

P-42

Formulation and Complex Morphological Characterization of Core-Shell Fibrous Mats for Chronic Wound Healing

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1. Introduction

In the recent past, one of the major challenges of the pharmaceutical industry was to overcome the poor aqueous solubility and permeability of new drug candidates, leading to their low bioavailability [1]. To solve these problems, novel structures were developed involving the polymer-based nanofibrous drug delivery systems [2,3]. The unique properties of the nanofibers as the high porosity with interconnected pore network and the increased surface area of the fibrous sheets, together with the active pharmaceutical ingredients can be embedded into the polymeric matrix carrier in an amorphous state, could lead to an increased dissolution and thus the bioavailability of drugs with a lower solubility [4,5]. Due to their structure, the formulation of nanofibrous materials loaded with different drugs have been widely used as drug delivery systems, scaffolds for tissue engineering and wound bandage.

Electrospinning is a well controllable, simple and cost-effective technique for preparing matrices with nanometer-sized fibers with similar features and morphologies to the extracellular matrix (ECM) [6]. The ECM is the non-cellular component presents within all tissues and organs and plays a vital role in the wound healing process [7]. Therefore from those materials which can mimic their structure are believed to stimulate cell proliferation and could help the wound healing [6].

The diverse field of application of the nanofi-

brous materials required adequate functionality-related characteristics. One of the emerging improvements is the development of a bi-component core-shell fiber structure [8], which can offer several benefits for these samples: the core polymer/composite can provide the required mechanical, physicochemical properties, and can control the release of the incorporated drug(s). The shell materials could preserve the unstable active pharmaceutical ingredients embedded into the core from the unfavorable environmental effect, which can increase the hydrophilicity and the biocompatibility of the fibrous samples. Besides that, one of the significant advantages of this core-shell nanostructures lies in the potential to tailor release properties of the incorporated drug and combine features of different polymers to achieve the required functionality-related characteristic and mechanical properties also [5].

2. Aims

The goal of the project was to prepare polylactic acid (PLA) - poly(vinylpyrrolidone) (PVP) bi-component core-shell fibrous mats and examine the electrospinnability of the precursor combinations. The major challenge of the study lies in the development of a morphological characterization technology that can provide quantitative information of the fiber and also suitable for monitoring the physical state of the active pharmaceutical ingredients incorporated into the fibers.

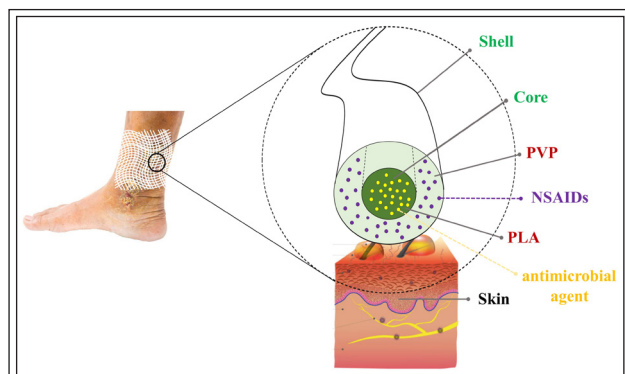


Figure 1 Schematic picture of the developed nanofibrous formulation

3. Materials and methods

A full factorial experimental design was used to determine the best combination of the core (PLA)- and shell (PVP) viscous solutions for coaxial electrospinning (SpinSplit Ltd., Budapest, Hungary).

The morphology structure of the prepared sample was studied by scanning electron microscopy (SEM), transmission electron microscopy (TEM) and X-ray photoelectron spectroscopy (XPS). Besides of the traditional characterization techniques, the electrospun samples were analyzed using Raman mapping.

4. Results and discussions

The SEM photos showed that fibrous structures were obtained, without any beads and film-like areas in case of the preliminary study prepared with single-needle electrospinning and also in case of the coaxial electrospun samples.

The PLA has a higher density that is resulted in a darker appearance in TEM photos; thus this method was suitable to detect the core-shell structure and their homogeneity as well. In the case of each composition, the expected structure was obtained, but the homogeneity difference was observed. The best sample morphology was obtained with 15% (w/w) shell concentration combined with 8 % (w/w) PLA solution concentration.

The XPS spectra of the nanofiber surfaces highlighted that the interfacial stability between the inner and outer solution was excellent.

The Raman mapping results also confirmed the core-shell structure and pointed out that amorphous solid dispersion was formed and homogeneous drug distribution was obtained for each of the nine samples.

5. Conclusions

Core-shell fibers of different compositions were successfully prepared with various structural homogeneities. A novel Raman spectroscopy method was developed, which confirmed the core-shell structure of the PLA/PVP nanofibers, and pointed out that the active pharmaceutical ingredients embedded in the polymer matrix in an amorphous state.

6. Acknowledgement

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