Characteristics of Electrospun PVA-*Aloe vera* Nanofibres Produced via Electrospinning

N.A. Abdullah@Shukry, K. Ahmad Sekak, M.R. Ahmad, and T.J. Bustami Effendi

Abstract

The aim of this work was to investigate the characteristics of polyvinyl alcohol (PVA) nanofibres with the incorporation of *Aloe vera* as a novel polymer-drug carrier. The nanofibres were produced via the electrospinning technique. The morphological structure and properties were characterized using field emission scanning electron microscopy (FESEM), Fourier transform infrared spectroscopy (FTIR) and differential scanning calorimetry (DSC). The FESEM image shows homogenous and linear fibre when PVA is mixed with *Aloe vera*. The average size was 123 nm, smaller than the PVA nanofibre. The presence of aloin in DSC showed that the *Aloe vera* was successfully embedded within the PVA nanofibre.

Keywords

Nanofibres • Electrospinning • PVA • *Aloe vera*

Introduction

Electrospinning is a very simple yet versatile method of creating polymer-based high-functional and high-performance nanofibres where it can revolutionize the world of structure materials including the textile field, wound dressings [1, 2], drug delivery systems and tissue engineering [2] in biomedical site or as a membrane of filtration [3] and electronic component coating in an industrial application. Electrospinning, as the name implies, is a process by which nanofibres from a solution or melt (polymer or polymer mixed) are generated in the presence of electric field. Unlike other techniques of producing 1D polymeric nanostructure like top-down method which involves photolithography or soft lithography, electrospinning is incredibly straightforward, simple and cheaper. Instead of using mechanical force of pulling or stretching like conventional spinning process, electrospinning used electrostatic or coulombic [4–7] force as the driving mechanism in drawing nanofibres (Fig. 1). But the most remarkable effect of electrospinning is that it can draw fibres with a diameter as low as tens of nanometres.

Electrospun nanofibre web exhibits a number of outstanding properties such as high surface area compared to film, light weight [1, 8–12] and high porosity [2]. Through the interesting characteristics of nanofibres, many researches were done on various types of polymer as the carrier in drug delivery application [13–17]. PVA has been identified as the suitable candidate that can be used in releasing biological and medical materials in a controlled way [13]. PVA has unique properties such as good chemical resistance, thermal stability, biocompatibility and nontoxicity which make its suitable to be electrospun as polymer-drug carrier [18]. PVA has also been studied intensively due to its good film forming and physical properties, high hydrophilicity and processability [18]. In the past few years, research on electrospun PVA nanofibres has looked at various parameters such as solution concentration, solution flow rate,

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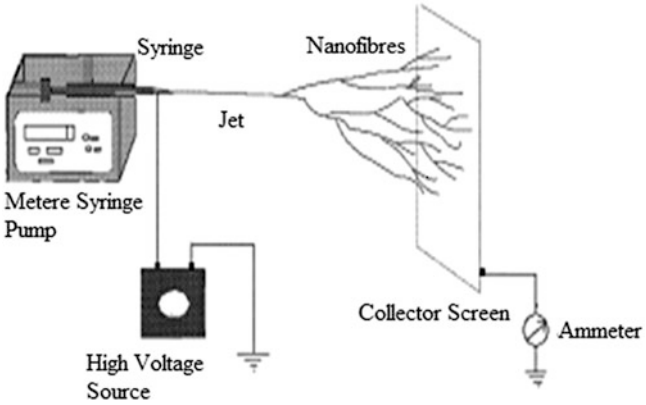

Fig. 1 Electrospinning process

degree of hydrolysis, applied voltage, tip-target distance, ionic salt addition, pH and surfactant addition that affect the morphological structures and diameters of electrospun PVA [1, 3, 18]. Therefore, it has become more interesting to explore *Aloe vera* as a drug carrier.

The aim of this work was to produce PVA-*Aloe vera* nanofibres via electrospinning. *Aloe vera* is known as the oldest therapeutic herb and has the ability to promote wound healing as well as treat burn area on the skin. It consists of two important parts in which the outer layer is called vascular bundle and the inner layer is known as colourless parenchyma containing *Aloe vera* gel. *Aloe vera* has three compositions that include structural, chemical and polysaccharide. Polysaccharide plays the major role in promoting wound healing. It contains salicylic acid together with other chemical components such as proteins, lipids, amino acids, vitamins, enzymes, inorganic compounds and small organic compounds [19–21]. Not many research works are done on the incorporation of *Aloe vera* with polymer membrane. Therefore, this study attempts to encapsulate *Aloe vera* drugs in electrospun polymeric nanofibres through electrospinning. This was done by dissolving PVA mixed with *Aloe vera* in deionized water. The solution was electrospun to form long and continuous nanofibre. For comparison, PVA nanofibre membrane was prepared. The morphological structures of PVA-*Aloe vera* nanofibres were characterized using field emission scanning electron microscopy (FESEM) and different scanning calorimetry (DSC), and the functional group was determined using Fourier transform infrared spectroscopy (FTIR).

Materials and Methods

Materials

Polyvinyl alcohol (PVA) (Mw: 125,000 g/mol) was purchased from Sigma-Aldrich. *Aloe vera* powder extract was received and used without further purification. Distilled water was used as the solvent in the experiment.

Sample Preparation

10 g of PVA powder was dissolved into 90 ml of distilled water at 10 % w/v concentration. The solution was stirred at 80 °C for 3 h using electromagnetic stirrer to get homogenous and crystal clear solution.

Meanwhile, 5 % of *Aloe vera* powder extract (according to 10 g of PVA) was mixed with PVA at 10%v/w and stirred directly using the same method as mentioned above. Both solutions were cooled down at room temperature for several hours before electrospinning.

Electrospinning

Electrospinning was carried by setting the positive electrode on high-voltage DC power supply to the solution that contained 3 ml syringe. The negative electrode was connected to the needle that was used as the nozzle and the grounded electrode to a rotating metal drum wrapped with aluminium foil. The solutions were carefully loaded inside the syringe during the electrospinning process. A pressure was applied on top of the syringe to maintain a steady flow of polymer solution from capillary needle. The tip of the needle and ground collector were placed horizontally facing each other (Fig. 1).

The voltage was applied at 15 kV across the distance of 8 cm between the tip of the needle and aluminium collector. The feed rate was controlled at 0.5 mol/h and the solution was electrospun for about 6 h in order to produce a neat polymer-drug membrane. A collector was rotated at 50 rpm. Finally, the nanofibres were removed from the collector and placed in the oven overnight at 37 °C.

Membrane Characterization

The morphological structure and fibre diameter of electrospun PVA and PVA-AV nanofibre were observed under FESEM (Zeiss) at 2 kV. The membranes were coated with platinum for 3 min. Three hundred readings of fibre diameter were collected and measured with the image visualization software, ImageJ.

The functional groups of the sample were characterized using FTIR (Perkin Elmer).

Differential Scanning Calorimetry (DSC)

The prepared samples were measured at glass transition over a temperature range about 30–120 °C and possibly a thermal degradation range from 250 to 350 °C with 10 °C/min under DSC (Perkin Elmer).

Result and Discussion

Morphological Structure of Electrospun PVA and PVA-AV Nanofibre

Figure 2 shows the image of fine fibre formation and homogeneous and continuous fibre for pure PVA nanofibres. There is no formation of beads within the PVA nanofibres. The average diameter of PVA nanofibres was 168 nm.

Meanwhile, Fig. 3 shows the image of PVA-AV nanofibres in fine, homogenous and linear fibres. There is also no presence of beads indicating that the *Aloe vera* powder had been completely entrapped inside the PVA membrane. This was also discussed by Li et al. [22] where the riboflavin and caffeine were encapsulated homogeneously in the PVA matrices. However, the fibres are slightly distorted but there is no formation of branch in PVA-AV nanofibres.

The average diameter of PVA-AV nanofibre was reduced to 123 nm as compared with PVA nanofibres. This may be because of the interaction between the hydrogen groups in PVA and *Aloe vera* which increased the coulombic repulsion and electrostatic force where the molecules pull closer to each other. It was explained by Taepaboon et al. [16] that coulombic repulsion works to stretch the charged jet and electrostatic force brings the jet to the target. It also involves the conductivity of the solution. Due to the presence of *Aloe vera*, the conductivity may have decreased which leads to beaded-free fibre formation.

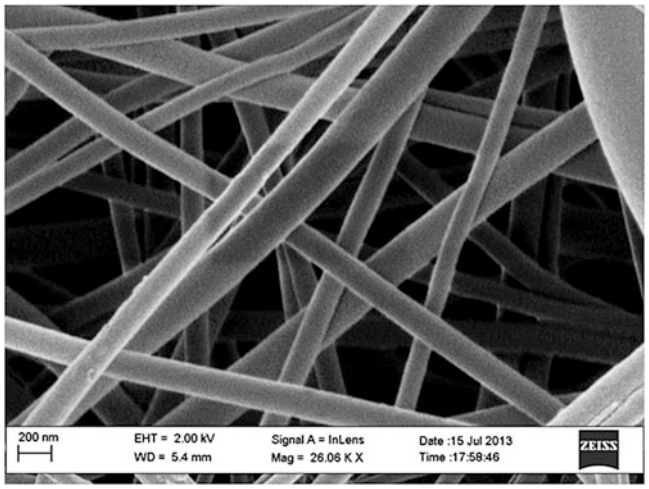

Fig. 2 10 % w/v PVA nanofibre

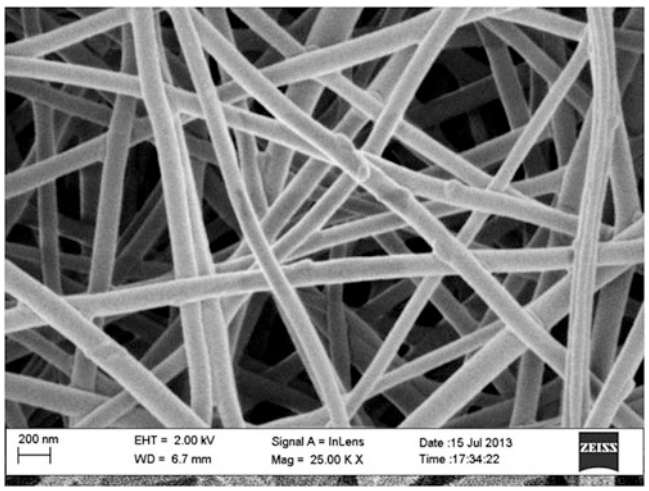

Fig. 3 10 % w/v of PVA, 5 % w/v of AV

Fourier Transform Infrared Spectroscopy

The infrared spectra (Fig. 4) illustrate the characteristic of PVA and PVA-AV. The peak appeared at 3,480 cm^{-1} in *Aloe vera* extract powder, which indicates the presence of phenolic-OH group. *Aloe vera* consists a lot of chemical compound and phenolic-OH group is one of them where it can be found in anthraquinones. Similar results also were achieved by [23, 24].

The peak that also appeared at 3,400–3,380 cm^{-1} in both PVA and PVA-AV indicates the presence of hydroxyl group in the membrane. It is due to the properties of PVA and *Aloe vera* that both contain hydroxyl group. The peak (b) at 2,780 cm^{-1}, however, was slowly distinguished when PVA

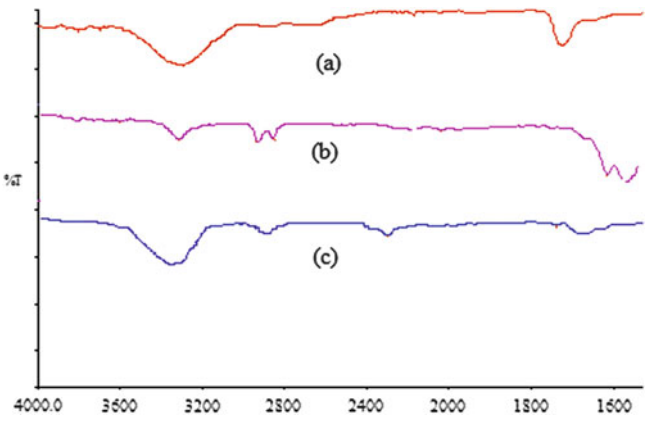

Fig. 4 FTIR spectra for (**a**) *Aloe vera* extract powder, electrospun fibres of (**b**) 10 %w/v of PVA and (**c**) 10 % w/v of PVA, 5 % w/v of AV

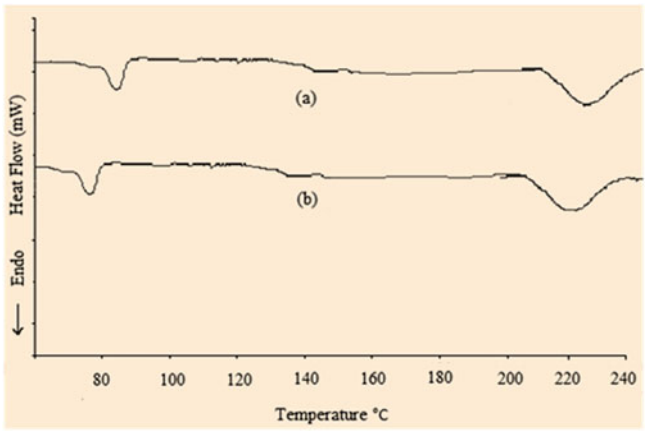

Fig. 5 DSC thermograms for nanofibre of (**a**) 10 % w/v PVA and (**b**) 10 % w/v PVA and 5 % of AV

was mixed with *Aloe vera* due to the stretching of hydroxyl group that contained in both polymer and drug. It also attributed to intermolecular interaction between the hydrogen group with carbonyl among PVA chains and *Aloe vera* due to hydrophilic forces when the peak at Fig. 4c shifts from 1,679 to 1,690 cm^{-1}.

Differential Scanning Calorimetry (DSC)

The DSC thermograms for PVA and PVA-AV nanofibre membranes are shown in Fig. 5. The peak of glass transition occurred at 81 °C, indicating pure PVA nanofibre. However, the peak reduced to 76 °C in glass transition when adding the *Aloe vera* powder. This is due to the presence of aloin in *Aloe vera* [23, 24]. Aloin can be found in polysaccharide that contains anthraquinones. It is particularly used for medical purposes such as for skin treatment and beauty cream product. At melting point, when (b) shifted to 222 °C from 226 °C, it may also be due to the presence of aloin. This phenomenon is due to small particles of *Aloe vera* extract powder that completely dissolved in PVA matrix which affect the crystal structure as well as form an amorphous structure. However, the results contradicted with Ulsu et al. [15] where the peak was reduced at melting point. It may be because of the state of *Aloe vera* in extract powder form that gave better result as compared to *Aloe vera* in a gel form. It can be said that the *Aloe vera* extract powder was entrapped inside PVA which can provide promising wound dressing.

Conclusion

The fabrication of electrospun nanofibres using *Aloe vera* was successfully done and homogenously mixed with PVA. The SEM images show reduction of diameter in electrospun PVA-AV nanofibre as compared to electrospun PVA membrane. Besides, the functional group also indicates that there is no formation of new groups in the membrane proving that both PVA and *Aloe vera* were compatible. The shift of DSC thermograms occurred at melting point provided solid evidence on the effect of *Aloe vera* in electrospun PVA membrane.

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