AUTEX 2022 Conference Proceedings 978-83-66741-75-1

DOI: 10.34658/9788366741751.42

COMPARISON OF BACTERIAL CELLULOSE PRODUCED FROM NATA-DE-COCO AND KOMBUCHA

Ke Wang[1], Qian Ma[1], Ju-Mei Zhao[1], Miao Cao[2(*)], Shu-Dong Wang[1(*)]

[1] Jiangsu Engineering Center of Biomass Functional Textile Fiber Development and Application, Department of Textile and Clothing, Yancheng Polytechnic College, No.285 South Jiefang Road, Yancheng, China

[2] Key Laboratory of Yarn Materials Forming and Composite Processing Technology of Zhejiang Province, College of Material and Textile Engineering, Jiaxing University, No.899 Guangqiong Road, Jiaxing, China

(*) *Email:* caomiao0823@163.com (Miao Cao), sdwang1983@163.com (Shu-Dong Wang)

ABSTRACT

In the current study, two different bacterial cellulose including nata-de-coco bacterial cellulose (NBC) and kombucha bacterial cellulose (KBC) were compared. The morphological features, functional groups and crystals were carried out by scanning electron microscopy (SEM), attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR) and X-ray diffraction (XRD). Thermogravimetric analysis was used to investigate the stability. Mechanical property and water content were evaluated by tensile strength tester and gravimetric method. Results revealed slightly loose fibril arrangement in KBC compared to NBC. The crystallinity, thermal and mechanical properties of KBC were lower than those of NBC. Water content of KBC was slightly higher than that of NBC.

KEYWORDS

Nata-de-coco bacterial cellulose (NBC), kombucha bacterial cellulose (KBC), structure, crystallinity, thermal stability, mechanical property.

INTRODUCTION

Bacterial cellulose (BC) is a natural biopolymer synthesized by bacteria. It is well known that BC exhibits a unique three-dimensional (3D) nanofibril network and a high crystallinity which endow it excellent mechanical properties and water holding capability [1]. The morphologies and crystallinity of BC depend on a series of factors such as bacterial species and nutrient sources [2]. For instance, Vazquez et al. produced BC with different carbon sources (glycerol from biodiesel, grape bagasses glucose, commercial glycerol, and cane molasses) by *Gluconacetobacter xylinum (G. xylinum)*. They find that most of the BCs have crystallinity levels in the range of 74-79 %, however the use of cane molasses as carbon source leads to BC with lower crystallinity (67%) [3]. Hassan et al. synthesized BC with *Acetobacter xylinum (A. xylinum)* and *Komgataeibacter saccharovorans (K. saccharivorans)*. They demonstrate that the *A. xylinum* BC shows a higher crystallinity (54.14 %) than that of *K. saccharivorans* BC (52.76 %) [4].

BC has been extensively investigated for food, biomedical, paper and textile applications [5–8]. Nata-de-coco bacterial cellulose (NBC) is the most typical commercial product of BC, which is harvested from static fermentation of coconut water by G. xylinum [9]. Kombucha bacterial cellulose (KBC) is another interesting BC which can be produced by SCOBY (a symbiotic colonies of bacteria and yeast), sugar, tea and water at home [10]. It is of great interest to compare microscopic morphology, functional groups, crystals, and thermal degradation behaviour of NBC and KBC. However, little study has focused on this point. In this study, the differences between NBC and KBC were characterized by means of scanning electron microscopy (SEM), attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR), X-ray diffraction (XRD), and thermogravimetric analysis (TGA). This study may be used as preliminary study in the evaluation of NBC and KBC as a promising candidate for application in biomedical textile industries.

MATERIALS AND METHODS

NBC was purchased from Hainan Yeguo Foods Co, Ltd., China. SCOBY, black tea, and organic cane sugar were purchased from Fermentaholics Co, USA. Sodium hydroxide and acetic acid were purchased from VWR International. KBC was prepared according to the following protocol. Briefly, black tea (10 g) and organic cane sugar (200 g) was boiled in 500 ml DI water for 10 min. Next, A SCOBY was added after the obtained solution was cooled to room temperature, and the total volume and pH value of the solution were adjusted to 2500 mL and 4.0 with DI water and acetic acid, respectively. Subsequently, KBC was grown at dark static conditions for 7 days at 35°C. NBC and KBC were purified with 2 wt% NaOH at 25°C for 24 h, washed by DI water until neutral, freeze-dried and used in this study. SEM was performed using a JEOL JSM-7600F instrument operating at 5 kV. FTIR and XRD were analysed by a Thermo Scientific Nicolet 8700 FTIR Spectrometer at 4000-650 cm^{-1} and a Bruker D8 Discover X-ray diffractometer over 5-60º respectively. Thermal properties were studied using a TGA-Q500 thermogravimetric analyzer from 25°C to 600°C. Mechanical properties were tested (ASTM D882-02) on an Instron 5545 mechanical tester. Water content was evaluated by gravimetric method.

RESULTS AND DISCUSSION

Morphological Features

SEM images of NBC and KBC are presented in Figure 1. Both NBC and KBC show a surface with interwoven mesh of nanofiber (35-70 nm) (Figure 1a&b), and a layer cross structure with connected pores (Figure 1c&d), which are similar to typical BC morphological features [11]. However, the fibrils of NBC are relatively compacter than that of NBC (Figure 1a&b). The layers of NBC are tightly combined with more fibrils and there are fewer pores than KBC (Figure 1c&d). Moreover, KBC still contains yeast (red rectangle in Figure 1a). The variation in the fibril arrangement may be caused by the different microbial species [12]. The presence of a vast and diverse microbial population, including *Acetobacter* bacterial species (such as *Acetobacter*, *Gluconobacter* and *Komagataeibacter*) and various yeasts (such as *Saccharomyces* and *Zygosaccharomyces*) in the SCOBY, makes it more complex to biosynthesis KBC [10]. The various by-products can also increase the presence of impurities (such as melanoidins and carboxylic acids) in KBC compared to NBC. The various microbial and impurities can affect the bacterial cells activity and development of fibril network [8,10,13]. It is important to note that the potential harmful impurities should be completely removed before further use.

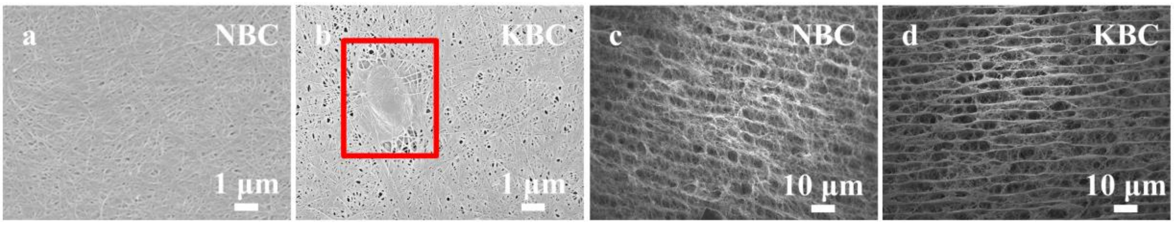

Figure 1. SEM images of the surface of NBC (a), KBC (b), and the cross section of NBC (c), KBC (d).

FTIR analysis

Figure 2a shows the FT-IR spectra of NBC and KBC. Both NBC and KBC show the characteristic absorption peaks of bacterial cellulose. The spectrum of NBC reveals characteristic peaks at 3423 (O–H stretching vibration), 2902 (C–H stretching of CH_2 and CH_3 groups), 1639 (H–O–H bending of absorbed water), 1564 (C–O stretching vibrations), 1421 (CH_2 symmetric bending and O–H in plane bending), 1317 (out-of-plane wagging of the CH_2 groups), 1162 (C–O–C antisymmetric bridge stretching), 1110 (C–C and C–O bending vibration) and 1066 (C–O–H bending and C–O–C pyranose ring skeletal vibration) cm^{-1} [14-16]. Compared with NBC, KBC shows similar peaks at 3328, 2895, 1652, 1428, 1316, 1162, 1110 and 1058 cm^{-1}. However, O–H stretching of NBC at band 3423 cm^{-1} shift to 3348 cm^{-1}. This indicates that there are less hydrogen-bonding interactions between KBC than NBC [17].

XRD analysis

XRD patterns of NBC and KBC are shown in Figure 2b. NBC shows three prominent peaks at 14.4°, 16.9°, and 22.7°, which correspond to the (100), (010), and (110) planes of cellulose Iα respectively [18,19]. KBC also shows three similar peaks at 14.3°, 16.5° and 22.4° with a slightly broad and weak. The crystallinity was calculated according to the method described by Vazquez group [3]. The variation in the crystallinity of NBC (73.57%) and KBC (55.45%) might be due to the different fibril arrangement as shown in SEM analysis results. Both the above results suggest that KBC might be suitable for water-holding materials (such as biomedical textiles for wound healing and cosmetic) because the lower crystallinity and the looser fibril arrangement can cause the KBC to have a greater water-holding capacity [20].

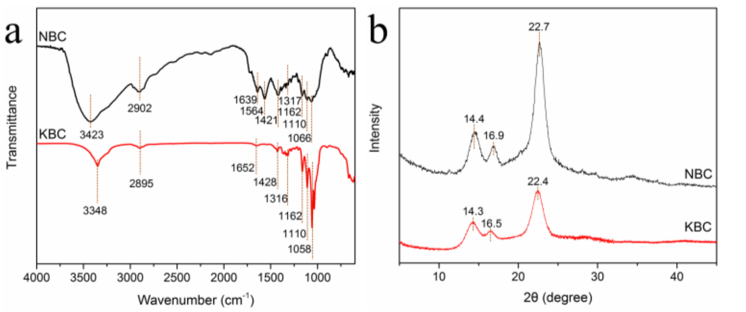

Figure 2. FTIR (a) and XRD (b) spectra of NBC and KBC.

Thermogravimetric analysis (TGA)

Figure 3 shows the thermogravimetric (TGA) and derivative thermogravimetric (DTG) curves of NBC and KBC. Two stages of weight loss can be observed. The first one takes place at 60-100°C and it is associated with the dehydration. The second and the largest weight loss occurred at 200-400°C, which is due to the thermal decomposition of cellulose. Comparing the maximum decomposition temperature (T_{max}) of NBC (347.5°C) and KBC (340°C) indicates that NBC has a higher thermal stability when compared with KBC. The lower thermal stability of KBC can be justified from the SEM (Figure 1) and XRD (Figure 2b) analysis. The closely compacted fiber structure and the higher crystallinity in NBC could be the reason for thermal behaviour observed [3,13]. The carbon ash of NBC (19.36%) is also higher than that of KBC (13.85%).

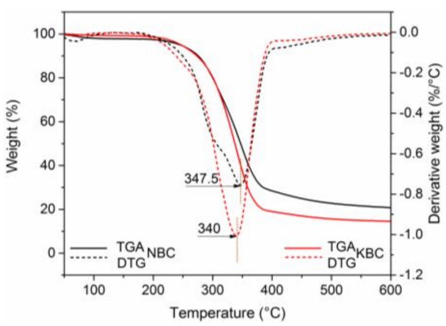

Figure 3. TGA and DTG spectra of NBC and KBC.

Table 1. Mechanical property and water content of NBC and KBC.

	Tensile strength (MPa)	Strain at break (%)	Water content (%)
NBC	4.52±0.94	21.50±1.25	98.82±0.17
KBC	3.59±0.73	26.80±1.88	99.33±0.17

Mechanical properties and water content

The mechanical properties of NBC and KBC are compared in Table 1. It can be observed that NBC had a higher tensile strength value. The strain at break of KBC was higher. In addition, KBC had slightly higher water content than that of NBC.

CONCLUSION

Bacterial species and nutrient sources have an impact on the morphologies and properties of BC. The structure of NBC is more compact than KBC. The crystallinity, thermal and mechanical properties of NBC are also higher than those of KBC. The water content of KBC is higher than that of NBC. However the analysis performed did not show the existence of significant differences between NBC and KBC. Overall, the results of the study provide a broad idea for the use of NBC and KBC as biomedical textiles.

ACKNOWLEDGMENT

The authors would like to express appreciation for the support of the Natural Science Foundation [BK20201216], Qinglan Project [Jiangsu Teacher 2022], and Integration Platform of Industry and Education of Jiangsu Higher Vocational Education [Jiangsu Vocational Education 2019-26] of Jiangsu Province. The authors acknowledge the financial from the Open Project Program of Key Laboratory of Yarn Materials Forming and Composite Processing Technology [MTC2021-04] and the Jiaxing Public Welfare Technology Application Research Project [2021AD10012] of Zhejiang Province.

REFERENCES

[1] Moniri M.A., et al., *Production and status of bacterial cellulose in biomedical engineering*, Nanomaterials 2017, vol. 7, no 9, p. 257.
[2] Zhong C.Y., *Industrial-scale production and applications of bacterial cellulose*, Frontiers in Bioengineering and Biotechnology 2020, vol. 8, no 605374.
[3] Vazquez A., et al., *Bacterial cellulose from simple and low cost production media by Gluconacetobacter xylinus*, Journal of Polymers and the Environment 2013, vol. 21, pp. 545-554.
[4] Hassan E.A., et al., *The characterization of bacterial cellulose produced by Acetobacter xylinum and Komgataeibacter saccharovorans under optimized fermentation conditions*, British Microbiology Research Journal 2015, vol. 9, no 3, pp. 1-13.
[5] Parte F. G.B., et al., *Current progress on the production, modification, and applications of bacterial cellulose*, Critical Reviews in Biotechnology 2020, vol. 40, no 3, pp. 397-414.
[6] Yim S.M., et al., *Production and characterization of bacterial cellulose fabrics by nitrogen sources of tea and carbon sources of sugar*, Process Biochemistry 2017, no 59(A), pp. 26-36.
[7] Han J., et al., *Effects of cultivation, washing, and bleaching conditions on bacterial cellulose fabric production*, Textile Research Journal 2019, vol. 89, no 6, pp.1094-1104.
[8] Kamiński K., et al., *Hydrogel bacterial cellulose: a path to improved materials for new eco-friendly textiles*, Cellulose 2020, vol. 27, pp. 5353-5365.
[9] Taokaew S., et al., *Bacterial cellulose: Biosyntheses, modifications, and applications*, IGI Globalal (Hershey) 2017, pp. 255-283.
[10] Laavaya D., et al., *Current challenges, applications and future perspectives of SCOBY cellulose of Kombucha fermentation*, Journal of Cleaner Production 2021, vol. 291, no 126454.
[11] Gromovykh T.I., et al., *Structural organization of bacterial cellulose: The origin of anisotropy and layered structures*, Carbohydrate Polymers 2020, vol. 237, no 116140.
[12] Wang J., et al., *Bacterial cellulose production, properties and applications with different culture methods-A review*, Carbohydrate Polymers 2019, vol. 219, pp. 63-76.

[13] Khattak W.A., et al., *Production, characterization and physico-mechanical properties of bacterial cellulose from industrial wastes*, Journal of Polymers and the Environment 2015, vol. 23, pp. 45-53.
[14] Wang S.S., et al., *Physicochemical characterization of high-quality bacterial cellulose produced by Komagataeibacter sp. strain W1 and identification of the associated genes in bacterial cellulose production*, RSC Advances 2017, vol. 7, pp. 45145-45155.
[15] Halib N., et al., *Physicochemical properties and characterization of nata de coco from local food industries as a source of cellulose*, Sains Malaysiana 2012, vol. 41, pp. 205-211.
[16] Irham W.H., et al., *Characterization of bacterial cellulose from coconut water supplemented Curcuma Longa Linn and Ziziphus Mauritiana extract*, AIP Conference Proceedings 2020, vol. 2267, no 020056.
[17] Lamboni L., et al., *Silk sericin-functionalized bacterial cellulose as a potential wound- healing biomaterial*, Biomacromolecules 2016, vol. 17, pp. 3076-3084.
[18] French A.D., *Idealized powder diffraction patterns for cellulose polymorphs*, Cellulose 2014, vol. 21, pp. 885-896.
[19] Wang X., et al., *Production and characterization of bacterial cellulose membranes with hyaluronic acid and silk sericin*, Colloids and Surfaces B: Biointerfaces 2020, vol. 195, no 111273.
[20] Qi G.X., et al., *Comparison of bacterial cellulose production by Gluconacetobacter xylinus on bagasse acid and enzymatic hydrolysates*, Journal of applied polymer science 2017, vol. 134(28), no 45066.