Dextran

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Contributor: Elsa Díaz-Montes

Dextran is an exopolysaccharide (EPS) synthesized by lactic acid bacteria (LAB) or their enzymes in the presence of sucrose. Dextran is composed of a linear chain of d-glucoses linked by α-(1→6) bonds, with possible branches of d-glucoses linked by α-(1→4), α-(1→3), or α-(1→2) bonds, which can be low (<40 kDa) or high molecular weight (>40 kDa). The characteristics of dextran in terms of molecular weight and branches depend on the producing strain, so there is a great variety in its properties. Dextran has commercial interest because its solubility, viscosity, and thermal and rheological properties allow it to be used in food, pharmaceutical, and research areas.

lactic acid bacteria exopolysaccharides dextran structure properties

1. Introduction

Lactic acid bacteria (LAB) are microorganisms that produce lactic acid as the main or only product of carbohydrate fermentation (heterofermentation or homofermentation, respectively). The nutritional requirements are complex, since they are based on vitamins, minerals, fatty acids, amino acids, peptides, and carbohydrates, which are usually in their natural habitats [1]. LAB have been isolated from dairy foods, meats, cereals, vegetables, soil, water, and vaginal waste. According to their characteristics and taxonomy, LAB include bacteria belonging to the genera *Aerococcus*, *Alloiococcus*, *Carnobacterium*, *Dolosigranulum*, *Enterococcus*, *Globicatella*, *Lactococcus*, *Lactobacillus*, *Leuconostoc*, *Oenococcus*, *Pediococcus*, *Streptococcus*, *Vaiscoccus*, and *Weiscoccus* [2]. LAB are considered probiotic bacteria because they can be incorporated into food to improve the consumer's intestinal microbial balance, and they are also generally recognized as safe (GRAS) because they are not pathogenic for humans [3]. On the other hand, they are responsible for a great diversification of flavors and textures of food products, which is why they are mainly used to produce different fermented products such as yogurt, cheese, sourdoughs, pickles, sausages, and soy products [4]. In addition, some LAB can produce extracellular polysaccharides (called exopolysaccharides, EPS) that are repeat units of sugars such as glucose, galactose, and rhamnose, which are secreted during bacterial growth [5]. EPS can be classified into two groups depending on the units that comprise it. Heteropolysaccharides consist of different monosaccharide units, for example, xanthan and gellan. Homopolysaccharides are composed of repeating units of a single type of monosaccharides (e.g., glucose or fructose), for example, glucans and fructans. Levan and inulin are the fructans produced by LAB, while the most commonly produced glucans are cellulose, pullulan, curdlan, mutan, alternan, and dextran [6]. These natural polysaccharides have been used as carriers, encapsulants, thickeners, binders, lubricants, and additives in the pharmaceutical and food industries [7]. However, the most important EPS for medical and industrial use is dextran, which was initially believed to be synthesized only by *Leuconostoc mesenteroides*, but subsequent research reported its segregation by another type of LAB (see Section 2) [8]. The literature on the identification or characterization of dextrans produced by LAB has been increasing in the past decade. Therefore, the aim of this review is to show the advances that have been made in the discovery and characterization of new dextrans, their structural characteristics (molecular weight, links, and branches), and a brief description of their possible applications in medical, food, and research areas. In addition, emphasis is placed on extraction sources for dextran-producing bacterial strains.

2. Synthesis of Dextran

Dextran is synthesized in a particular way by LAB when exposed to a medium with sucrose as a carbon source [8]. In some LAB (e.g., *Lactobacillus*), sucrose can enter the cell directly via the phosphotransferase system (PTS) and metabolize to form d-lactate or become dextran [9]. Bacterial dextransucrases, located extracellularly, are responsible for hydrolyzing sucrose in its fructose and glucose monomers, forming an intermediate with glucose (glycosyl-enzyme) to later carry out their polymerization and form dextran [10], while the resulting fructose enters the bacteria through PTS to meet its metabolic demand [11]. LAB that report dextran production are mainly of the genus *Leuconostoc*, *Weissella*, *Lactobacillus*, and *Streptococcus* [10], which have been isolated from different plant sources (e.g., Agave salmiana and pummelo) [12][13] and fermented products (e.g., rice batter, cabbage, idli batter, and pickles) [14][15][16][17]. However, dextran can also be synthesized via enzymatic, directly using dextransacarases (sucrose: 1,6-α-d-glucan 6-α-d-glucosyltransferase, EC 2.4.1.5) [18], which polymerize the glucoses of the sucrose in dextran.

In industry, dextran is obtained through the culture of *Leuconostoc mesenteroides* NRRL B512, because it is considered a bacteria generally recognized as safe (GRAS) and very stable [19]. The fermentation of the NRRL B512 strain is carried out in a sucrose medium, which is nourished with yeast extracts, malt extracts, casein, peptone, and tryptone; in addition, low levels of calcium and phosphate are added [20][21][22][23]. During fermentation, the pH drops from 7 to 5 due to the generation of lactic acid; therefore, non-ionic detergents are usually added to maintain the stability of the bacteria and its enzymes [8]. In the clinical area, dextran is usually obtained from the acid hydrolysis (e.g., sulfuric and hydrochloric acids) of the native dextran from *Leuconostoc mesenteroides* NRRL B512, which allows controlling the molecular weights of the resulting dextrans [24][25].

3. Characteristics and Properties of Dextran

Dextran is a complex glucan formed by a main chain of d-glucoses linked by α-(1→6) bonds with possible branches of d-glucoses with α-(1→4), α-(1→3), or α-(1→2) bonds [26]. Dextrans have molecular weight of up to 440 MDa [27], and they can be classified into two types according to the length of their chains—those with molecular weight greater than 40 kDa are simply called dextrans [8], while those with molecular weight less than 40 kDa can be called oligodextrans [28]. However, some authors name high molecular weight dextran, low molecular weight dextran, and just dextran to generalize [29].

Variations in dextran characteristics (e.g., molecular weight and branching) cause its properties to be different [15][30]. The main chain of dextran with α-(1→6) bonds adopts a helical shape, which is modified by the presence of branches (α-(1→2), α-(1→3) or α-(1→4)), such that the linear structure of glucan is repeatedly folded [31][32][33].

The solubility and rheological properties of dextran are affected by its molecular weight and branching [34]. The solubility of polymers refers to the interaction of the molecule with water through interactions by hydrogen bridges [35]. Some research asserts that if the dextran molecule were totally linear (without branches), it would be totally soluble, because its hydroxy groups (–OH) would be exposed to interact with water molecules [36]. Other investigations affirm that the greater the number of branches, the greater the solubility of the dextran due to the increase in amorphous areas in the molecule that favor water adsorption and retention [31][32][33]. There are even reports that, in general, all low molecular weight polysaccharides have a higher solubility compared to long chain polysaccharides [37]. There is no direct relationship between the characteristics of the molecule and the variation of the properties [14][38][39][40][41]. However, regardless of the degree of solubility, dextrans are considered soluble EPS due to their ability to incorporate large amounts of water and form hydrogels [42].

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