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Exopolysaccharide: A General Review

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EPS contains high molecular weight polysaccharides generally ranging from 10-30 kDa and have homopolymeric and sometime heteropolymeric composition. They have novel applications due to their unique properties they possess. Therefore, EPS have found multifarious applications in the food, environment, pharmaceutical and other industries. A major class of compounds that can be isolated from oceanic creatures is polysaccharides. Exopolysaccharide have the potential to enhance the quality, shelf life, and acceptability of diverse food products. The huge information made available through recent research has made it necessary to consolidate our current understanding on marine polysaccharides, particularly with respect to their food applications. There has been a great concern from scientists to investigate marine microorganisms as a new source of antimicrobial compounds, because of the emergence of bacterial resistance to the current antibiotics (Pabba *et al*., 2011).

Microbial exopolysaccharide are high molecular weight compound and generally carbohydrate in nature and they are mostly present either at the outer membrane as lipopolysaccharides (LPS) that principally determine the immunogenic properties or secreted as capsular polysaccharides (CPS) forming a discrete surface layer (capsule) associated with the cell surface or excreted as EPS that are only loosely connected with the cell surface, is non-adherent to the cell and imparts a sticky consistency to bacterial growth on a solid medium or an enhanced viscosity in a liquid medium.(Chawla *et al*., 2009).These are structural components of the extracellular matrix in which cells are embedded during biofilm development (Marvasi *et al*., 2010). In a wide sense an EPS can be defined as any long chain polysaccharide linear or branched that is soluble in water, has the capacity, in solution, of increasing the viscosity and/or form gels.

The term exopolysaccharide (EPS) was coined by Sutherland in 1972 to described high molecular weight carbohydrate polymers produced by many marine bacteria.

Exopolysaccharides (EPSs) are high molecular weight, biodegradable polymers biosynthesized by a wide range of bacteria (Vijayabaskar *et al*., 2011) These are metabolic products that accumulates on the cell surface of bacteria (Morgan *et al*.,1990).The term Exopolysaccharide was introduced by Sutherland. Microbial exopolysaccharides served different functions in the microbial cells and are distinguished into three main types mainly intracellular, structural and extra or exopolysaccharides. However, microorganisms are known for their ability to synthesize polysaccharides with different structural complexities (Sevior *et al*., 1992; Sutherland 1994).

Marine bacterial exopolysaccharide are fascinating industrial uses and bioactive compounds. Exopolysaccharides are generally composed of monosaccharide and some non carbohydrate substituent, like acetate, succinate .These EPS possess regular structures and thus have unique rheological properties and these molecules are highly pure.EPS could be acidic or basic in nature. Exopolysaccharide may be either homopolysaccharide or heteropolysaccharides. Many of the homopolysaccharides possess regular structures, but the dextran and leans don't. With exception of bacterial alginate, the heteropolysaccharides are composed of regular repeat units of 2-8 monosaccharide (Mayer *et al*., 1999). The EPS matrix is generally ranging from 0.2 to 1.0µm thick. In some bacterial species the thickness of the EPS layer does not exceed values from 10 to 30nm (Czaczyk & Myszka, 2007).

Exopolysaccharides have been termed "adhesive polymers." So, EPSs fulfill a variety of diverse functions including adhesion, cell to-cell interactions, biofilm formation, and cell protection against environmental extremes keeping the microbes in contact. Exopolysaccharides determine living conditions for microorganisms in biofilms, because they affect the porosity, density, water content, charge, hydrophobicity, and mechanical stability of biofilms (Rinaudi & Giordano, 2010).

In the natural environment, Exopolysaccharide (EPSs) is generally heteropolymeric (made of different monomeric units), non-sugar components like uronic acid, methyl esters, sulfates, pyruvates, proteins, nucleic acids and lipids.

EPS also contain several organic ester-linked substituent's and pyruvate ketals that can confer the EPS an anionic character, increase its lipophilicity. Chemical composition, molecular structure, average molecular weight and distribution determine the properties of bacterial EPS (Freitas *et al*., 2011).EPS produced by both prokaryotes (eubacteria and archaebacteria) and eukaryotes (phytoplankton, fungi, and algae).has a great deal of research interest (Kumar *et al* .,2007)

Flemming *et al.,*(2002)proposed seven categories of exopolysaccharide based on functionality. These are constructive or structural, sorptive, surface-active, active, informative, redox-active and nutritive exopolysaccharides respectively.

- Structural exopolysaccharide includes neutral polysaccharides as they serve architectural purposes in the matrix facilitating water retention and cell protection.
- Surface active exopolysaccharide includes molecules with amphiphilic behavior; they have varied chemical structures and surface properties and may be involved in biofilm formation and/or sometimes possess antibacterial or antifungal activities.
- Sorptive exopolysaccharide are composed of charged polymers, whose function is sorption to other charged molecules involved in cell-surface interactions (Schembri *et al* .,2004 Esko *et al*.,1999)

Biopolymers could either be intracellular or extracellular .The intracellular biopolymers are few and have very limited use; however ,the range of extracellular biopolymers are vast and may be grouped into four major classes ;polysaccharide, Inorganic polyanhydrides such as polyphosphate, polyester and polyamides and have collectively termed as extracellular polymeric substances (Cerning .,1995)

Exopolysaccharides can be derived from many natural sources. They may be plant based (e.g. guar gum, cellulose, starch and pectin), marine originated (e.g. agar, carrageenan and alginate), animal originated (e.g. chitin and chitosan) or of microbial origin (e.g. alginate, dextran ,xanthan, gellan and pullulan) (Kaur *et al*., 2012). Polysaccharides extracted from plants or algae can be directly replaced in traditional applications by some bacterial EPS, because of their improved physical properties (Freitas *et al*., 2011). The environment provides various sources of polysaccharides, and that scientific research on their exploitation as food materials is increasingly active, a relatively low number of polysaccharides are authorized for use as food ingredients so therefore there is need of alternative sources to get a maximum yield and its novel functionality.

The compensation of microbial polysaccharides over plants polysaccharides are their novel functions and constant chemical and physical properties. Numerous new microbial EPSs with novel chemical compositions, structures and properties, has been found to have potential applications in fields such as adhesives, textiles, pharmaceuticals, and medicine for anticancer, food additives, oil recovery, and industrial waste treatments, and metal removal in mining etc.

Plant derived polysaccharide

❖ Starch is the major plant polysaccharide which is reserve material. It is deposited as semi- crystalline granules in the plastid compartment of plant cells such as in the amyloplast of plant storage organs, in leaf cell chloroplasts. (Rahman *et al*., 2000)

❖ Cellulose is also a plant polysaccharide containing long, linear chains of cellobiose units. Because of its crystallinity, insolubility and infusibility, it must be chemically modified to make it useful as a packaging plastic. The materials based on the cellulose have been extensively used in biomedical field (Onofrei *et al*., 2016), such as the adsorbent beads, filter, artificial tissue, and protective clothing.

Animal-derived polysaccharides

The polysaccharides derived from animals also play a very important role as tissue composition and show evidence of significant effect in biomedical science. These extracellular matrix in animal tissues, had interlocking meshwork of heteropolysaccharides and fibrous proteins. It is filled with a gel-like material, which supports cell adhesion, growth and provides a porous pathway for the diffusion of nutrients and oxygen to individual cells (Rusnati *et al*., 1996)

❖ **Hyaluronic acid** owning high molecular weight (Cyphert *et al*., 2015), which is an anionic and non-sulfate polysaccharide and consists of alternating units of D-glucuronic acid, and *N*- acetyl-D-glucosamine and it is the component of ECM. According to research studies, hyaluronic acid (HA) owns various biological activities. It has chondro protective effects in vivo and can evidently influence on the articular cartilage (Elmorsy *et al*., 2014).

❖ **Chitosan**, the deacetylated derivative of chitin obtained from arthropods usually exists in the form of granules, sheets, or powders. Chitosan and chitin are both linear polysaccharides, composed of the repeated units of N-acetyl-2-amino-2-deoxy-D-glucose, i.e. N-acetylated groups and 2-amino-2-deoxy-D-glucose residues i.e. N-deacetylated groups, amino groups. Chitosan as a heteropolysaccharide also includes linear β-1,4-linked units (Younes *et al*.,2015). Numerous studies suggest that chitosan and chitin can be used for various applications in tissue engineering , like wound healing, and drug delivery (Anitha *et al*.,2014).

EPS of Marine bacteria

A number of common marine bacteria widely dispersed in the oceans which has ability to produce EPS. In recent years, there has been a growing interest in isolating new exopolysaccharides (EPSs)-producing bacteria from marine environments, particularly from various extreme marine environments (Nichols, Guezennec, & Bowman, 2005). The main properties of marine EPSs—their rheology, flocculating and emulsifying properties, and film-forming capacity—make them good alternatives to other natural polysaccharides.

Many marine microorganisms produce exopolysaccharide which form a layer surrounding the cells that helps them to withstand or resist adverse and extreme environmental conditions. At the same time it is also true that these extreme environments offer novel microbial biodiversity that produces varied and remarkable types of EPS (Mancuso Nichols *et al*., 2005; Margesin and Schinner, 2001; Vincent *et al.,* 1991).

Marine bacteria offer a huge diversity of polysaccharides which could play an important role in biotechnology and various industry as well as in future development of cell therapy ,wound dressing therapy and regenerative medicine among others applications. *Spirulina* polysaccharide shaving anti- inflammatory properties therefore can be used in pharmaceutical additives and for nutritive purposes . Spirulan is a sulfated polysaccharide produced by *Arthrospira platensis* has been documented as an inhibitor of pulmonary metastasis in humans and a preventer of adhesion and proliferation of tumor cells.(Morais *et al*.,2010) .*Vibrio diabolicus* produces polysaccharides that are hyaluronic acid under trade name "Hyalurift". The polysaccharide has been shown to have restoration activity to bone integrity.

EPSs production from marine microorganisms such as; *Zoogloea* sp. (Ikeda *et al*., 1982), *Pseudomonas* sp. (Matsuda and Worawattanamateekul, 1993), *Vibrio fischeri* (Rodrigues and Bhosle, 1991), *Cyanothece* sp. (Philippis *et al*., 1993), and *Alteromonas macleodii* (Raguenes *et al*., 1996) were reported and their properties were studied well.

Quesada *et al*.,2004, Arena *et al*., 2006 isolated *Bacillus licheniformis* strain B3-15 from hot marine shallow vents of Vulcano island (Italy), is able to produce interesting EPSs that show antiviral activities .The *Bacillus licheniformis* strain T4 isolated from the Panarea Island (Italy) is able to produce a +fructo-fucan polymer that has an anti-cytotoxic activity also. (Spano *et al*.,2013).

Exopolysaccharide of Marine actinobacteria

Marine actinobacteria are one of the most efficient groups of secondary metabolite producers .Polysaccharide produced by Streptomyces species, however, has not been fully studied. Manivasagan *et al*.,2013 reported the production and characterization of an extracellular polysaccharide from *Streptomyces violaceus* MM72, isolated from the marine sediments of Tuticorin coast, India.

Exopolysaccharide from fungi

Fungal exopolysaccharides (EPSs) have been recognized as high value bio macromolecules for the last two decades. These products, including pullulan, scleroglucan, and botryosphaeran, have several applications in industries, pharmaceuticals, medicine, foods etc. Most of the EPS produced by fungi are highly hygroscopic b-glucans, suggesting that its production could be related with the tolerance to desiccation; Wasser (2002) reported that many kinds of exopolysaccharide (EPS) derived from filamentous fungi had potent anticancer activities and immunoregulatory properties. EPS production by fungi including *Ganoderma lucidum*, *Agaricus blazi*, *Cordyceps*sp., *Lentinus edodes*, and *Grifola frondosa* through submerged cultures had been reported, all of which have different and interesting biological activities.(Yang *et al*., 2008) .

Exopolysaccharide from Edible Mushroom

Certain edible mushrooms are known to produce exopolysaccharide with anti tumor, antioxidant, antivirus and immunomodulating activities .Mushroom which have the ability to produce notable amount of exopolysaccharide include *Cordyceps sinensis*, *Shiraia bambusicola*, *Pleurotus sajor-caju*, *Agaricus brasilinsis*, *Gomphidius rutilus*, *Lentinus edodes* (Feng *et al.,*2010), *Agaricus bisporus*, *Hypsizigus marmoreus*, *Tricholoma lobayense*, *Ganoderma lucidum*, *Dictyophora indusiata* (Liu *et al*.,2012). *Cordycepsbrasiliensis* (Yang *et al*., 2007) ,*M. esculenta* (Meng *et al*., 2010) *Lentinula edodes* (Lu *et al*., 2010) *Pholiota squarrosa* (Zhao *et al*., 2007) *Morchella esculenta* (Xu *et al*., 2008) ,*P. sajor-caju* (Confortin *et al*., 2008)

Exopolysaccharide of seaweeds:

The sea is a rich reserve of a multitude of resources. Numerous marine organisms, including shellfish, seaweed, microalgae, and corals, can be good sources of polysaccharides having interesting functional properties. The major kelps, which include such genera as *Macrocystis*, *Laminaria*, *Sargassum*, *Pterygophora*, and *Nereocystis*, grow upward like trees and spread their blades at the surface of the water, where they obtain the maximum amount of light.

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