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Review

Welan gum: Microbial production, characterization, and applications

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ABSTRACT

Microbial exopolysaccharides are of high molecular weight, environment friendly valuable natural polymers, having applications in diverse areas such as food industry, pharmaceutical industry, cement systems and cosmetics industries. Welan gum, a microbial product holds an important place among the exopolysaccharides due to its novel properties and potential applications. The biopolymer welan gum is synthesized by the fermentation process mainly by the *Alcaligenes* sp., and is composed of polymer of tetrasaccharide backbone chain containing L-mannose, L-rhamnose, D-glucose, and D-glucuronic acid. It acts as a thickening, suspending, binding, emulsifying, stabilizing and viscosifying agent. It has important commercial applications in the cement systems. This review is primarily focused on the microbial production, purification, recovery, and the characterization based on the available published literature on the welan gum. Besides this, the biosynthesis and the various process factors affecting the production as well as properties of welan gum and its various applications have also been addressed.

Contents

1. Introduction

Exopolysaccharides (EPS) are ionic or non-ionic water soluble biopolymers having important commercial applications in the food, pharmaceutical and chemical industries. Microbial production of biopolymers has a long history and dextran was the first glycopolymer synthesized in 1880. Microbial polysaccharides are becoming economically competitive with natural gums, produced from marine algae and other plant origins [1]. Plant and seaweed-derived gums used traditionally are affected by environmental factors, but microorganisms can be grown under controlled conditions and offer a range of polymers because of their unique structural properties [2]. Xanthan from *Xanthomonas campestris* [3], sphingans from *Sphingomonas* sp.[4], alginates from *Pseudomonas* sp., *Azotobacter vinelandii* and *Azotobacter chrococcum* [5], cellulose from *Acetobacter xylinium* [6], hyaluronic acid from *Streptococcus equii* [7], succinoglycan from *Rhizobium* [8], pullulan secreted by *Aureobasidium pullulans* [9] are all microbial

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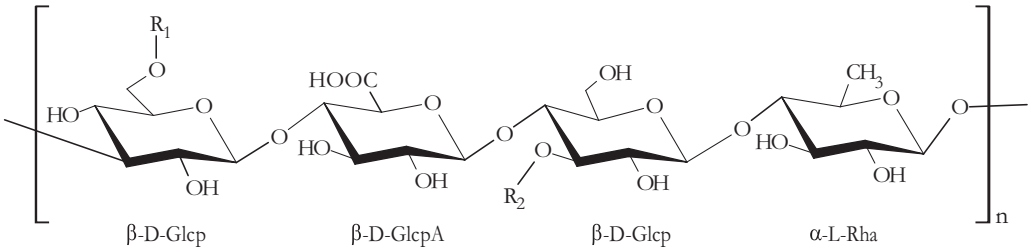

Name of sphingan	R_1	R_2
Gellan	H	H
Welan	H	← 1)-α-L-Rha or ← 1)-α-L-Manp
Rhamsan	← 1)-α-D-Glcp-(6← 1)-β-D-Glcp	H
Diutan	H	← 1)-α-L-Rha -(4← 1)-α-L-Rha

Fig. 1. Basic tetrasaccharide backbone structure in sphingan family showing different sidechains and their linkage positions for gellan, welan, rhamsan, diutan.

polysaccharides studied extensively due to their commercial importance. All these biopolymers have potential applications in the food, pharmaceutical, and other industries due to their unique structure and physical properties. These have been used as adhesives, absorbents, lubricants, soil conditioners, cosmetics, drug delivery vehicles and as high-strength structural materials [10].

Sphingans (gellan, welan, diutan, etc.) are structurally closely related EPS having similar backbone structure except for the location of side chains. This group have a common linear tetrasaccharide backbone structure [→3)-β-Glcp-(1→4)-β-D-GlcpA-(1→4)-β-D-Glcp-(1→4)-α-L-Rha-(1→ or -β-L-Manp(1→], where Glcp is glucose, GlcpA is glucuronic acid, Rha is rhamnose, and Manp is mannose to which different side groups are attached [4,11,12]. The presence of distinct side groups imparts different physical properties to these biopolymers. This group is called as sphingan group based on the presence of glycosphingolipids in the outer membranes instead of common lipopolysaccharide in Gram-negative bacteria [13]. Among these biopolymers, currently more attention is being paid to gellan because of its recent addition to the sphingan group of EPS with novel properties and industrial applications. An attempt is required to explore the potency of other sphingan group biopolymers like welan gum.

Welan gum is produced by *Sphingomonas* sp. ATCC 31555, (also known as *Alcaligenes* sp. ATCC 31555) a Gram-negative microorganism [14,15,82]. It is structurally (Fig. 1) similar to gellan which has the same tetrasaccharide repeating units, except the side chains [16]. Both biopolymers have different aqueous solution properties. Gellan form gel in aqueous solution whereas welan is a non-gelling polysaccharide [10]. Welan gum is an anionic polysaccharide and therefore, has polyelectrolyte properties due to the presence of D-glucuronic acid in its chemical structure. Welan gum has commercial application in the area of cement systems. It acts as a thickening, suspending, binding and emulsifying agent, stabilizer and viscosifier. It also has potential applications in oil-well drilling because it retains its stability and viscosity at elevated temperature [14,17–19]. This review manifested about welan gum structure, biosynthetic pathway, production, conformational characterization, and its potential applications. The factors affecting the welan gum production and its properties have also been discussed.

2. Occurrence and structure of welan gum

Welan gum (previously known as S-130) is a novel fermentative product of *Sphingomomas* sp., a Gram-negative bacterium and is commercialized by CP Kelco, division of J.M. Huber Corporation. It is an acidic hetero-polysaccharide having approximate molecular weight (Mw) 1.0×10^6 g/mol, as determined by photometric analysis [14,20–22]. A mutant strain, *Alcaligenes* sp. NX-3-1 has been developed from wild strain *Alcaligenes* sp. NX-3 (CGMCC 2428), using low-energy ion beam (20 keV N^+ ion beam irradiation) implantation technique. This mutated strain produced higher welan gum yield than produced by wild-type strain [23].

The extracellular polysaccharide welan gum contains L-mannose, L-rhamnose, D-glucose, and D-glucuronic acid in the molar ratios 1.0:4.5:3.1:2.3. The structure has been determined by partial acid hydrolysis and base-catalyzed β-elimination to form a series of oligosaccharides. These oligosaccharides were isolated as their alkylated alditol derivatives by reverse-phase HPLC and characterized by fast atomic bombardment mass spectrometry (FABMS), proton nuclear magnetic resonance (^{1}H NMR) spectroscopy and gas liquid chromatography (GLC), resulting in a structure with D-glucose, D-glucuronic acid and L-rhammose units with singular side chains containing either L-rhammose or L-mannose substituted on C3 of every 1,4-linked glucose repeating unit [15,16,24,25], as shown in Fig. 1.

3. Biosynthetic pathway

Recently the genome of welan gum producing strain, *Sphingomonas* sp. ATCC 31555, has been sequenced. The coding sequences (CDs) responsible for welan gum synthesis (10 CDs) and associated with monosaccharide metabolism (55 CDs) have annotated [83]. The biosynthetic mechanism for the production of extracellular polysaccharide involves uptake of carbon source and the central metabolic pathway. The periplasmic direct oxidative pathway exists alone or together with the intracellular phosphorylative pathway for uptake of glucose [26]. Central metabolic pathways consists of the Embden–Meyerhof–Parnas (EMP) pathway, the pentose phosphate pathway (PPP), and the tricarboxylic acid cycle (TCA) that provides energy and reducing power for the cell's physiological activities and product synthesis [27]. In *A. eutrophus*, the Entner–Doudoroff (ED) pathway plays a role as the central metabolic pathway for glucose catabolism [28]. The mechanism for the production of polysaccharide involves the following steps, (1) synthesis of sugar nucleotide precursors, (2) polymerization of repeat units, (3) export of polymerized repeat unit [29].

The enzymes important in the biosynthetic pathway of nucleotide sugar precursors are: phosphoglucomutase (PGMG),