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Microbial exopolysaccharide - an inevitable product for living beings and environment

Abstract

Exopolysaccharides (EPS) are organic macromolecule, synthesized by various microbes using different carbon sources during fermentation process and are secreted outside the cell wall or as slime or into the extra cellular medium as jelly like material. They are formed by polymerization of simple or identical building blocks, which may be arranged as repeating units within the polymer molecules. For the cells, EPSs are thought to play a role in protection against desiccation, toxic compounds, bacteriophages, osmotic stress, permit adhesion to solid surfaces and helps in biofilm formation. In recent years the increased demand of natural polymers for the industrial applications has led to the remarkable attention to EPS. By studying their structure and physico-chemical properties, it is possible to gain insight into their commercial applications. The aim of this article is to give an overview on applications of microbial EPS.

Keywords: exopolysachharides, role of microbial polymer, biocompatibility, bacteria

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Shailesh R Dave,[1] Avni M Vaishnav,[2] Kinjal H Upadhyay,[2] Devayani R Tipre[2]

[1]Department of Forensic Science, Gujarat University, India
[2]Department of Microbiology and Biotechnology, Gujarat University, India

Correspondence: Shailesh R Dave, UGC Emeritus Professor, Department of Forensic Science, School of Sciences, Gujarat University, Ahmedabad 380 009, India, Email shaileshrdave@yahoo.co.in

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Introduction

Several bacteria, algae, fungi and yeasts are known to produce exopolysaccharides (EPS). Ability of microorganisms to produce EPS is direct and logical response to selective pressures in that natural environment. Exopolysaccharides are studied from hydrothermal vent bacteria, halobacteria, methanogens, autotrophic organisms, acidophiles as well as from ground water and sewage sludge microorganisms. Several microorganisms isolated from extreme environments, such as deep-sea hydrothermal vents, Antarctic ecosystems, saline lakes and geothermal springs have started to be studied as potential sources of valuable biopolymers, including EPSs.[1,2] Successful commercial application of microbial exopolysaccharide depends on exploiting physical properties, which concerns with rheology of exopolysaccharides in solution and ability to form gel at low concentration. Technological advancement has led to discovery of the usefulness of bacterial biopolymers to man.[3] Microbial polysaccharides are susceptible to biodegradation in nature and less harmful to environment than synthetic polymers. This contributes to their environment friendliness in industrial applications as well as sewage disposal or environmental uses.

Role of microbial EPS

Application of microbial polymer began in 1960s and since then there has been a remarkable increase in their commercial use. Microbial EPS play important role in cellular associations, in nutrition as well as micro- and macro environments. EPS producing organisms survive better under oligotrophic situation in environment and live below the threshold nutrient concentration required in the absence of EPS.[4] They are used in food, textile, detergents, beverages, pharmaceutical, biotechnology, agricultural, paper, paint and petroleum industries, drug delivery and cancer therapy, and in formulation of the culture media.[5] Exopolysaccharides (EPS) synthesized by lactic acid bacteria (LAB) play a major role in the manufacturing of fermented dairy products such as yogurt, drinking yogurt, cheese, fermented cream, milk based desserts.[6] There is large variability in EPS production by LAB in terms of quantity, chemical composition, molecular size, charge, presence of side chains, and rigidity of the molecules. One of the major sensory attributes important for consumer preference of dairy products is firmness and creaminess. EPS may act both as texturizers and stabilizers, firstly increasing the viscosity of a final product, and secondly by binding hydration water and interacting with other milk constituents, such as proteins and micelles, to strengthen the rigidity of the casein network.[7] As a consequence, EPS can decrease synthesis of harmful byproducts and improve product stability. Furthermore, it has been reported that EPS can positively affect gut health. Exopolysaccharide producing *S. thermophiles*[8] can enhance the functional properties of Mozzarella cheese, but they are not phage-proof. Exopolysaccharides improves the quality of processed food. They interact with the water molecules and control the rheological properties and physical stability of foods.

The development of nutraceutical products has offered another great opportunity for the food industry. The most critical issue in nutraceutical products is the retention of effectiveness in addition to explicit control of the active ingredients in the product. The high suspending and stability properties of EPS are exploited by the animal feed industry for transporting liquid feeds with added vitamins and other supplements that would otherwise sediment out with transport or storage time.[9]

The inherent biocompatibility and apparent non-toxic nature of some of these bacterial exopolysaccharides has prompted their uses in numerous medical applications; as scaffolds or matrices in tissue engineering, drug delivery and wound dressing, thus making them more attractive as compared to polysaccharides obtained from plants and microalgae.[10–12] Polysaccharides found in Spirulina have anti-inflammatory properties amidst other therapeutic functions.[13] Additionally, Spirulan; a sulfated polysaccharide produced by Arthrospira platensis (formely Spirulina platensis), has been documented as an inhibitor of pulmonary metastasis in humans and a preventer of adhesion and proliferation of tumor cells. Similarly, the marine bacteria; Vibrio diabolicus produces polysaccharides that are hyaluronic acid like and have been commercialized with "Hyalurift" trade name.[3,14] The polysaccharide has been shown to have restoration activity to bone integrity.[15] Polysaccharides of Basidiomycetes mustran are known to have antitumor and immune stimulating polysaccharides.[16] They also possess antiviral activity. Exopolysaccharides are known to exert health-promoting effects such as cholesterol lowering, immune modulating and prebiotic activities.[17] Some polysaccharides form integral components of vaccines, usually when coupled to a suitable protein. Meningitis vaccines have been prepared in this way and multivalent polysaccharide vaccines have been formulated against *Streptococcus pneumoniae* and *Klebsiella.*[18] The high suspension stability is made use in pharmaceutical cream formulations and in barium sulphate preparations. This high cream stability advantage is taken also of by the cosmetic industry, including toothpaste technology where the toothpaste will hold its ingredients (high viscosity) and then easily brush onto and off the teeth (high shear thinning). Uniform pigment dispersal, along with other ingredients and long-term stability, make xanthan a good base for shampoos.[9]

Extracellular polymers of bacterial origin have been identified to have potential for facilitating transport of polynuclear hydrocarbons. EPS producing microorganisms and EPS as product used for oil recovery, which is known as microbial enhance oil recovery (MEOR).[19] This is a distinct field of secondary oil mining/recovery. Bacterial, Archaean and Fungal cell walls and their associated EPS and spores, interact with mineral surfaces and ions; microbes eventually die, and all of their substances, composed of both living and dead cells are reprocessed and may become part of rock coatings and biominerals such as forsterite or opal.[20,21]

Bacterial polysaccharides have indeed been shown to have the ability to bind cations and ion uptake properties, which strengthens its role in bioremediation processes. The selectivity for metal binding sites of some EPS is being influenced by the level of acetylation.[22] These properties are potentially of great importance in sewage treatment specifically for the removal of toxic heavy metal pollutants.[23] They have superior metal complexing capacity so they are supplementary means or potential alternate to existing method of metal removal from mining industries and from industrial wastes. Mineral solubilization is found to influence significantly in the presence of EPS layer. *Acidithiobacillus* ferrooxidans also produce EPS layer and it facilitate metal extractions from sulphidic minerals.[24] Exopolysaccharide producing bacteria have also been used as a bioinoculant to improve the aggregation and the water retention capacity of rhizosphere soil as a function of soil water content. Microorganisms such as *Rhizobium sp*., *Acetobacter sp.*, *Agrobacterium sp.* and *Alkaligenes sp*. have been shown to possess the ability to co-synthesis two or more chemically distinct exopolymers.[25] These include low molecular weight exopolysaccharides (LMWEPS), such as the b 1-2 glucans. It is possible, therefore, that these additional polymers are synthesized and secreted in response to a nearby surface. Consequently, high molecular weight EPS formation is manifested in subsequent events such as stabilization and persistence of the colony.[26,27] In the rhizosphere ecosystem, the successful invasion of alfalfa by *Rhizobium meliloti* is dependent upon both a high and low molecular weight EPS production.[28] The LMWEPS is required to initiate alfalfa root nodule invasion, the high molecular weight polymer stabilizes the symbiotic interaction. Role of EPS is also reported for nodulation in plants. Extracellular polymeric products play important role in adhesion of microorganisms to surface. This result in biofilm formation. EPS also play potential role in maintenance of structure and integrity of the biofilm. Major part of biofilm is mainly of EPS. Microbial EPS enhance attachment of the cells to solid surfaces; it also helps in aggregates formation so it may play an indirect role in exchange of genetic materials.[29] Marine bacteria offer a great diversity of polysaccharides, which could play an important role in biotechnology and industry as well as in future development of cell therapy and regenerative medicine among others applications. Diversity study of cultivable EPS producing bacteria from marine ecosystem of Alang, India indicates presence of 22 genera with as high as 10.7g/l of EPS production.[30,31] The wealth and diversity of the marine biosphere, which includes the deep sea hydrothermal vents, Arctic and Antarctic sea ice has not been fully explored hence, great prospects abound for discovery of novel polysaccharides.

Conclusion

The mini review gives insight in the role of EPS in the modification of micro- and macro environments, which leads to several useful products, transformation and services for the benefit of living being and sustainability of the environment. Detail review will provide more information on applications and role of EPS in environments.

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Conflict of interest

The author declares no conflict of interest.

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