Characteristics and Application of Bacterial Cellulose

Guizhi Quan
Tianjin Agricultural University, Tianjin, 300384, China

Abstract: Bacterial Cellulose (BC or Microbial Cellulose) is a biodegradable natural nanostructured macromolecule material mainly produced by bacteria. It can be widely used in food, paper making, medicine, acoustic equipment, textile, chemical industry, etc,. In the developed countries such as the United States, Japan and Germany, bacterial cellulose industry has initially formed a market of billions of dollars a year. Therefore, it is helpful to study the chemical structure, properties and synthesis mechanism of bacterial cellulose, which can promote the large-scale commercial application of bacterial cellulose. This paper introduces chemical structure, characteristics, Biosynthetic pathway and application of bacterial cellulose, and prospects for its development.

Keywords: Bacterial cellulose; The fermentation; Synthetic pathway; Application

1. Introduction

Bacterial Cellulose (BC or Microbial Cellulose) is synthesized by some microorganisms under the different conditions, such as Acetobacter, Agrobacterium, Rhizobium and Sarcina. Bacterial cellulose is a kind of natural nano-polymer material with high purity, high water holdability, high adhesiveness and high stability. In recent years it become one of research focuses in biological materials at home and abroad. In fact, as early as in 1886, Brown has discovered the bacterial cellulose, it has been one hundred years. But its application is limited because of high production costs and lack of adequate understanding of its physical and chemical characteristics. In recent decades, the production and application of bacterial cellulose have been widely concerned with the in-depth research on the biosynthesis mechanism of bacterial cellulose and the progress of fermentation technology. In the developed countries such as the United States, Japan and Germany, bacterial cellulose industry has initially formed a market of billions of dollars a year. It It has been widely used in food industry, paper making, medicine, acoustic equipment, textile, chemical industry, etc. In our country, the research and development of bacterial cellulose is still in infancy, except in the field of food. The domestic enterprises engaged in the production and application of bacterial cellulose are far less than foreign companies such as Europe and the United States.

2. Chemical Structure and Properties of Bacterial Cellulose

2.1. Chemical structure of bacterial cellulose

After a long-term study, there was no significant difference in chemical composition and structure between bacterial cellulose and plant cellulose. Direct chain polysaccharides formed by D-glucose monomers whitch is connected by the beta-1,4 glycosidic bond, direct chain polysaccharides is parallel to each other, without helical structure and no branching structure. But the six carbon atoms that are adjacent to each other are not in the same plane, but are stable in the chair shape. Several adjacent glucan chains form a stable, insoluble polymer through the hydrogen bond between the chain and the chain.

2.2. Characteristics of bacterial cellulose

Bacterial cellulose has the same molecular structure as the natural cellulose produced by plants or algae, but bacterial cellulose have many unique properties.
Compared with plant cellulose, bacterial cellulose has no lignin, pectin and hemicellulose and other accompanying products, with high crystallinity and high degree of polymerization;
Ultra fine mesh structure;
The elastic modulus of bacterial cellulose is several times to ten times more that of general plant fiber, and the tensile strength is high.
The bacteria cellulose has a strong water retention values (WRV). The WRV value of
undried bacterial cellulose is more than 1000%, and the water holding capacity after freeze-drying is still more than 600%. After drying at 100 ℃ , the swelling force of bacterial cellulose in water is similar to that of cotton wool;
The bacteria cellulose has higher biocompatibility, adaptability and good
biodegradability.
The controllability of bacterial cellulose biosynthesis.

3. Biosynthesis Pathway of Bacterial Cellulose

Biosynthesis of bacterial cellulose is a green process of low energy consumption. Water soluble D glucose is carbon source, the cellulose is produced by the non-pathogenic acetic bacteria, which is cultured between the medium liquid and the air interface. At present except Acetobacter, bacterial cellulose is also produced by certain kinds of bacteria, such as Rhizobium, Sarcina, Pseudomonas, Achromobacter, Alcaligenes, Aerobacter, Azotobacter.

Which typically is Acetobacter xylinum, it has high cellulose production capacity, has been identified for the study of cellulose synthesis and crystallization process and structural model. The biosynthesis of bacterial cellulose was involved in the metabolic pathway of pentose HMP and TCA. After more than a lot of enzyme complex system (cellulose synthase, cellulose synthase, CS) multi-step reaction process of precise contro. The first is the synthesis of UDPGlu. Then oligomeric CS compound, also known as end compound (terminal complexe, TC) will continuously pyran glucose residues from UDPGlu moved to the new generation of polysaccharide chain, forming glucan chains, and through the outer membrane secreted to the outside of the cell. With the growth of Acetobacter, about 12 to 70 molecules of bacterial cellulose are secreted from the cell surface and secreted into the medium. On the cell surface these cellulose molecules are connected by hydrogen bonds to form pure cellulose fibers. This fiber is superior to plant cellulose fiber in purity and supermolecular structure. An Acetobacter through the beta-1,4 glycosidic bond polymerization of 20, 000 glucose molecules, can form a single, twisted, ribbon microfiber in culture medium .The microfibers of the ribbon are not fractured along with the growth of the cell, and the conjunctions of glucose and microcellulose are two steps that are closely linked together. In the biosynthesis of cellulose, the activity of Acetobacter controls the accumulation and arrangement of microfibers which is secreted. Generally, Acetobacter in the culture medium usually free movement in the three-dimensional direction, the formation of highly developed fine network structure.in the three-dimensional direction of free movement, forming a highly developed fine network texture structure.

4. Application of Bacterial Cellulose

4.1. Medical materials

Bacterial cellulose has unique biocompatibility, biocompatibility, biodegradability, biocompatibility and no allergic reaction, as well as high water retention and crystallinity, good nanofiber network, high tension and strength . In particular, it has good mechanical toughness, so it has a wide range of uses in tissue engineering stents, artificial blood vessels, artificial skin, and treatment of skin lesions. It is one of the hot spots in biomedical materials research. Biofillo and Gengiflex are two typical bacterial cellulose products that have been widely used as surgical and dental materials. For secondary and tertiary burns, ulcers, etc., Biofillo has been successfully used as a temporary replacement for artificial skin. Gengiflex has been used for restoration of the root membrane tissue. Based on the in situ plasticity of bacterial cellulose, BASYC, a novel biological material, is expected to be used as a synthetic blood vessel in microsurgery.

4.1.1. Application of tissue engineering scaffold

At present as bone scaffold engineering materials has a lot of, such as: ceramic, metal and polymer can be as a bone repair and bone substitute material. Cellulose is an attractive natural biopolymer material, and its fibrous structure is consistent with the morphology of the collagen fibers that make up the bones.Bacterial cellulose is a very promising bioscaffolding material in cartilage tissue engineering. There are many materials currently used for bone scaffold engineering, such as ceramics, metals and polymers can be used as bone repair and bone replacement materials. While cellulose is an attractive natural biopolymer material, its fibrous structure and the collagen fibers that make up the bone are consistent in morphology

BC can be used as a suitable matrix for bioceramic deposition and nucleation. Its high hydrophilicity allows the microparticles to penetrate into its internal network structure, while the presence of hydroxyl groups and aldehyde groups can promote the formation of microparticles. At physiological pH and temperature, calcium phosphate particles are finally formed on bacterial cellulose by successively culturing in calcium chloride solution followed by incubation in sodium phosphate. X-ray diffraction confirmed that the microparticles are low calcium hydroxyapatite and are the main components of the bone. The compound is expected to become an excellent biological material for plastic surgery. The study also found that the material can be used as a therapeutic implant for bone regeneration and for the treatment of bone damage.

4.1.2. The application of BC in artificial blood vessels

When a blood vessel fails to work due to arteriosclerosis, aging of the blood vessel or breakage, etc., it is necessary to reconstruct the blood vessel, and artificial synthetic blood vessels are often used as substitutes. At present, biotechnological means can directly form bacterial cellulose with a tubular structure with an inner diameter of less than 3 mm in glucose medium.

Klemm in 2001 and Klemm in 2004 all confirmed the feasibility of BASYC (Bacterial Synthesized Cellulose) as an artificial blood vessel in microsurgery. It was found that BASYC with a 1 mm internal diameter has high mechanical strength in a wet state. Water holding capacity, low roughness internal diameter does not form thrombus and perfect biological activity and compatibility and other excellent characteristics, these properties fully comply with the physical and biological requirements of artificial blood vessels in microsurgery.. Furthermore, the results of relevant studies indicate that the strain capacity of BASYC is similar to that of arterial blood vessels. The adsorption, proliferation, and ingrowth of human smooth muscle cells on bacterial cellulose are good.

4.2. Paper industry

The high crystallinity, high chemical purity, high tensile strength and elastic modulus, excellent shape retention and tear resistance of bacterial cellulose provide excellent conditions for papermaking. It is added to plant fiber raw materials. It can overcome the deficiency of natural plant cellulose, produce high-quality paper, and at the same time solve the problem that the strength of paper fiber is greatly reduced after the waste paper is recycled and reused. Ajinomoto Co., Ltd. and Mitsubishi Co., Ltd. have developed special grade paper for circulation currency manufacturing. They are of good quality, water resistance, and high strength. The high-grade writing paper modified with bacterial fibers has good ink absorption uniformity and adhesion.

4.3. Food industry

Because the bacterial cellulose has a very good water-holding capacity, viscosity and stability, it can be used as a thickener, colloid filler, dispersant, anti-dissolving agent, casing and certain foods in the food industry. Bacterial cellulose has become a new type of important food base and dietary fiber. For example, in the traditional fermentation process, pure culture of Acetobacter or mixed culture of Acetobacter and other microorganisms can produce fermented foods rich in cellulose. "Nata de coco" (which contains 0.5 g/100 mL of bacterial cellulose) is a dessert product made from the fermentation of Acetobacter and rice flour sugar. It is one of Japan's 30 most popular foods. In addition, bacterial cellulose can also be used for the synthesis of meat, synthetic fish, and synthetic poultry. However, due to the high production costs, it is currently mainly used in areas with high added value.

4.4. Textile industry

The structural characteristics and functional properties of bacterial cellulose enable it to be used as a binder instead of or in combination with a variety of commonly used resins for nonwovens. It can improve the strength, breathability, hydrophilicity, and product properties of nonwovens, feel and other characteristics. The high specific surface of bacterial cellulose produces a strong hydrogen bonding ability, promotes entanglement, and thus exhibits excellent binding properties, allowing the mechanical homogenization of bacterial fibers with various incompatible organic and inorganic fibers. The material mix is very strong. In the manufacture of carbon fiber plates that filter and adsorb toxic gases, the addition of Acetobacter bacteria cellulose can increase the adsorption capacity of carbon fiber plates and reduce the leakage of fillers in paper.

5 . Conclusions

The main technical barriers of bacterial cellulose application is the low level of fermentation, low yield, high cost, do not cover the price of the common plant cellulose, the second is to further research and utilization of the BC ChengMo and molding technology has not yet been solved, 3 it is as a biomedical material, its long-term effect with organisms, in vivo degradability, and with the host tissue and cell compatibility, and the BC when in the body such as the change of the mechanical, physical and chemical properties of a series of problems still need further study. In order to solve the above problems, there are two main research directions in the future. First, we should study the design of viable fermentation equipment and fermentation technology to increase the production of cellulose and reduce its cost. The second is to develop and develop BC biomedical materials with independent intellectual property rights.

At present, one of the main technical obstacles for the application of bacterial cellulose is the low level of fermentation, low yield, high cost, and the price does not match that of ordinary plant cellulose. Second, the technology for further research and use of BC molding and molding has not yet been resolved. As a biomedical material, its long-term effects on organisms, its degradability in vivo, compatibility with host tissues and cells, and the changes in mechanical, physical and chemical properties of BC, these problem require a further study .To solve the above problems, there are two main research directions in the future: First, we must study and design feasible fermentation equipment and fermentation process to increase cellulose production and reduce its cost; Second, we must research and develop BC biomedical materials with independent intellectual property rights. .

Because biomedical materials are directly related to the life and health of human beings and are facing the huge market demand of the global population, they have received extensive attention from countries in the world. At present, researches on bacterial cellulose mainly focus on medical biological materials with high added value, such as tissue engineering scaffolds, bone scaffolds, cartilage scaffolds, artificial blood vessels, artificial skin, and drug carriers. However, there are not many products that can be applied clinically. Apart from Brazil's commodity/BioFill0, most of the research still stays at the initial stage of cell level and animal experiments, and there is still a certain distance from clinical application. In China, people's understanding and understanding of bacterial cellulose is still insufficient. Research is still in its infancy. Most of them focus on food, food additives and papermaking, and there are less reports on the development and application of biomedical materials. . As bacterial cellulose has excellent biological affinity, biocompatibility, biocompatibility and good biodegradability, the cellulose will surely become a new type of bio-nano high-tech material with excellent performance in the world.

References

[1] Liu Sixin, Li Congfa. Bacterial cellulose[M]. Beijing: China Agricultural University Press, 2007.

[2] DENG Mao-cheng, ZHU Xiao-li, LI Sheng. Study on the Production of High Fibre Coconut Fruit by Yeast Fermentation with Acetobacter xylinum[J]. China Brewing, 2008(5): 71-73.

[3] Liu Sixin, Li Meiqiu. Study on Fermentation Conditions of Coconut Natta [J]. Food and Fermentation Industries, 1998, 25(1): 36-39.

[4] MA Xia, WANG Ruiming, GUAN Fengmei. Effect of Sugar Sources on Bacterial Cellulose Production[J]. Cellulose Science and Technology, 2002, 10(3): 31-35, 46.

[5] Hong Feng, Wei Bin, Yang Guang, et al. Bacterial cellulose-based antibacterial dry film for acute trauma and its preparation method and application.

[6] Xue Yu, Yang Qian. Optimization of Cellulose Fermentation Medium Produced by Acetobacter[J]. FOOD SCIENCE, 2004, 25(11): 213-215.

[7] Hong Feng, Wei Bin, Yang Guang. BC fever-refreshing brain tissue for fever auxiliary therapy and emergency physical cooling and preparation thereof

[8] Xiu Huijuan, Wang Zhijie, Li Jinbao. Effect of Bacterial Cellulose on Paper Properties[J]. China Pulp and Paper, 2005, 24(3): 14-17.

[9] Sun Dongping, Yang Jiazhi. Bacterial cellulose functional materials and their industrial applications[M]. Beijing: Science Press, 2010

[10] Tan Yujing, Hong Feng, Shao Zhiyu. The application of bacterial cellulose in biomedical materials [J]. Chinese Journal of Biological Engineering, 2007, 27

[11] Food Industry Application [M]. Beijing: Science Press, 2010.

[12] Sun Dongping, Yang Jiazhi. Bacterial Cellulose Functional Materials and Their Industrial Applications[M]. Beijing: Science Press,

[13] Hong Feng, Wei Bin, Yang Guang. BC fever-refreshing brain tissue for fever auxiliary therapy and emergency physical cooling and preparation thereof

[14] Chen Liang, Yang Jia Influence of BC on Human Cells [J] Biology Journal 2001