Rice Straw Extracted Cellulose Biocompatible Nanofiber

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ABSTRACT

This article focuses on the electrospinning of nanofibers from rice straw as a renewable, cheap natural resource. To facilitate the formation of cellulose nanofiber, PVA was utilized as a secondary plasticizing polymer. The polymer solution contained 75% w/w cellulose and 25% w/w PVA using water/formic acid solvent resulting in 8% w/w solid content was successfully prepared as spinning solution. According to SEM images, temperature and voltage have significant impact in producing continuous cellulose nanofibers without beads. A microscopic observation reveals the formation of nanofiber with an average diameter of 177 ± 25 nm. This narrow diameter distribution is a direct outcome of temperature, voltage, volumetric flow rate and tip to collector distance adjustment respectively on 60, 25 kv, 1 µl/hr and 10 cm. The biocompatibility tests using human skin fibroblast cell culture demonstrate the nontoxicity of cellulose nanofiber scaffold compared to a control sample.

KEYWORDS

Biocompatibility, Cellulose Nanofiber, Electrospinning, Rice Straw

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1. INTRODUCTION

Cellulose with an approximate annual natural production of $1.5 \times 10^{12}$ tons is the most abundant biopolymer in the world. Cellulose is mainly accessible in lignocellulosic resources such as wheat, rice, maize and soybeans. In the last 50 years, a great deal of studies has been carried out to use straw as an cellulosic by-product from crop production (Luo & Zhang, 2011; Wu et al., 2010). Rice straw with annual production of 731 million ton is the largest cereal crop in the world. It represents around 45% of the volume in rice production, as the largest quantity of crop residue. In terms of total production, rice is the third most important grain crop in the world behind wheat and corn (Binod et al., 2010; Ranjan & Moholkar, 2011). Rice straw contain about (32-47)% cellulose, (19-27)% hemicellulose and (5-24)% lignin (Karimi, Kheradmandinia, & Taherzadeh, 2006; Lu & Hsieh, 2012). Some of these waste lignocellulosic sources such as pine, vine, bamboo linen, jute, hemp, ramie, abaka, sisal, bagase, wheat straw rice husk and straw have diverse cellulose, hemicellulose, and lignin and wax content. These extracted cellulose fiber has been proposed to use in energy and fuel (Gomez et al., Mabee, McFarlane, & Saddler, 2011; Yousef, 2012), chemical materials (Conde et al., 2011; Dhillon et al., 2011), construction and biocomposites (Jarabo et al., 2012; Nourbakhsh & Ashori, 2010; Sahoo, Misra, & Mohanty, 2011).

Cellulose is a linear syndiotactic homopolymer containing β-(1-4)-Glycoside linked to D-anhydroglucopyranose units. Until now various studies have been done for extraction of cellulose microfiber and nanofiber through some renewable lignocellulosic resources and also several methods such as mechanical extraction (Abe & Yano, 2010; Jonoobi, Mathew, & Oksman, 2012) enzyme and biological techniques (Henriksson & Henriksson, 2007) chemical/mechanical extractions (Alemdar & Sain, 2008), high pressure homogenizing processes (Nakagaito & Yano, 2008) acid hydrolysis (Liu & Liu, 2010) steam explosion (Chen et al., 2011) high-intensity ultrasonication (Wang & Cheng, 2009) have been presented for this purpose. However, according to literature, ligno cellullosic sources and the extraction method is effective on nanofiber and microfiber morphology (Khalil, Bhat, & Yusra, 2012). In the cell walls, the cellulose chains fix together by hydrogen bonds to form microfibrils of several nanometers in diameter and millimeters in length. These crystalline microfibrils have major effect on high tensile and mechanical strength of the straw cell walls. These microfibrillar biocomposites fixes by a gel matrix collected from hemicellulose, lignin and other carbohydrate polymers. However, the difficulties arise for cellulose microfiber extracting from rice straw are due to the strong crystalline structure of cellulose and the presence of a complex structure of lignin and hemicellulose within cellulose. Thus, various methods have been examined to break up the structure of cellulose (Chen et al., 2011; Liu et al., 2006). Alkaline extraction is an effective and biocompatible method for destroying the cell walls which gradually remove the hemicellulose, lignin and silica. This reaction is caused to break of lignin’s and hemicellulose’s α- ethery and α- estery bonds (Wissel, Mayr, & Lücke, 2008). Steam explosion method using the acetic acid in high temperaturet leads to hydrolysis of the acethyle groups and glycoside bonds of hemicellulose and lignin’s ether bonds (Chen et al., 2011). The ultrasonic process is another efficient technique to extract low molecular weight cellulose with high purity and crystalinity. Cellulose nanofibers have gained importance due to their unique characteristics such as very large surface to volume ratio, high surface area, good mechanical properties including a high Young’s modulus, high tensile strength and a very low coefficient of thermal expansion, highly porous mesh as compared to other commercial fibers. Functional hydroxyl groups in cellulose also enable chemical modifications for further applications (Kaushik & Singh, 2011). Electrospinning has become one of the most effective modern methods of nanofibre production, which uses electric power to produce various polymer fibers with dimeter about 5 nm (Tan et al., 2005) to micrometers (Ahn, 2012). In electrospeining process, a strong electric field is applied on a droplet of polymer solution (or melt) held by its surface tension at the tip of a syringe’s needle (or a capillary tube). As a result, the pendent drop will become highly electrified and the induced charges distributes over its surface. Increasing the intensity of electric field, the surface of the liquid drop distorts to a conical shape.
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