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Radiation induced synthesis of (gelatin-co-PVA)-g-poly (AAc) copolymer as wound dressing material

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Abstract. Copolymers of gelatin and poly (vinyl alcohol), (PVA) grafted by acrylic acid (AAc) with excellent water absorption and retention abilities under neutral conditions were successfully synthesized using ^{60}Co gamma radiations in presence of ammonium persulphate (APS), as water soluble initiator and sodium bicarbonate ($NaHCO_3$) as foaming agent. The optimum synthesis conditions pertaining to maximum swelling percentage were evaluated as a function of gelatin/PVA ratio, amount of water, concentration of APS, $NaHCO_3$, monomer concentration and total irradiation dose. Maximum percent swelling (1694.59%) of the copolymer, gelatin-co-PVA, was obtained at optimum [APS] = 2.92×10^{-1} mol/L, [$NaHCO_3$] = 7.94×10^{-2} mol/L and 1.5 mL of water at total dose of 31.104 kGy while in case of grafted copolymer, (gelatin-co-PVA)-g-poly(AAc), maximum percent swelling (560.86%) was obtained using 8.014x10-1 mol/ L of AAc in 9 mL water with 31.104 kGy preirradiation dose. The pristine and grafted copolymers were characterized by Fourier Transform Infrared Spectroscopy (FTIR), Scanning electron Microscopy (SEM), Thermal gravimetric analysis (TGA) and X-Ray Diffraction (XRD) methods. The copolymers loaded with an antiseptic, Povidone, were used as wound dressing materials for wounded gastrocnemius muscle of mice and the results exhibit that (gelatin-co-PVA)-g-poly (AAc) copolymer is a potent wound dressing material as compared to the copolymer.

Keywords: PVA; gelatin; acrylic acid; gamma ray irradiation; APS, sodium bicarbonate

1. Introduction

Hydrogels are 3-dimensional cross-linked polymeric networks with excellent hydrophilic properties and are used in various biomedical applications. They swell to a considerable extent in aqueous medium without being dissolved at physiological temperature and pH. They can be used as reliable polymeric scaffolds to provide structural integrity to tissue constructs and as drug delivery devices and protein delivery systems to tissues and cultures. They can also serve as bonding agent or barriers between tissue and material surfaces and, thus, are worthy to be explored as biomaterials.

Poly (vinyl alcohol) (PVA), a synthetic polymer, has hydrophilic nature, good biocompatibility, and a consistency similar to that of soft tissue and has desirable physical properties such as

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rubbery nature, high degree of swelling in water and excellent water retention properties and has, therefore, gained popularity as a scaffold supporting material in tissue engineering. It surpasses the natural polymer made scaffolds as it provides better mechanical strength and flexibility to the conventional scaffolds **(**Nho *et al.* 2005**)**. Therefore, in the present study, PVA, because of its popularity in the biomedical community (Kim *et al.* 2003, Ruiz *et al.* 2002) has been used as one of the components of the hydrogel.

The second component used for the preparation of the hydrogel is a natural polymer, gelatin, a protein derived upon partial hydrolysis of collagen (Pal *et al.* 2006). It is well known for its non-toxic, non-irritant, hydrophilicity, biodegradability and excellent cyto-compatibility with many pendent functional groups making it flexible for modification and chemical cross-linking. These advantages make gelatin-based controlled release systems useful in diverse applications ranging from tissue engineering to drug delivery and gene therapy (Koob and Hernandez 2003, Young *et al.* 2005, Balakrishnan and Jayakrishnan 2005, Abed and Bohidar 2005). However, it has drawbacks like brittleness, lack of flexibility and uncontrollable degradation rates and therefore has been considered to have limited practical applications (Tan *et al.* 2009, Yung *et al.* 2007).

Nevertheless, a combination of gelatin and PVA can endow the optimal properties necessary for tissue engineering applications. Therefore, in the present study, gelatin-PVA hybrid hydrogel-type scaffolds have been prepared to overcome the limitations of gelatin based scaffolds. Gelatin-PVA copolymeric scaffolds have been prepared using wide range of chemical techniques employing low molecular weight cross-linkers. But, these cross-linked products have been found to be cytotoxic (Kwon *et al.* 2003). Radiation induced cross-linking method, on the other hand, emerges as a potential candidate. It is reproducible and the amount of radiation dose can be easily controlled (Park and Nho 2003). The final product formed is free from the left over material needed to initiate any chemical cross-linking, thereby, minimizing the prospect of cytotoxicity and enhance the biocompatibility of the prepared material to meet the requirements of the fast-growing field of tissue-engineering making it potent for various applications.

Free-radical graft copolymerization of vinyl monomers onto polymeric back-bones is one of the methods for the synthesis of biopolymer based networks, with improved inherent properties and hence allows the product copolymers to be used in novel applications (Teramoto and Nishio 2003, Bardajee *et al.* 2008). Graft copolymers of acrylic acid (AAc) have received much attention because of their increased industrial potential associated with drug delivery systems, flocculation and settling of aqueous suspension, paper treating, resins and as gelling and stabilizing agent for soils and mud (Yang *et al.* 2004).

Numerous studies have been carried out to produce gelatin-PVA copolymer for biomedical applications (Pal *et al.* 2007a). You *et al*. (2007) studied hemocompatibility with human blood and diffusion of salicylic acid for the esterified PVA-gelatin copolymer. Synthesis of cross-linked PVA-gelatin copolymer by using γ- ray irradiations was carried out by Seo *et al*. (2009) and it was observed that the copolymer exhibited desirable physical properties as 3-D constructs for diploid cell culture. In vitro and in vivo study of the biocompatibility and biodegradation of hydroxyapatite/ PVA/gelatin composite was carried out by Wang *et al*. (2008) while Pal *et al*. (2007b) fabricated radiation induced 3D gelatin-poly (vinyl alcohol) hybrid hydrogel type scaffolds to overcome the limitation of gelatin scaffold. Taleb *et al*. (2009) carried out radiation induced cross-linking and graft copolymerization of PVA and methacrylic acid (MAAc) onto gelatin to produce PVA/MAAc/gelatin copolymer since γ- rays cross-linked hydrogels can be considered biocompatible and can, therefore, be used for antibiotic drug carrier and as promising material for wound healing purposes.

In view of the above, in the present study, an attempt has been made to carry out the synthesis of gelatin-co-PVA copolymer and its modification by grafting with AAc by pre-irradiation technique. The prepared hydrogel has been characterized with FTIR, SEM, TGA, XRD and swelling studies. The water retention studies and application of hydrogels as wound dressing materials have also been carried out. Release dynamics of Povidone-iodine from the loaded pristine and grafted copolymer was carried out to evaluate drug release mechanism of the copolymer taking mice as the subject of study.

2. Experimental

2.1 Materials and method

PVA (molecular weight 14000) (E. Merck, Mumbai), gelatin (S.D. Fine Chemicals, Boisar), sodium bicarbonate (Loba Chemie, Mumbai), a foaming agent and ammonium persulphate (APS) (S.D. Fine Chemicals, Mumbai), a free radical initiator, and acrylic acid (AAc), the monomer (E.Merck, Mumbai) were used as received. Distilled water was used throughout the study as reaction and as swelling medium.

All experimental procedures were conducted after the approval of institutional ethics animal committee (IAEC/BIO/12-2009), Himachal Pradesh University.

2.2 Synthesis of gelatin-co-PVA copolymer

The synthesis of gelatin-co-PVA copolymer has been discussed in our previous paper (Kaur *et al.* 2014). Gelatin (0.250 g) was added to PVA (0.250 g) dissolved in distilled water (1.5 mL) at 90°C and the mixture was mixed to prepare a thick dispersion by vigorous shaking for about 15 min. To it was added the initiator, APS (2.92×10^{-1} mol/L) and the resulting dispersion was stirred for 3-4 min at 100°C and while stirring, $NaHCO_3$ ($7.94\text{x}10^{-2}$ mol/L) was also added. The thick dispersion so obtained was irradiated from γ-rays for 24 h at a constant dose rate of 1.296 kGy/ h. The product obtained was washed with water and dried in oven at 50°C till constant weight was achieved.

2.3 Graft copolymerization

The pre-irradiated sample was transferred to a standard joint two necked flask, fitted with a water condenser and a thermometer. To it was added, known amount of monomer (AAc). The reaction mixture was placed in a rota-mantle and refluxed for a definite time period, maintained at a constant temperature. After the reaction was over, the grafted copolymer was washed several times with distilled water so as to eliminate the residual monomer and homopolymer, if present. The graft copolymer, (gelatin-co-PVA)-g-poly (AAc), free from homopolymer, was dried till constant weight was obtained. The percentage of grafting was calculated from the increase in weight of the cross-linked copolymer after grafting as follows:

$$\text{Grafting (\%)} = \left(\frac{W_g - W_o}{W_o} \text{ x } 100 \right)$$

where W_o and W_g are, respectively, the weights of pristine cross-linked and grafted cross-linked copolymers after the complete removal of the homopolymer.

2.4 Swelling studies

Swelling studies of the polymeric networks were carried out in distilled water. Accurately weighed samples of (gelatin-co-PVA) and (gelatin-co-PVA)-g-poly (AAc) copolymer were immersed in 20 mL distilled water and kept undisturbed at room temperature (~25°C) for 24h. The samples were then removed from water and dried between the folds of filter paper to remove the liquid adhering to the surface and weighed quickly. Swelling percentage was measured after every half an hour till it became constant. Percentage of swelling was calculated as follows:

$$\text{Swelling (\%)} = \left(\frac{W_s - W_d}{W_d} \text{ x } 100 \right)$$

where W_s and W_d are the weights of the swollen and initial dried samples respectively.

2.5 Characterization

Gelatin-co-PVA and (gelatin-co-PVA)-g- poly (AAc) copolymers were characterized by FTIR, SEM, TGA and XRD techniques. FTIR spectra of the pristine and grafted copolymer were obtained by 5700 Thermas IR spectrophotometer. Surface topology and homogeneity of ungrafted and grafted (gelatin-co-PVA) copolymer was studied by Scanning Electron Microscopy of model LEO 1430 VP. TGA was carried onto Schimadzu DTA-60H Thermal Analyzer in air at a heating rate of 10°C/min. X-ray diffraction pattern of the sample was recorded using Philips PAN ANALYTICAL X'PERT PRO X-Ray Powder Diffractometer.

2.6 Water retention studies

As a part of characterization study, the water retaining capacity of the hydrogels was investigated as a function of time at 20°C. Weighed swollen samples with maximum swelling percentage were placed in petri plates at kept at room temperature. The decrease in the weight due to loss of water was measured gravimetrically as a function of time. The percentage of water retention (%WR) has been obtained by the following equation:

$$\text{Water retention (WR) (\%)} = \left(\frac{W_s - W_t}{W_s} \text{ x } 100 \right)$$

where W_s and W_t represent initial weight of the swollen sample and the weight of the sample after time, t.

2.7 Drug loading onto the polymer matrix

The loading of the antiseptic drug, Povidone-iodine, (0.5% aq. solution of I_2 in vinyl pyrrollidone) onto cross-linked and grafted cross-linked copolymer was carried out by swelling equilibrium method. The copolymer was placed in the drug solution of known concentration for 24h at 37°C and was allowed to attain the swelling equilibrium. The drug release device was, thus obtained by drying the loaded copolymer samples.

2.8 Hydrogel as wound dressing material

The pristine and graft copolymers loaded with Povidone antiseptic were used as materials for the release of the drug to the wounded area of gastrocnemius muscle of the mice and also investigated simultaneously the tissue regenerating/wound healing properties of the samples. For these studies, mice (Swiss albino mice; Balb C strain) weighing about 18g were taken as the model for carrying out the release of the antiseptic for wound healing/ tissue engineering process. The mice were anesthetized by diethyl ether and the gastrocnemius muscle of each was exposed by removing the skin for wound dressing. Povidone loaded gelatin-co-PVA and (gelatin-co-PVA)-g-poly (AAc) copolymers were placed on the wounds supported with dressing. The healing process was regularly monitored a function of number of days with a gap of two days each.

Mice were divided into following groups (each group containing 4 mice):

- The first group of mice were kept as control. To these, wounds were indicted and left open to heal naturally.
- In the second group, the inflicted wound was covered with the pristine copolymer loaded with povidone-iodine, supported with dressing.
- The mice of third group were inflicted with wound and Povidone-iodine loaded on (gelatin-co-PVA)-g-poly (AAc) was applied, supported with dressing.

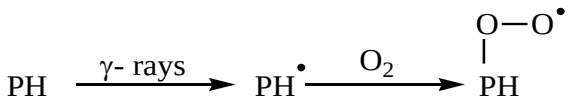
3. Results and discussion

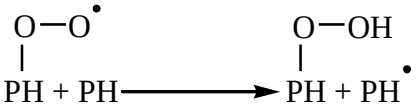
3.1 Synthesis of a porous (gelatin-co-PVA) copolymer

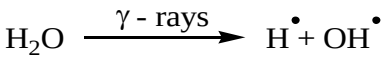
The porous cross-linked gelatin-co-PVA copolymer was synthesized through radiation induced mutual method. To an aqueous mixture of PVA and gelatin, APS and sodium bicarbonate was added, this helped in generating the foam by releasing CO_2. The reaction mixture was irradiated for stipulated period of time during which cross-linking of the two polymers takes place giving a porous product, gelatin-co-PVA.

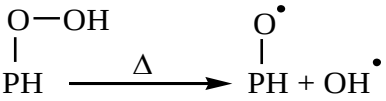
3.2 Mechanism of graft copolymerization of acrylic acid onto gelatin-co-PVA

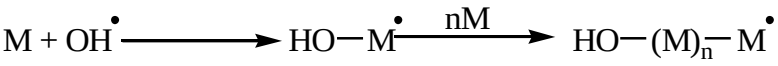
Irradiation of gelatin-co-PVA in the presence of water generates hydroperoxide groups on the copolymer. These groups decompose on heating and generate macro oxy free radicals, which in the presence of monomer lead to the formation of the graft copolymer.

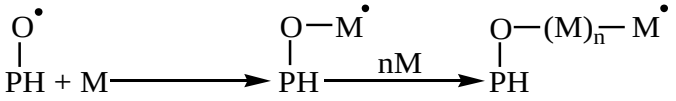


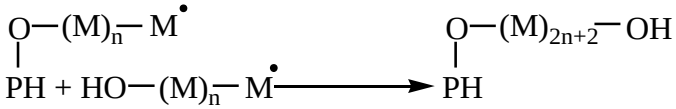












where PH represents the copolymer and M , the monomer, acrylic acid.

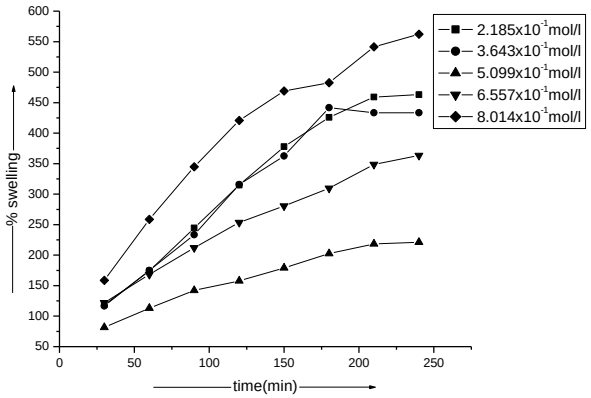


Fig. 1 Percentage of swelling of (gelatin-co-PVA)-g-poly(AAc) as a function of time: Effect of [AAc]

3.3 Optimizing the parameter affecting the swelling capacity

The synthesis of the copolymer, gelatin-co-PVA, was studied as a function of various reaction parameters such as gelatin/PVA ratio, amount of water, concentration of APS, $NaHCO_3$ and total dose and optimization of these variables was based on the ultimate swelling capacity of the copolymer. The details of the results have been discussed in our previous paper (Kaur *et al.* 2014). Taking the optimum conditions for the formation of the copolymer, grafting of AAc onto the copolymer was studied as a function of monomer concentration and the optimization of the monomer concentration was also based on the swelling capacity of the graft copolymer.

3.3.1 Effect of monomer concentration:

The effect of concentration of AAc on grafting onto gelatin-co-PVA and hence on water absorbency of the graft copolymer was investigated and the results are presented in Fig. 1. The figure reveals that the swelling capacity of the copolymer continuously increased with time of swelling and increasing monomer concentration, reached maximum and became constant. Maximum swelling percentage (560.86%) after 240 min was attained for the sample prepared at [AAc] = 8.014 x 10^{-1} mol/ L. With increasing time and [AAc], the diffusion of the monomer into the bulk of the copolymer also increased leading to increased grafting. The grafted poly (AAc) chains carrying pendant carboxylic acid groups interacted with water to give higher swelling capacity of the graft copolymer.

3.4 Characterization

3.4.1 FTIR spectroscopy

IR spectra of (gelatin-co-PVA) and (gelatin-co-PVA)-g-poly (AAc) are presented in Fig.2.(a) & (b) respectively.

The major peaks due to asymmetric –C-H stretching (2854.61cm^{-1}), associated hydroxyl groups

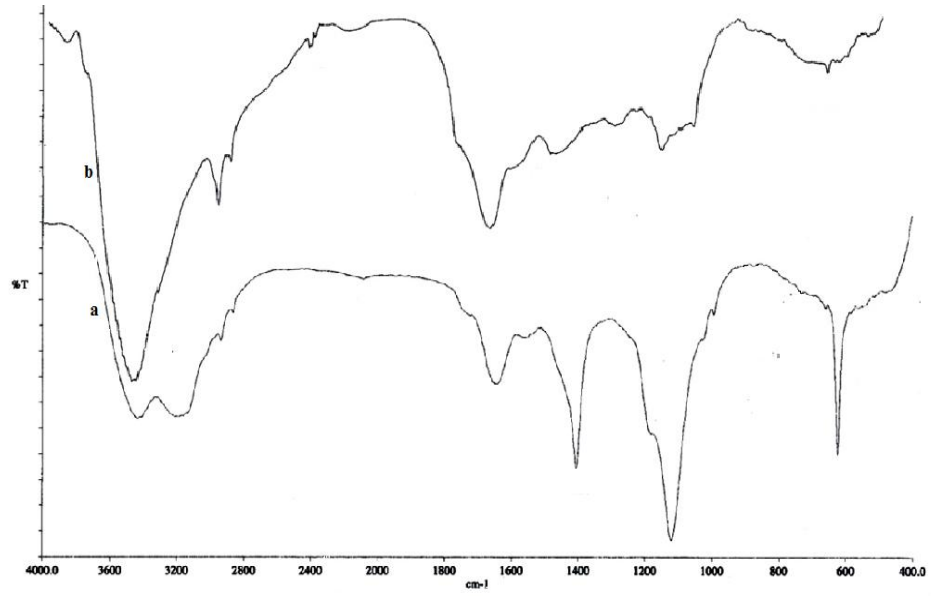


Fig. 2 FTIR of (a) gelatin-co-PVA and (b) (gelatin-co-PVA)-g-poly (AAc)

of PVA (3422.25cm^{-1}) and amide groups of gelatin (3199.02cm^{-1}) are observed in the copolymer as in Fig 2(a). In case of the grafted sample, Fig.2(b), the intensity of some of these peaks decreased and additional peaks at 1727 cm^{-1} due to $\nu_{(C=O)}$ stretching, 1597 cm^{-1} due to $\nu_{(C=O)}$ asymmetric stretching of grafted poly (AAc) and at 1252.3 cm^{-1} due to $\nu_{(C-O)}$ stretching coupled with $\nu_{(O-H)}$ in plane bending are observed. The presence of additional peaks due to grafted polymeric chains confirms the formation of graft copolymer.

3.4.2 Thermo gravimetric analysis

The respective primary thermograms of gelatin-co-PVA and (gelatin-co-PVA)-g-poly (AAc) are presented in Fig.3(a & b) respectively. Temperatures depicting initial decomposition (IDT), final decomposition (FDT) and decomposition (DT) at each 10% weight loss are presented in Table 1.

It is observed from the thermogram that gelatin-co-PVA shows three stages of decomposition. After losing about 3% weight due to water desorption at 122.1^{o}C, initial decomposition begins at 256^{o}C with 11.7% of weight loss and continues up to 395.9^{o}C losing 40.5% weight. Thereafter, starts the second stage of decomposition that continues up to 503.7^{o}C with further losing 21.3% weight. The third stage lies between 503.7^{o}C and 560.1^{o}C during which 20.6% weight is lost leaving about 4% of residue. The difference between the decomposition temperatures at every 10% weight loss is high, indicating slow rate of decomposition.

The DTG curve of the cross-linked copolymer shows that the decomposition rate varies with rise in temperature. The rate of decomposition increases from 0.096 mg/min at 190.7^{o}C to 0.533 mg/min at 307.3^{o}C, thereafter it decreases to 0.437 mg/min at 421.6^{o}C and again rises to 0.675 mg/min at 534.3^{o}C. The DTA curve, which provides the information in the chemical reactions, phase transformations and structural changes that occur during heat up or cool down cycles, does not reveal much information except for major decomposition occurring at 532.1^{o}C.

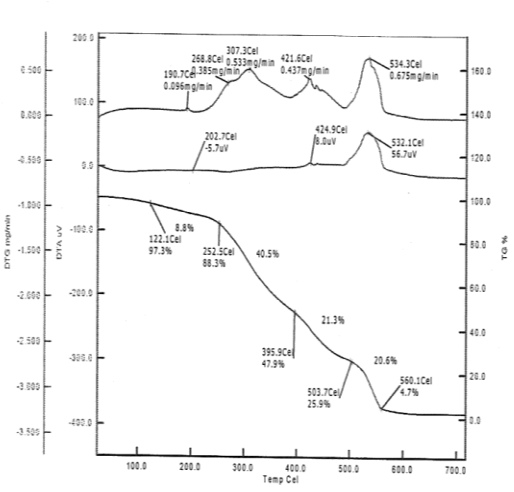


Fig. 3(a) Thermogram of gelatin-co-PVA copolymer

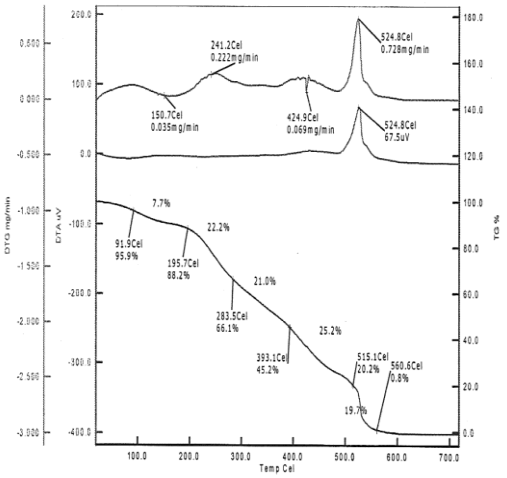
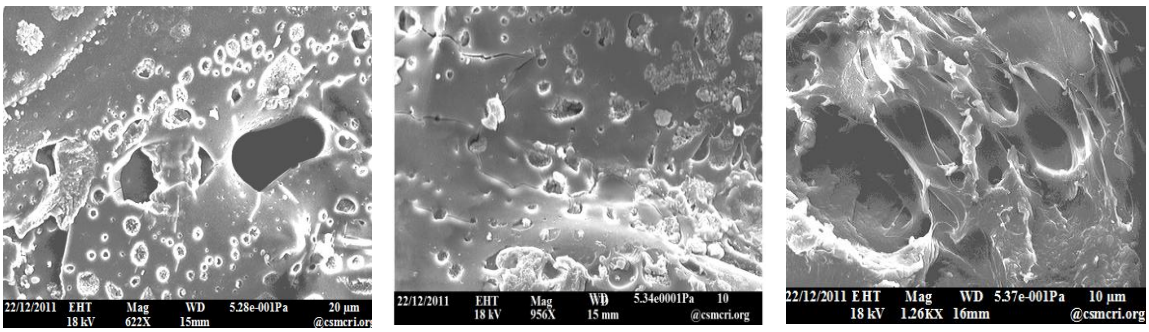
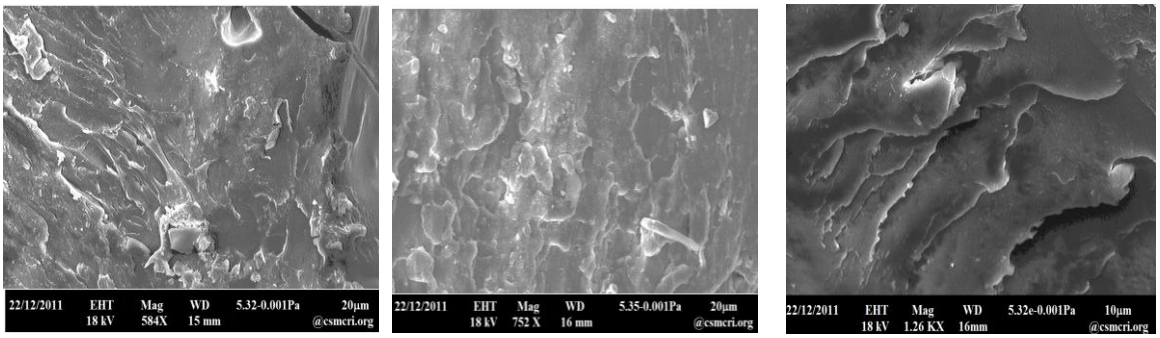


Fig. 3(b) Thermogram of (gelatin-co-PVA)-g-poly (AAc) copolymer



622 X 956 X 1.26 K X

Fig.4 (a) SEM of gelatin-co-PVA copolymer at different magnifications



584 X 752 X 1.26 K X

Fig.4 (b) SEM of (gelatin-co-PVA)-g-poly (AAc) copolymer at different magnifications

Table 1 Thermogravimetric data of gelatin-co-PVA and (gelatin-co-PVA)-g-poly (AAc)

Sample	IDT (^{0}C)	FDT (^{0}C)	DT(^{0}C) at every 10% weight loss									Residue (%)
			10	20	30	40	50	60	70	80	90	
Gelatin-co-PVA	256.0	560.1	241.62	282.36	309.73	340.01	384.53	426.51	468.56	529.42	547.99	4.00
(Gelatin-co-PVA)-g-poly(AAc)	212.0	532	168.39	235.31	267.46	313.71	369.94	412.92	454.29	515.86	529.31	0.00

On perusal of the thermal data of acrylic acid grafted gelatin-co-PVA, it is observed that the initial decomposition starts at a lower temperature (212^{o}C) with 22.2% weight loss in comparison to the cross-linked copolymer (256^{o}C with 11.7% weight loss). This is due to the reason that the grafted polymeric chains with pendent carboxylic groups starts decomposition at a lower temperature and the adjacent carboxylic groups interact intra-molecularly to lose water to form stable cyclic anhydride groups. Further decomposition of the graft copolymer continues with lower

DT values at every 10% weight loss in comparison to the pristine copolymer. However, the temperature difference between DT values of the grafted copolymer at each 10% weight loss is higher than the pristine copolymer up to 60% weight indicating slow rate of decomposition and hence thermal stability. Beyond 60% weight loss, the temperature difference between DT values at each 10% weight loss becomes parallel to that of the pristine copolymer. The final decomposition begins at 532^{o}C and continues leaving behind no residue.

The DTG curve of grafted cross-linked polymer shows a smooth decomposition with much lower rate of decomposition in comparison to the pristine copolymer. The decomposition starts with 0.035mg/min at 150.7^{o}C that increases to 0.222 mg/min at 241.2^{o}C, further decreases to 0.069 mg/min at 424.9^{o}C much lower than the pristine (0.437 mg/min). Major decomposition with higher rate (0.72 mg/min) at 524.8^{o}C is observed. The DTA curve of the graft also does not reveal much information except that the major decomposition occurring at 524.8^{o}C.

From the results, it is thus observed that AAc grafted gelatin-co-PVA copolymer has lower IDT and DT values in comparison to the pristine copolymer, however, higher temperature difference between DT values at each 10% weight loss indicates slow rate of decomposition which is also corroborated by the DTG curves. Grafting of AAc onto the copolymer has, therefore improved the thermal stability to the copolymer.

3.4.3 Scanning electron microscopy

Surface topology and homogeneity of gelatin-co-PVA and (gelatin-co-PVA)-g-poly(AAc) has been studied by Scanning Electron Microscopy.

While examining the surface topology from scanning micrographs of (gelatin-co-PVA)-g-poly (AAc) (Fig.4(b)), it is observed that the grafted copolymer shows a dense structure in comparison to the ungrafted copolymer (Fig.4(a)). The images at magnification 584 X and 752 X show the formation of grafts in the cavities. The grafted chains are clearly visible being trapped into the cavities at magnification of 1.26 K X.

3.4.4 X-Ray diffraction studies

XRD pattern of (gelatin-co-PVA) and (gelatin-co-PVA)-g-poly (AAc) are presented in Fig.5 (a

& b) respectively. It is observed from Fig.5(a) that a peak appears at 20.1250^o at 2Θ covering the region between 13.5^o and 27.9^o with intensity of 429.09 counts for the copolymer. In case of the grafted sample, Fig.5(b), a small shift in the peak (19.2750^o) at 2Θ with little increase in the intensity with respect to the counts (486.61) is observed. In addition, increase in percent relative intensity (from 34.09 to 45.17%), d-spacing (from 4.4195 to 4.6073) and area (from 22.21 to 36.48) and decrease in FWHM (from 0.2460 to 0.1476) is observed in the grafted copolymer indicating a small shift from a micro crystalline towards crystalline structure. The attachment of the poly (AAc) chains as grafts helps to attain an ordered structure. Decrease in the angle on the 2Θ scale and increase in d-spacing, decrease in FWHM points towards the improving crystalline structure.

Applying Scherrer equation, the particle size calculated from the major peak was found to be 34.28 nm of the copolymer which increases to 57.2971 nm in the graft copolymer. Both the observations, namely, the increase in the size and d-spacing as well indicate that grafting has occurred and the grafted chains intrude into the structure of the copolymer thereby increasing d-spacing as well as the particle size.

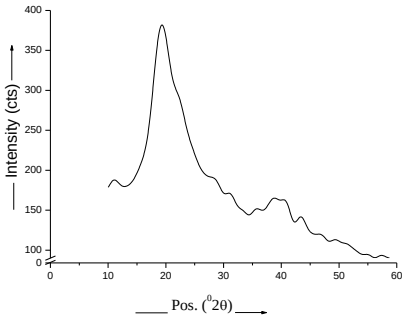


Fig.5(a) XRD pattern of the gelatin-co-PVA copolymer

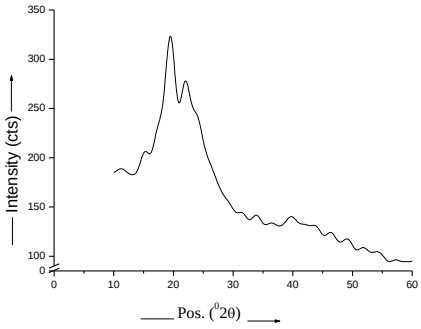


Fig.5(b) XRD pattern of the (gelatin-co-PVA)-g-poly (AAc) copolymer

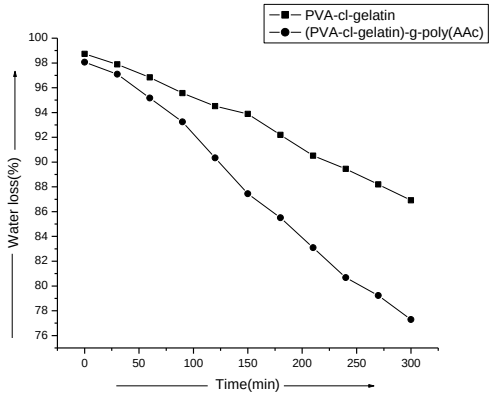


Fig.6. Water retention studies of the gelatin-co-PVA and (gelatin-co-PVA)-g-poly (AAc)

3.5 Water retention

The water retention studies performed as a function of time revealed that the percentage of water retained by the (gelatin-co-PVA)-g-poly (AAc) copolymer was much more as compared to the gelatin-co-PVA copolymer (Fig.6). In case of the ungrafted copolymer, the absence of the graft chains may provide enough space for the water molecules to get absorbed thereby leading to the larger swelling capacity but the lack of binding forces may lead to faster release of water from the polymer whereas in case of the grafted sample, water molecules once entrapped into the copolymer matrix, it binds them through interaction with the carboxylic pendent groups of the grafted poly (AAc) chains thus preventing release of water.

3.6 Copolymers as wound dressing material

Hydrogels exhibit properties that make them desirable candidates for biocompatible and blood compatible materials. One of their typical short term applications is as a temporary support device which is used in those circumstances in which the natural tissue bed has been weakened by disease, injury or surgery and requires some artificial support. The hydrogel implant gives mechanical support till the healing of the natural tissue during which the connectivity of open pore is required where the cells need to migrate and grow homogeneously over the complete scaffold. The gelatin-co-PVA and (gelatin-co-PVA)-g-poly (AAc) copolymers with adequate characteristics of a hydrogel being hemocompatible with good moisture retentive property, indicating its possible use in moist wound care have, therefore, been used as a wound dressing material.

The healing of the wound inflicted on the mice, divided in three groups, one left for open healing, second covered with povidone loaded copolymer and the third covered with povidone loaded graft copolymer was regularly monitored as a function of days and the results are presented in Fig.7(b).

It was observed from the figure that the wound that was left open underwent slow healing process. The size of the wound started decreasing slowly with the repair of the skin on the fifth day which also grew slowly leaving about an inch of the wound unhealed as observed on the 7^{th} day.

Mice applied with povidone-iodine loaded copolymer showed much faster wound healing with the gap in the wound smaller (one-fourth of the size) than that in the open wound. However, in case of the grafted copolymer, the healing process was much faster. On the fourth and the seventh

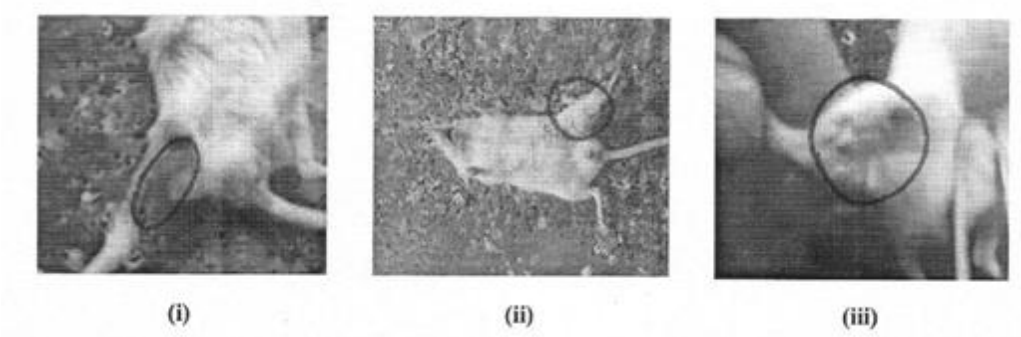


Fig. 7(a) (i) Exposed gastrocnemius muscle, (ii) Wound supported with dressing, (iii) Open wound after 7 days

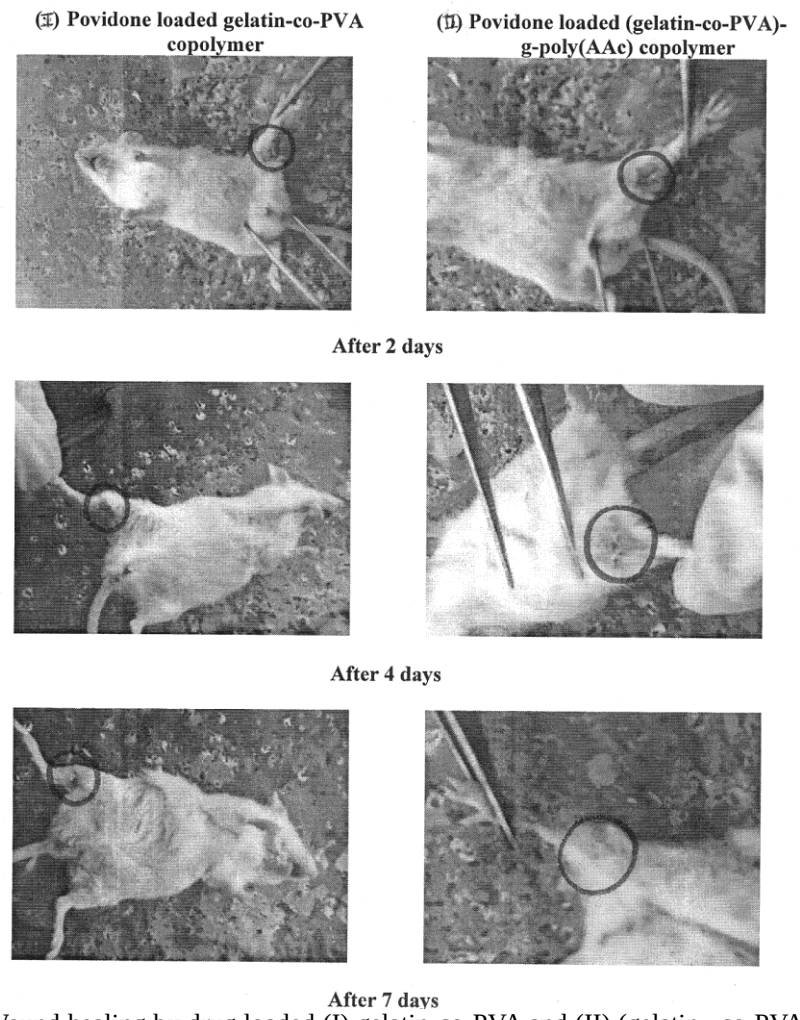


Fig. 7(b) Wound healing by drug loaded (I) gelatin-co-PVA and (II) (gelatin –co-PVA)-g-poly (AAc) copolymers after 2,4 and 7 days

day, the same observation with complete healing of the wound and formation of the skin on the wound surface i.e. no wound gap was visible. These observations indicate that AAc grafted copolymer offers a better biomaterial for wound healing process as compared to the ungrafted gelatin-co-PVA copolymer which may be due to the better water retention property of the graft that helps in early healing of the wound.

4. Conclusions

Successful synthesis of gelatin-co-PVA copolymer and the grafting of acrylic acid onto the copolymer have been carried out respectively by mutual and pre-irradiation methods. The grafted

and the pristine copolymers have been characterized using different techniques. Both the copolymers have excellent swelling properties as those of superabsorbent hydrogel with good water retention properties. The copolymers have been used as a matrix for loading povidone, an antiseptic, for use as a wound dressing material and it was observed that the grafted samples have better healing properties than the pristine copolymer. Therefore, it can be concluded that γ-ray cross-linked gelatin-PVA hydrogels can be promising material for tissue engineering applications, it can be useful in delivering drug or nutrient or growth factors directly to the wound site by putting a swab over the hydrogel without removing the hydrogel from the wound site.

Animal Ethics clearance

All experimental procedures were conducted after the approval of institutional ethics animal committee (IAEC/BIO/12-2009), Himachal Pradesh University.

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