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The influence of UV irradiation on the mechanical properties of chitosan/poly(vinyl pyrrolidone) blends

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Abstract

The mechanical and surface properties of chitosan, poly(vinyl pyrrolidone) (PVP) and chitosan/PVP blends before and after UV irradiation have been investigated by mechanical testing (Instron) and by contact angle measurements. Air-dried specimens were submitted to treatment with UV irradiation (wavelength 254 nm) for different time intervals. The changes in mechanical properties, such as breaking strength, percentage elongation and Young's modulus have been investigated. The results have shown that the mechanical properties of the blends were greatly affected by UV irradiation, but the level of the changes of these properties were smaller in the blend than in pure chitosan and strongly dependent on the time of irradiation and the composition of the samples. The contact angle and the surface free energy were altered by UV irradiation, which indicates photooxidation and an increase of polarity. The range of these changes points to greater sensitivity of chitosan to photooxidation in comparison with PVP and chitosan/PVP blends.

Keywords: Chitosan; Poly(vinyl pyrrolidone); Blend; UV irradiation; Mechanical properties; Surface properties

1. Introduction

Mechanical properties of new materials are very important if we wish to employ them for future tissue biomedical applications. The polysaccharide chitosan can be used as a natural biomaterial for tissue replacement, as well as other tissue engineering efforts. For designing new biomaterials, chitosan and its blends with other polymers and biopolymers can be used and new properties can be met, which are different to those of single components [1–3].

Chitosan and poly(vinyl pyrrolidone) PVP do not exist together as blends in nature, but the specific properties of each may be used to produce synthetic blends that confer unique structural and mechanical properties. The use of relatively low cost, low pollution biomaterials with specific properties has great potential, for instance in developing a new generation of prosthetic implants [4–6].

In our previous study we have shown that chitosan/PVP blends are miscible in the solid state and interact at the molecular level. New hydrogen bonding networks appear to alter the biological character of chitosan and therefore the overall physical parameters of the blend [7].

The interaction of UV light and the blends is of importance, as the behaviour of the blends under potentially harsh conditions needs to be understood, and UV light may be used to refine the blend preparation process to produce blends of specific structural and chemical characteristics.

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The aim of this study was to compare the mechanical properties of chitosan/PVP films with mechanical properties of chitosan films and to determine the influence of UV irradiation on the mechanical properties of chitosan/PVP blended films.

2. Experimental

Chitosan was obtained from Fluka, Switzerland. Polymeric blends were prepared by mixing of suitable volumes of PVP and chitosan in 0.4 M acetic acid. Solutions were produced of blends ranging from 100% chitosan to 100% PVP at 10% weight contribution intervals.

Polymer films were obtained by casting the solutions onto glass plates. After solvent evaporation, the samples were dried under air at room temperature.

The air-dried films were irradiated in air at room temperature using a mercury lamp, Philips TUV-30, emitting light mainly at 254 nm. The intensity of irradiation was 0.263 J/(cm^2/min). The intensity of the incident light was measured using an IL 1400A Irradiometer (International Light, USA). Irradiation experiments were at a distance of 5 cm from the light source.

Stress–strain curves were recorded using an INSTRON Testing Machine Model 1026. Whilst stretching the sample, it measures the amount of force (F) exerted. When we know the force being exerted on the sample, we then divide that number by the cross-sectional area (A) of our sample and calculate the stress that our sample is experiencing.

$$\frac{F}{A} = \text{stress}$$

A linear increase in force is exerted and the extension of the sample is measured until the sample fails. The extension of the sample is expressed here as a % elongation of the sample from the original length, and stress vs. elongation studied with respect to UV

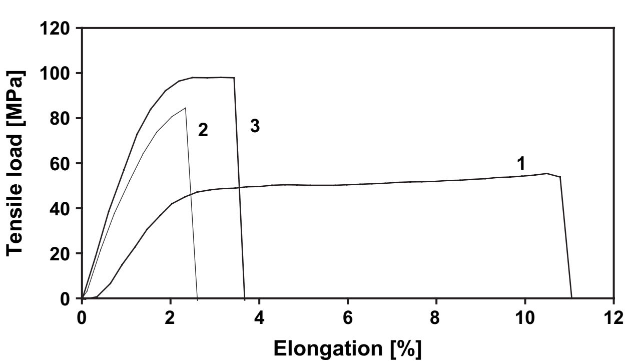

Fig. 1. Typical stress–strain curves recorded for chitosan films before (1) and after 4 (2) and 8 (3) hours of UV irradiation.

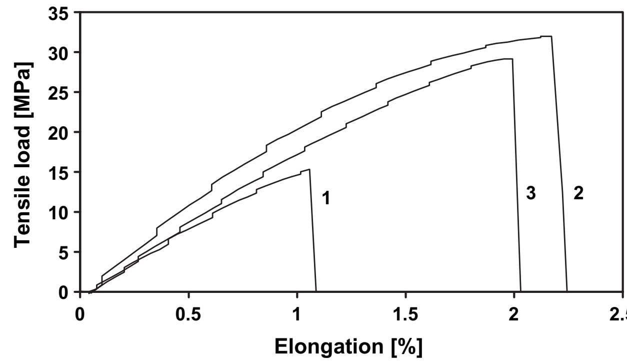

Fig. 2. Typical stress–strain curves recorded for PVP films before (1) and after 4 (2) and 8 (3) hours of UV irradiation.

irradiation, the linear region of the stress extension curve gives the Young's modulus E, giving the inherent stiffness of the material. The stress needed to break the sample is the ultimate tensile strength of the material.

Air-dried films were tested using 20 samples for each measurement. The thickness of the samples was determined using an ultrameter type A-91 (producer: Manufacture of Electronic Devices, Warsaw, Poland). The ultrameter A-91 uses electromagnetic methods to measure the thickness of nonmagnetic specimens.

Blends were tested in the dried state before and after different intervals of UV irradiation using a strain rate of 5 mm/min. Force extension curves were obtained and used to calculate stress–strain behaviour, ultimate tensile strength (UTS), and Young's modulus.

3. Results and discussion

The characteristic stress–strain curves of chitosan, PVP and chitosan/PVP films before and after UV irradiation are reported in Figs. 1, 2 and 3, respectively. It was observed that irradiated chitosan film exhibits higher value of ultimate tensile strength, UTS, than before irradiation (Fig. 1). However, ultimate percentage elongation, UPL, is higher for non-irradiated chitosan films. PVP films after irradiation exhibits

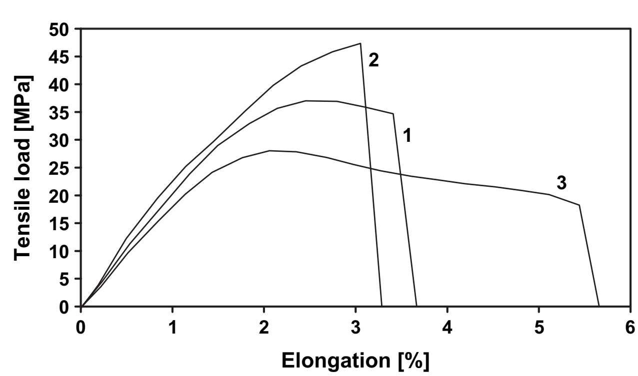

Fig. 3. Typical stress–strain curves recorded for chitosan/PVP films (50/50) before (1) and after 4 (2) and 8 (3) hours of UV irradiation.