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Commentary

The Properties and Applications of Bacterial Cellulose

Sanming Hu*

Department of Biomedical Engineering and Imaging, Hubei University of Science and Technology, Hubei Province, China

DESCRIPTION

Bacterial Cellulose (BC), also known as Microbial Cellulose (MC), refers to the cellulose synthesized by a certain microorganisms in the genera *acetobacter*, *agrobacterium*, *rhizobium*, and *sarcina* etc. under different conditions [1]. One of the more typical ones is glucoacetobacterxylinum, formerly known as *acetobacter xylinum* in the genus *acetobacter*, which has the highest cellulose production capacity and has been recognized as a model strain for the study of cellulose synthesis, crystallization processes and structural properties [2]. As a new type of nano-biomaterials, BC has a modified and wide range of applications in the fields of food, medicine, electronic devices, and textile and so on due to its many unique properties.

Synthesis and cultivation

The synthesis of BC can generally be divided into four major processes polymerization, secretion, assembly and crystallization [3]. Taking B. xylosoxidans as an example, its glucose synthesis cellulose mainly has four enzymatic reaction steps (A) Glucose is converted to 6 monophosphate glucose under the action of glucokinase (B) 6 monophosphate glucose is converted to 1-phosphate glucose under the action of glucose phosphate isomerase (C) 1-phosphate glucose generates Uro-Di-Phospho-Glucoside under the action of pyrophosphorylase (UDPG) (D) On the cell membrane, cellulose synthase synthesizes UDPG into Β-l,4-glycosidic bond chains, which are then polymerized into cellulose. There are static and dynamic methods of culturing BC, and since bacillus xylosus is aerobic, oxygen and nutrients are essential for the culture process.

Structure and composition

BC is a straight-chain polysaccharide made of D-glucopyranose monomers linked by β-l,4-glycosidic bonds, with straight chains parallel to each other, no helical structure, no branching structure, also known as β-1,4-glucan. However, 6 carbon atoms of adjacent glucopyranose bacterial cellulose are not in the same plane, but a stable chair-like three-dimensional structure [4]. Several neighboring β-1,4-glucan chains form stable water-insoluble polymers through intra- and inter-chain hydrogen bonding. In addition to β-glucan, BC also contains α-glucan, γ-glucan, protein, trace elements and other components. In the microstructure, BC possesses distinctive three dimensional porous network and crystalline nanofibrils with diameters at 10-100 nm [5].

Unique properties

High crystallinity: Compared with plant cellulose, BC is free of lignin, pectin and hemicellulose and other associated products, and has a high degree of crystallinity (up to 95%, compared with 65% for plant cellulose) [6].

High water holding capacity: BC is a three-dimensional network structure, the middle of the formation of a lot of "pore", and the molecular memory has a large number of hydrophilic groups, so it has good air permeability, water permeability and water holding properties. According to the different external conditions, it can absorb 60-700 times more water than its own dry weight.

High elasticity modulus and tensile strength: BC has a Young's modulus as high as 10 MP and high tensile strength due to the fiber diameter reaching the nanometer level. Furthermore, BC microfibers prepared by wet-drawing and wet-twisting methods have record high tensile strength (826 MPa) and Young’s modulus (65.7 GPa) owing to the alignment of nanofibers [7].

Degradability and biocompatibility: Since BC is produced by microbial metabolism, it has good biocompatibility. In addition, bacterial cellulose is a higher purity cellulose, which is more likely to interact with cellulose degrading enzymes, and also can be directly degraded under acidic and natural conditions in the presence of microorganisms, thus presenting good biodegradability [8].

Synthetic tunability: When different culture conditions are used, BC of varying shapes, sizes, thicknesses and properties can be prepared. Utilizing the electro taxis of the bacterium, it is possible to prepare BC with nanofiber oriented in the presence of an electric field [9]. Additionally, during the synthesis process, functional materials such as conductive or magnetic nanomaterials can be added to prepare functional composites.

Correspondence to: Sanming Hu, Department of Biomedical Engineering and Imaging, Hubei University of Science and Technology, Hubei Province,China, E-mail: 790856974@qq.com

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Easy chemical modification and physical doping: The synthesized BC, due to the three-dimensional network structure and rich hydroxyl groups, easily chemically modified and doped nanomaterials for the preparation of functional composites [10].

Typical applications

Medical material: The main characteristics of BC as a medical material are high mechanical strength under humid conditions, good permeability to liquids and gases, good compatibility with the skin, non-irritation, and extremely fine structure, good antimicrobial and isolation properties, which is conducive to the growth of skin tissues and limiting infections. BC has been prepared into artificial skin, gauze, bandages, "band-aid" and other wound dressing products [11]. Moreover, BC films or hydrogels can also be used as a slow-release drug carrier to carry a variety of drugs, used for skin surface drug delivery to promote wound healing and rehabilitation [12].

Food industry: BC has gel and high water-holding properties and its products (acetic acid, lactic acid, etc.) have a special flavor, which makes BC can be used as food molding agent, thickening agent, dispersing agent, and taste improvement material in artificial meat, artificial fish, ham and sausage. Furthermore, BC is used as health food, which has the effect of preventing constipation, clearing stomach and bowels, detoxification and lowering cholesterol [13].

Textile industry: BC can be used as a binder for nonwoven fabrics instead of or in conjunction with various commonly used resins to improve the strength, breathability, hydrophilicity and comfort of the product.

Plastic alternatives: Biodegradable straws made from BC-based composites have significantly better heat resistance, tensile strength, and bending strength than the current commercial hydrophobic-coated paper straws, which has a great potential in solving white pollution [14].

Electric equipment: BC can be easily chemically modified and physically doped to prepare a variety of functional materials, which have a wide range of applications in the fields of supercapacitors, chemical batteries, and flexible sensors [15].

In addition, BC has a wide range of applications in paper-making, acoustics, optics, and medical equipment.

Challenges and future outlook

BC is produced by bacteria, and the current yield of strains is not sufficient for large-scale commercial application, so it is crucial to obtain high-yielding cellulose bacteria. In addition, new culture methods need to be developed to reduce cost, increase cellulose yield and optimize the structural properties of cellulose products. With the development of society, humans are beginning to emphasize environmental protection and pursuit a healthy and green life. BC as an environmentally friendly, renewable nanomaterial with many excellent performance, will surely have a wider applications in human life.

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REFERENCES

1. Kiziltas EE, Kiziltas A, Gardner DJ. Synthesis of bacterial cellulose using hot water extracted wood sugars. Carbohydr Polym. 2015;124:131-138.
2. Tahara N, Tabuchi M, Watanabe K, Yano H, Morinaga Y, Yoshinaga F. Degree of polymerization of cellulose from Acetobacter xylinum BPR2001 decreased by cellulase produced by the strain. Biosci Biotechnol Biochem. 1997;61(11):1862-1865.
3. Heo MS, Son HJ. Development of an optimized, simple chemically defined medium for bacterial cellulose production by Acetobacter sp. A_9 in shaking cultures. Biotechnol Appl Biochem. 2002;36(1): 41-45.
4. Koyama M, Helbert W, Imai T, Sugiyama J, Henrissat B. Parallel-up structure evidences the molecular directionality during biosynthesis of bacterial cellulose. Proc Natl Acad Sci. 1997;94(17):9091-9095.
5. Mühlethaler K. The structure of bacterial cellulose. Biochim et Biophys Acta. 1949;3:527-535.
6. Watanabe K, Tabuchi M, Morinaga Y, Yoshinaga F. Structural features and properties of bacterial cellulose produced in agitated culture. Cellulose. 1998;5:187-200.
7. Wang S, Jiang F, Xu X, Kuang Y, Fu K, Hitz E, et al. Super-strong, super-stiff macrofibers with aligned, long bacterial cellulose nanofibers. Adv Mater. 2017;29(35):1702498.
8. Chen K, Li Y, Du Z, Hu S, Huang J, Shi Z, et al. $CoFe_2O_4$ embedded bacterial cellulose for flexible, biodegradable, and self-powered electromagnetic sensor. Nano Energy. 2022;102:107740.
9. Wang L, Mao L, Qi F, Li X, Ullah MW, Zhao M, et al. Synergistic effect of highly aligned bacterial cellulose/gelatin membranes and electrical stimulation on directional cell migration for accelerated wound healing. Chem Eng J. 2021;424:130563.
10. Zhang J, Hu S, Shi Z, Wang Y, Lei Y, Han J, et al. Eco-friendly and recyclable all cellulose triboelectric nanogenerator and self-powered interactive interface. Nano Ener. 2021;89:106354.
11. Mao L, Hu S, Gao Y, Wang L, Zhao W, Fu L, et al. Biodegradable and electroactive regenerated bacterial cellulose/MXene ($Ti_3C_2T_x$) composite hydrogel as wound dressing for accelerating skin wound healing under electrical stimulation. Adv Healthc Mater. 2020;9(19): 2000872.
12. Solomevich SO, Dmitruk EI, Bychkovsky PM, Nebytov AE, Yurkshtovich TL, Golub NV. Fabrication of oxidized bacterial cellulose by nitrogen dioxide in chloroform/cyclohexane as a highly loaded drug carrier for sustained release of cisplatin. Carbohydr Polym. 2020;248:116745.
13. Shi Z, Zhang Y, Phillips GO, Yang G. Utilization of bacterial cellulose in food. Food Hydroc. 2014;35:539-545.
14. Khami S, Khamwichit W, Suwannahong K, Sanongraj W. Characteristics of bacterial cellulose production from agricultural wastes. Adv Mater Res. 2014;931:693-697.
15. Hu S, Han J, Shi Z, Chen K, Xu N, Wang Y, et al. Biodegradable, super-strong, and conductive cellulose macrofibers for fabric-based triboelectric nanogenerator. Nanomicro Lett. 2022;14(1):115.