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Vitamin E-loaded silk fibroin nanofibrous mats fabricated by green process for skin care application

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ABSTRACT

In the present study, we reported fabrication and skin benefit of a novel vitamin E (VE)-loaded silk fibroin (SF) nanofibrous mats. *RRR*-α-Tocopherol polyethylene glycol 1000 succinate (VE TPGS), a water-soluble derivative of VE, was incorporated into SF nanofiber successfully by aqua solution electrospinning for the first time. Morphology of the composite nanofibers changed with the different amount of VE TPGS: a ribbon-like shape for lower loading dose of VE TPGS, while a round shape for higher loading dose (more than 4% (wt/wt) based on the weight of SF). After treated with 75% (v/v) ethanol vapor, the composite nanofibrous mats showed an excellent water-resistant ability. *In vitro* study disclosed a sustained release behavior of VE TPGS disassociated from the nanofibrous mats. The mouse skin fibroblasts (L929 cells) cultured on the VE-loaded SF nanofibrous mats spread and proliferated much better than on cover slips. Moreover, the incorporation of VE TPGS was found strengthening the ability of SF nanofibrous mats on protecting the cells against oxidation stress induced by *tert*-butyl hydroperoxide. Our data presented impressive skin benefits of this VE-loaded SF nanofibrous mats, suggesting a promising applicative potential of this novel product on personal skin care, tissue regeneration and other related area.

1. Introduction

Interfacing with the environment, the skin is a target organ for pollution, ultraviolet radiation and other damage, which lead to skin aging and disorders. α-tocopherol (Vitamin E, VE) is demonstrated to have a dual role as an antioxidant and a stabilizing agent in biological membranes [1]. Whether taken orally or topically, studies suggested that VE has anti-tumorigenic, photoprotective, and skin barrier stabilizing properties, which makes VE a commonly used ingredient for skin care products [2]. While almost all forms of VE are fat-soluble, and require the presence of bile salts for absorption, some researchers suggested that a water-soluble form of VE is a better option for individuals who have difficulties in absorbing fat-soluble VE forms [3,4]. *RRR*-α-Tocopherol polyethylene glycol 1000 succinate (VE TPGS), a water-soluble derivative of VE, is prepared by ester linkage onto the end of α-tocopherol succinate, and has been documented has good safety [5–8]. VE TPGS has proved to be intracellularly hydrolyzed releasing α-tocopherol after crossing cell membranes, thus finding applications in personal care and cosmetic products [6,7].

As well as VE, Silk fibroin (SF) from *Bombyx mori* is also favored by skin tissues and has been widely used as an additive to cosmetics [9–12]. SF is beneficial to biosynthesis of collagen, re-epithelializing, wound healing, and helps to alleviate atopic dermatitis and eliminate scarring [10–12]. Moreover, SF is able to maintain aqueous environment for skin, which is extremely important for skin tissues [13,14]. SF is also an excellent biopolymer with diverse properties such as good biocompatibility, blood compatibility, good oxygen and water permeability, biodegradability and minimal inflammatory reaction [15,16]. Recently, electrospun SF nanofibers have been widely applied in tissue engineering, wound healing and drug delivery [17–19]. However, few investigation reported on the benefit of SF nanofibrous mats used in the field of cosmetics. One of the obvious advantages of nanofibrous skin care product is the very small interstices and high surface area which allows nutrients to transfer to the skin tissue much more efficiently [20,21]. Therefore, we hypothesize that vitamin-loaded SF nanofibers could be more powerful for skin care and skin regeneration.

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In our previous study, we successfully fabricated vitamin C-loaded SF nanofibrous mats which showed great beneficial to skin cells [22]. Here, we reported a novel SF nanofibrous mats containing VE TPGS fabricated by the similar eco-friendly electrospinning process as used before [22,23]. The morphology and structure of nanofibrous mats were investigated using scanning electronic microscope (SEM), and the disassociation of VE from SF nanofibrous mats was determined with UV spectrophotometer. The skin benefits of the VE-loaded SF nanofibrous mats were tested using 3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyl tetrazolium bromide (MTT) assay and an oxidative injury model *in vitro*. The present work provided a basis for further studies or practical applications of this novel nanofibrous mats in skin care, wound healing and skin regeneration.

2. Experimental

2.1. Materials

Cocoons of *B. mori* silkworm were kindly supplied by Jiaxing Silk Co. (China). VE TPGS was purchased from Eurochem Asia Limited, each gram of VE TPGS contains VE 387 IU (260 mg), and *tert*-butyl hydroperoxide (*t*-BHP) were purchased from Sigma–Aldrich China Inc. L929 cells were provided by Institute of Biochemistry and Cell

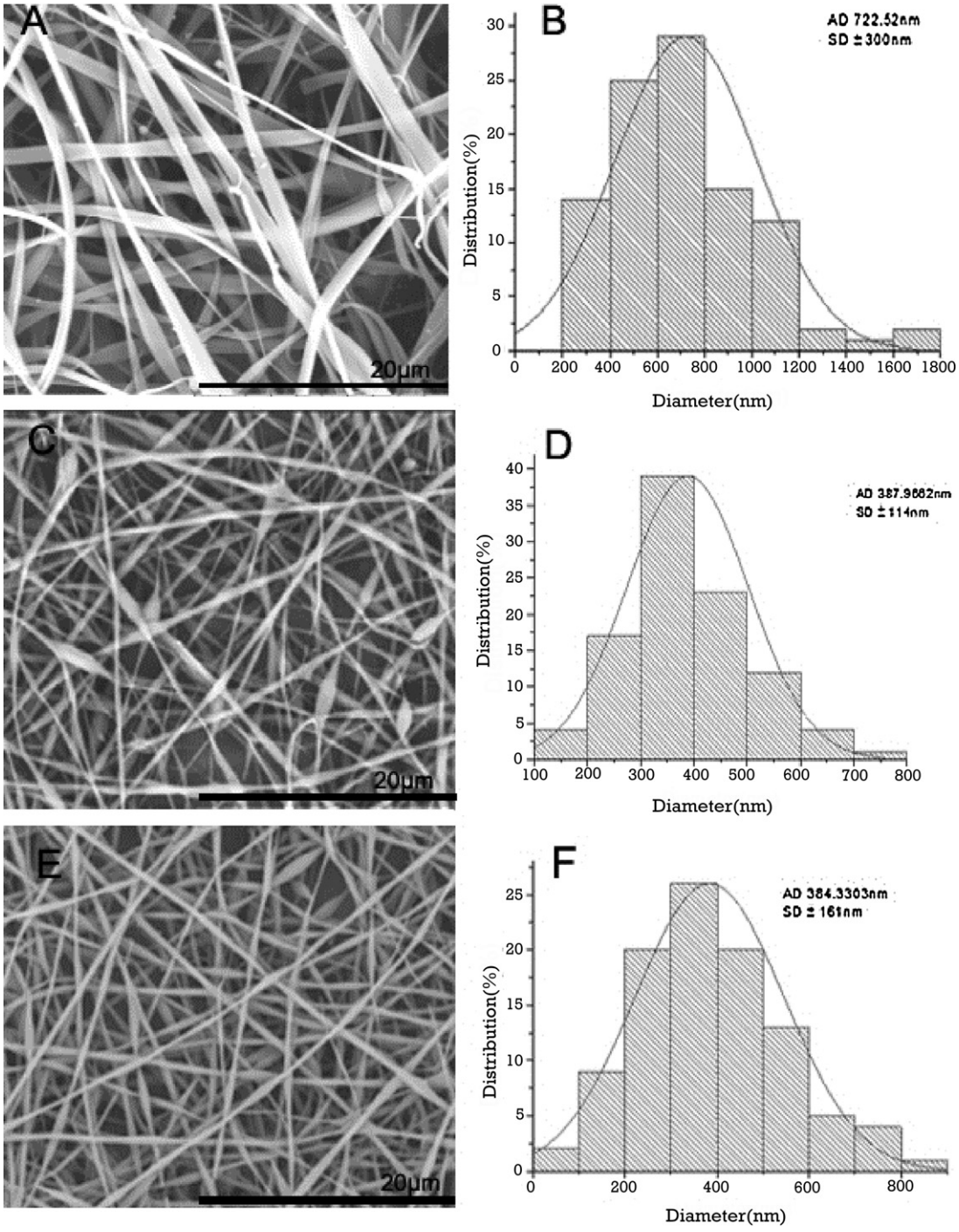

Fig. 1. SEM images (5000×) and diameter histograms of the VE-loaded nanofibers. A and B: SF/VE (2%); C and D: SF/VE (4%); E and F: SF/VE (8%).