8

Potential Differences of Plant Nanocellulose and Bacterial Nanocellulose in Water Purification

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CONTENTS

8.1 Introduction

Cellulose is an abundant raw material used for a variety of biocompatible products. The chirality, biodegradability, hydrophilicity, high chemical-modifying capacity, and multipurpose semi-crystalline fiber morphologies are of greater importance for using cellulose in omnipresent environment-friendly applications. Cellulose is the main fundamental building block of plant, algal, and some bacterial cell walls. The microfibrillar arrangement of cellulose strengthens the cell wall and controls the cell growth [1]. Crystallite shape, nanometric size, and crystallinity are important physical features of cellulose microfibrils that help maintain the cell's physical stability. The chemical structure of these microfibrils is made up of linear chains of glucose units linked by β-1,4-glycosidic bonds. Two crystalline phases of cellulose with similar conformations are cellulose Iα and Iβ. The crystal structures of these two phases are different from each other. In cellulose Iα, triclinic unit cells are present, wherein cellulose Iβ monoclinic unit cells are present. The proportion between Iα and Iβ is different among different groups of organisms. The cell walls of higher plant cells contain a high percentage of Iβ monoclinic unit cells, and the cell walls of algal and bacteria cells have a high percentage of Iα. Cellulose is the starting material for nanocellulose [2].

The nanoscale cellulose fibers are attained by separating the microfibrils from a cellulosic material. These raw cellulosic materials are obtained from various substances, such as trees, algae, plant-based waste materials, and some bacteria, and are known as nanocellulose. The nanoscale cellulose fibers contain many hydroxyl groups as a structural component, resulting in their high hydrophilicity [3]. There are three main types of nanocellulose materials: Cellulose nanofibers (CNFs), cellulose nanocrystals (CNCs), and bacterial nanocellulose (BC). The nanofibrillated cellulose (NFCs) and CNCs are plant-based nanocelluloses. The preparation method of these three types of nanocellulose differs from each other. High-pressure homogenization, grinding, and chemical or enzymatic treatment are used for the isolation of NFCs. However, CNFs are produced using low-impact fiber separation techniques compared to those used in preparing NFCs. Physical separation of cellulose fibers, such as grinding, homogenization, and ultrasonication, is the major method for producing CNFs [4–6]. *Acetobacter*, *Rhizobium*, *Agrobacterium*, *Aerobacter*, *Achromobacter*, *Azotobacter*, *Salmonella*, *Escherichia*, and *Sarcina* are the major bacterial genera used in preparing BCs [7].

Wide applicability of nanocellulose-based raw materials in many fields is due to their biocompatibility, mechanical strength, renewability, and low cost of preparation. These nanocelluloses are applied as raw materials in bio-composites, pharmaceuticals, tissue engineering, bio-sensing, and pollution remediation. This chapter reviews the applicability of plant nanocellulose and BC in water purification. Further, it focuses on the prospects and potential improvements incorporated into nanocellulose-based water purification.

8.2 Plant Nanocellulose

Plant nanocellulose is the cellulosic material extracted from plant fibers. Natural plant cellulose microfibrils contain well-arranged crystalline portions and some disorganized amorphous portions. The proportions of crystalline and amorphous portions are variable among different groups of plants. When nanocellulose is extracted, mechanical, chemical, and enzyme treatments are applied to separate these cellulose microfibrils. The plant nanocellulose extraction involves several steps. Among them, the first step is the pretreatment process to remove lignin and hemicellulose. There are two pretreatment methods: Alkali treatment and acid chlorite treatment. In alkali treatment, alkali reagents such as sodium hydroxide or potassium hydroxide are used to remove the amorphous portion of hemicelluloses and lignin from the cellulosic fibers. The acid chlorite treatment is a delignification process used to remove lignin from the lignified cellulose. After the pretreatment process, the isolation of nanocellulose is done by either acid hydrolysis, enzymatic hydrolysis, or mechanical treatment processes. The detailed process of plant nanocellulose extraction is given in Fig. 8.1.

There are two types of plant nanocelluloses, i.e., CNF and CNC.

8.2.1 Cellulose Nanofibers (CNFs)

Synonyms for CNFs are micro-fibrillated cellulose (MFC), nanofibrils, micro-fibrils, and NFCs. These are extracted using mechanical treatment process, and pretreatment process can be present or absent depending on the source of cellulose. CNFs are three-dimensional (3D) structures made up of very long and ultrathin nanofibril structures. The arrangement of the fibrils provides a high aspect ratio for NFC. The high strength and high water-holding capacity of NFC compared to other types of nanocellulose are provided by this fibrils arrangement [8]. CNFs have a larger particle size compared to CNCs. The microscopic structure of NFCs consists of a complex, highly entangled, web-like structure with twisted/untwisted, curled/straight, and entangled/separate bundles of nanofibrils [9].

8.2.2 Cellulose Nanocrystals (CNCs)

CNCs are also known as crystallites, whiskers, rod-like cellulose, and microcrystals. The acid hydrolysis of cellulose microfibers digests the amorphous regions, and the crystalline regions are separated to form CNCs [10]. These are stiff rod-like structures and of lower viscosity, lower yield strength, and lower water-holding capacity than NFCs [11].