BACTERIAL CELLULOSE- A SMART BIOMATERIAL IN FOOD INDUSTRY

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INTRODUCTION

Bacterial cellulose (BC), first described as "a sort of moist skin, swollen, gelatinous and slippery" by R. M. Brown in 1886, is an exocellular residue of bacteria(D. Lin et al., 2020). Bacterial cellulose (BC) with higher hydrophobicity is needed for a variety of applications, such as packaging(Frone et al., 2018). This environmentally friendly polymer is gradually garnering more attention in modern culture(Shi et al., 2014). Existing polymer-based packaging materials (polyethylene, polypropylene) have a number of negative effects on both the environment and human health. It is therefore desirable to find a greener solution or means of reducing the issue. The finest cellulose produced by microbes is called bacterial cellulose (BC) (Bandyopadhyay et al., 2018). The abundance, affordability, longevity, biodegradability, biocompatibility, and environmental friendliness of biopolymer-based food packing are its key draws(Xie et al., 2020).

PRODUCTION OF BACTERIAL CELLULOSE

Growing interest in commercially generating BC on a wide scale has emerged in recent years(Czaja et al., 2007). However, BC is relatively pricey compared to other widely used commercial organic products; as a result, its use is restricted(Sheykhnazari et al., 2011).

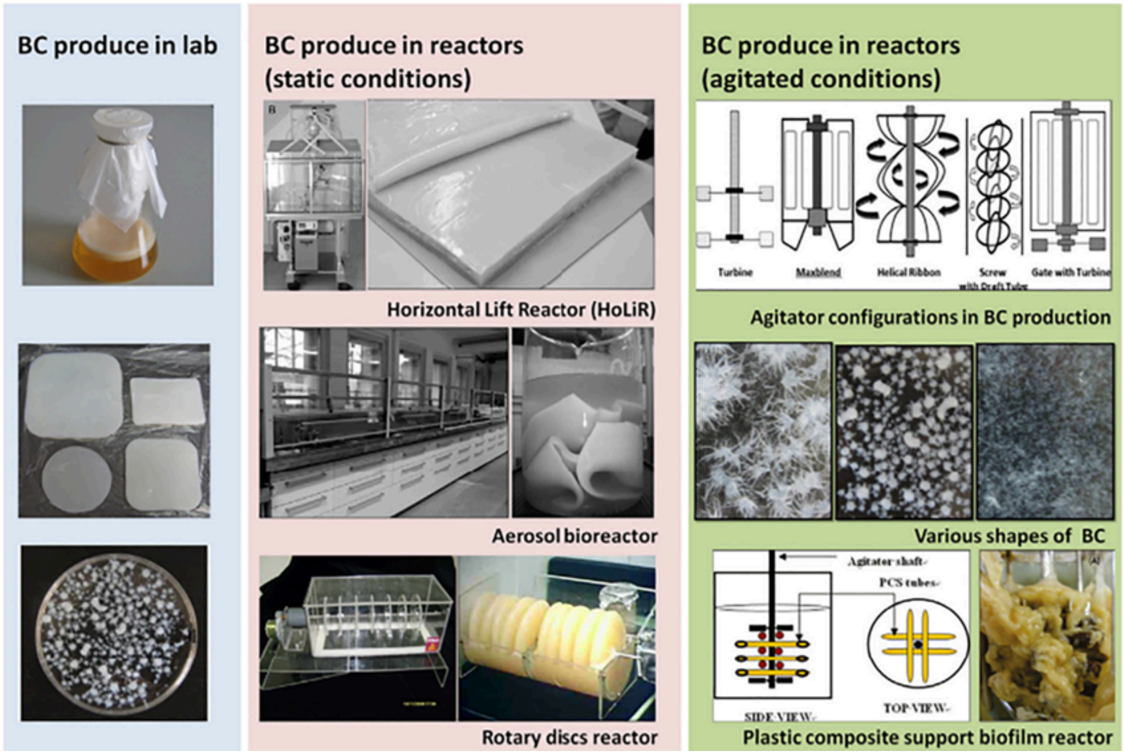

Fig. 1. Different shapes of BC produced in static, shaking, and agitation conditions(D. Lin et al., 2020).

Selection of Strain- Achromobacter, Alcaligenes, Aerobacter, Agrobacterium, Azotobacter, Gluconacetobacter, Pseudomonas, Rhizobium, Sarcina, Dickeya, and Rhodobacter are just a few of the bacteria that can create BC. BC is manufactured both by a microbiological system and a cell-free method. Due to its higher productivity and capacity to utilize various carbon sources as carbon sources, the Gluconacetobacter species, which Yamada et al. designated as a new genus Komagataei bacter, is used as a model strain and is widely employed in research and commercial production(D. Lin et al., 2020).

Culture medium- It is worthwhile to investigate the lower cost culture media for the BC production as the poor yield and elevated manufacturing expenses of BC are significant limitations, which limit its industrial production and a wider variety of applications(D. Lin et al., 2020). Aerobic bacteria, such as Achromobacter, Alcaligenes, Aerobacter, Agrobacterium, Azotobacter, Komagataeibacter (formerly Gluconacetobacter), Pseudomonas, Rhizobium, Sarcina, Dickeya, and Rhodobacter, excrete the BC as exopolysaccharide(Mohammadkazemi et al., 2015). The genus Komagataeibacter has the most well researched bacteria, which can digest a variety of carbon/nitrogen sources(Azeredo et al., 2019).

Cultivation methods- BC can be used in a variety of industries, so its production must be improved to make it cost-effective. Through a range of media, growing techniques, and cultivation specifics (such as agitated or static, carbon and nitrogen sources, incubation time, and medium volume), many investigations have been undertaken to discover the ideal growth parameters required to obtain high yields of BC(Gururaj Bhadri, 2013). As the cellulose ultrastructure and its mechanical and physical qualities are strictly influenced by culture technique, the cultivation technique in BC production is considered depending on further BC destination(Krystynowicz et al., 2002).Different types of Bacterial cellulose can be produced by different means of techniques as shown in Fig 1(D. Lin et al., 2020).

STRUCTURE AND PROPERTIES

Bacterial cellulose, a natural exocellular polysaccharide synthesized by bacteria, has several superior features to plant-derived cellulose, such as huge water holding capacity, large surface area, rheological capabilities, and biocompatibility. BC has been proved as an ensuring low

calorie bulking element for the development of novel rich functional foods in various forms such as powder gelatinous or shred foams, which facilitates its usage in the food industry owing to its water holding, suspending, thickening, bulking, stabilizing, and fluid properties(D. Lin et al., 2020). BC is a long, unbranched polymer made up of several (1-4) -glycosidic linked glucose units. By forming intra- and intermolecular hydrogen bonds, the almost linear glucan chains produce highly regular nanofibrils with nanoscaled cross-sectional dimensions. These nanofibrils can combine to generate microfibrils that are 3–8 nm thick and 50–80 nm wide, creating a 3D network structure(D. Lin et al., 2020).

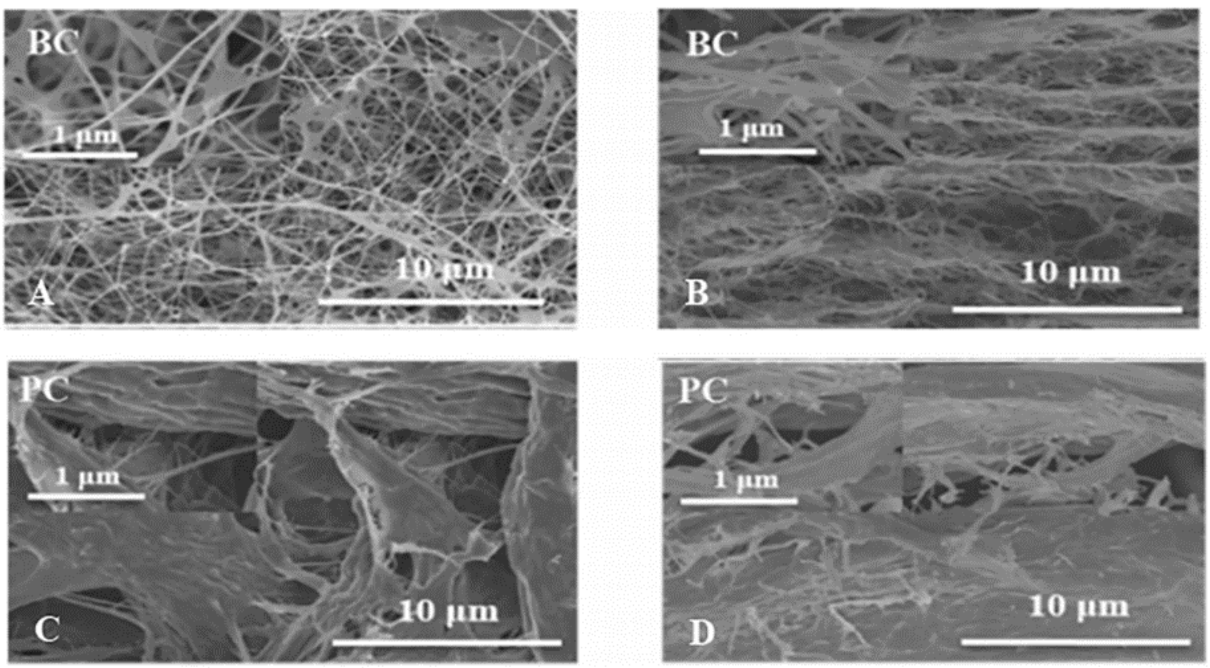

Fig: Micro-morphology of Bacteria Cellulose

The micro-morphologies of BC are depicted in Fig. While the average DP of plant polymers ranges from 13,000 to 14,000, BC has a high degree of polymerization (DP) between 16,000 and 20,000. The dimensions of BC with nanoscaled dimensions are often smaller than those of

cellulose of plant origin. In contrast to cellulose of plant origin mixed with hemicellulose and lignin, BC is also incredibly pure. As a result, the purification process for BC is more affordable, efficient, and environmentally benign(D. Lin et al., 2020).

Relative to other poly- saccharides, BC has superior mechanical qualities, thermal stability, and barriers to water vapor, oxygen, and UV radiation, making it a good replacement for synthetic materials that are not biodegradable. The handling and production of cellulose films are nevertheless constrained by their reduced flexibility. Additionally, the raw materials used to create novel films must have great optical qualities, including a high level of transparency and low opacity(Imran et al., 2012).

BC IN FOOD APPLICATIONS

Advantages-

In 1992, the US Food and Drug Administration recognized bacterial cellulose as a form of dietary fiber and designated it as "generally recognized as safe" (GRAS).

1) Unlike cellulose generated from plant sources, which needs to be isolated and purified using harsh chemicals, bacterial cellulose produced by microorganisms is a very pure form of cellulose.

2) Bacteria may grow, multiply, and secrete in situ the flavor and color of a culture media resource, such as fruit syrup. The BC grown in these media can develop the fruit's natural flavor and pigment.

3) The ability to create a variety of shapes and textures, including films, multi-shaped pulps, filaments, spheres, particles, whiskers, etc., can give BC a wide range of uses in the food industry.

Raw materials for food- Employed as food industry raw materials, which traditionally arises in the production of the dessert Nata de coco and the tea Kombucha(D. Lin et al., 2020). In Southeast Asia, nata, a bacterial cellulose gel with Philippine origins, is a common dessert. This meal has grown quite famous and is now swiftly spreading over the world due to the pleasant tongue feel and straightforward manufacturing technique. There are numerous varieties of Nata, including

Nata de coco and Nata de pina, and the culture medium determines the flavor (Fig.).While Nata de pina employs pineapple flavor, Nata de coco uses coconut. As a result, the market for Nata keeps expanding. Consequently, BC will be widely employed in the retail sector as Nata gains in popularity (Phisalaphong & Chiaoprakobkij, 2012).

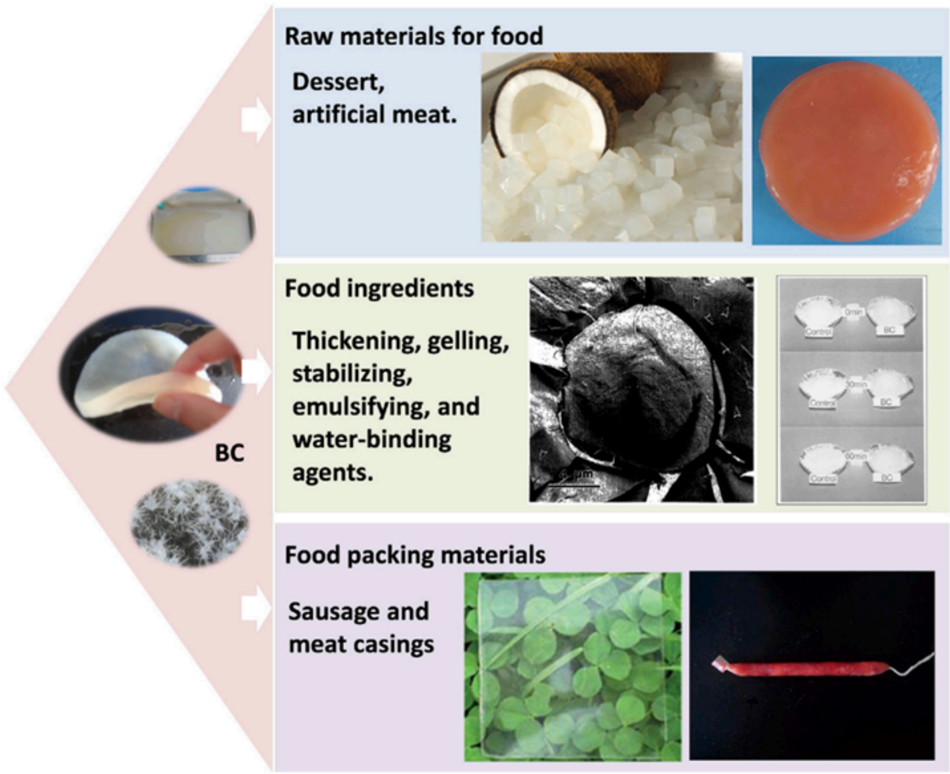

Fig: BC in food applications(Okiyama et al., 1993). Copyright 2010, The Korean Society of Food Science and Technology and Springer Netherlands and Copyright 1993, Elsevier

Multifunctional food ingredients- BC has the capacity to manufacture low-calorie food ingredients. New food additives that are fat-free or low-fat are generally needed. Utilizing plant cellulose as a texturizer, bulking agent, and all-natural low-fat ingredient were the initial areas of focus in the 1960s. The improved purity and fiber width of the polysaccharide are now the driving forces behind interest in it. Meatballs with 10% BC had sensory and shelf-stable qualities similar to the control meatball. These meatballs are considered to be a viable substitute for the fat in emulsified meat products since they are juicy and chewy(Qualities, 2004). BC is now recognized as an acceptable fat-replacement in this class of food because the product maintains its original structure and has strong mechanical qualities(S. Bin Lin et al., 2011).

BC has the capacity to make products with reduced cholesterol. In an experimental analysis Chi-Fai Chau et al. did an vivo tests to determine the fiber's capacity to lower cholesterol, and the results revealed a significant decrease in blood triglycerides, serum total cholesterol, and liver cholesterol when compared to the fiber-free group. In comparison to the plant cellulose group, the BC group also exhibited higher water-holding and cation-exchange capabilities. BC may therefore serve as a helpful substance for the food business in this context(Chau et al., 2008).

BC to improve the rheology of food- The characteristics and structure of BC make it possible for it to promote food stability throughout a wide range of pHs, temperatures, and freeze-thaw conditions while preventing taste interaction even at low concentrations. Applications for thickening, gelling, stabilizing, and water binding are possible(Shi et al., 2014). The role of BC in changing the rheology of food was examined by Okiyama et al. (Okiyama et al., 1993).

Food packing materials- Fresh fruits and vegetables can now be stored in innovative food packaging. Typically, ingredients used to produce films include alginate, cellulose, chitosan, carrageenan, or pectins and their derivatives. Among these, celluloid-based packaging and wrapping films and coatings are of commercial importance because they work well with a variety of food products. Additionally, it has been demonstrated that these films and coatings significantly lower moisture loss and the amount of oil that fried foods absorb(D. Lin et al., 2020).

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