A Review on Commercial Applications of Exopolysaccharide Derived from Pseudomonas Species

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Abstract: ***The exopolysaccharides are bioactive polymers synthesized by Pseudomonas Species with diverse application across the environment, biomedical and industrial domains. The review includes recent knowledge, functional properties and commercial applications of exopolysaccharide derived from Pseudomonas species. Pseudomonas EPS shows antioxidant, antimicrobial, antiviral, antibiofilm, cryoprotective, emulsifying, and rheological properties. The properties are based on their structure, monosaccharide composition and high molecular weight. These properties are responsible for their application such as thickeners, emulsifiers, texturing agents, flavouring agents and fragrance ingredients in the cosmetic and food industry. EPS also has its contribution in Bioremediation and Agricultural development as its properties include biosorption of heavy metals and enhancement of soil-water retention capacity. Thus, Pseudomonas derived EPS constitutes bioactive polymers with promising eco-friendly commercial application.***

Keywords: *Pseudomonas aeruginosa,* Exopolysaccharide, Biopolymer, Biosorption

1. Introduction

The microbial exopolysaccharides are produced by both gram-positive and gram-negative bacteria. The EPS are bioactive compounds with a wide range of application in a variety of scientific, industrial (food, cosmetic, petroleum), medical and environmental domains [4].

The *Pseudomonas* are gram-negative, rod-shaped bacteria which produce exopolysaccharide at extreme environments in order to survive adverse conditions. Bacterial exopolysaccharide serves various biological functions such as, encompassing cell adhesion, protection from harsh environments, resistance against antimicrobials, preventing desiccation and role in biological interactions like symbiosis with plant and nutrient compartmentation [4]-[8].

Antimicrobial resistance has become the reason for a world-wide crisis, including in developed countries. Moreover, the viral infection has also caused morbidity all over the world since vaccination is effective against only specific viral species. The oxidative stress occurs when production of reactive oxygen species (ROS) goes beyond the body's capacity of repairing the damage. ROS can damage DNA and disintegrate cells; it can also develop several chronic conditions such as coronary heart disease and Carcinomas.
Increasing concerns about the toxicity of artificial antioxidants, draws attention towards natural and safer alternatives. The bioactive properties of EPS provide anticancer and antioxidant effects along with boosting immunity against viruses [4].

The water scarcity at arid and semiarid regions has caused reduced crop production. The bacteria like *Pseudomonas* survives in an arid environment due to production of physiologically active exopolysaccharide. In the arid regions, EPS contributes to irreversible attachment of bacterial colonies to the root of plants improving soil structure and aggregation enabling them to cope with drought [6]. As heavy metals resist degradation, accumulate in the environment, and cause toxicity, they are considered a global contaminant leading to toxins to environment and human health. Some bacterial EPS are effective as biological adsorbents for metalloids. The *Pseudomonas* species with higher capacity of producing exopolysaccharide have higher capacity of absorbing lead from the environment [7].

Most of the commercial sectors such as oil recovery, food industries and cosmetic industry use emulsifiers. Since most emulsifiers are obtained from pig fat, the research focuses on biological alternatives. The biological alternative aims at production of bacterial exopolysaccharide which serves as a good emulsifier used for preparation of safer creams and lotions [8].

The sponge-like nature of EPS makes them ideal for applications in diverse sectors including food industries to the field of biomedical sciences. The porous structure of EPS allows absorption of large amounts of water, hence functions as additive to improve texture and utility as gelling , stabilizing and emulsifying agent. The three-dimensional structure of EPS makes it a potential candidate for drug delivery and as a scaffold to support cells, which facilitates transportation of nutrients and metabolic waste [5].

Despite all the applications, *Pseudomonas aeruginosa* is still an opportunistic pathogen. The mucoid stains of *Pseudomonas aeruginosa* cause cystic fibrosis, a fatal disease in immunocompromised hosts. The mechanism of forming biofilms helps *Pseudomonas aeruginosa* to elude the host immune system and the alginate of biofilm acts as a barrier for antibiotic penetration. Furthermore, during initial stages of infection the antigen flagellin is first exposed to dendritic cells, suggesting its role in producing defensive immune responses. The possible treatment for *Pseudomonas aeruginosa* infection could be alginate-flagellin conjugate vaccine [3].

2. Review of Literature

R. Vidhyalakshmi, C. Valli Nachiyar, G. Narendra Kumar, Swetha Sunkar, Ifat Badsha (2018) examined marine bacterium isolates that produces exopolysaccharide with emulsifying property, proposing natural alternatives to synthetic emulsifier for cosmetic industry. The EPS was analysed using various instrumental techniques and demonstrated good emulsifying activity.

Ornella Carrión, Lidia Delgado, Elena Mercade (2014) studied the emulsifying and cryoprotective property exopolysaccharide, derived from cold adapted bacteria, *Pseudomonas* sp.ID1. The bacterium is a psychrotolerant (cold-adapted) strain. The EPS produced from such bacteria demonstrated the ability to emulsify food and cosmetic oils. It also provides strong cryoprotection to the bacterium.

Hana Maaleja, Dorsaf Moallab, Claire Boissetd, Sana Bardaab, Hanen Ben Ayeda, Zouheir Sahnounb, Tarek Rebaic, Moncef Nasria & Noomen Hmidet (2014) evaluated the in vitro antioxidant activity of the exopolysaccharide produced by *Pseudomonas stutzeri* ,and its effectiveness as a hydrogel for dermal wound healing, including rheological and moisture-absorption characteristics. The hydrogel demonstrated high water absorbing ability enhancing wound healing activity. Biopsies of treated wounds show tissue regeneration, re-epithelization with well-structured dermis and epidermis.

Amira Mohamed Ghanaim, Heba I. Mohamed and Abeer E. El-Ansary (2025) had produced and characterized exopolysaccharide from *Pseudomonas aeruginosa.* They analysed and demonstrated its activity against oxidation, microbes, biofilms, tumor, and viruses. The EPS was characterized by FT-IR and HPLC confirming function groups and monosaccharides in its composition.

Ghfren S. Aloraini, Mona Othman I. Albureikan, Aisha M. A. Shahlol, Taghreed Shamrani, Hussam Daghistani,

Mohammad El-Nablaway, Nagwa A. Tharwat, Ahmed M. Elazzazy, Ahmed F. Basyony, and Ahmed Ghareeb (2024) explored the Biomedical and Therapeutic potential of Marine *Pseudomonas* isolates. It was found that the EPS exhibited a wide range of bioactive properties against inflammation, obesity, diabetes and oxidation suggesting its potential as a "promising green therapeutic compound".

Sobhan Faezi, Ahmad Reza Bahrmand, Mehdi Mahdavi, Seyed Davar Siadat, Soroush Sardari, Iraj Nikokar, Korosh Khanaki, Ebrahim Mirzajani, Gholamreza Goudarzi (2017) prepared and tested the conjugate vaccine against Pseudomonas aeruginosa. High molecular weight alginate was conjugated to recombinant type b-flagellin (FLB) using ADH and EDAC. The alginate-FLB conjugate was verified by determining polysaccharide/protein content. The conjugate vaccine expressed a high specific IgG titer against alginate.

Jessica M Bedoya Vélez, José Gregorio Martínez, Juliana Tobón Ospina, Susana Ochoa Agudelo (2021) studied the capacity of *Pseudomonas* genus to tolerate lead through EPS production and biosorption. This study identified the EPS derived by three *Pseudomonas* spp. (*Pseudomonas aeruginosa, Pseudomonas nitroreducens, Pseudomonas alcaligenes)* ,demonstrated the biosorption of lead(Pb).

Mohammad Naseem, Farah Naz ,Ghulam Jilani, Arshad Nawaz Chaudhry, Riaz Ullah, Muhammad Zahoor, Shah Zaman, Tajwar Alam, Sohail (2024) studied the potential of exopolysaccharide (EPS) derived from bacterial strains. The inoculation of exopolysaccharide producing bacteria (EPB) resulted in enhanced soil-water retention capacity, phosphorus solubilization, and improved maize growth under drought-stressed conditions. The EPS production improved soil-water retention capacity. The EPB inoculation resulted in increased growth, higher protein and sugar content, and reduced accumulation of stress indicators in maize crops leading it to tolerate drought conditions.

Table 1: Applications of Pseudomonas derived Exopolysaccharides

Category	Applications	EPS properties	*Pseudomonas* species	Reference
Biomedical applications	Surface coating or Antibiofilm coatings for medical devices	Antimicrobial and antibiofilm property	*Pseudomonas aeruginosa* AG01	[4]
	Production of conjugate vaccine (alginate-FLB conjugate)	As the conjugate elicits high specific IgG titer against alginate	*Pseudomonas aeruginosa* 8821 M *Pseudomonas aeruginosa* E6692	[3]
	Topical hydrogel for wound healing	High moisture absorbing capacity and enhanced collagen formation	*Pseudomonas stutzeri* AS22	[5]
	Antioxidant	Shows the metal (iron) Chelation activity	*Pseudomonas stutzeri* AS22	[5]
Pharmaceutical industry	Topical skin care products	Rapid viscosity recovery and temperature stability	*Pseudomonas stutzeri* AS22	[5]
	Fucose derived therapies	Act as an anticancer and anti-inflammatory agent	*Pseudomonas* sp.ID1	[2]
Cosmetic industry	Emulsifying agent for formulation of Creams and lotion	Strong emulsifying activity against cosmetic oil (Cetiol V)	*Pseudomonas* sp.ID1	[2]
	Fucose derived cosmetic	Fucose has anti-aging activity	*Pseudomonas* sp.ID1	[2]

	Thickening agent in Cosmetic formulation	As the EPS contains mannose, rhamnose, fructose, galactose and glucose.	*Pseudomonas fluorescens*	[8]
	Fragrance ingredients and surfactant in cosmetic formlation	As stearic acid is present in the exopolysaccharide	*Pseudomonas fluorescens*	[8]
	Cleansing agent in cosmetic formlation	As Myristic acid act as cleansing agent	*Pseudomonas fluorescen*	[8]
Food industry	Texturing, gelling, stabilizing agent	Sponge like and porous structure of EPS	*Pseudomonas stutzeri* AS22	[5]
	Emulsifying agent	High emulsifying activity against Sunflower, olive and corn oil	*Pseudomonas* sp.ID1	[2]
	Thickening and flavoring agent	Myristic acid used as flavoring agent	*Pseudomonas fluorescens*	[8]
Biotechnology	Tissue engineering Scaffold	The structure of EPS allows transport of nutrients and metabolic waste	*Pseudomonas stutzeri* AS22	[5]
	Cryoprotection for cell preservation	Protect cell viability at -20°C to -80°C	*Pseudomonas* sp.ID1	[2]
Environmental and Bioremediation	Biosorbants in waste water plant (Removal of heavy metals)	EPS had found to be biosorbant for lead (Pb)	*Pseudomonas* species	[7]
	Biofertilisers and inoculants	Phosphorus solubilization ability and It has helped plants to cope with water scarcity	*Pseudomonas aeruginosa*	[6]
	Bioremediation	Emulsifying diesel and kerosene and increasing bioavailability of pollutants degradation	*Pseudomonas fluorescens*	[8]

3. Conclusion

Exopolysaccharides produced by *Pseudomonas* species contain a structural diverse group of biopolymers with applications at multiple scientific and industrial domains. The biochemical complexity of exopolysaccharides is characterized by different monosaccharide compositions, functional groups ,along with lipid or protein residues. The variable composition of exopolysaccharide is the reason for its broad spectrum of application.

In the biomedical domain, EPS derived from *Pseudomonas stutzeri* and *Pseudomonas aeruginosa* demonstrates antioxidant and therapeutic activities, thus having potential application in wound-healing hydrogels, vaccine conjugates, and anti-infective coatings. Their properties such as collagen deposition and metal chelation highlight their functionality as biomaterials. Similarly, in the pharmaceutical industries, *Pseudomonas* EPS is used as a functional ingredient in their products.

In Cosmetics and food industries *Pseudomonas* EPS serves as natural emulsifier and stabilizer. The cryoprotective property of EPS and its use as scaffold secure its application in microbial preservation and tissue engineering respectively. EPS derived from *Pseudomonas* strains also has properties for hydrocarbon biodegradation, heavy-metal biosorption, and soil moisture retention due to which it has secured position in bioremediation and sustainable agriculture.

Overall, *Pseudomonas*-derived exopolysaccharides contain multifunctional biomolecules which can be utilized for further development in medicine, environmental sustainability, and industrial innovation. The continued exploration of EPS is likely to produce natural and safe solutions with broad scientific and commercial applications.

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