CHAPTER 5
Conversion of Lignocellulosic Biomass to Nanocellulose

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5.1 INTRODUCTION

Nanocellulose can be extracted from biomass, which is defined as any organic substance derived from plants or animals (Autet, 2022). Lignocellulosic biomass is the most affordable, highly sustainable, and renewable natural resource in the world, which is produced at a rate of around 1.3×10^{10} metric tonnes per year. Examples of lignocellulosic biomass include (1) Agricultural wastes like palm trunks and empty fruit bunches, wheat straw, corn stover, corncobs, sugarcane bagasse, wheat rice, and coconut husks, (2) Forest wastes like softwood and hardwood, (3) Energy crops like switch grass, (4) Food wastes, and (5) Industrial and municipal wastes like demolition wood and waste paper (Lee et al., 2014). Lignocellulosic biomass has a complex biopolymer cell wall structure made primarily of cellulose, hemicellulose, and lignin (Phanthong et al., 2018; Langan et al., 2014). The chemical composition of these three constituents varies by type, species, age, and origins of biomass (Agbor et al., 2011; Langan et al., 2014; Phanthong et al., 2018). The inherent nature of the entangled biomass ultrastructure, including tough lignin layers, high lignin content, cellulose coating by hemicellulose, high cellulose crystallinity, low cellulose accessibility to chemicals, and strong fibre strength, preclude the biomass from being digested for cellulose extraction (Lee et al., 2014; Agbor et al., 2011; Langan et al., 2014). This scenario presents both challenges and opportunities for the development of biomass bio-refineries that utilise the cellulose from biomass. To ensure the breakdown of non-cellulosic components in biomass while retaining cellulose for subsequent hydrolysis into nanocellulose, multiple-stage bio-refinery methods are necessary (Lee et al., 2014).

Generally, there are two stages involved in the extraction of nanocellulose from biomass: (1) Pre-treatment of the biomass and (2) Nanocellulose isolation from cellulose (Autet, 2022). In order to preserve the cellulose fibres for subsequent isolation of nanocellulose, the pre-treatment of biomass is an important step that reduces fibre size, cleans the fibre, removes various non-cellulosic substances such pectin, ashes, waxes, extractives, lignin, hemicellulose, and other substances (Shrestha et al., 2021; Gupta & Shukla 2020). The pre-treatment techniques for the biomass are (1) Physical treatment, including milling, clipping, grinding, ultrasonic, irradiation, and heat treatment; (2) Chemical treatment, including acid or alkali hydrolysis, solubilisation, distillation, organosolv, and solvent extraction; (3) Biological treatment using degrading enzyme generating from bacteria and fungi; and (4) Combine/hybrid techniques (Amin et al., 2017; Shrestha et al., 2021; Anukam & Berghel, 2020). Then, nanocellulose can be extrated from the cellulose fibre using a variety of techniques, for example, mechanical process, acid hydrolysis, and enzymatic hydrolysis (Phanthong et al., 2018). The type, composition, dimensions, and characteristics of the produced nanocellulose for various applications are mostly influenced by the extraction techniques (Pradhan et al., 2022; Peng et al., 2011) and also the chemical composition of biomass (Shesan et al., 2019).

Developing sustainable and financially viable methods to synthesise nanocellulose is one of the core components in accomplishing the wide applications of nanocellulose (Song et al., 2018). The use of biomass-derived nanocellulose extract in the production of several sustainable and renewable goods has attracted a lot of interest. Cellulose Nanocrystals (CNC), cellulose Nanofibre (CNF), and Bacterial Nanocellulose (BNC) are the three different forms of nanocellulose that can be categorised (Nasir et al., 2017). Bacteria produce BNC from low molecular weight carbohydrates through the processes of polymerisation and crystallisation from the bottom-up method (Nasir et al., 2017; Abol-Fotouh et al., 2020). On the contrary, the top-bottom method is used to produce CNC and CNF. Although both CNC and CNF are comprised of cellulose, they differ from one another in terms of crystallinity, morphology, size, strength, composition, and other characteristics (Thompson et al., 2019; Phanthong et al., 2018), which ultimately determine their suitability for particular applications. CNC can be applied as a reinforcing agent in nanocomposites, as well as in the biomedical and healthcare sectors, constructions, electrical and electronic, food packaging, paints, coatings, and inks for 3D printing (Santos et al., 2013; Pradhan et al., 2022). Contrarily, CNF has been utilised in a broad range of sectors, including food packaging, tissue engineering scaffolds, regenerative medicine, medication delivery, textiles, catalysis, surface coatings, water treatment, green nanocomposite materials, oilfield servicing fluids, 3D printing inks, etc (Deepa et al., 2015; Pradhan et al., 2022). Thus, this chapter aims to provide a quick overview of the research on nanocellulose, covering extraction techniques, properties, and particular applications. It also provides a forecast for the future. This chapter also intends to review information on the successful extraction of nanocellulose from biomass and its future possible applications.