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EFFECTS OF STERILIZATION ON POLY(VINYL ALCOHOL) (PVAl) HYDROGELS MATRICES

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ABSTRACT

The poly(vinyl alcohol) (PVAl) is a polymer of great interest for new materials development due to its specific characteristics particularly for biomedical applications. PVAl with polyethylene glycol (PEG) 300 was processed using freezing-thawing sequence of thermal cycles for hydrogel preparation. The samples were evaluated by gel fraction (%), water uptake (%) and thermogravimetry analysis (TGA). The hydrogel was sterilized under ionizing radiation from Cobalt-60 source at 25 kGy dose and the effects of the radiation on the hydrogel properties was discussed in this work. The results of swelling, gel fraction and thermal stability are in part influenced by the sterilization method. The presence of PEG in PVAl hydrogels forms less dense hydrogels under freeze/thawing cycles. The swelling in the sterilized hydrogels is higher than the not sterilized hydrogel in consequence of chain scissions in the polymeric structure due to the radiation process.

1. INTRODUCTION

The current study of the polymeric science considers the biomedicine as one of the most important areas for application of modified polymeric structures as new materials. An example, is the poly(vinyl alcohol) (PVAl), a polymer of great interest due to its specific characteristics for biomedical applications. The synthesis of the modified polymeric hydrogel of PVAl with polyethylene glycol (PEG) 300 was processed using freezing-thawing known as sequence of thermal cycles.

PVAl is a water-soluble polymer employed in practical applications due to its excellent chemical resistance, processing properties, biodegradability and physical properties [1, 2]. The presence of a second polymer can performs significant change in the overall crystalline structure of the hydrogel. Softening PVAl hydrogel could be obtained with crosslink of PVAl in the presence of PEG. Morphological changes can lead to different performance of the hydrogel and the characteristics of swelling degree and diffusional behavior may change under physiological stimuli [3] representing an important feature for controlling release of bioactive species.

Parameters affecting the final properties of PVAl gels prepared by freeze/thaw cycling include those that describe the starting materials (degree of substitution, tacticity) and those that define the processing steps (solution concentration, number of both the freezing and thawing steps). Despite the intense study there is a little understanding of how freeze/thaw cycling actually enhances gelation and whether the final gels microstructure depends significantly on the cycling protocol selected [1]. Many related and possibly relevant studies

have examined PVAl gelation by thermal processing in water/co-solvent mixtures [4], or by chemical crosslinking with borate ions [5]. The propensity of PVAl gels to age by expulsion of water complicate the elucidation of all relevant factors in gels structure formation [6].

2. METHODS AND MATERIALS

PVAl (M_w = 85000 degree of hydrolysis 98.4%) from Celvol^{TM} 325 Dermet Agekem. PEG 300 from Oxiteno.

PVAl (10% m/v) was prepared by the dissolution in deionized water under reflux at 85 °C for 40 minutes for total dissolution. After that three different formulations were prepared by the addition of PEG in the proportions 0.5; 2.0 and 4.0%; in the PVAl solution and heated for 5 minutes at 85 °C.

The samples were prepared from 35 mL formulations in Petri dishes and kept at room temperature for 10 hours and then frozen at -15 °C for 14 hours. At the end of this period the samples placed at room temperature until completely defrosting. This thermal freezing-thawing cycle was repeated ten times. After thermal cycle the hydrogels were exposed to gamma rays from Cobalto-60(dose rate of 10 kGy h^{-1}) at 25 kGy

2. 1. Swelling

After synthesis, the samples were immersed in distilled water and weighed in periods of time until 72h according to the equation A.

$$\text{Swelling} = (m_s - m_d)/m_d * 100 \quad (\%H_2O \text{ per g hydrogel}) \qquad (A)$$

where: m_s is the mass of swelled polymer and m_d is the mass of the hydrogel.

2.2 Gel content

The gel fraction was obtained by immersion of the samples in water 45 – 55 °C for 10h to proceed the extraction, under stirring. The water was replaced after each 4h. After that the samples were dried in oven (45 – 55 °C) and the gel fraction was calculated by the equation B.

$$\text{Gel fraction} = mf / ms * 100 \qquad (B)$$

where: m_s is the mass before extraction and m_f is the mass of the dried sample after extraction.

2.3 Instrumental analysis

TGA technique was accomplished in a Mettler-Toledo TGA/SDTA 851 thermobalance, using inert atmosphere of N_2 from 25 to 600 °C at heating rate of 10° C min^{-1}.

DSC curves were obtained in a Mettler-Toledo 822, under nitrogen atmosphere, for PVAl from 25 to 400°C at 10°C min^{-1}.

3. RESULTS AND DISCUSSION

Fig. 1 shows the profile of water uptake of the hydrogels with different PEG concentration as a function of time, before sterilization.

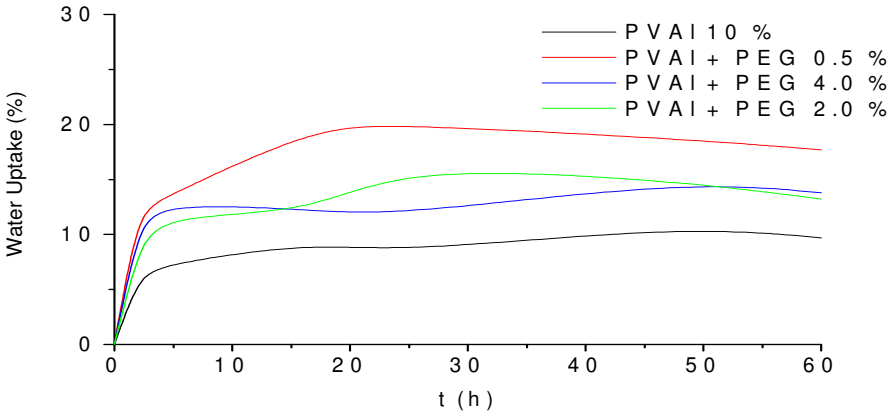

Figure 1 - Equilibrium water uptake of hydrogel composed of PVAl and PEG 300

The swelling profiles (Fig. 1) of all freezing-thawing membranes are showed and the values are higher than PVAl membrane (black line). The equilibrium water was picked up after 60h when were noted that membranes containing PEG swell more intensely than PVAl membrane. The freezing of the water molecules forces PVAl to phase separation and crystallization causing the solution to form a physically crosslinked gel upon subsequent thawing of the ice crystals [7]. Table 1 shows the equilibrium water values for each sample.

Table 1 – Equilibrium water uptake of the hydrogel membranes at different concentration of PEG 300 before sterilization.

Samples	Uptake water UW (%)
PVAl 10 %	9.7
PVAl + PEG 0.5 %	18.7
PVAl + PEG 2.0 %	13.3
PVAl + PEG 4.0 %	14.2

These results showed that presence of PEG forms less dense PVAl matrix of hydrogel. After sterilization the swelling profiles were changed due to the radiation process modification of the hydrogels. In the same manner the water uptake of the sterilized membranes (Fig. 2) was

reached after 60h and the values of the equilibrium water (Table 2) increase in the PEG content samples. As the uptake water values are higher after sterilization we postulate that PVAl not crystallized suffers chain scission in all cases increasing the UW%.

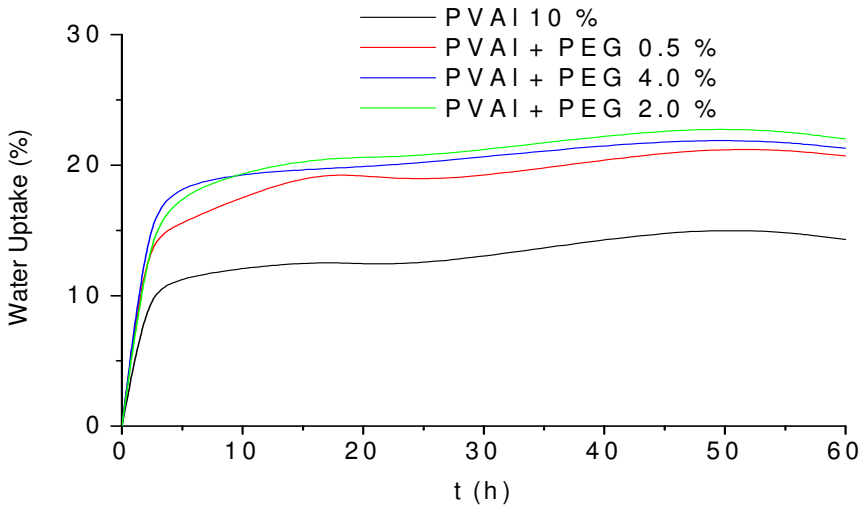

Figure 2 - Equilibrium water uptake of sterilized hydrogel composed of PVAl and PEG 300

Table 2 shows the values of the equilibrium water for each hydrogel after radiation sterilization.

Table 2 – Equilibrium water uptake of sterilized hydrogel at different concentration of PEG 300.

Sample	Equilibrium water (%)
PVAl 10 %	14.3
PVAl + PEG 0.5 %	20.8
PVAl + PEG 2.0 %	22.0
PVAl + PEG 4.0 %	21.4

The uptake water results increase after sterilization and were demonstrated that the process of sterilization modify the crosslink of the membranes by the chain scission mechanism, in consequence, the swelling increases in all membranes including the PVAl sterilized one. In the other hand the physical crosslink obtained by freeze-thawing is not destroyed by the radiation but is enhanced as observed by the gel content, (Table 3), mainly in the presence of PEG. This is an evidence that network was modified also by crosslink formation in competition with chain scission occurring in the chain segments not crosslinked.

Table 3 – Values of gel fraction hydrogel composed of PVAl and PEG 300.

Samples	Not sterilized	Sterilized
PVAl 10 %	7.9	10.0
PVAl + PEG 0.5 %	5.71	12.4
PVAl + PEG 2.0 %	5.72	11.8
PVAl + PEG 4.0 %	4.83	8.8

The decomposition temperatures of the polymeric composition are showed in table 4 and refer to the curves of the membranes before sterilization reported in Fig. 3 and membranes after sterilization, in Fig. 4.

Table 4 – Values of the T_{onset} and the residue for hydrogel sterilized or not

Sample	T_{onset} (°C)	T_{onset} (°C) sterilized	Residue (%) sterilized	Residue (%)
PEG 300 pure	259.0	ND	ND	0.002
PVAl pure	273.3	ND	ND	8.0
10% PVAl + PEG 0.5 %	257.4	254.8	1.5	1.0
10% PVAl + PEG 2.0 %	257.4	256.7	1.2	1.2
10% PVAl + PEG 4.0 %	252.0	252.2	2.7	1.6

ND- Not determined; T_{onset}: initial decomposition temperature

The T_{onset} values of the samples demonstrated that the polymeric fraction of the sterilized hydrogel is slightly less stable maintaining the same residue content.

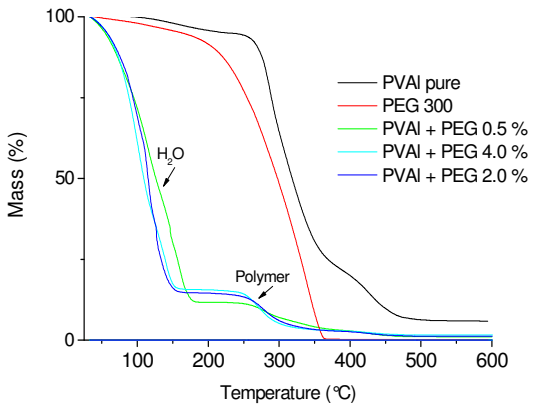

Fig. 3 – TGA curves of the PVAl / PEG hydrogels before sterilization.

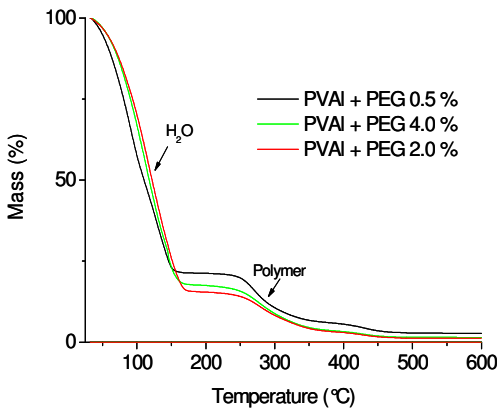

Fig. 4 – TGA curves of the PVAl / PEG hydrogels after sterilization by radiation

Fig. 5 illustrates the hydrogel membrane as a flexible and soft material. In contact with water it swells moderately suggesting applications to drug release. PVAl is presently being used for this purposely [8].

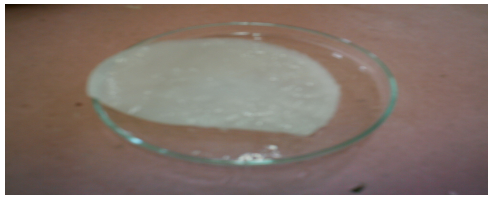

Fig. 5 - Hydrogels prepared by thermal cycle

4. CONCLUSIONS

The presence of PEG in PVAl hydrogels forms less dense hydrogels in the process of the crosslink formation by freeze/thawing cycle. The swelling in the sterilized hydrogels is higher than the not sterilized hydrogel in consequence of chain scissions in the polymeric structure due to the radiation process. The radiation process also promoted crosslink as verified by the gel content of sterilized membranes however the results not presented evidences about PEG crosslinking with PVAl.

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