Carbohydrate Polymers 118 (2015) 165–169

Contents lists available at ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

Short communication

The reuse of wastepaper for the extraction of cellulose nanocrystals

Wan Hazman Danial[a], Zaiton Abdul Majid[a,b,*], Mohd Nazlan Mohd Muhid[a], Sugeng Triwahyono[a,c], Mohd Bakri Bakar[a], Zainab Ramli[a]

[a] *Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia*
[b] *Institute of Environment and Water Resource Management, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia*
[c] *Ibnu Sina Institute for Fundamental Science Studies, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia*

ARTICLE INFO

Article history:
Received 29 April 2014
Received in revised form 12 October 2014
Accepted 27 October 2014
Available online 20 November 2014

Keywords:
Cellulose
Cellulose nanocrystals
Wastepaper
Nanomaterials

ABSTRACT

The study reports on the preparation of cellulose nanocrystals (CNCs) from wastepaper, as an environmental friendly approach of source material, which can be a high availability and low-cost precursor for cellulose nanomaterial processing. Alkali and bleaching treatments were employed for the extraction of cellulose particles followed by controlled-conditions of acid hydrolysis for the isolation of CNCs. Attenuated total reflectance Fourier Transform Infrared (ATR FTIR) spectroscopy was used to analyze the cellulose particles extracted while Transmission electron microscopy images confirmed the presence of CNCs. The diameters of CNCs are in the range of 3–10 nm with a length of 100–300 nm while a crystallinity index of 75.9% was determined from X-ray diffraction analysis. The synthesis of this high aspect ratio of CNCs paves the way toward alternative reuse of wastepaper in the production of CNCs.

1. Introduction

Cellulose, a type of polysaccharides, which is in abundant consists of both crystalline phase and amorphous region. The removal of the amorphous region by acid hydrolysis results in the formation of highly ordered (crystalline) structure, the cellulose nanocrystal (CNCs). Reviews in the field of cellulosic nanomaterial has been reported by Moon, Martini, Nairn, Simonsen, and Youngblood (2011), Lin, Huang, and Dufresne (2012), Klemm et al. (2011) and Azizi Samir, Alloin, and Dufresne (2005). The geometry and characteristic of CNCs made it an ideal material for various potential applications such as in biomedical (Wang & Roman, 2011), gel nanomaterial (Heath & Thielemans, 2010), polymer nanocomposite membrane (Paralikar, Simonsen, & Lombardi, 2008), and polymer electrolyte (Azizi Samir, Alloin, Gorecki, Sanchez, & Dufresne, 2004).

Preparation of CNCs can be achieved through isolation of cellulose particles from many sources such as tunicate (Anglès & Dufresne, 2000), bacteria (Roman & Winter, 2004), ramie (Peresin, Habibi, Zoppe, Pawlak, & Rojas, 2010), sisal (Garcia De Rodriguez, Thielemans, & Dufresne, 2006), cotton (Uddin, Araki, & Gotoh, 2011), *mengkuang* leaves (Sheltami, Abdullah, Ahmad, Dufresne, & Kargarzadeh, 2012) and wood pulps (Dong et al., 2012).

Wastepaper, being a cellulose biomass provides a potential source of raw material for the production of CNCs. Several million tons of paper which are produced and used globally undoubtedly gives rise to a tremendous amount of wastepaper. Despite recycling efforts, wastepaper continues to constitute considerably to the municipal and industrial waste. Recycling of wastepapers results in a lower grade paper due to shortening of the fiber length and the paper quality is far poorer than a paper made from virgin pulps. Since the maximum ratio of paper-to-paper recycling is reported to be 65% (Ikeda, Park, & Okuda, 2006), this results in the production of large quantities of by product which ultimately have to be disposed. With higher cost of producing paper from recycled paper, and disposal of waste fibers unfit for use, finding alternative ways to recycle wastepaper is a necessity. Due to its cellulosic content, wastepaper has the potential as a source material for the production of cellulose nanocrystals (CNCs). The production of CNCs from wastepaper would provide an alternative to paper recycling and possibly address the issue of byproducts arising from paper to paper recycling.

To the best of our knowledge, the use of wastepaper as the raw material for the extraction of CNCs has not been reported. In this work, the extraction of cellulose particles from wastepaper was carried out by subjecting wastepaper to alkali and bleaching treatments followed by controlled-condition of acid hydrolysis for the isolation of CNCs. The aim of the alkali treatments is to ensure

* Corresponding author at: Department of Chemistry, Faculty of Science, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia. Tel.: +60 7 5534129; fax: +60 7 5566162.
E-mail addresses: zaiton@kimia.fs.utm.my, tonmajid@gmail.com (Z. Abdul Majid).

http://dx.doi.org/10.1016/j.carbpol.2014.10.072
0144-8617/

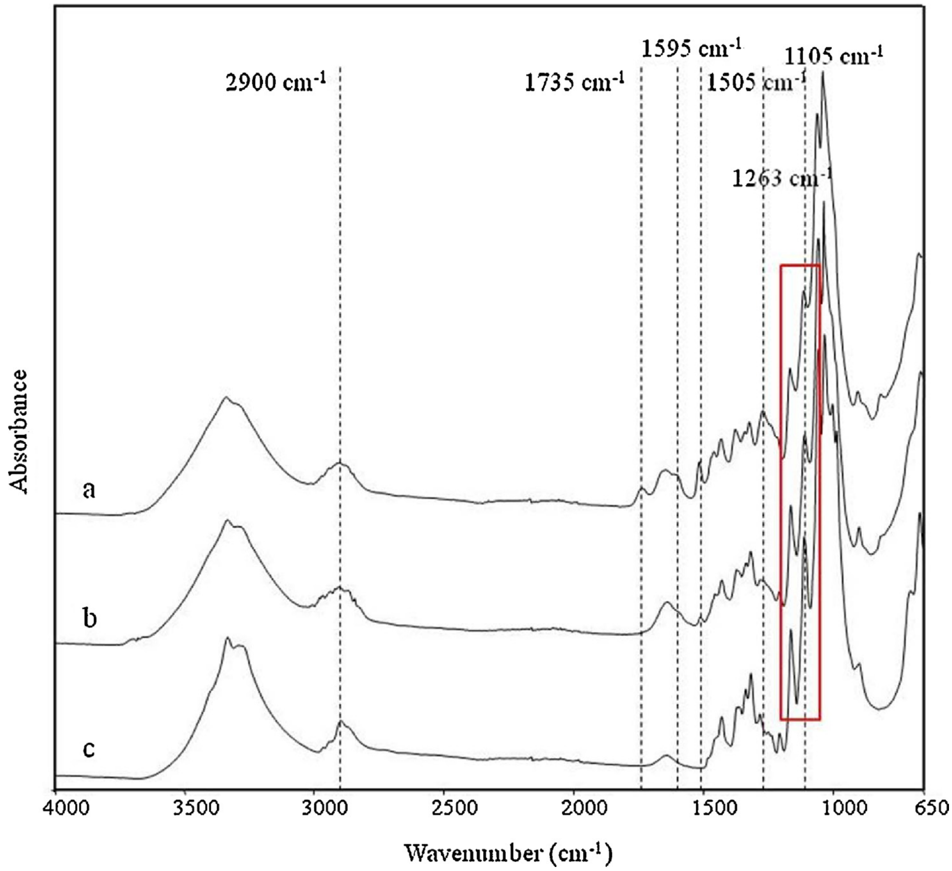

Fig. 1. FTIR spectra of (a) raw wastepaper, (b) treated wastepaper, and (c) pure cellulose.

the hydrolysis of hemicelluloses and removal of undesirable amorphous type polymer components, while the bleaching treatment is primarily aimed at removing lignin (Cherian et al., 2010; Li et al., 2009; Ndazi, Nyahumwa, & Tesha, 2007). Successful treatment will result in the extraction of semicrystalline cellulose particles.

Physical chemical characterizations were carried out by ATR FTIR spectroscopy, scanning electron microscopy (SEM), transmission electron microsopy (TEM), and X-ray diffraction (XRD).

2. Experimental

2.1. Extraction of cellulose particles

The wastepaper used in this work was sourced from old newspaper, cut into small pieces and boiled for more than 12 h, during which distilled water was added periodically. It was then ground to form a slurry, filtered and rinsed several times with distilled water. The slurry was re-boiled and treated with 5% (w/v) reagent grade sodium hydroxide, NaOH (Merck) followed with 2% (v/v) of reagent grade sodium hypochlorite, NaClO (Rinting Scientific). The slurry was then filtered and washed with distilled water until neutral pH was achieved. The resulting material was analyzed using ATR FTIR Spectroscopy to confirm the presence of cellulose particles from the source material. Cellulose powder was purchased from (Sigma-Aldrich) and was used as a reference material.

2.2. Preparation of cellulose nanocrystals

The procedure for the preparation of CNCs was adapted from Sheltami et al. (2012) whereby CNCs were obtained by acid hydrolysis of the pretreated source material using 60% (v/v) H_2SO_4 solution at 45 °C with constant stirring. The optimum reaction time was

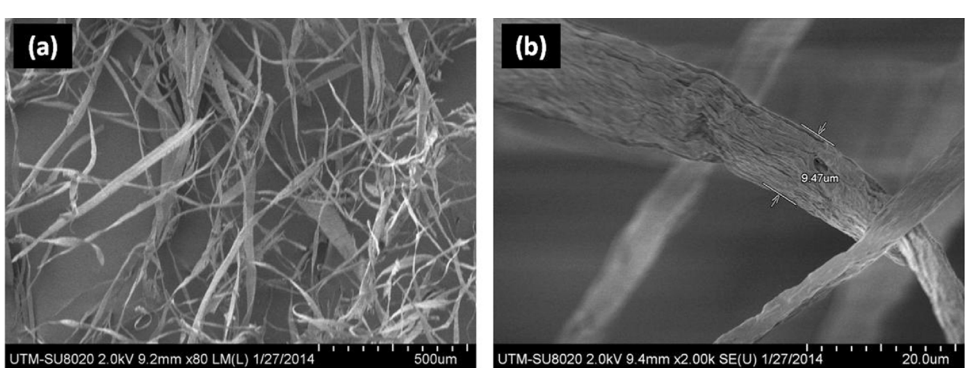

Fig. 2. FESEM images of cellulose particles extracted from wastepaper at (a) 80× magnification (b) close-up of the individual fiber at 2000× magnification.