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Chapter 7

Obtaining Hydrogels based on PVP/PVAL/Chitosan Containing Pseudoboehmite Nanoparticles for Application in Drugs

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Additional information is available at the end of the chapter

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Abstract

People with skin lesions caused by burns, ulcerations and other complications, independent of degree and extension of the problem, has induced the search for methods and materials to optimize the process of tissue repair in matter of time and quality. Thus, materials made by synthetic polymers have been used and improved due to overwhelming demand. The efficacy of dressings and bandage depends on a variety of factors such as biocompatibility, composition uniformity, low cost, long validity, flexibility, and so on. In this chapter, hydrophilic membranes based on polyvinylpyrrolidone-PVP/poly(vinyl alcohol)-PVAl and chitosan containing nanoparticles of pseudoboehmite for use in pharmaceuticals were developed and studied. The hydrogels were obtained by ionizing radiation in electron-beam accelerator at a dose of 25 kGy and characterized by mechanical, thermal and physicochemical tests. Pseudoboehmite nanoparticles were obtained from aluminum nitrate by a sol–gel process. The characterization of the hydrogels was done by various tests such as tensile, swelling, thermal analysis, sol-gel fraction and dynamic mechanical analysis. The results show that the presence of PVAl hydrophilic membrane causes lower degree of swelling, greater attraction and greater resistance to elongation at break in tension, although significantly lower fraction of gel membranes contains only agar and PVP. It was verified that the presence of chitosan nanoparticles and pseudoboehmite promotes a decrease in the formation of cross-links during irradiation of hydrophilic membranes.

Keywords: PVP, PVAl, chitosan, pseudoboehmite, nanotechnology, hydrophilic membranes

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1. Introduction

Hydrophilic membranes based on hydrogels can be defined as a polymeric material, which is insoluble in water, can absorb it and retain a significant fraction in its structure [1]. The material that forms the membranes with these characteristics is composed of two water-insoluble cross-linked hydrophilic polymer systems, due to the existence of a three-dimensional network connecting their chains, and is perceived that water was retained in its structure [2–4].

Hydrogels can be expanded by water and ion absorption, above the equilibrium state and retain their original shape and mechanical properties. In addition, they present permeability to biologically active substances with low molecular weight, being used in dressings directly on contact with the skin and can be used as dressing or bandage in burn wounds, vascular prostheses, artificial cartilage membranes for hemodialysis, among other applications [5, 6].

Hydrogels obtained by ionizing radiation, having as precursors poly(n-vinyl-2-pyrrolidone) (PVP), agar and plasticizing agents such as polyethylene glycol that have been used in pharmaceuticals and have advantages over the previously obtained methods, they eliminate the sterilization phase, as this is still being obtained in the process of ionizing radiation [1].

Due to its properties, PVAl is one of the synthetic polymers that are used as a biomaterial, being of great importance in the industry, mainly in cosmetics, where it is used as an additive, providing texture to the products. Its main function is that of a plasticizer. Its use in the synthesis of hydrophilic membranes presents some restrictions when used alone, because the obtained membrane presents low elasticity and rigidity. To improve these properties, it is used in conjunction with other polymers [7, 8].

Chitosan is a natural polymer that can be obtained through the process of deacetylation of chitin, a polysaccharide of great abundance in nature, and present a similar chain to cellulose. Among its main characteristics, of great importance and industrial interest, it is atoxic and has an easy way to create gel [9].

Chitosan nanocomposites have been used in the cotton coating for application in dressings and bandage with the purpose of increasing the absorption of the exudate as well as improving the antibacterial activity [10].

Chitosan and PVAl are biocompatible polymers being in the composition of several hydrogels used today [11, 12]. Hydrophilic membranes based on PVAl and chitosan have been synthesized because the presence of chitosan improves the mechanical, hydrophilic and antibacterial properties of membranes obtained from PVAl [13, 14]. These membranes modified by the presence of nanoclays for use in dressings have been obtained with good mechanical and absorption properties [15, 16].

Hydrophilic membranes obtained from polyvinyl alcohol, poly(N-vinylpyrrolidone) and antibiotic containing chitosan have been synthesized by Yu et al. [17].

The pseudoboehmite obtained by the sol-gel process is a ceramic nanoparticle with high surface area, bioinert, which can be used in drug delivery systems [18]. Pseudoboehmite has the same structure as the boehmite (ɣ-ALOOH). It has an orthorhombic structure and presents two layers of octahedral oxygen partially filled with aluminum cations [19]. Through the sol:

gel process, it is possible to obtain nanoparticles of pseudoboehmite, having as precursors aluminum nitrate and ammonium hydroxide [20].

The sol-gel process consists of synthesis of materials, caused by the transition of a sol system, dispersion of colloidal particles (dimension from 1 to 100 mm) in a fluid; in a gel system, rigid structure system of colloidal particles or chains polymerization by immobilizing the liquid phase [21].

Pseudoboehmites obtained by the sol-gel process have been successfully used in drug delivery systems [18].

The aim of this chapter is to obtain a polymer system based on PVP, PVAl and chitosan containing pseudoboehmite nanoparticles, through the action of ionizing radiation, although the excellent biomedical properties in clinical practice of PVP-based hydrogels are confirmed, the difficult handling of these materials has been observed on their poor mechanical properties. Therefore, it is important to study new systems that maintain the properties required for these materials and at the same time to implement the physical:chemical and mechanical properties

2. Experimental study

2.1. Materials

The following reagents were used: aluminum nitrate $Al(NO_3)_3$, supplied by Dinâmica LTDA; ammonium hydroxide (NH_4OH), supplied by Audaz Reagente Tecnológico; polyvinyl alcohol, supplied by Bandeirante Química; poly(N-vinyl-2-pyrrolidone) (PVP), supplied by GAF Co.; chitosan, supplied by Polymar; poly(ethylene glycol), supplied by Oxiteno Brasil and agar supplied by Oxide.

2.2. Methods

The synthesis of nanoparticles of pseudoboehmite (PSB): The nanoparticles of the pseudoboehmite were obtained through the sol-gel process, according to Munhoz Jr. et al. [22], aluminum nitrate solution in H_2O, solution of ammonium nitrate in H_2O and solution of polyvinyl alcohol in H_2O, which is used to increase the viscosity of the aluminum nitrate solution. The solution of aluminum nitrate and polyvinyl alcohol was mixed with the ammonium hydroxide solution. The obtained product was washed with distilled water and dried through air.

Obtaining chitosan solution: The chitosan was dissolved in acetic acid solution, 2 wt% in H_2O, which was stirred for 48 h. After dissolution of chitosan, it was neutralized with 1 wt% sodium hydroxide solution in H_2O until pH 7.

Preparation of PVP/PVAl/PSB/chitosan membranes reinforced with PSB: Membranes with 3 wt% PSB were obtained. **Table 1** shows the composition of the membranes obtained.

The hydrogels were produced from a solution of PVP, PVAl, chitosan, agar and PEG in H_2O, which was heated and subsequently PSB was added to the solution. The solution was poured into polyethylene molds and after cooling, a physical gel was obtained.

Materials	Compositions (wt%)							
	Comp. 1	**Comp. 2**	**Comp. 3**	**Comp. 4**	**Comp. 5**	**Comp. 6**	**Comp. 7**	**Comp. 8**
PSB	0	0	0	0	0	0	3	3
PVP	10	10	2.5	2.5	2.5	2.5	2.5	2.5
PVAl	0	0	7.5	7.5	7.5	7.5	7.5	7.5
Chitosan	0	0	0	0	1	1	1	1
PEG	3	3	3	3	3	3	3	3
Agar	1	3	1	3	1	3	1	3
Water	86	84	86	84	85	83	82	80

Table 1. Membranes composition.

The physical gel was irradiated in Dynamitron electron beam, with energy of 1.5 MeV, with a dose of 25 kGy and a dose rate of 11.3 kGy/s, which promoted the formation of the cross-links and also the sterilization of the material.

2.2.1. Characterization of hydrogels

Hydrogels were characterized by visual test, mechanical test, gel fraction, thermal properties and swelling.

- *Mechanical test*: Tensile strength tests for the hydrated membrane were performed in a dynamometer of the Q-Test, model 65 J at 25 mm/min (ABNT-NBR 6241/80, with specimen type I).
- *Sol-gel fraction*: The samples were washed in Soxhlet extractors with boiling water for 36 h. The obtained gels were dried until reaching constant weight. The gel fraction was determined in relation to the initial weight of the sample according to Eq. (1).

$$\text{Sol} - \text{gel fraction}\ (\text{wt}\%) = (\text{Wfg}/\text{Wi}) \times 100 \tag{1}$$

where Wfg = final weight (after drying); and Wi = initial weight of the sample.

- *Swelling*: The samples were maintained in water for 240 h. The water absorption was checked every hour step in the first 24 h. After that, each measurement was performed using 24-h steps until reaching constant weight. The hydration grade was determined by the difference of the weight before and after swelling according to Eq. (2).

$$\text{Swelling}\ (\text{wt}\%) = [(\text{Wfs} - \text{Wi})/\text{Wi}] \times 100 \tag{2}$$

where Wfs = final weight (after swelling); and Wi = initial weight of the sample.

- *Thermal properties (DTA, TG and DTMA)*: Thermal analyses were performed by the Netzsch Thermische Analyze STA 409 equipment. The rate used in DTA and TG analysis was 10°C/min from ambient temperature until 600°C with 40 mL/min nitrogen flow. The

thermodynamic-mechanical properties were determined in a Perkin Elmer equipment in the range from −80 to 0°C. The rate used in analysis was 1°C/min with 40 mL/min nitrogen flow.

3. Results and discussion

Visual characterization: **Figure 1** shows the obtained membranes with 25 kGy dose.

The membranes with the compositions 1, 2, 3 and 4 (**Figure 1**) are transparent, while others are translucent and slightly yellowish. Therefore, the presence of chitosan makes the hydrogels less transparent.

In the membranes with the compositions 1, 2, 3 and 4 were firm and without bubbles, the membranes of compositions 5, 6, 7 and 8 showed a greater adhesion or tack due to the presence of chitosan (**Figure 1**).

Tensile strength: **Table 2** and **Figures 2** and **3** present the results to the tensile strength tests to 7 days after irradiation.

The results show that comparing the obtained hydrogels, the Comp. 4 (based on PVP/PVAl/3wt% agar) and Comp. 3 (based on PVP/PVAl/chitosan/3wt% agar) (**Figure 2**) showed higher tensile strength and higher elongation.

The hydrogels Comp. 1 (PVP/1wt% agar), Comp. 2 (PVP/3wt% agar), Comp. 7 (PVP/PVAl/chitosan/PBS/1wt% agar) and Comp. 8 (PVP/PVAl/chitosan/PSB)/3wt% agar) exhibit lower tensile strength (**Figure 2**).

The Comp. 2 hydrogels (PVP/3 wt% agar) (**Figure 3**) show the smallest elongation.

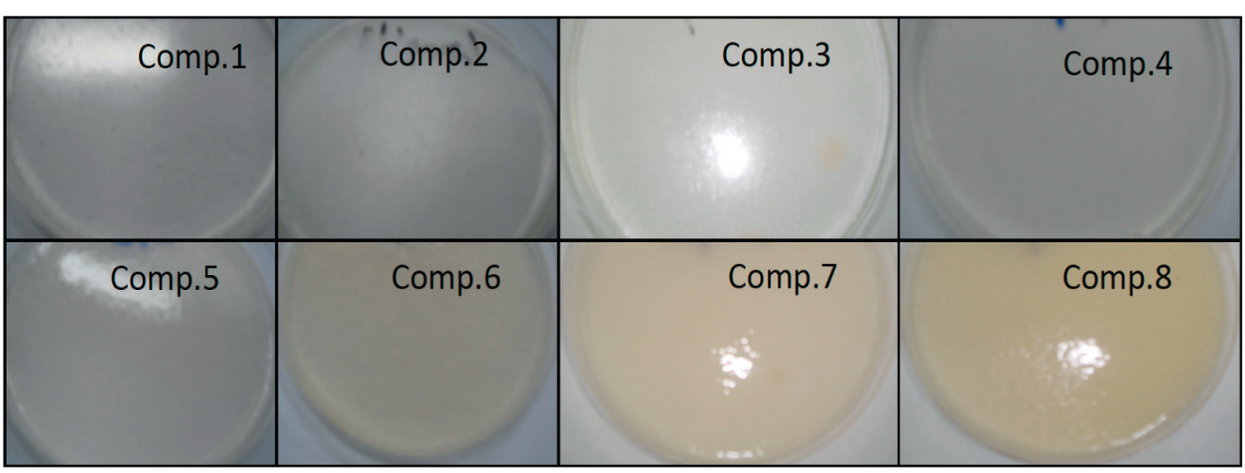


Figure 1. Comp. 1 (PVP/1wt% agar); Comp. 2 (PVP/3 wt% agar); Comp. 3 (PVP/PVAl/1 wt% agar); Comp. 4 (PVP/PVAl/3wt% agar), Comp. 5 (PVP/PVAl/chitosan/1 wt% agar), Comp. 6 (PVP/PVAl/chitosan/3wt% agar); Comp. 7 (PVP/PVAl/chitosan/PSB)/1wt% agar) and Comp. 8 (PVP/PVAl/chitosan/PSB/3 wt% agar).

Hydrogels	Tensile strength (MPa)	Elongation at rupture (%)
Comp. 1 (PVP/1wt% agar)	0.016 ± 0.006	136.±29
Comp. 2 (PVP/3wt% agar)	0.022 ± 0.006	42 ± 8
Comp. 3 (PVP/PVAl/1wt% agar)	0.108 ± 0.007	490 ± 70
Comp. 4 (PVP/PVAl/3wt% agar)	0.232 ± 0.020	568 ± 83
Comp. 5 (PVP/PVAl/chitosan/1wt% agar)	0.054 ± 0.008	289 ± 55
Comp. 6 (PVP/PVAl/chitosan/3wt% agar)	0.046 ± 0.005	496 ± 19
Comp. 7 (PVP/PVAl/chitosan/PSB/1wt% agar)	0.012 ± 0.007	227 ± 22
Comp. 8 (PVP/PVAl/chitosan/PSB/3wt% agar)	0.027 ± 0.007	339 ± 24

*The values obtained are the average of 16 experiments.

Table 2. Results of the tensile strength tests.

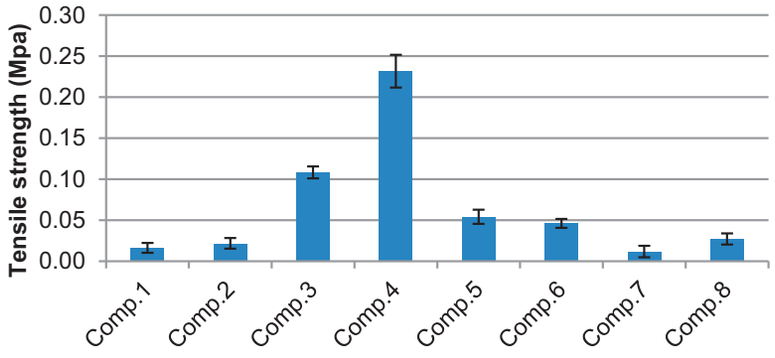


Figure 2. Results of the tensile strength.

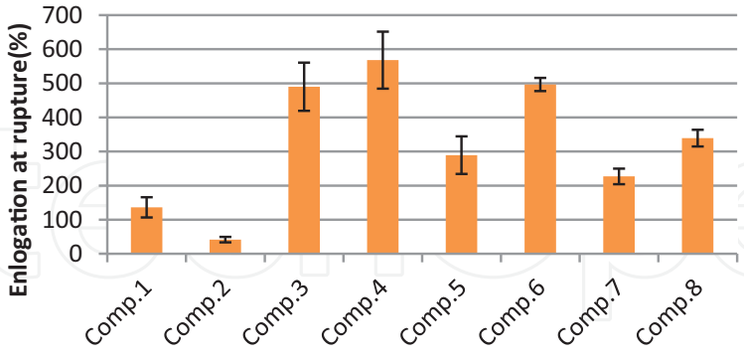


Figure 3. Results of elongation at rupture (%).

In general, hydrogels containing 3 wt% of agar in the composition, presented higher tensile strength and elongation at break, than their versions containing 1 wt% of agar (**Table 2**; **Figures 2** and **3**).

The data show that the association of chitosan with the increasing percentage of agar may have favored the elongation of the hydrogels (**Figure 3**);

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The hydrogels containing pseudoboehmite presented lower results of tensile strength and lower results for elongation at rupture (**Table 2**; **Figures 2** and **3**).

Probably, the amount of pseudoboehmite present absorbs part of the free radicals during the irradiation process by decreasing the formation of cross-links.

Sol-gel fraction: **Table 3** and the **Figure 4** present the results obtained for the sol-gel fraction.

By results obtained in **Table 3** and **Figure 4**, it is observed that the hydrogels obtained with compositions 5, 6 and 7, containing PVAl, chitosan and pseudoboehmite, presented the smallest percentage of gel fraction. The presence of PVAl, chitosan and pseudoboehmite, probably, absorb part of the free radicals during the irradiation process, decreasing the formation of cross-links.

The hydrogels obtained with compositions 1 and 3 presented the highest percentages of gel fraction, although the conventional composition containing PVP/agar had a higher percentage of gel fraction than those containing PVP/agar/PVAl (**Figure 4**).

Hydrogels	Sol fraction (%)	Gel fraction (%)
Comp. 1 (PVP /1wt% agar)	15.37	84.63
Comp. 2 (PVP/3wt% agar)	43.27	56.73
Comp. 3 (PVP/PVAl/1wt% agar)	30.99	69.01
Comp. 4 (PVP/PVAl/3wt% agar)	44.38	55.52
Comp. 5 (PVP/PVAl/chitosan/1wt% agar)	54.05	45.95
Comp. 6 (PVP/PVAl/chitosan/3wt% agar)	61.85	38.15
Comp. 7 (PVP/PVAl/chitosan/PSB/1wt% agar)	57.53	42.47
Comp. 8 (PVP/PVAl/chitosan/PSB/3wt% agar)	44.63	55.37

*The values obtained are the average of 16 experiments.

Table 3. Results obtained for sol-gel fraction.

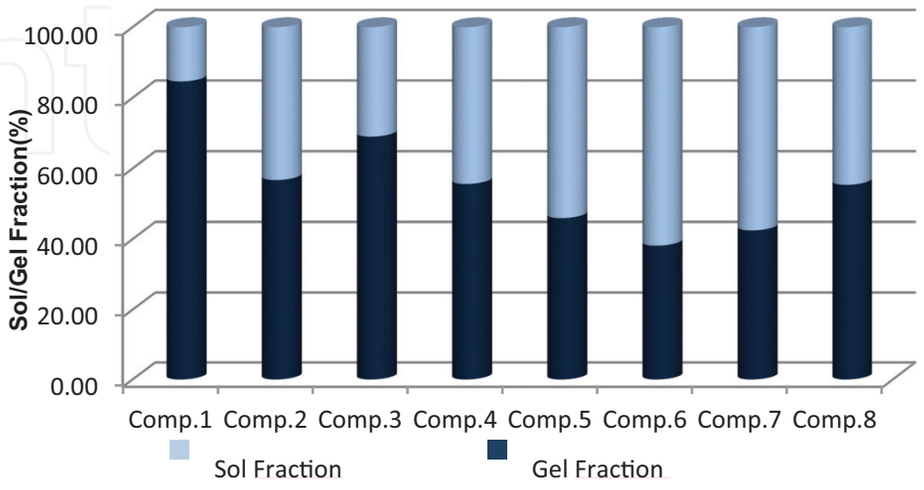


Figure 4. Results obtained for sol-gel fraction.

Comparing the hydrogels containing PVP/agar/PVAl with the hydrogels containing PVP/agar/PVAl/chitosan and PVP/agar/PVAl/chitosan/PSB, it is observed that the first have higher gel fraction indicating that the PVAl, probably absorbs a smaller part of the free radicals during the irradiation process than the chitosan and the pseudoboehmite (**Figure 4**).

The hydrogels obtained with compositions 2, 4 and 8 presented intermediate percentages of gel fraction. When comparing the agar concentration in the samples, it is observed that the increase in the agar concentration increases the gel fraction. Probably, the agar promotes the increase of the cross-link formation (**Figure 4**).

Comparing the results obtained for the gel fraction of the hydrogels containing chitosan and pseudoboehmite with those containing only one of these components, the values obtained were intermediates, indicating that these compounds acted independently of one another (**Figure 4**).

The Comp. 6 presents higher gel fraction. This sample does not contain pseudoboehmite in the composition (**Figure 4**).

Swelling: Swelling tests were performed for 7 and 30 days after irradiation of the hydrogels. **Figures 5** and **6** show the results obtained for the swelling tests.

The results show that hydrogels presented higher percentages of swelling after 30 days of irradiation (**Figures 5** and **6**).

The hydrogels based on only PVP and agar (Comp. 1 and Comp. 2) had a low swelling percentage after 7 days of irradiation (**Figure 5**), and after 30 days of irradiation had a significant increase in swelling percentage (**Figure 6**). Probably, some macroradicals are recombined during this stage.

For the PVP/PVAl/1 wt% Agar (Comp. 3) hydrogels, the swelling percentage was low after 7 days of irradiation and remained low after 30 days of irradiation (**Figures 5** and **6**). While for

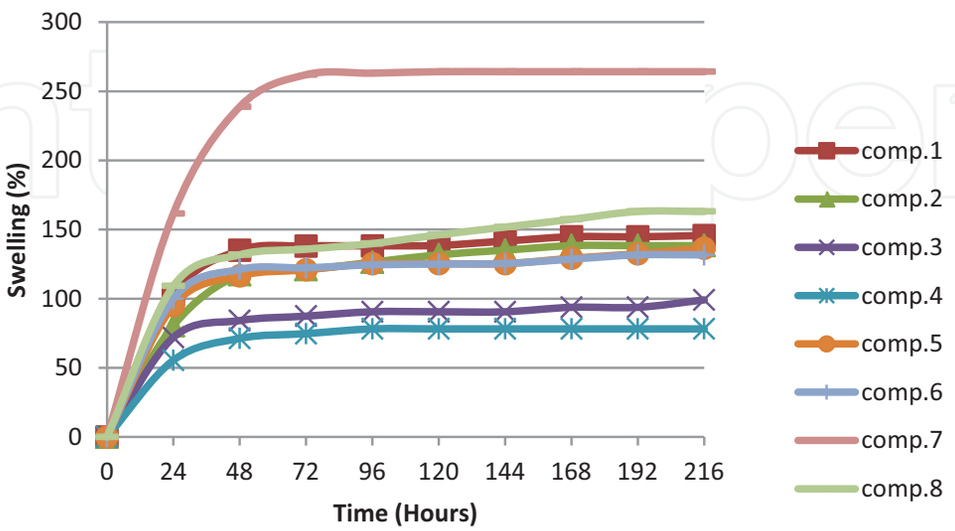


Figure 5. Results obtained for swelling tests of the hydrogels obtained after 7 days of the irradiation.

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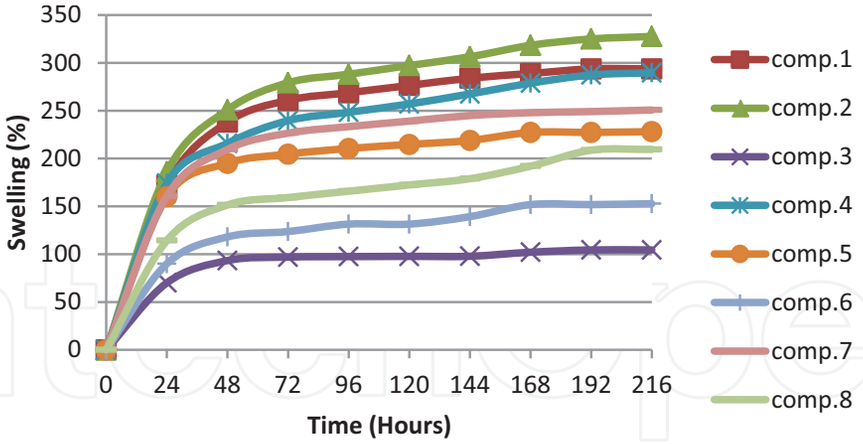


Figure 6. Results obtained for swelling tests of the hydrogels obtained after 30 days of the irradiation.

the hydrogels of similar composition only with variation in composition of 3 wt% agar, the increase in swelling percentage was significant. Probably, this difference is due to the presence of agar in a higher concentration that causes a greater absorption of water in the hydrogel structure because probably the agar promotes the increase of the cross-link formation.

The hydrogels containing PVP and PVAl, chitosan, Comp. 5 and Comp. 6 had low percentages of swelling after 7 days of irradiation (**Figure 5**), and the increase was not representative for the tests after 30 days of irradiation (**Figure 6**). Probably, the chitosan avoid the posterior cross-link.

The hydrogels containing PVP/PVAl/chitosan/PSB/1 wt% agar, Comp. 7, presented the highest percentage of swelling after 7 days of irradiation (**Figure 5**), but the increase was not significant after 30 days of irradiation (**Figure 6**). The hydrogels containing PVP/PVAl/chitosan/PBS/3 wt % agar, Comp. 8, presented low water absorption after 7 days of irradiation and significant increase after 30 days of being irradiated (**Figures 5** and **6**).

DTA and TG: The DTA and TG results for the obtained hydrogels are shown in **Figures 7–11**.

The results show that for the Comp. 1 hydrogels, containing PVP as the matrix, it can be observed that the PVP melts at a lower temperature, decreases the Tm and its degradation. For this composition, the Tg did not show considerable variation in relation to the pure PVP, and also its degradation temperature (**Figure 7**).

For the Comp. 2 hydrogels, where the matrix is also PVP, containing a higher percentage of agar, there was a decrease in Tg. PVP molecules have probably gained greater mobility at a lower temperature. However, T_m occurred at a higher temperature, indicating that degradation in the PVP molecules present in the hydrogel probably occurred. An increase occurred in temperature of degradation was observed (**Figure 7**).

For the Comp. 3 hydrogels, where the PVAl is found in greater proportion, the molecules gained greater mobility at lower temperature, that is, it decreased the Tg and the fusion occurred at lower temperature, and also, it decreased the Tm (**Figure 8**). The same occurred for the Comp. 4 hydrogels with PVP and PVAl matrix and 3 wt% agar (**Figure 8**), that compared with the other samples, the molecules gained greater mobility at lower temperature,

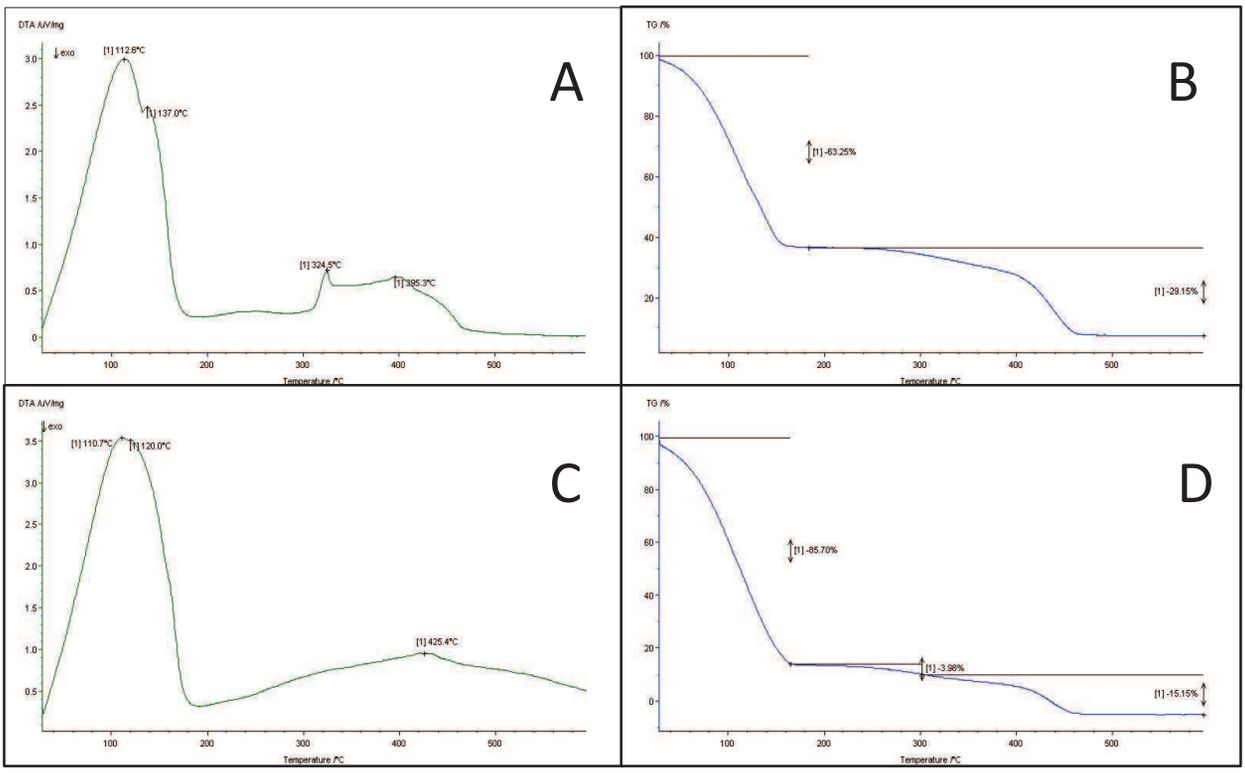


Figure 7. (A) DTA of pure PVP with 1 wt% of agar, (B) TG of pure PVP with 1 wt% of agar, (C) DTA of pure PVP with 3 wt% of agar; (D) TG of pure PVP with 3 wt% of agar.

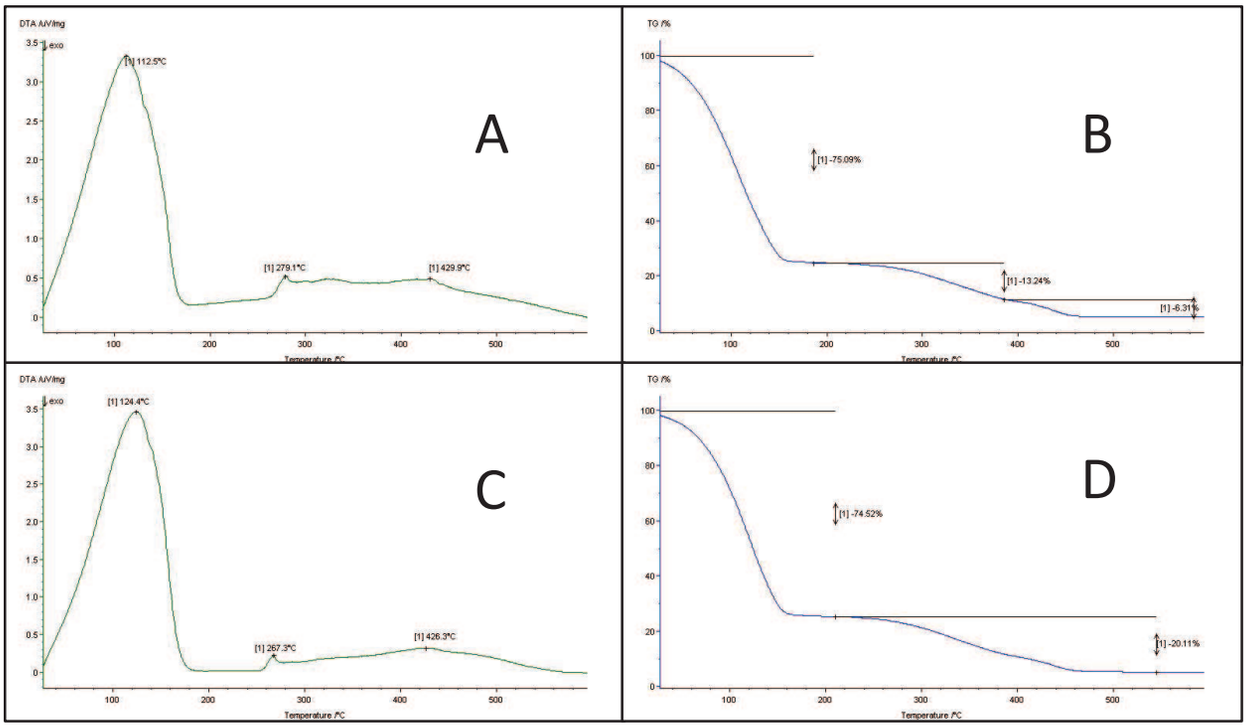


Figure 8. (A) DTA of the PVP/PVAl with 1 wt% of agar, (B) TG of the PVP/PVAl with 1 wt% of agar, (C) DTA of the PVP/PVAl with 3 wt% of agar and (D) TG of the PVP/PVAl with 3 wt% of agar.

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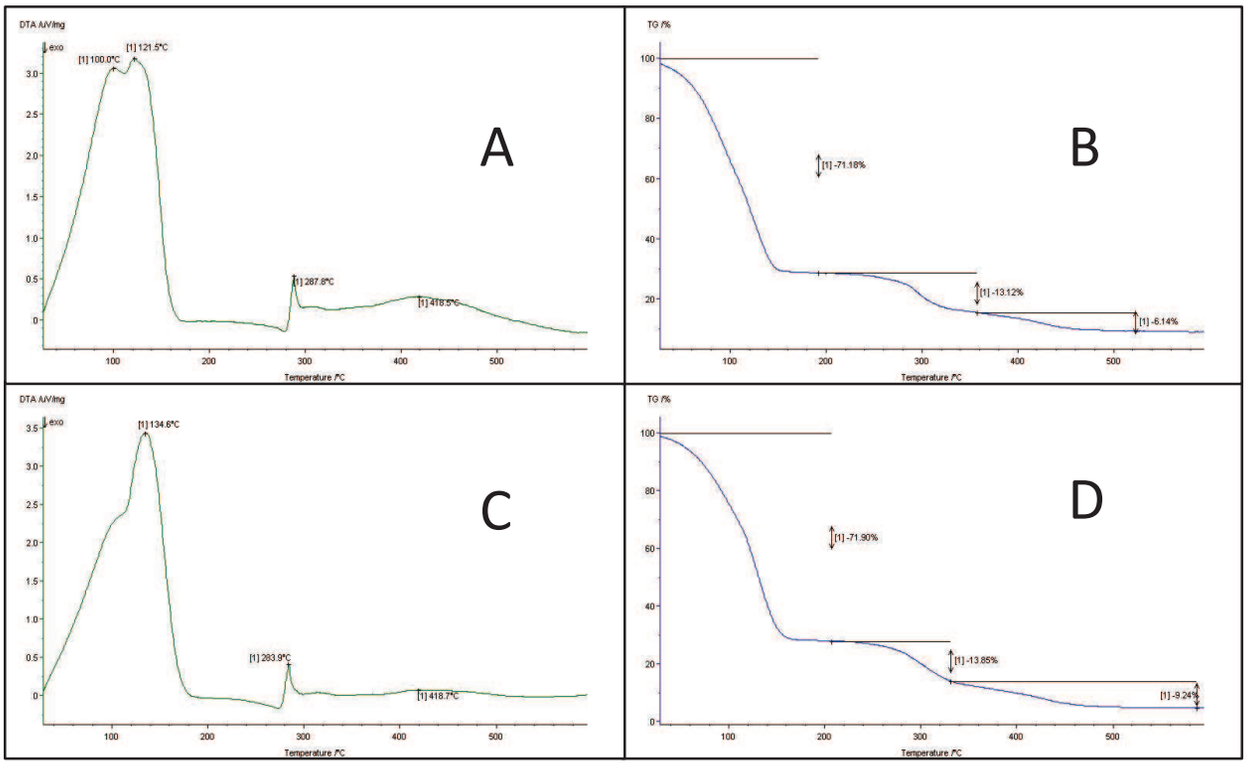


Figure 9. (A) DTA of the PVP/PVAl/chitosan with 1 wt% of agar, (B) TG of the PVP/PVAl/chitosan with 1 wt% of agar, (C) DTA of the PVP/PVAl/chitosan with 3 wt% of agar and (D) TG of the PVP/PVAl/chitosan with 3 wt% of agar.

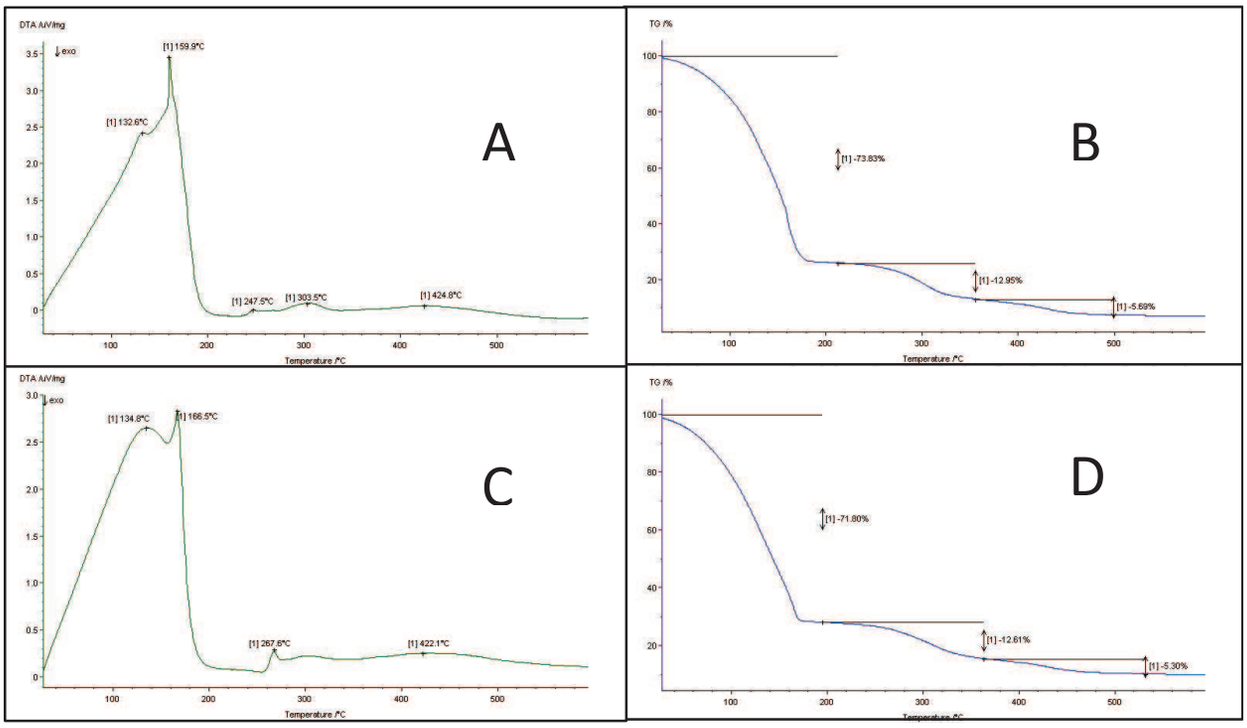


Figure 10. (A) DTA of the PVP/PVAl/chitosan/PSB with 1 wt% of agar; (B) TG of the PVP/PVAl/chitosan/PSB with 1 wt% of agar; (C) DTA of the PVP/PVAl/chitosan/PSB with 3 wt% of agar; and (D) TG of the PVP/PVAl/chitosan/PSB with 3 wt% of agar.

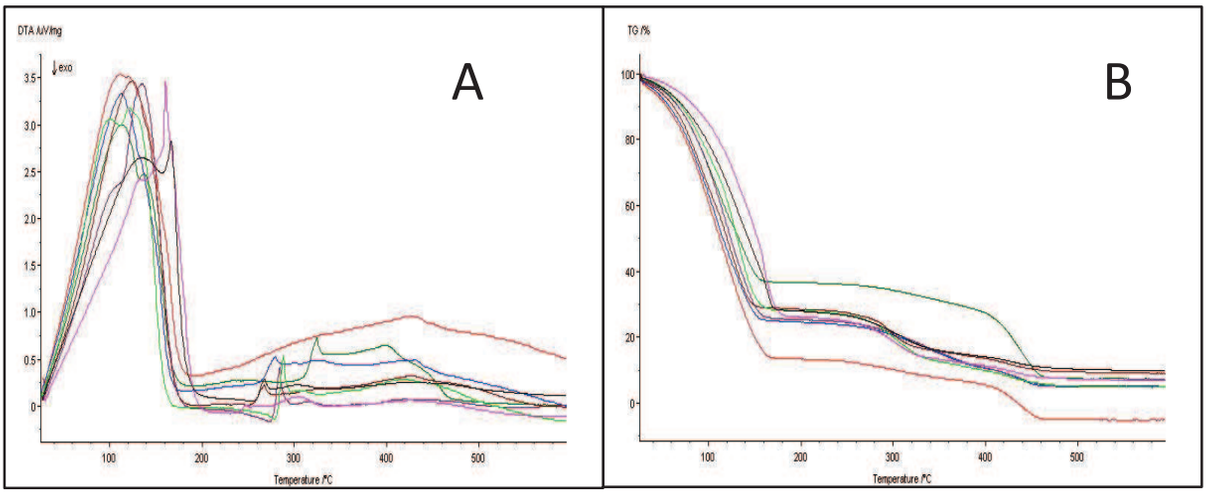


Figure 11. (A) DTAs and (B) TGs of the all compositions.

decreasing Tg and Tm at a lower temperature. It was observed that the decomposition occurred at a higher temperature for samples Comp. 3 and Comp. 4.

For membranes with composition 5 containing PVP/PVAl/chitosan/1 wt% agar, it was concluded that the water was not strongly retained and the molecules gained mobility at a lower temperature, decreasing Tg and Tm (**Figure 9**). However, the degradation was delayed, that is, it occurred at higher temperature than pure PVP (**Figure 7(A)** and **(B)**).

For Comp. 6 hydrogels with PVP/PVAl/chitosan/3 wt% agar, it can be concluded that the addition of agar did not hinder the loss of water. However, the molecules gained mobility at higher temperature (Tg higher), and the melting temperature was almost the same as temperature of sample 5. However, the degradation was delayed, occurring at a higher temperature (**Figure 9**).

DMTA: The DMTA results for the obtained hydrogels are shown in **Figures 12–15** and **Table 4**.

The results show that when comparing Comp. 1 and Comp. 2 hydrogels, the presence of a higher concentration of agar decreases the Tm value, causing an increase in the viscoelasticity of the material. This result can also be observed for the Comp. 4 hydrogels.

When comparing Comp. 1 and Comp. 3 hydrogels (**Figures 12** and **13**), the presence of PVAl causes an increase in T_m, and consequently, a decrease in the viscoelasticity of the material.

The presence of chitosan and pseudoboehmite in the hydrogels causes an increase in the T_m of the material, reducing its viscoelasticity (**Figures 14** and **15**). It is observed that the effect of chitosan is more effective in process. Probably, the chitosan structure, containing several hydroxyl groups (which may form hydrogen bonds), causes a bigger decrease in the viscoelasticity in the hydrogel of than the pseudoboehmite.

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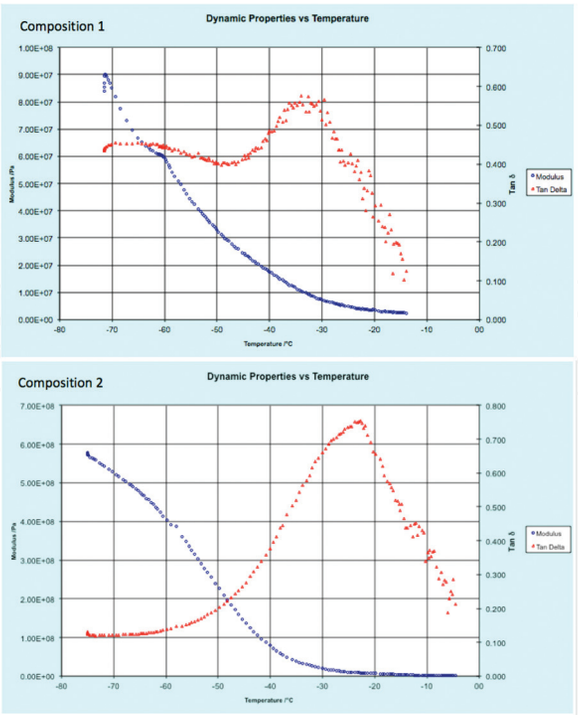


Figure 12. DMTA results of the Comp. 1 and Comp. 2.

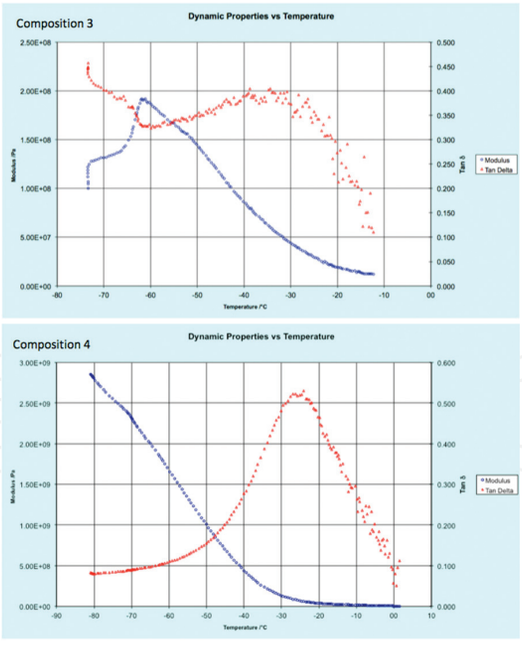


Figure 13. DMTA results of the Comp. 3 and Comp. 4.

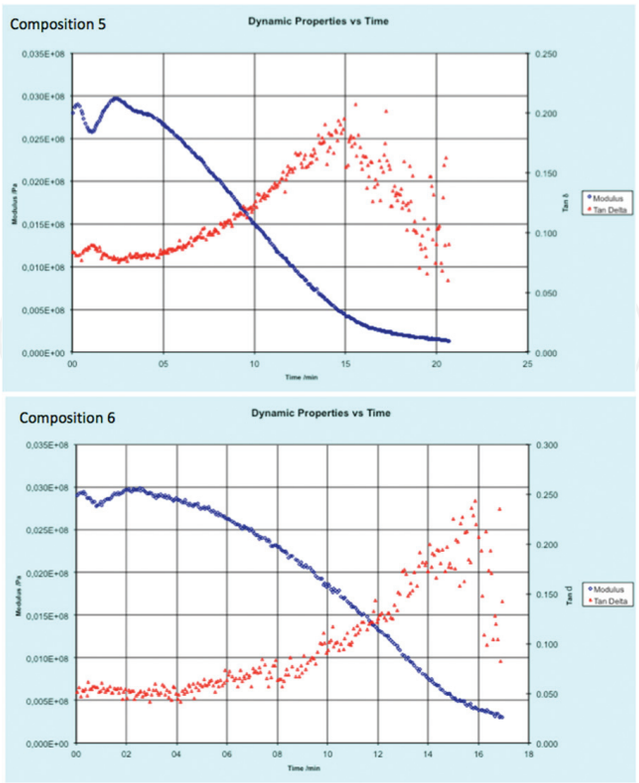


Figure 14. DMTA results of the Comp. 5 and Comp. 6.

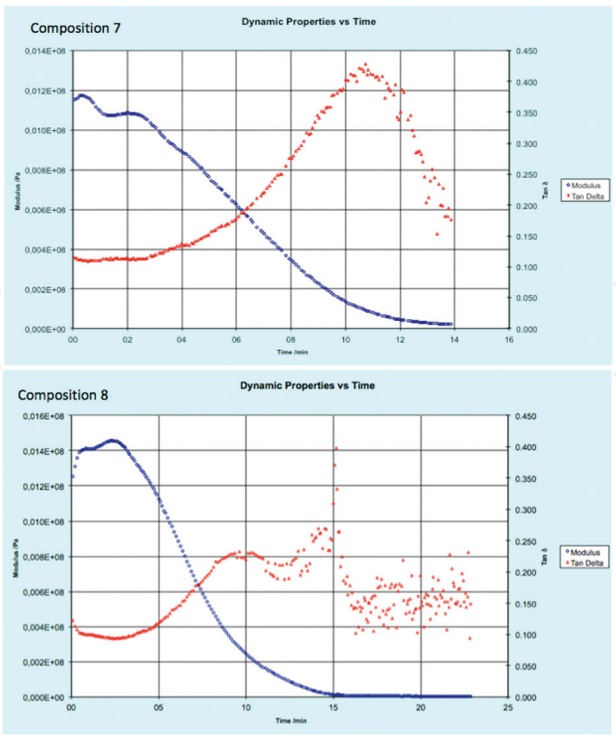


Figure 15. DMTA results of the Comp. 7 and Comp. 8.

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Hydrogel	T_m (°C)	tan δ
Comp. 1 (PVP/1 wt% agar)	−33.9	0.5752
Comp. 2 (PVP/3 wt% agar)	−22.8	0.7540
Comp. 3 (PVP/PVAl/1 wt% agar)	−38.7	0.4045
Comp. 4 (PVP/PVAl/3 wt% agar)	−24.6	0.5202
Comp. 5 (PVP/PVAl/chitosan/1 wt% agar)	1.5	0.1953
Comp. 6 (PVP/PVAl/chitosan/3 wt% agar)	6.6	0.2439
Comp. 7 (PVP/PVAl/chitosan/PSB/1 wt% agar)	−24.5	0.4280
Comp. 8 (PVP/PVAl/chitosan/PSB/3 wt% agar)	2.7	0.2699

Table 4. Results obtained from T_m and tan δ of the studied hydrogels.

4. Conclusion

According to the results, the conclusions are as follows

- It is possible to obtain hydrogels based on PVP, PVAl and chitosan containing pseudoboehmite nanoparticles in the studied concentrations;
- The presence of chitosan makes the hydrogels less transparent and makes the hydrogels more adherent;
- The association of chitosan with increasing percentage of agar promotes the higher elongation at rupture of hydrogels;
- The hydrogels containing pseudoboehmite presented lower results of tensile strength and lower results for elongation at rupture. Probably, the pseudoboehmite absorbs part of the free radicals during the irradiation process by decreasing the formation of cross-links;
- The presence of PVAl increases the tensile strength and causes higher elongation at the rupture;
- In general, membranes containing 3 wt% of agar in the composition presented higher tensile strength and higher elongation at break than their versions containing 1 wt% of agar;
- The association of chitosan with increasing percentage of agar may have favored the elongation of the membranes;
- How much bigger the concentration of agar in the hydrogel, higher is the tensile strength and the higher is the elongation at break. Probably, the agar promotes the increase of the cross-link formation.
- The hydrogels containing PVAl, chitosan and pseudoboehmite presented the smallest percentage of gel fraction. The presence of PVAl, chitosan and pseudoboehmite, probably, absorb part of the free radicals during the irradiation process, decreasing the cross-links formation;
- All hydrogels' compositions studied showed higher percentages of swelling after 30 days of irradiation;

- Hydrogels based on PVP and agar had a low percentage of swelling after 7 days of irradiation, and after 30 days of irradiation, they had a significant increase in swelling percentage;
- For the hydrogel based on PVP, PVAl and agar, the presence of agar in a higher concentration promote a higher absorption of water in the hydrogel structure;
- The hydrogels containing PVP, PVAl, agar and chitosan had low percentages of swelling after 7 days of irradiation and the increase was not representative for the assay after 30 days of irradiation;
- The hydrogels based on PVP, PVAl, chitosan and pseudoboehmite containing agar in lower concentration presented the highest percentage of swelling after 7 days of irradiation, but the increase was not significant after 30 days of irradiation. The same hydrogels, containing agar in higher concentration presented low water absorption after 7 days of irradiation and significant increase after 30 days of irradiation;
- Comparing the hydrogels based on PVP and agar, the presence of a higher concentration of agar decreases the Tm, causing an increase in the viscoelasticity of the material. This result can also be observed for the hydrogels based on PVP, PVAl and agar;
- Comparing the hydrogels based on PVP and agar with the hydrogels based on PVP, PVAl and agar, the presence of PVAl causes an increase in Tm, that is, there is a decrease in the viscoelasticity of the material;
- The presence of chitosan and pseudoboehmite in the hydrogels causes an increase in the Tm of the material, reducing your viscoelasticity. It is observed that the effect of chitosan is greater. Probably, the structure of the chitosan, containing several hydroxyl groups promotes a pronounced decrease in the viscoelasticity of the material than the pseudoboehmite; and
- As the pseudoboehmite probably absorbs free radicals, to obtain hydrogels with higher mechanical properties, the dose irradiation must be increased to increase the density of cross-links.

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