azobis(2-metilpropionitrila) u acetonu. Sadržaj zaostalih monomera u sintetizovanim kopolimerima analiziran je pomoću HPLC metode. Vrednosti se nalaze u granicama od 0,19 do 0,49% za N-izopropilakrilamid i od 0,13 do 0,63% za 2-hidroksipropilmetakrilat računajući na količinu kserogela. Ispitan je stepen bubrenja dobijenih hidrogelova u zavisnosti od temperature. Najveći stepen bubrenja (α = 29,59) pri konstantnoj temperaturi od 20 °C dostigao je uzorak hidrogela sa 5 mol% 2-hidroksipropilmetakrilata i 1 mol% umreživača EGDM-a, a najmanji (α = 2.17) pri temperaturi od 40 °C dostigao je uzorak hidrogela sa 20 mol% 2-hidroksipropilmetakrilata i 3 mol% umreživača EGDM-a.

Ključne reči: termoosetljivi hidrogelovi; bubrenje; rezidualni monomeri; N-izopropilakrilamid; 2-hidroksipropilmetakrilat.