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Enhancing physical properties of polyvinyl alcohol by crosslinking method

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Application No. 2430262

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ABSTRACT: In the presented work, the physical properties of Polyvinyl film (PVA) such as swelling, and strength are enhanced by crosslinking it by Succinic Acid (SuA). Low swelling and good strength are necessary for biomedical application and packaging. The 5% PVA without crosslinking has swelling of 650% in 1 hour and tensile strength of 37 MPa. The 5% PVA crosslinked with 2.5 millimole SuA showed strength of 63 MPa and swelling of 121% in 1 hour.

KEYWORD Biodegradable Polyvinyl Film, Succinic Acid, Swelling, Tensile strength, Crosslinking, FTIR

Introduction

Polyvinyl alcohol (PVA) is a synthetic polymer known for its excellent film-forming, emulsifying, and adhesive properties. Due to its water solubility and biocompatibility, PVA is widely used in various applications, including biomedical devices, packaging materials, and industrial processes. However, one of the challenges with PVA films is their tendency to swell in the presence of water, which can limit their practical applications.

Crosslinking PVA with suitable agents can potentially enhance its mechanical properties and reduce its swelling behaviour.

Materials and Methods

PVA, degree of polymerization (1700–1800), degree of hydrolysis (98–99%).
Succinic Acid (SuA) powder (99%).

Preparation of the film

The preparation of PVA films involved a systematic process to ensure consistent film formation and effective crosslinking. Initially, a 5% PVA solution was made by dissolving 2.5 g of PVA in 50 ml of water, with stirring at 90°C for one hour to achieve a homogeneous solution. Following this, three different concentrations of succinic acid (1.25, 2.5, and 3.75 mmol) were individually dissolved in separate batches of the 5% PVA solution, each stirred for an additional hour to ensure complete dissolution and uniform distribution of the crosslinking agent. The resulting solutions were then poured into petri dishes to form thin films and placed in an oven set at 45°C for 24 hours to allow for gradual drying and film formation. Once dried, the films were subjected to a crosslinking process by heating them at 120°C for one hour. This step was crucial to study the effects of crosslinking time on the swelling and tensile properties of the PVA films. The prepared films were then ready for further testing to assess their swelling behaviour and mechanical strength.

Swelling Study

For this study film was cut into 1 x 1 cm square and was submerged into water to measure the weight gain in the intervals of 15 min for 1 hour.

$$\text{Swelling \%} = \left(\frac{W-W_o}{W_o}\right) \times 100$$

W is the weight of the film after time t of submerging the film in water.
Wo is the weight before submerging the film.

Tensile Study

The film is to be cut into five rectangular strips, each measuring 70 mm by 10 mm. From each end of these strips, 15 mm will be designated as the grip length for the tensile machine. It is crucial to ensure that the gauge length, the section between the grips, is cut neatly and in a straight line to maintain the accuracy of the tensile test.

Results and Discussion

Swelling Study

The swelling characteristics of PVA are influenced by the availability of hydroxyl groups and the mobility of PVA chains. Hydroxyl groups on PVA chains attract water molecules, causing the PVA chains to absorb water, displace, and swell. Crosslinking reduces hydroxyl groups and restricts PVA chain mobility, thus limiting water absorption and swelling. The degree of swelling depends on the permeability of the PVA film and the extent of crosslinking.

Figure 1 shows the swelling data after 1 hour of three concentrations of SuA used. It is evident that crosslinking significantly reduces water uptake.

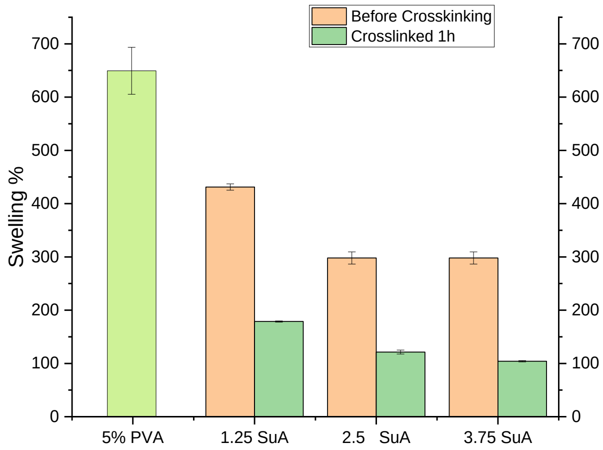

Fig.1 Comparison of swelling % for all the three-conc. of SuA after 1 hour of swelling.

Figure 2 represents the swelling profile crosslinked PVA film over the interval of 15 min for 1 hour. There is significant water uptake in the first 15 min and then it saturates with increasing time.

With increasing concentration of the acid swelling percentage reduces due to the reduced mobility of PVA chains in the effect of forming ester bonds.

Tensile Study

The strength of 5% PVA was observed around 37 MPa and after crosslinking the strength was significantly increased.

From figure 3 it is evident that among the crosslinked films strength reduces with increasing acid concentration. Therefore, there will be a trade-off between swelling and strength of the film. The optimal concentration of the acid should be considered for the biomedical application and packaging.

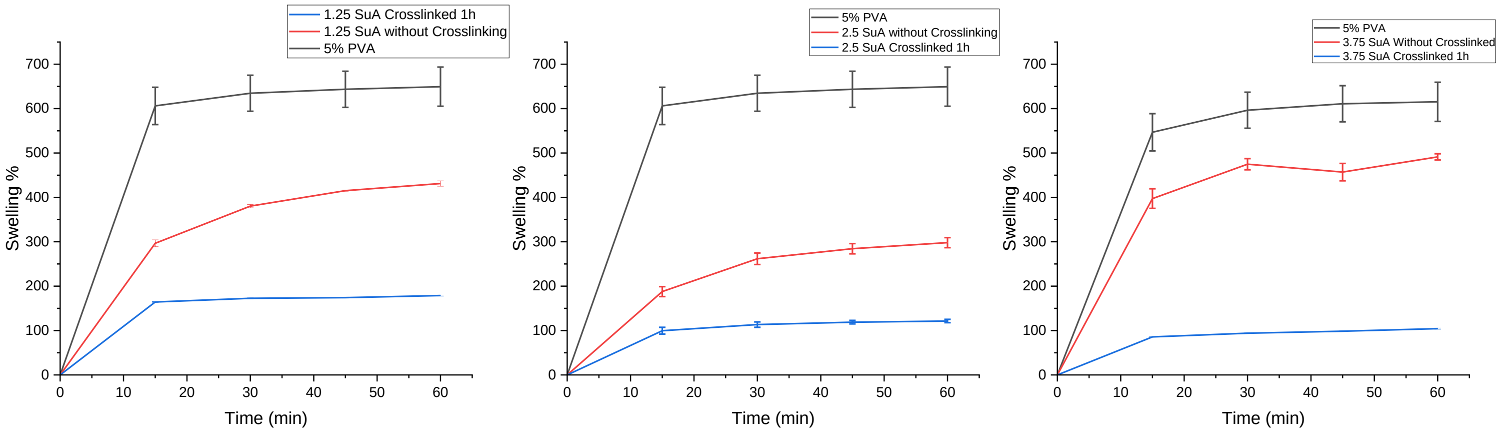

Figure 2 Swelling profile of the 1.25, 2.5, 3.75 mmol SuA crosslinker

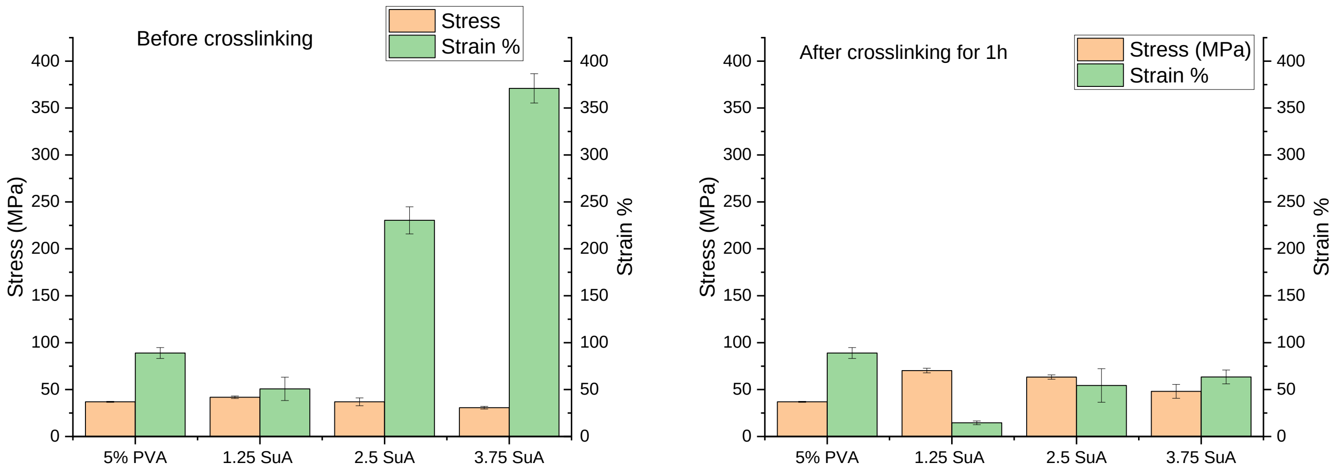

Figure 3 Stress and strain % at fracture point of the sample.

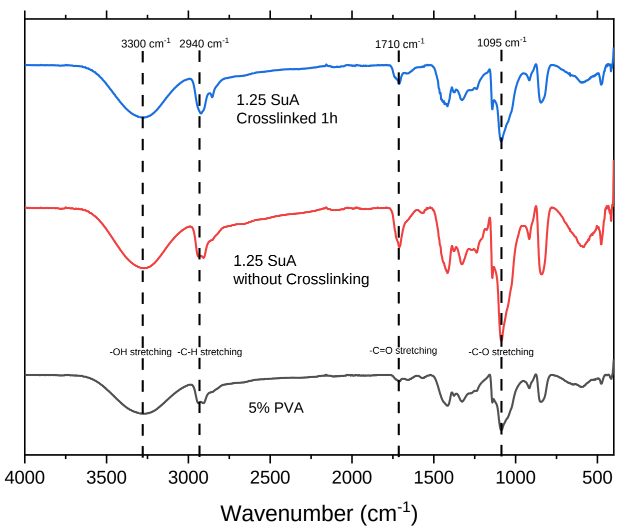

Figure 4 FTIR of 1.25 mmol SuA Crosslinker

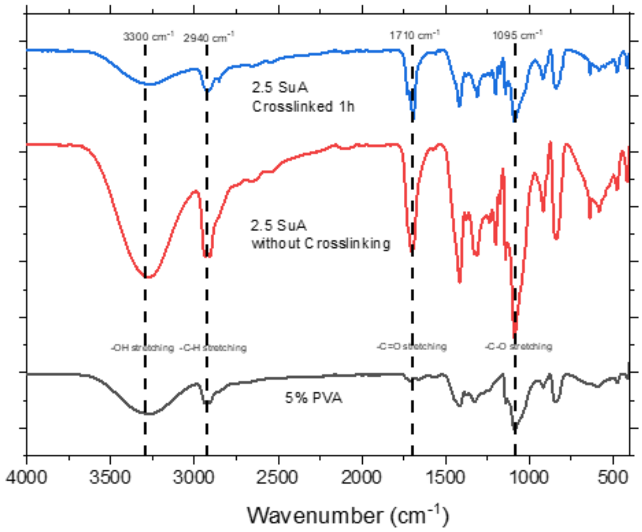

Figure 5 FTIR of 2.5 SuA Crosslinker

FTIR Analysis

Chemical Bond	Frequency
-OH	3200-3400
-CH	2940
-C=O	1710
-CO	1090

Table 1. gives the stretching frequency of the chemical bond mentioned. The FTIR data confirms the formation of the ester bond as the OH peak broadness reduces in every crosslinked film. This can be observed in the figure 4 and figure 5.

Conclusion

Comparing the performance of three films, the film with 2.5 mmol of acid crosslinker showed the best results in terms of physical properties for biomedical applications. The PVA film strength was increased by 70% and swelling was reduced by 80% after crosslinking with 2.5 mmol SuA. Reduction in strain values provide durability to the films.

Acknowledgment

This study is majorly adapted and modified from the previous paper for the purpose of imparting a tint of research experience. The paper, *"Synergistic effect of cellulose nano whiskers reinforcement and dicarboxylic acids crosslinking towards polyvinyl alcohol properties."*
Amit Kumar Sonker, Naveen Tiwari, Rajaram Krishna Nagarale, Vivek Verma.

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