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Effect of clay content on morphology and processability of electrospun keratin/poly(lactic acid) nanofiber

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ABSTRACT

This research work has concerned the development of volatile organic compounds (VOCs) removal filters from biomaterials, based on keratin extracted from chicken feather waste and poly(lactic acid) (PLA) (50/50%w/w) blend. Clay (Na-montmorillonite) was also added to the blend solution prior to carrying out an electro-spinning process. The aim of this study was to investigate the effect of clay content on viscosity, conductivity, and morphology of the electrospun fibers. Scanning electron micrographs showed that smooth and bead-free fibers were obtained when clay content used was below 2 pph. XRD patterns of the electrospun fibers indicated that the clay was intercalated and exfoliated within the polymers matrix. Percentage crystallinity of keratin in the blend increased after adding the clay, as evidenced from FTIR spectra and DSC thermograms. Transmission electron micrographs revealed a kind of core-shell structure with clay being predominately resided within the keratin rich shell and at the interfacial region. Filtration performance of the electrospun keratin/PLA fibers, described in terms of pressure drop and its capability of removing methylene blue, were also explored. Overall, our results demonstrated that it was possible to improve process-ability, morphology and filtration efficiency of the electrospun keratin fibers by adding a suitable amount of clay.

1. Introduction

The report from Barbut [1] revealed that over 3600 million tons of chicken feathers have been plucked each year around the globe and the chicken feathers waste has been disposed or used as animal feed. In order to utilize feather waste more effectively, extraction of valuable chemicals from the waste and further development of novel products from the chemicals deserve a consideration. Keratin is known to be the main component of chicken feathers. It is biodegradable, biocompatible, well adhered to cell, high polar and highly chemical reactive. Consequently, keratin has been used as a raw material to produce scaffolds for biomaterial applications [2–4] and filters for removal of heavy metals and some volatile organic compounds [5–7]. In the latter case, a kind of porous filter can be prepared by several techniques, including drawing [8]. template synthesis [9], phase separation [10], self-assembly [11] and electrospinning [12]. The electrospinning process is considered interesting and attractive due to the fact that the fabrication process is continuous and can be scaled up [12]. However, the fabrication of keratin nanofibers via an electrospinning process is difficult because of its inherent low molecular weight and low viscosity [2–4,13].

In general, the process-ability of low molecular weight proteins, such as gelatin [14,15] and collagen [16], can be improved by blending with high molecular weight polymers such as poly(vinyl alcohol) [17], polyamide 6 [18,19] and poly(ethylene oxide). Although there are several types of polymers which can be used to improve the electrospinning process-ability of protein nanofibers, poly(lactic acid) (PLA) is considered attractive for this purpose due to its good biodegradability [2,13,20].

Our previous work concerning a study on the effect of electrospinning parameters on morphology of keratin/PLA blend [13] suggested that the optimum conditions for preparing a smooth

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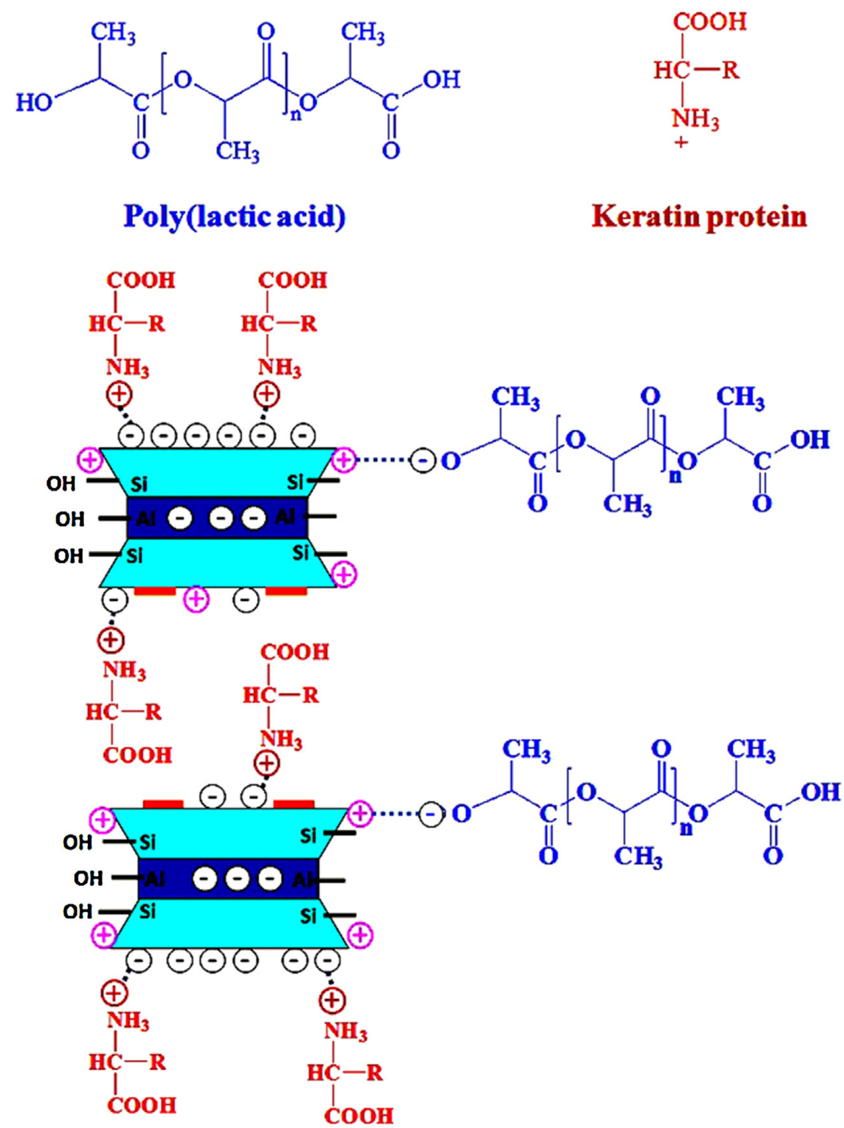

Scheme 1. Schematic illustration of interactions between keratin/clay and PLA/clay inside the blend solutions.

and bead-free nanofiber mat was the addition of of 50%w/w PLA and spin at the voltage of 19 kV. However, a work by Li, et al. [20] revealed that the keratin/PLA blend (50/50%w/w) was incompatible. This was probably due to different hydrophilicity of the two polymers.

In order to enhance a compatibility between PLA and keratin, the use of clay as a compatibilizer is interesting and worth exploring. This is due to the fact that clay has large surface area, high surface reactivity, and high ion exchange capacity [21–23]. In general, there are different types of clays available including montmorillonite (MMT), illite and kaolinite. It contains different binding sites. MMT, for example, has higher binding sites than the other two. This is because MMT has both interlayer and external surface sites, while illite and kaolinite contain only external surface, without expanding layers [24–26]. Consequently, the incorporation of MMT into protein fibers could improve physical properties of some protein such as silk fibroin [21,23]. The above effect is attributed to the interaction between hydrophilic octahedral surface of clay and positive ion of amino groups of proteins. In relation to our present study, it is of interest to explore a feasibility of using clay to enhance compatibility and process-ability of keratin/PLA blend (Scheme 1). To the best of our knowledge, the adding clay to improved electrospinning process, and a study on preparation and characterization of keratin/PLA blend compatibilized with clay have not been reported in any open literatures.

The aim of this work was to investigate the effects of clay content on viscosity, conductivity, microstructure and morphology of the electrospun keratin/PLA nanofiber mats. Performance of filters based on the various electrtospun nanofibers, described in terms of pressure drop and its capability of removing an organic compound, were also of our interest.

2. Experimental

2.1. Materials and chemicals

Chicken feathers waste was obtained from Better Foods Co., Ltd. (Thailand). PLA (2002D) from Nature Works LLC was supplied from the Fresh Bag Co., Ltd. Montmorillonite clay Cloisite Na^+ was supplied from Southern Clay Products (Gonzales, TX). Formic acid (analysis grade) was purchased from Merck Co., Ltd. Chloroform (analysis grade) was supplied from RCI Labscan, and acetone (laboratory grade) was supplied from Siam Beta Group Co., Ltd.