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Electrospun Poly (Vinyl Alcohol) Nanofibers Containing Siam Weed Crude Extract as Potential Wound Dressings

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Abstract

Maceration extraction of *Chromolaena odorata* (Siam weed) leaves was achieved using ethanol as a solvent. A free radical scavenging protocol using 2,2-diphenyl-1-picrylhydrazyl (DPPH) was used to measure the antioxidant activity. The inhibitory concentration at 50% antioxidant activity (IC_{50}) was 226 µg/mL. the electrospun poly (vinyl alcohol) ultrafine fibers containing Siam weed crude extract were successfully fabricated. The effect of Siam weed extract concentration on the size and morphology of fibers was investigated. The increasing concentration of Siam weed extract in a range of 5-20% w/v caused a higher viscosity of solutions and a larger average fiber diameter. To examine its potential for usage in wound dressing applications, only the electrospun PVA fiber mat containing 20% Siam weed extract was chosen. After submersion in a phosphate buffer solution (pH 7.4) at 37°C for a period of 2 to 24 h, the weight loss and water swelling of the electrospun Siam weed extract-loaded PVA fiber mat were measured, and it was discovered that the weight loss increased with immersion time, while the water swelling increased in the first 6 h and later decreased until 24 h of immersion. The antioxidant activity of the fiber mat was also investigated at the same immersion time, and the results were consistent with trends in weight loss and water retention. After 24 h of immersion, the antioxidant activity was about 81.2 ± 1.7%. The fiber mat exhibited a slight antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* bacteria, as evaluated by an agar disc method. In addition, the fiber mat exhibited superior hydrophilicity, as shown by the water contact angle analysis. According to the overall findings, the Siam weed extract-loaded PVA fiber mat is a potential material for applications as a wound dressing or topical transdermal patch.

Keywords: Electrospinning, Wound dressing, Siam weed, Herbal extract, Poly (Vinyl Alcohol), Nanofibers

1. Introduction

Electrospinning has increased in popularity as a process for producing ultrafine fibers during the last two decades. Electrospinning is an uncomplicate, adaptable, and inexpensive technique. Ultrafine fibers with diameters ranging from micrometers to nanometers are created using high electrical force [1, 2]. The charge species builds on the surface of a pendant drop at the nozzle tip when a high electrostatic field is applied to the polymer solution or polymer melt. The hemispherical drop destabilizes into a conical shape, known as Taylor's cone, until the electrostatic field reaches a critical magnitude. Above the critical value, the surface tension and viscoelastic force of the polymer liquid are defeated by the Coulombic repulsion and electrostatic forces, causing a charged polymer jet to be ejected into the collector [3]. The polymer jet solidifies throughout its flight to the collector

by either cooling down in the case of the melt or evaporating solvent in the case of the solution. Because of the remarkable properties of the electrospun fibers, which include a high surface area-to-volume or mass ratio and an interconnected porous structure, they have been proposed as ideal materials in a wide range of applications, such as air and water filtration membranes [4], reinforced composites [5], scaffolds in tissue engineering [6], and carriers for drug delivery in wound dressings [7-9]. The advantage of using ultrafine fibers as drug carriers in wound dressings is the ease with which drug molecules diffuse out of the fibers due to the porous nature and large surface area of the ultrafine fiber mats. Thus, prolonged medication or sustained release of drugs from the electrospun fibers is achieved [7, 9].

For the use of electrospun ultrafine fibers as wound dressings, one of the critical concerns is the choice of polymer matrix for fabrication into fibers. An ideal wound dressing should be capable of absorbing wound exudate and retaining wound moisture, be permeable to gases (i.e., oxygen and moisture), have adequate mechanical properties, be biocompatible or non-toxic, and be modestly priced [10]. Hydrogels are among the most intriguing because of their capacity to absorb water or fluid to keep wounds hydrated while not dissolving. Poly (vinyl alcohol) (PVA) and its blend with other matrix loaded with drugs are widely employed as potential wound dressings [8, 9, 11]. To improve physical stability during use and manage the degree of weight loss and swelling, PVA might be crosslinked using glyoxal [12], boric acid [13], diisocyanate, formaldehyde, and glutaraldehyde [14]. As potential wound dressings, the electrospun PVA fibers mixed with either medications, such as tranexamic acid and ceftriaxone [15], natural extracts, such as propolis [16], and herbal extracts of *Hyperici herba*, *Thymus vulgaris*, and *Salvia officinalis folium* [17] were highlighted.

Chromolaena odorata, a member of the *Asteraceae* family, is a weedy flowering shrub found in tropical and subtropical countries such as South America, Australia, Africa, and Asia [18]. *C. odorata*, synonyms as *Eupatorium odoratum*, is also known as Siam weed. It is an ancient botanical medicine used for wound treatment. Many parts of Siam weed have been utilized to cure wounds, skin infections, and burns. Additionally, it has been demonstrated to have anti-hepatotoxic, anticancer, anti-inflammatory, anti-diabetic, antioxidant, and antibacterial activities [19]. The important phytochemical constituents found in Siam weed leaves include alkaloids, flavonoids (chalcone, aurone, chalcone, flavonol, and flavone), cyanogenic glycosides, phenolics, tannins, terpenoids, saponins, and essential oils [19, 20]. The treatment of skin infections or soft tissue burns by using the extract of Siam weed leaf was revealed by a number of studies. Siam weed extract is one of the intriguing herbal extracts for wound healing treatment due to its interesting properties. The extract of Siam weed contains numerous antioxidant components that improve the ability to heal wounds [19, 21, 22]. It has been reported to decrease the bleeding time of wounds [23]. By suppressing inflammatory mediators, Siam weed extract can prevent the cells from being destroyed [24]. The ethanolic extract of Siam weed exhibited excellent radical scavenging and anti-oxidative properties with good cytocompatibility [21]. Both Gram-positive and Gram-negative bacteria are susceptible to Siam weed's antibacterial properties [25].

In the present contribution, the crude extract of Siam weed leaves was prepared. Encapsulation of Siam weed extract into PVA nanofibers was achieved using electrospinning. The morphology and diameter of the fibers were investigated with regard to the effects of Siam weed extract concentration loading. The use of the obtained electrospun fibers as topical transdermal patches or wound dressings was examined in terms of water swelling, weight loss, antioxidant activity, and water contact angle.

2. Experimental

2.1 Materials

Siam weed leaves were collected from a region in Pathumthani and Nonthaburi, Thailand. PVA (85,000-124,000 g/mol with 86.0-89.0% degree of hydrolysis) was purchased from SD Fine Chemicals (India). 2,2-diphenyl-1-picrylhydrazyl (DPPH) was purchased from Sigma-Aldrich (USA). Methanol, ethanol, disodium hydrogen phosphate (Na_2HPO_4), and monosodium phosphate monohydrate ($NaH_2PO_4.H_2O$) were purchased from Carlo Erba (Italy). Glutaraldehyde (25% solution in H_2O) was purchased from Acros Organics (USA). All of the chemicals were analytical grade.

2.2 Extraction of Siam weed leaves

Siam weed leaves were gathered, washed with water, and allowed to dry for 2 h at room temperature. They were later dried in an oven at 60°C for 9 h and ground into tiny pieces. Dried Siam weed leaves were mixed with 95% ethanol in a closed bottle at a solid: liquid ratio of 1:4 g/mL. The bottle was slowly shaken for 24 h at room temperature. The solid residue was removed from the mixture using filter paper. The obtained extracted solution was subjected to a rotary evaporator in order to remove solvent at a temperature of 60°C for 30 min. The weight of the extract was recorded and used for the calculation of the percentage of extraction yield according to Equation (1). The extract was kept in a desiccator before further use.

$$Yield\ (\%) = \frac{weight\ of\ extract\ (g)}{weight\ of\ dried\ Siam\ weed\ leaves\ (g)} \times 100 \quad (1)$$

2.3 Electrospinning of Siam weed extract-loaded PVA fibers

A weighed amount of PVA powder was dissolved in distilled water at 80°C to prepare a 10% w/v PVA solution. The Siam weed extract was dissolved in a 10% w/v PVA solution at various concentrations, including 5, 10, 15, and 20% w/v. The viscosity of the obtained solutions was measured using a viscometer (Cannon-Fenske Routine) at 40°C with a constant of 2.351 cSt/s. The pristine PVA solution without Siam weed extract loaded was designated "PVA", whereas those with extract loading were designated "PVA/SW5", "PVA/SW10", "PVA/SW15", and "PVA/SW20" regarding the amounts of loading.

For electrospinning, the solution was in a 10-mL plastic syringe connected to a metal needle. The diameter of a needle tip was 0.91 mm. A rotating drum covered with aluminum foil with a width of 25 cm and a diameter of 7.6 cm was used as a collector, which was set at a distance of 15 cm from the tip of the nozzle. The collector was rotated at a speed of about 100 rpm. A high applied potential of 15 kV was applied to the solution. The feed rate of solution was regulated at 1.0 mL/h utilizing a syringe pump. The electrospinning process was conducted for 8 h. The electrospun fiber mat with a thickness of about 60 ± 10 was produced.

The obtained electrospun Siam weed extract-PVA fibers were crosslinked using glutaraldehyde vapor. The fiber mats were laid in a closed box containing a vessel of 25% glutaraldehyde and kept at 40°C for 12 h. The residual glutaraldehyde was then allowed to evaporate by leaving the fiber mats in a hood for an additional hour.

2.4 Morphology of the electrospun Siam weed extract-loaded PVA fibers

The morphology of the electrospun fibers was examined by a scanning electron microscope (SEM). The SEM images were taken at magnifications of x1000 and x5000. The fiber diameters were measured from the SEM images using imageJ software (version 1.52). The average fiber diameters were calculated from 70 measurements and were presented as mean ± standard deviation. Statistical analysis was carried out by using a paired two sample for means: t-test using the Microsoft Excel software. The statistical difference between two sets of data was considered when $p<0.05$. The

selected PVA/SW fiber mat was chosen to be evaluated in further studies, including water swelling, weight loss, antioxidant activity, antibacterial activity, and water contact angle.

2.5 Water swelling and weight loss of the electrospun Siam weed extract-loaded PVA fibers

2.5.1 Preparation of phosphate buffer (pH 7.4)

The electrospun Siam weed extract-loaded PVA fiber mats were intended to be used as wound dressings under simulated physiological wound settings, such as pH 7.4 and 37°C. Therefore, a phosphate buffer solution (pH 7.4) was utilized in the experiments on water swelling, weight loss, and antioxidant activity. For the preparation of phosphate buffer solution (pH 7.4), 20.214 g of $Na_2HPO_4.7H_2O$ and 3.394 g of $NaH_2PO_4.H_2O$ were dissolved in distilled water and later made into a 1 L solution. A few drops of 1 M sodium hydroxide solution or concentrated hydrochloric acid could be added to adjust the pH to 7.4.

2.5.2 Water swelling and weight loss

The amounts of water swelling and weight loss of the electrospun Siam weed extract-loaded PVA fiber mats were evaluated after submersion in a phosphate buffer solution (pH 7.4) at 37°C over a period of time. The fiber mat sample was cut into a 2x2 cm^2 square shape and dried in an oven at 40°C for 8 h, in which the initial dry weight of the sample was noted as M_i. At 2, 4, 6, 8, and 24 h of submersion, the weight of the wet sample was noted as M. Later, the sample was dried in an oven at 40°C for 8 h, and the weight of the dry sample was noted as M_d. Equations (2) and (3) were applied to calculate the degrees of water swelling and weight loss, respectively.

$$\text{Water swelling}\ (\%) = \left(\frac{M-M_i}{M_i}\right) \times 100 \tag{2}$$

$$\text{Weight loss}\ (\%) = \left(\frac{M_i-M_d}{M_i}\right) \times 100 \tag{3}$$

2.6 Antioxidant activity

The DPPH radical scavenging experiment was employed to examine the antioxidant properties of the Siam weed extract and the electrospun Siam weed extract-loaded PVA fiber mat. As a reagent and control sample, a 0.5 mM DPPH solution in methanol was prepared and used in this work.

In order to test the antioxidant activity of Siam weed extract, a stock solution of Siam weed extract at a concentration of 50 mg/mL was made using ethanol as a solvent. Five distinct Siam weed extract solutions with concentrations ranging from 15.6 to 500 µg/mL were then created by diluting the stock solution. After preparing the mixture, which contained 3.0 mL of 0.5 mM DPPH and 1.0 mL of the Siam weed extract solution, it was left in the dark for 30 minutes. The pure 0.5 mM DPPH solution, which was utilized as a control sample, was kept in the same conditions as those of the tested samples. Later, using an I3-Hanon UV-visible spectrophotometer, the absorbance at 517 nm (λ_{max} of DPPH) of the control and tested solutions was determined. The ability of the tested sample to neutralize DPPH free radicals, or their antioxidant activity, was measured by the difference between their absorbance and that of the control. Equation (4) was used to calculate the antioxidant activity.

$$\text{Antioxidant activity}\ (\%) = \left(\frac{A_C-A_S}{A_C}\right) \times 100 \tag{4}$$

Where A_C and A_S are the absorbances of the control and the sample, respectively.

The plot between the concentrations of Siam weed extract solution and their antioxidant activities was created. The concentration of Siam weed extract at which 50% of DPPH radicals were destroyed (IC_{50}) was determined.

In order to evaluate the antioxidant activity of the electrospun Siam weed extract-loaded PVA fiber mats, the fiber mat sample was cut into a 2x2 cm^2 square and submerged in a 40 mL phosphate buffer solution (pH 7.4) at 37°C. 1.0 mL of the immersion medium was taken out at 2, 4, 6, 8, and 24 h after immersion and combined with 3.0 mL of a 0.5 mM DPPH solution. The mixture was kept in the dark for 30 minutes before measuring the absorbance at 517 nm. The antioxidant activity was repeatedly determined using Equation (4). Three duplicates of each experiment were run.

2.7 Antibacterial activity

An agar disc diffusion method was utilized to measure the antibacterial property of the electrospun Siam weed extract-loaded PVA fiber mats against *Staphylococcus aureus* (*S. aureus*: ATCC 6538; Gram-positive) and *Escherichia coli* (*E. coli*: ATCC 8739; Gram-negative) bacteria. The sample was 6 mm in diameter, placed in the agar disc, and incubated at 37°C for 24 h. The size of the inhibition zone was measured. Vancomycin and gentamicin were used as the positive controls for *S. aureus* and *E. coli*, respectively.

2.8 Contact angle of the electrospun Siam weed extract-loaded PVA fibers

The water contact angles of the electrospun Siam weed extract-loaded PVA fiber mats were evaluated using a contact angle goniometer (OCA25, Dataphysics) at 25°C. The volume and dosing rate of the distilled water droplet were 10.00 µL and 2.00 µL/s, respectively. At least five times of experiments were conducted.

3. Results and Discussions

3.1 Antioxidant activity of Siam weed extract

A maceration extraction, using 99% ethanol as the solvent, was performed to prepare the Siam weed leaf extract. To protect the active phytochemical components from heat destruction, the procedure was carried out as a cold process at room temperature. The crude extract of Siam weed leaves was obtained as a dark green sticky solid with an average yield percentage of 4.88 ± 0.65%.

Based on the DPPH free radical scavenging experiment, the antioxidant activity of Siam weed extract at concentrations in the range of 15.6 - 500 µg/mL was assessed. Figure 1 depicts the relationship between Siam weed extract concentration and antioxidant activity, which ranged from 20.5 to 80.8%. The half-maximal inhibitory concentration (IC_{50}) of Siam weed extract, which is the concentration at which 50% of DPPH free radicals are scavenged, was 226 µg/mL. Interestingly, the IC_{50} (based on DPPH assay) of Siam weed extract was lower than those of some plant extracts revealed in the literature, such as *Vernonia canescens*, *Clibadium funzike*, *Calea angosturana*, and *Pentacalia Americana* (IC_{50} ranged from 245-848 mg/L or µg/mL) [26], which determines the excellent antioxidant activity of Siam weed extract.

As a result, the electrospun Siam weed extract-loaded PVA fibers were further developed and studied. The properties of the electrospun Siam weed extract-loaded PVA fibers, including the degrees of water swelling, weight loss, water contact angle, antioxidant, and antibacterial activities, were assessed.

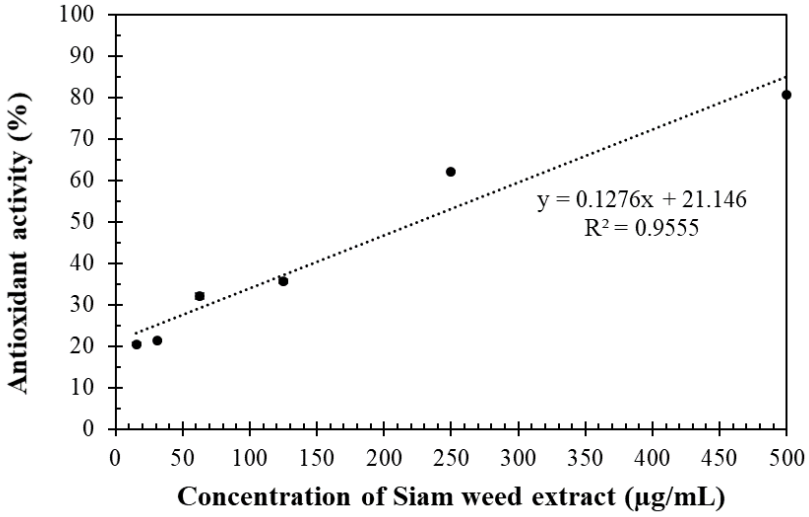


Figure 1 Antioxidant activity of Siam weed extract as evaluated by DPPH assay.

3.2 Morphology and size of the electrospun Siam weed extract-loaded PVA fibers

Prior to electrospinning, the kinematic viscosities of the neat and Siam weed extract-loaded PVA were measured by using a viscometer. The applied voltage of 15 kV and a fixed tip-to-needle distance of 15 cm were utilized during the electrospinning process. The selected SEM images of the electrospun PVA fibers with and without Siam weed extract loadings, along with the average fiber diameters and viscosities of the solutions, are displayed in Table 1.

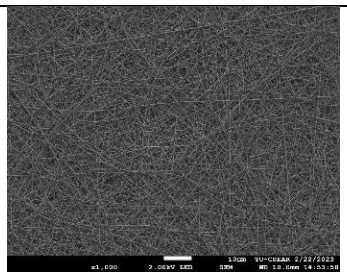
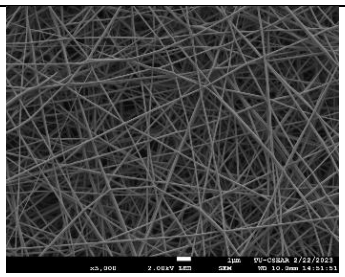
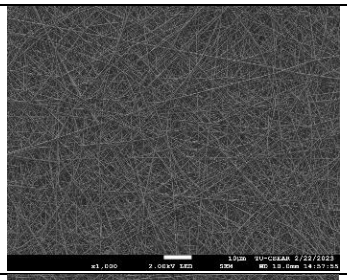
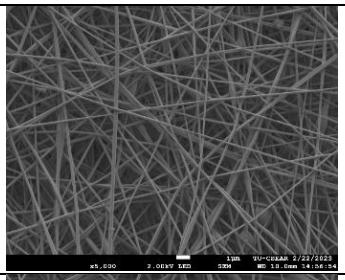
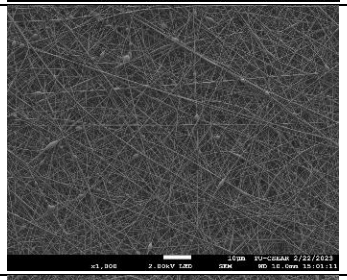
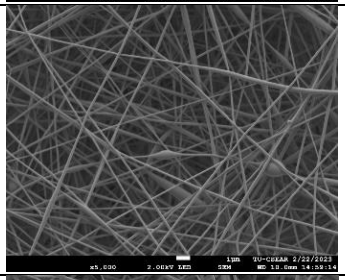
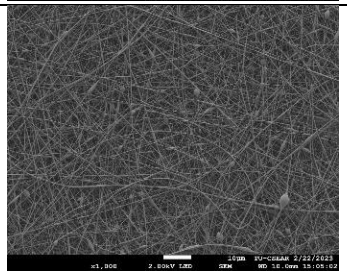
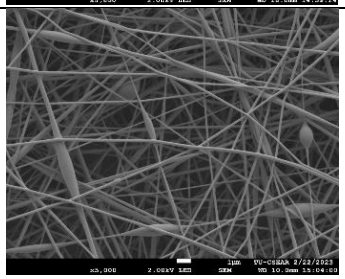
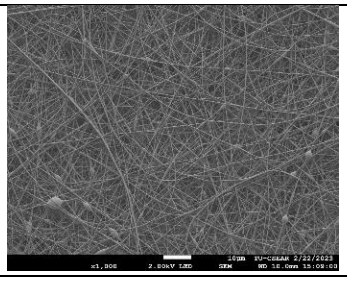
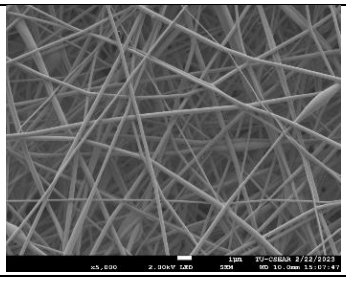
For the electrospinning of the neat PVA solution without Siam weed extract loading, ultrafine fibers with a round cross-sectional shape and smooth surface were obtained. The average fiber diameter was about 181 ± 17 nm. With the addition and increasing amounts of Siam weed extract into PVA solutions, the average fiber diameters were greater, ranging between 185-288 nm. For all types of electrospun Siam weed extract-loaded PVA fibers, including PVA/SW5, PVA/SW10, PVA/SW15, and PVA/SW20, there was no aggregation of any solid (i.e., Siam weed extract) on the surface of the fibers, indicating the homogeneity of the as-prepared solutions throughout the process.

For the PVA/SW5, the ultrafine fibers with a smooth surface and a round cross-sectional shape can still be obtained as similar to those of the PVA fibers. The viscosity of the PVA/SW5 and the average fiber diameter did not significantly differ from the PVA sample. However, few beaded fibers were observed for the PVA/SW10, PVA/SW15, and PVA/SW20. The significantly higher viscosities of the solutions with increasing amounts of extract in a range of 10-20% and the larger average fiber diameters were observed (see Table 1).

It is well known that one of the important factors determining the size of the electrospun fibers is the viscosity of the solution. As the viscosity of the solution increased, the viscoelastic force, which referred to the capacity of the charged jet to tolerate stretching caused by Coulombic repulsion and electrostatic forces, increased, resulting in smaller fiber diameters [27].

The electrospun PVA/SW20 fiber mat, which has the highest Siam weed concentration in this study, was selected to be investigated for additional experiments. These included determining the levels of water swelling, weight loss, antioxidant activity, and water contact angle. It should be noted that an inhomogeneous mixture was produced when the concentration of Siam weed extract in the PVA solutions was increased by more than 20%. Therefore, the maximum concentration of Siam weed extract at 20% was possible.

Table 1 Selected SEM images of the electrospun PVA fibers with and without Siam weed extract loadings, along with the average fiber diameters and viscosities of the as-prepared solutions**.**
*Significant at $p<0.05$ with respect to PVA sample.

Sample	Viscosity of solution (cSt)	SEM image (X1000)	SEM image (X5000)	Average fiber diameter (nm)
PVA	259 ± 11			181 ± 17
PVA/SW5	263 ± 13			185 ± 15
PVA/SW10	277 ± 10 *			214 ± 28 *
PVA/SW15	314 ± 15 *			236 ± 27 *
PVA/SW20	357 ± 22 *			288 ± 31 *

3.3 Water swelling and weight loss of the electrospun Siam weed extract-loaded PVA fibers

The amount of water swelling and weight loss of the materials used for wound dressings are two crucial properties. These factors particularly match the release behaviors of the active chemicals from the carriers [28]. The degree of water swelling relates to the ability of the matrix to allow drugs

or active molecules to diffuse out. It also indicates the matrix's capacity to hold water both in bulk and in the inter-porous space of the non-woven structure of the electrospun fibers [29, 30]. Additionally, one of the release processes can be defined in terms of how much weight of matrix is lost as a result of material erosion, allowing the drug molecules to be liberated from the matrix [30].

The electrospun PVA/SW20 fiber mat was investigated for its degree of water swelling and weight loss. After being submerged in a phosphate buffer solution (pH 7.4) at 37°C for varied time intervals ranging from 2 to 24 hours, the percentages of water swelling are shown in Figure 2. With increasing immersion duration, the degrees of water swelling increased in the first 6 h and later decreased, which were approximately 920 ± 10, 1171 ± 37, 1822 ± 50, 1437 ± 95, and 1094 ± 98% at 2, 4, 6, 8, and 24 h, respectively. Figure 3 illustrates the amounts of weight loss of the PVA/SW20 fiber mat after being submerged in a phosphate buffer solution (pH 7.4) at 37°C. At 2, 4, 6, 8, and 24 hours, the percentages of weight reduction were 10.1 ± 5.2, 36.6 ± 3.9, 49.9 ± 5.3, 95.4 ± 2.7, and 98.1 ± 0.8%, respectively.

According to the chemical structure of PVA, which is considered a hydrogel that has a high capacity to absorb water, the amounts of water swelling and weight loss of the electrospun PVA/SW20 fiber mat were remarkably high. Additionally, the interconnected pores and high surface area-to-volume ratio of the nanofibrous structure may enable more surfaces to interact with and hold the medium [31].

Noticeably, the amounts of weight loss drastically increased at 8 h of immersion and further increased until 24 h of immersion. Due to the fact that the degree of water swelling was determined based on the weight after immersion, the extremely high amounts of weight loss during the 8–24 h of immersion may be the cause of the decrease in water swelling during this time. The effects of water swelling and weight loss are further discussed in relation to antioxidant activity.

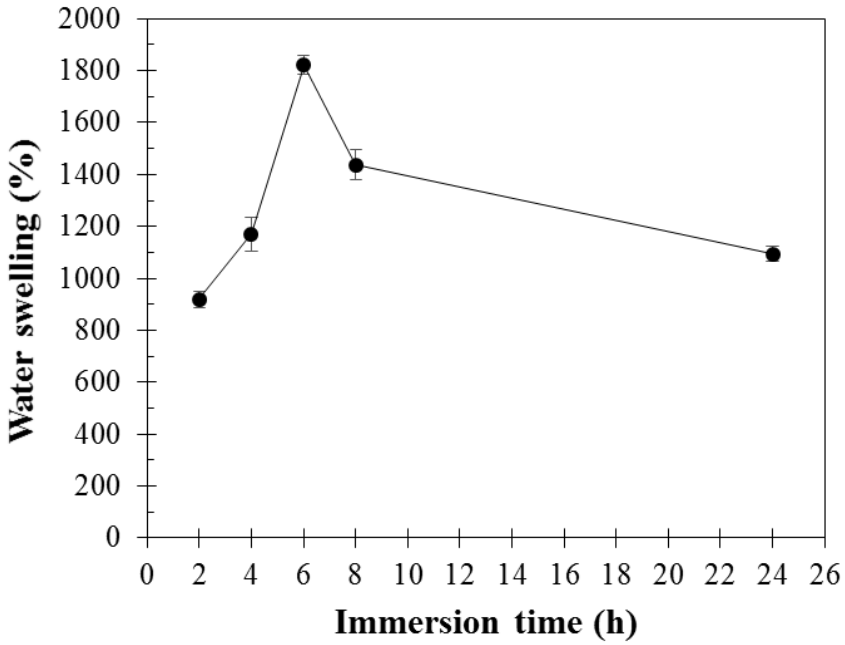


Figure 2 Amount of water swelling of the electrospun Siam weed extract-loaded PVA fiber mats after submersion in a phosphate buffer solution (pH 7.4) at different time points.

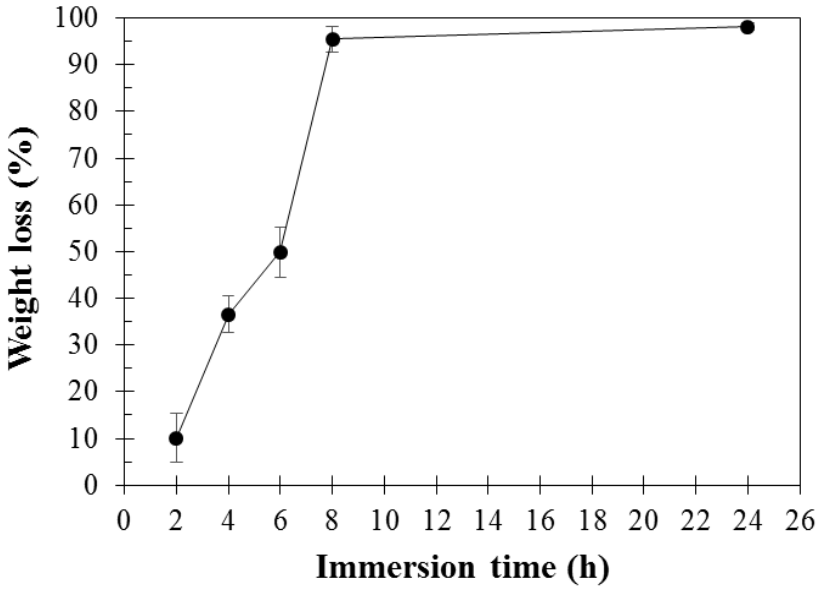


Figure 3 Degree of weight loss of the electrospun Siam weed extract-loaded PVA fiber mats after submersion in a phosphate buffer solution (pH 7.4) at different time points.

3.4 Antioxidant activity of the electrospun Siam weed extract-loaded PVA fibers

The DPPH test was carried out to determine the antioxidant activity of the electrospun Siam weed extract-loaded PVA fiber mat. The releasing media was collected and analyzed for antioxidant activity after the fiber mats were immersed in a phosphate buffer solution (pH 7.4) at 37°C. The experiments were conducted over a range of times, from 2 to 24 h. The ability to scavenge the hydrogen radicals of DPPH was indicated by a decrease in the absorbance at 517 nm (λ_{max} of DPPH) in comparison to the control.

The antioxidant activity of the electrospun Siam weed extract-loaded PVA fiber mats (PVA/SW20) at various times after being immersed in a phosphate buffer solution (pH 7.4) is shown in Figure 4. The antioxidant activities were 7.2 ± 4.4, 18.1 ± 1.8, 30.2 ± 1.8, 38.6 ± 0.9, and 81.2 ± 1.7%, respectively, at 2, 4, 6, 8, and 24 h of immersion. It was shown that the antioxidant activities increased with increasing immersion duration, which might be due to the higher release amounts of Siam weed extract from the fiber mats with increasing time. Moreover, the levels of water swelling and weight loss correlated with antioxidant activity values, which rose with immersion time. As was discussed previously in the preceding section, it is possible to explain the drug release behaviors in terms of both the weight loss caused by matrix erosion, which makes it possible for drug molecules to be released, and the water swelling, which makes it possible for drug molecules to diffuse out of the matrix. The excellent antioxidant activity of the electrospun Siam weed extract-loaded PVA fiber mat has emphasized its further investigation for usage as wound dressings that can reduce the oxidation stress of the wounds.

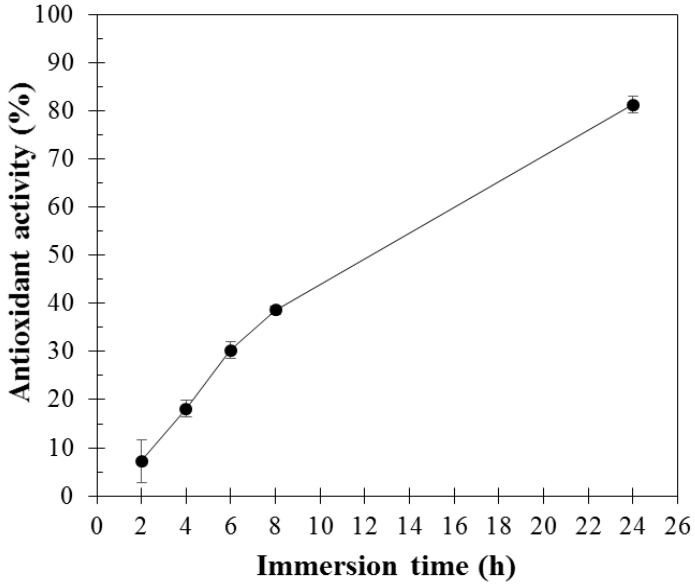


Figure 4 Antioxidant activity of the electrospun Siam weed extract-loaded PVA fiber mats after submersion in a phosphate buffer solution (pH 7.4) at different time points.

3.5 Antibacterial activity of the electrospun Siam weed extract-loaded PVA fibers

The antibacterial efficacy of the electrospun PVA/SW20 fiber mat against *S. aureus* and *E. coli* bacteria was examined using the agar disc diffusion method. The sizes of the inhibitory zones were 0.75 ± 0.33 mm for *S. aureus* and 0.28 ± 0.12 mm for *E. coli*. The PVA/SW20 fiber mat was discovered to possess a weak antibacterial action against both bacteria. These findings suggest the PVA/SW20 fiber mat is a promising material for wound dressings since it possesses both antioxidant and antibacterial activities.

3.6 Contact angle of the electrospun Siam weed extract-loaded PVA fibers

An ideal wound dressing should have the desired properties, such as good gas permeation (allowing oxygen and moisture vapor to pass through the wound), preventing contaminants from entering the wound, adequate mechanical properties, biocompatibility or non-toxicity, ease of removal, reasonable cost, and hydrophilicity (allowing it to absorb wound exudate and keep the surrounding area moist) [10].

This study measured the water contact angle of the electrospun Siam weed extract-loaded PVA fiber mat to determine its hydrophilicity. It was discovered that the contact angle of the fiber mat (PVA/SW20) cannot be measured because water droplets quickly vanish inside the fiber mats. This finding demonstrates the material's outstanding hydrophilicity. It could be due to both the hydrophilic properties of PVA and Siam weed extract themselves that allow rapid absorption of water and the porous structure of the electrospun fibers that contribute to the capillary force-driven liquid penetration.

In order to further investigate this study, the cast film of Siam weed extract-loaded PVA with the same composition as that of the electrospun PVA/SW20 fiber mat was made using a solvent-casting approach and examined for its contact angle. The cast film of PVA/SW20 with the smooth surface was found to have a contact angle of 75.73 ± 11.71°, which demonstrates the strong hydrophilicity of the constituents. Therefore, it should be reiterated that the hydrophilic properties of the components and the interconnected porous structure of the non-woven fibers both contributed to the superior hydrophilicity of the electrospun Siam weed extract-loaded PVA fiber mat.

Based on the overall results, the electrospun Siam weed extract-loaded PVA fiber mat (PVA/SW20) had a significant degree of antioxidant activity (81.2 ± 1.7% at 24 h of immersion),

which was correlated with the trends of water swelling and weight loss. Also, the slight antibacterial activity of the fiber mat was observed. In addition, the fiber mat's high hydrophilicity allows it to absorb wound exudate and keep wounds moist, making it a good choice for use as a wound dressing. The electrospun Siam weed extract-loaded PVA fiber mat demonstrated a potential material for use as a topical transdermal patch or wound dressing.

4. Conclusions

In the present contribution, Siam weed leaf extract, which is widely known for its antioxidant, antibacterial, and anti-inflammatory properties and is employed as local medicine to treat skin diseases and burns, was loaded in the electrospun PVA fiber mats. Siam weed extract was tested for its antioxidant and antibacterial properties. According to the DPPH assay, the inhibitory concentration of Siam weed extract at 50% antioxidant activity (IC_{50}) was 226 µg/mL.

The morphological appearance and fiber diameters of the electrospun Siam weed extract-loaded PVA fibers were impacted by the loading amounts of Siam weed extract, which changed the viscosities of the solutions. To examine its potential for usage in applications such as topical transdermal patches and wound dressings, the chosen electrospun PVA fiber mat containing 20% Siam weed extract (PVA/SW20) was further investigated. After being immersed in a phosphate buffer solution (pH 7.4) at 37°C for a period of 2 to 24 h, the weight loss of the fiber mat increased with immersion time, while the water swelling increased in the first 6 h and later decreased until 24 h of immersion due to the high degrees of weight loss at the late period of immersion time. After the fiber mats were submerged in the phosphate buffer solution, the antioxidant activities of the releasing medium were also investigated. The antioxidant activity rose with immersion duration and reached 81.2 ± 1.7% at 24 h. The trend of antioxidant activity correlated well with that of weight loss and water retention. The structure with interconnected pores and the high surface area-to-volume ratio of the electrospun fiber mats may be responsible for their high levels of water swelling, weight loss, and antioxidant activity. The fiber mats also exhibited a slight antibacterial activity against *S. aureus* and *E. coli* bacteria, as measured by an agar disc method. Additionally, the fiber mat demonstrated great hydrophilicity, as observed by the water contact angle measurement. The electrospun Siam weed extract-loaded PVA fiber mat revealed potential for use as a topical transdermal patch or wound dressing based on the overall findings.

5. Conflict of interest

The authors declare that they have no conflict of interest.

6. Acknowledgment

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