Chapter 12
Bacterial Cellulose: Biosyntheses, Modifications, and Applications

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ABSTRACT

Bacterial cellulose, synthesized by bacteria, is one of the most highly pure cellulose sources. It has gained a great attention due to its unique properties. With molecular similarity to cellulose derived from plants, bacterial cellulose can be modified based on diverse techniques established for the plant-derived cellulose. Modification of cellulose has become one of the major areas of cellulose research to provide cellulose-based materials with novel properties. The progress in cellulose science has also opened up more potentials for bacterial cellulose. This chapter describes an overview of biosyntheses, modifications, and applications of bacterial cellulose.

INTRODUCTION

Cellulose, a straight chained polymer of β-(1,4)-linked D-glucose units, is the most abundant biopolymer on earth. It plays an important role in contributing to the high strength of plant cell wall. Sources of plant-derived cellulose include wood, cotton, tunicate, and algae. To obtain pure cellulose from the plant-derived cellulose, other bio-polymeric components, e.g. lignin and hemicellulose, are required to be removed by bleaching with toxic chemicals (Klemm et al., 2005). One environmentally-friendly approach to obtain pure cellulose is utilizing biosynthesis by bacteria.

Bacterial or microbial cellulose is obtained by extracellular secretion of single chains of cellulose from a certain type of bacteria genera such as:

Among those bacteria, *Acetobacter xylinus* (currently called *Gluconacetobacter xylinus*) appears to be the most-studied cellulose-producing bacterium due to its capability of greater cellulose production from multiple carbon and nitrogen sources (Iguchi et al., 2000a). Single chains of cellulose are polymerized by cellulose synthases using glucose as the monomer, and then extruded as glucan chains through the bacterial cell wall. The glucan chains assemble into a bundle, ribbon, and nanofiber (Ross et al., 1991). The 3-dimensional structure of nanofibers is then formed by inter- and intra- hydrogen bonds with a number of hydroxyl groups bound with water.

The bacterial cellulose exhibits the same chemical structure of linear β-1,4-glucan chains as those found in plant cellulosics, but has very different properties from those of the plant-derived cellulose. For instance, it possesses a high crystallinity, a nano-sized fiber network with high porosity and surface area, a high mechanical strength, a great liquid absorption capacity, and an excellent flexibility for fabricating into various sizes and shapes (Czaja et al., 2006). Moreover, it shows outstanding biological characteristics and good biocompatibility owing to the complex network imitating the natural extracellular matrix (ECM). Unlike plant-derived cellulosics, bacterial cellulose is free of lignin and hemicellulose, which need to be eliminated by treatment with toxic chemicals. This suggests that some high pollution generations in steps of pulping and bleaching cellulose contained in plants can be removed. Techniques from the genetic and engineering viewpoints have been investigated by researchers to enhance cellulose production from the natural habitats to lab- and mass-scale production (Shoda & Sugano, 2005). In addition, to overcome some limitations and achieve other properties of the native cellulose for perspective applications, modifications such as turning surface properties or introducing additives to alter the bulk properties during or after cellulose biosynthesis can be performed.

**BACKGROUND**

It has been over a century since bacterial cellulose was discovered by Adrian J. Brown in 1886. He originally observed jelly-like translucent mass formed by *Bacterium aceti* or *Acetobacter xylinus* on the surface of “vinegar plant” or acetic ferment liquid. That polysaccharide mass was found to chemically behave the same as cellulose (Brown, 1886). In 1949, K. Muhlethaler studied the structure of bacterial cellulose by means of electron microscopy (Mühlthaler, 1949). He found that the acetic bacteria could secret cellulose fibers having an approximate diameter of 250 Å within the slime. On the basis of its high purity and unique physicochemical properties that are different from those of plant-derived cellulosics, bacterial cellulose becomes attractive to researchers. For the past 20 years, over 4,000 publications relating to the investigation on improving cellulose production from different microbial strains, developing large-scale production, and modifying bacterial cellulose for food, medical, and biotechnological appli-