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Synthesis and Characterization of Electrospun Edible Bird's Nest/Polyvinylpyrrolidone Nanofibers

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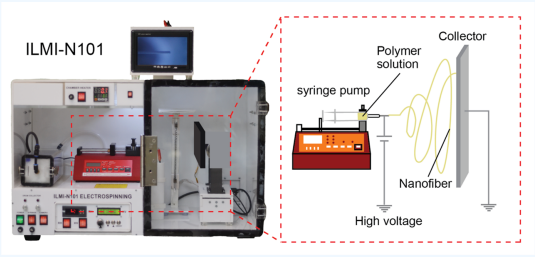
ABSTRACT

Edible Bird's nest (EBN) is a highly valuable food product due to its rich nutritional content and potential health benefits. In this study, we investigated the morphology and diameter of electrospun EBN/PVP nanofibers by exploring different solution and electrospinning parameters. Smooth, homogeneous, and defect-free nanofibers were obtained using EBN:PVP ratios ranging from 10:90 to 60:40. Increasing the concentration of EBN in the solution resulted in fibers with larger diameters. The fiber diameter was found to decrease with increasing voltage of the electrospinning process. In addition, increasing the needle-to-collector distance resulted in fibers with smaller diameters. The FTIR spectrum of EBN/PVP showed a combination of the spectral characteristics of both components. The EBN/PVP nanofiber blend showed improved thermal stability, probably due to the interaction between EBN and PVP, which strengthened the blend structure. EBN/PVP nanofibers with dominant EBN content can be very useful as a matrix to protect bioactive ingredients from environmental degradation while allowing controlled release.



Keywords: *Edible bird's nest, Electrospinning, Nanofiber, Polyvinylpyrrolidone*

1. INTRODUCTION

Edible Bird's Nest (EBN) is a secretion produced by swiftlets that has been known and used as a functional food and natural medicine [1, 2]. EBN has gained popularity for making various dietary supplements such as capsules, drinks and snacks [3, 4]. EBN produced from hardened swiftlet saliva is rich in nutrients such as protein, essential amino acids, and various minerals, making it a potential material for the development of health and wellness products [5, 6, 7]. EBN has interesting potential to be used as a matrix in the form of nanofibers, especially because of its rich nutritional content, biocompatibility, bioactive properties, and multifunctional applications [5, 7, 8, 9].

Electrospun nanofibers from pure EBN may not be possible due to the glycoprotein content, which provides bioactive and nutritional properties. These glycoproteins often have low solubility in common solvents, making it difficult for the electrospinning process to produce nanofibers from pure EBN [10]. To overcome the solubility problem, EBN often needs to be mixed with other polymers. One of the polymers often used in composites with bioactive materials is polyvinylpyrrolidone (PVP) [11]. PVP is a biocompatible and water soluble polymer commonly used in electrospinning [12, 13]. The use of PVP as a carrier material for EBN can increase the solubility of EBN in solvents and promote the formation of uniform and stable nanofibers during electrospinning, thus producing nanofibers with higher EBN content.

Nanofibers can be synthesized by several methods, such as self-assembly [14], phase separation [15], lyophilization [16] and electrospinning [17]. However, the electrospinning technique is the most popular method for fabricating nanofibers due to its ability to produce fibers with very small diameters and good control over morphology [18].

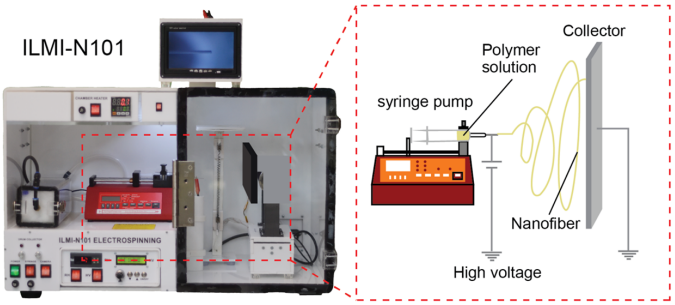


Figure 1. ILMI-N101 electrospinning device and it's schematic illustration

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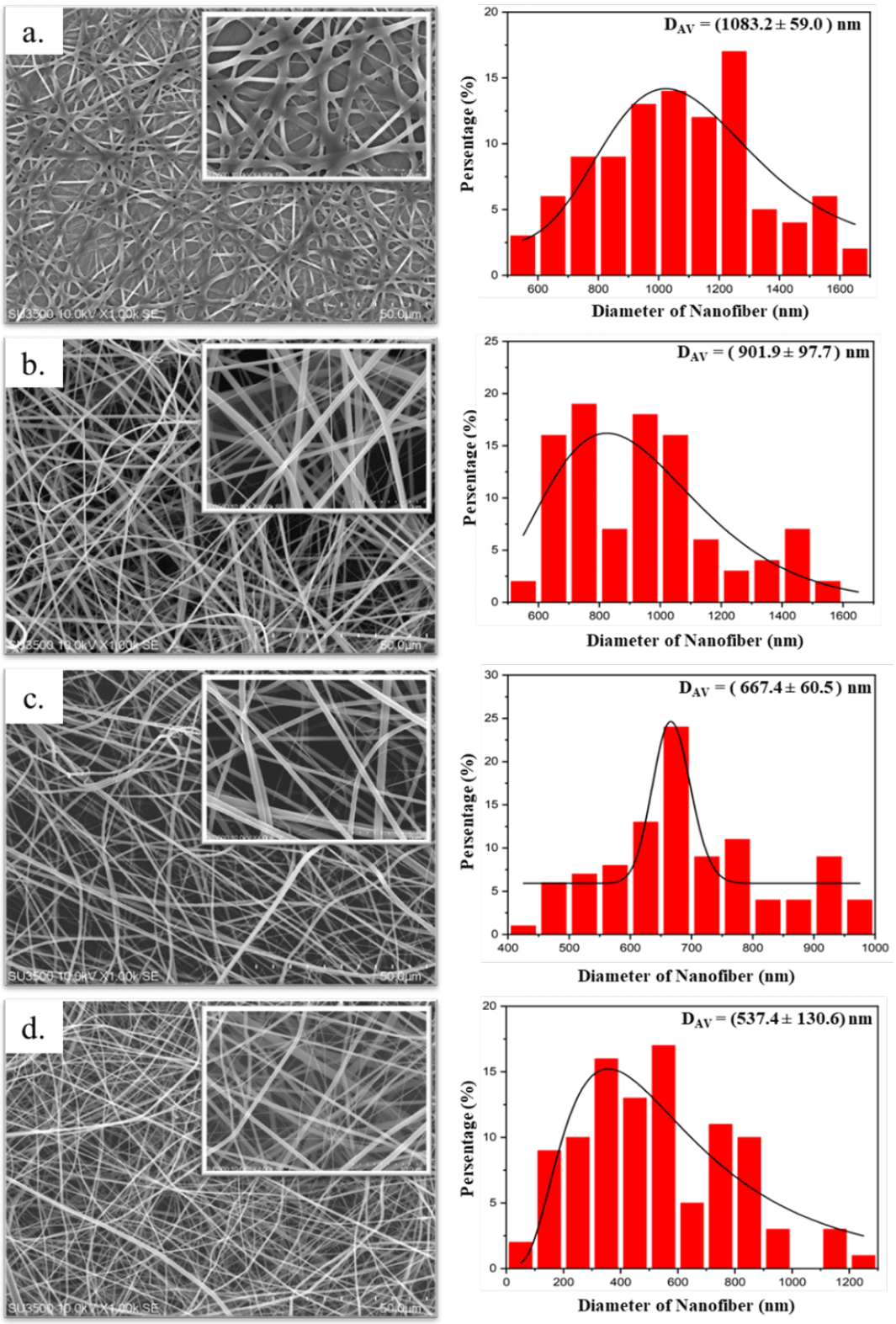

Figure 2. SEM images of EBN/PVP nanofibers and their corresponding diameter distributions at various voltages of (a) 10 kV, (b) 12.5 kV, (c) 15 kV and (d) 17.5 kV.

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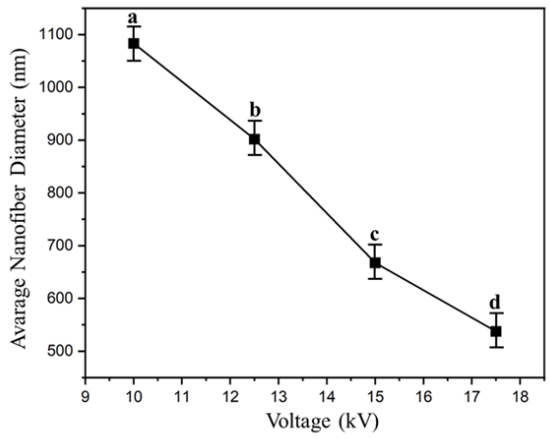

Figure 3. The effect of electrospinning operating voltage on the average diameter of EBN/PVP nanofibers. Statistical analysis was performed using Tukey's one-way ANOVA with $p < 0.05$, and alphabetical differences indicate significant differences.

Electrospinning is a versatile technique to produce nanofibers with high surface-to-volume ratios, small diameters, and excellent morphology. These unique properties make electrospun nanofibers useful in various fields such as biomedical engineering [17, 19], energy storage [20], and food packaging [21, 22].

Therefore, this study aims to investigate the optimization of electrospinning parameters for producing EBN/PVP nanofibers. Some parameters are studied, including the EBN to PVP weight ratio, electrospinning voltage, and collector distance on the diameter and morphology of the obtained fibers. Some physical characterizations were also conducted for the nanofibers, including scanning electron microscopy (SEM), Fourier transform infrared (FTIR) spectroscopy, and thermal analysis.

2. METHODS

2.1 Materials for Precursor Solution

EBN was obtained from a local market in Indonesia. Meanwhile, polyvinylpyrrolidone (PVP) with an average molecular weight of ~360,000 g/mol and absolute ethanol were obtained from Sigma-Aldrich Chemicals. The precursor solution was prepared by dissolving the PVP in ethanol to form a homogeneous solution with polymer concentration of 10 wt%. Then, EBN powder was added to the PVP solution at various EBN:PVP weight ratios of 10:90, 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20, 90:10, and 100:0.

2.2 Electrospinning Process

Nanofiber were produced using an electrospinning machine (ILMI-N101 Electrospinning, Indonesia), as shown in Figure 1. The precursor solution was dispensed using a syringe pump at a constant flow rate of 0.8 mL h^{-1}. A high voltage power supply was connected to the syringe needle which will draw the solution jet toward a grounded plate collector, forming fine nanofibers. The fabrication process was conducted at a constant temperature of 26 C and relative humidity of 55%. Some parameters were varied for the electrospinning process, including the EBN ratio in the precursor solution, working voltage, and collector distance.

2.3 Nanofiber's Characterization

The morphology and diameter of the nanofibers were analyzed using Scanning Electron Microscopy (SEM, SU3500). The diameter distribution was determined from SEM images using ImageJ software (National Institutes of Health, Bethesda, MD, USA) [23]. The functional groups of EBN/PVP nanofiber samples was investigated using Fourier Transform Infrared Spectroscopy (FTIR, Bruker, Alpha Platinum ATR A220/D-01) in wave number range of 500 to 4500 cm^{-1}. Thermal characterization was also performed to determine the thermal stability of the nanofiber samples using thermogravimetric and differential thermal analysis (TG/DTA, STA7300, Hitachi). The TG/DTA measurements were performed using the temperature range of 30 C to 600 C, and heating rate of 10 C/min. The statistical analysis was also performed to the samples using Tukey's one-way ANOVA with $p < 0.05$ [24]. Minitab software version 17 (Minitab, LLC, State College, PA, USA) was used for this statistical analysis.

3. RESULTS AND DISCUSSION

3.1 Spinnability of Precursor Solution with Various EBN/PVP Ratio

To evaluate the spinnability of the precursor solutions, various weight ratios of EBN to PVP were prepared. The precursor solutions were prepared with various EBN:PVP weight ratios of 10:90, 20:80, 30:70, 40:60, 50:50, 60:40, 70:30, 80:20, 90:10, 100:0. Each solution was processed at a constant voltage of 15 kV, a fixed collector distance of 20 cm, and a constant flow rate of 0.8 mL h^{-1}. The results indicate that smooth, beads free nanofibers were successfully produced from solutions with EBN:PVP ratio of 10:90, to 60:40. The smooth morphology of nanofibers can be obtained by careful selection of the EBN/PVP ratio. It is likely that the ratio between 10:90 and 60:40 provide a favorable balance of the solution conductivity and viscosity for successful electrospinning, resulting in the formation of uniform, defect-free nanofibers.

In contrast, nanofibers were not formed for the EBN:PVP ratio of 70:30, 80:20, 90:10, 100:0. This suggests that EBN alone lacks sufficient electrospinnability and must be blended with polymeric additives such as PVP. The inability to form fibers at higher EBN content may be attributed to excessive solution viscosity, which impedes the electrospinning process [10]. Since maximizing the functional benefits of EBN is essential, nanofiber samples with the highest EBN content were selected for further optimization of electrospinning process parameters. Accordingly, the EBN:PVP ratio of 60:40 was chosen as the precursor formulation for subsequent optimization studies.

3.2 Effect of Process Parameters on the Nanofibers Diameter

The diameter of nanofibers produced by electrospinning is highly dependent on the electrospinning voltage. Figure 2 shows the morphology and diameter distribution of EBN/PVP nanofibers (EBN:PVP ratio of 60:40) obtained from various electrospinning voltages at constant solution flow rate of 0.8 mL h^{-1}, and a needle-to-collector distance of 20 cm. Generally, as the voltage increases, the average diameter of the nanofiber decreases as indicated by Figure 3. Statistical analysis using Tukey's test, represented by different alphabetical groupings, further confirms the significant differences in fiber diameters obtained at varying electrospinning voltages.

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