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Bacterial synthesized cellulose nanofibers; Effects of growth times and culture mediums on the structural characteristics

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ABSTRACT

In this study the effects of growth times and culture mediums on the structural characteristics of bacterial cellulose have been investigated. Bacterial cellulose (BC) nanofibers were synthesized by *Gluconacetobacter xylinus*. BC pellicles were compared using SEM, FT-IR and X-ray diffraction techniques. The crystallinity index (CrI) and crystallite size (CrS) were calculated based on X-ray measurements. Three growth times (7, 14 and 21 days) and three culture mediums (A, B and C) were applied. SEM micrographs showed that increasing growth time up to 7 days improves the microfibril branches crossing to each other and the number of bundles. However, further increase in growth time (21 days) results in decrease in the microfibril network. On the other hand the hydrogen and C–H bonds were developed by the increase in growth time. In conclusion, BC synthesized in medium B for 7 days had superior properties in terms of CrI, CrS and microfibril networks.

1. Introduction

Cellulose, the most abundant biopolymer in nature, can be synthesized by plants, some animals and a large number of microorganisms (Castro et al., 2011; Czaja, Romanovicz, & Malcolm Brown, 2004). It is composed of glucose monomers connected by β(1–4) glycosidic linkages, and its chemical formula is $(C_6H_{10}O_5)_n$. Cellulose forms the basic structural matrix of cell walls in almost all plants, in many fungi, and in some types of algae. However, this form of cellulose contains many impurities, including hemicellulose and lignin, and therefore, harsh chemical treatments are required to remove these impurities. Chemical treatments result in irreversible changes in cellulose structure, which permanently strip the polymer of its useful characteristics. Plant-derived cellulose has been important in the production of paper and wood-based products. However, the increasing demand for natural cellulose and thus increased consumption of wood as raw material of cellulose, are causing deforestation and creating global environmental issues (Park, Park, & Jung, 2003).

In recent years, a great deal of interest has been created worldwide on the production of cellulose by using a new process (biotechnology technique) that reduces the environmental impact to a minimum. Studies suggest that bacterial cellulose or biocellulose (BC) may be a better choice for manufacturing cellulose products (Castro et al., 2011; Keshk, Razek, & Sameshima, 2006; Nakagaito, Nogi, & Yano, 2010; Pourramezan, Roayaei, & Qezelbash, 2009). It has a chemical structure similar to the cellulose, where hydroxyl functional groups exist (Fig. 1).

Bacterial cellulose, an exopolysaccharide, is produced by many species of bacteria, such as those in the genera of *Acetobacter*, *Agrobacterium*, *Achromobacter*, *Aerobacter*, *Azotobacter*, *Sarcina ventriculi*, *Salmonella*, *Escherichia* and *Rhizobium* (Moosavi-Nasab & Yousefi, 2011; Sani & Dahman, 2010). The structural features of bacterial cellulose are influenced by the kind of bacterial strain (Table 1). Among the mentioned genera, *Gluconacetobacter xylinus* (formerly *Acetobacter xylinum*) is one of the most commonly used/studied sources of bacterial cellulose (Keshk et al., 2006; Nguyen, Gidley, & Dykes, 2008). It was also reported as the most efficient producer (El-Saied, Basta, & Gobran, 2004). This is a gram-negative bacterium, strictly aerobic, capable of producing cellulose extracellularly at temperatures between 25 and 30 °C and pH from 3 to 7, using glucose, fructose, sucrose, mannitol, among others, as carbon sources (Castro et al., 2011).

In terms of chemical structure, bacterial cellulose is identical to that produced by plants. However, it exhibits higher crystallinity (Nakagaito et al., 2010), water-holding capacity (Saibuatong & Phisalaphong, 2010), degree of polymerization (Dahman, Jayasuriya, & Kalis, 2010), and mechanical strength and

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