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Biosurfactants: An Overview

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Abstract

Biosurfactants are the biologically synthesized surface-active agents. They are amphiphilic compounds consisting of hydrophilic and hydrophobic domains, that award the organism the ability to accumulate between fluid phases thus reducing surface and interfacial tension. Biosurfactants are produced by a number of microorganisms which include *Bacillus* sp., *Rhodococcus*sp., *Candida* sp., *Pseudomonas aeruginosa*. They are classified based on their molecular weight and chemical composition. Several advantages of biosurfactants over the chemical surfactants are biodegradability, low toxicity, simplicityand bioavailability, specificity of action, structural diversity and effectiveness at extreme conditions. The physiological functions of biosurfactant production in microorganisms includes activities like, antimicrobial, anti-adhesive, antioxidant and the capability to compose substrates readily accessible for uptake by the cells in unfavorable environmental circumstances. Biosurfactants have several applications in petroleum, agriculture, medicine and food sectors.

Keywords:Biosurfactants, Amphiphilic compounds, *Pseudomonas aeruginosa*, Biodegradability, Antimicrobial activity.

Introduction

Surfactants are surface active agents that can reduce surface and interfacial tensions between two liquids. Biosurfactants are the biologically synthesized surface-active agents. They are amphiphilic compounds consisting of hydrophilic and hydrophobic domains. The hydrophilic domain can be carbohydrate, amino acid, phosphate group or some other compounds whereas the hydrophobic domain usually is a long chain fatty acid (Lang, 2002). They are extracellular secondary metabolites, their structure depends on carbon and nitrogen ratio and influences on total production (Janek*et al*., 2013).

Synthetic surfactant causes environmental problems due to their toxicity and resistants to biodegradation in ecosystem. Biosurfactants are considered as one of the high values of microbial products, which have gained considerable interest in recent years that have become an important product of biotechnology for industrial and medical applications. The reasons for their publicity are lower toxicity, specificity of action, simplicity of preparation and extensive applicability (Kaskatepe*et al.*, 2015).

The bacterial strains are responsible for the type and production of biosurfactants produced, it also depends on the carbon source and the physico-chemical conditions provided for the production. Many researchers had reported production of these surface active agents from microorganisms. Most of the work was carried out with glucose, glycerol, crude oil, diesel, gas oil etc. as a carbon source. A wide range of microbial genera were reported as the biosurfactant producers. The characteristic of biosurfactant varies from strain to strain; therefore, it is essential to assess different available strains for their biosurfactant potential and their characterization(Panesar*et al.*, 2011).Biosurfactants are widely used for industrial, agricultural, food, cosmetics and pharmaceutical applications (FakruddinMd, 2012).

Properties and Classification of Biosurfactants:

The studies and production of biosurfactants have been increased in recent years because of its different beneficial characters as compare to the chemical surfactans. They reduces the surface tension of water, have excellent capacity of forming critical micelle concentration (CMC) and good compatibility and digestibility.Moreover, they includes bioavailability, biodegradability, structural diversity (Datta*et al*., 2011), effectiveness at extreme conditions of temperature, pH and salinity, the potential for in situ production, the ability to be produced from cheap raw materials and the organisms producing them can be modified genetically to overproduce these compounds (Bodour*et al*., 2003).

In compliance with such properties the biosurfactants are classified in two different ways, based on their molecular weight and chemical composition.

1. Classification based on molecular weight:

(i) Low molecular weight biosurfactants: These compounds lower the surface and interfacial tension at the air/water interfaces (Salihu*et al*., 2009). Glycolipids, lipopeptides, flavolipids, corynomycolic acids and phospholipids are several examples of such type of biosurfactants.

(ii) High molecular weight biosurfactants: They are generally referred to as bioemulsans and reported as more effective in stabilizing oil in water emulsions. This includesemulsan, alasan, liposan, polysaccharides and protein complexes (Salihu*et al*., 2009).

2. Classification based on Chemical Structure:

(i) Glycolipids: Carbohydrates are incorporated in these types of biosurfactants as a constituent of mono-, di-, tri and tetrasaccharides including glucose, mannose, galactose, rhamnose, galactosesulphate and glucoronic acid to a long-chain aliphatic acid or lipopeptide (Vijayakumar and Saravanan, 2015).

(ii) Lipopeptides and Lipoproteins: They are consisting of a lipid attached to a polypeptide chain. A large number of cyclic lipopeptides including decapeptide antibiotics (gramicidin) and lipopeptide antibiotics (polymyxin) produced by *Bacillus brevis*and *B. polymyxa*respectivelyhad notable surface active properties (Desai and Banat, 1997, Muthusamy*et al*., 2008).

(iii)Fatty Acids and Neutral lipids: Microbial oxidations of alkanes results in the production of straight chain fatty acids which have been considered as a surfactant. Complex fatty acids like corynomuolic acids containing –OH groups and alkyl branches are also produced by microorganisms (Rahman and Gakpe, 2008).

(iv)Phospholipids: They are major components of microbial membranes, when certain hydrocarbon degrading bacteria or yeast are grown on alkane substrates their level increases greatly. For example, when *Acinetobacter*sp. HOI-N utilizes Hexadecane as a substrate, it produces the phospholipids that are mainly phosphatidyl ethanolamine (Muthusamy*et al*., 2008).

(v)Polymeric microbial surfactants: Mainly these are polymeric heterosaccharide containing proteins, including emulsan, liposan, mannoprotein and polysaccharide protein complexes (Desai and Banat, 1997).

(vi)Particulate Biosurfactant: There are some bacteria that produce extracellular membrane vesicles partition hydrocarbons that form micro-emulsion, which play an essential role in uptake of alkane by microbial cells for example in case of *Acinetobacter*sp. (Desai and Banat, 1997).

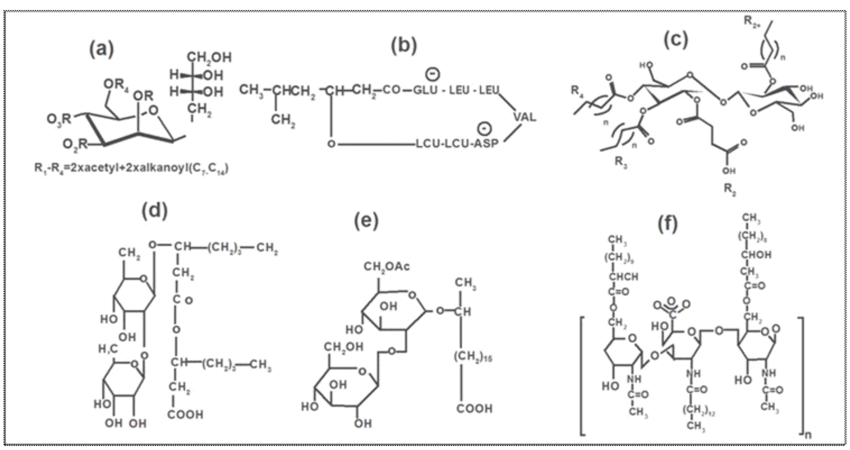

Figure 1: Chemical Structures of Major Classes of Biosurfactants(FakruddinMd, 2012): (a) Mannosylerythritol lipid (b) Surfactin (c) Trehalose lipid (d) Sophorolipid (e) Rhamnolipid (f) Emulsan.

Microorganisms Producing Biosurfactants:

A variety of microorganisms produce biosurfactants that are diverse in chemical composition. The composition and yield of the biosurfactant produced exclusively depends upon the site from where the microorganism is isolated and the various nutritional factors available for their growth (Mulligan, 2005). Many microorganisms have been isolated from different sources for industrial utilization of the various types of agro-industrial waste products (Table-1). Thus, these have an ability to grow on substrates considered potentially harmful for other non-producing microorganisms. Where the field of production of biosurfactants by bacterial species is well explored, relatively fewer fungi are also known to produce biosurfactants.

Table 1: Microorganisms Producing Potential Biosurfactants (Bhardwaj*et al.*, 2013):

Microorganism	Sources of Isolation	By-products/ Carbon Sources	Biosurfactant
Pseudomonas sp.	Oil spilled soil	Glucose/ Molasses/ Cheese whey	Rhamnolipid
Pseudomonas sp.	Used edible oil	Used edible oil/ Rice-water/ Diesel/Petrol/ Whey	Rhamnolipid
Bacillus subtilis	Crude oil contaminated Localities	Glucose/ Rapeseed oil supplementedwith crude oil	Iturin
Bordetellahinizi-	Crude oil contaminated	Sucrose/ Molasses	Trehalose-2,3,4,2'-
DAFI	Localities	supplementedwith crude oil	Tetraester
Pseudomonas aeruginosa	LBI, Petroleum contaminated Soil	Soap-stock	Rhamnolipids
Serratiamarcescens	Petroleum contaminated Soil	Glycerol	Lipopeptide
Candida sp. SY-16	Oil-containing soil sample	Soybean oil and Glucose	Mannosylerythritol (Glycolipid)
*Pseudomonas aeruginosa*SP4	Petroleum contaminated Soil	Palm oil	Rhamnolipid
*Rhodococcus*sp.	Oil contaminated soil	Sucrose/ Kerosene/ n-heptane/ n-octane/ n-hexadecane/ n-paraffin/Gas oil	Extra-cellular Lipids and Glycolipid
Bacillus subtilis	Oil contaminated soil	Vegetable oil/ Kerosene/ Petrol/ Diesel	Surfactin
Pseudomonas	Oil contaminated soil	Vegetable oil/ Kerosene/	Rhamnolipid

Applications:

Biosurfactants have gained considerable interest in recent years as they have several commercial and potential applications in many industrial regions such as: petroleum, organic chemicals, pharmaceuticals and cosmetics, beverages and foods, metallurgy, mining, petrochemicals, biological control and management and many others because of their amphiphilic properties (Table-2).

Table-2: Potential biosurfactants and their Applications (Banat *et al.*, 2000; Shah *et al.*, 2016):

Biosurfactants	Applications
Lipopeptide	Bioremediation of marine oil pollution Bioremediation of hydrocarbon contaminated sites Oil recovery Granulocyte colony stimulating factor (G-CSF) Granulocyte-macrophage colony stimulating factor (GM-CSF) inducing activity
Rhamnolipid	Food processing Bioremediation of oil-contaminated sites Bioremediation of hydrocarbon-contaminated sites Bioremediation of marine and soil environments Insecticidal effect Waste water treatment
Sophorolipids	Oil recover Control of environmental oil pollution Removal of petroleum and motor oil
Glycolipid	Recovery of oil from an oil well or oil sands Bioremediation of marine environment Removal of petroleum derivate motor oil from sand Induction of cell differentiation in the human promyelocytic leukemia cell line HL60 and anti-tumor agents
Surfactin	Anti-mycoplasma agent Anti-tumor agents Anti-fungal agent Anti-viral agents
Iturin	Anti-fungal agent
Mannosylerythritol lipid	Oil removal Bioremediation of marine environment
Pumilacidin	Anti-viral agent
Viscoelastic	Microbial Enhanced Oil Recovery

The range of their applications includes microbial enhanced oil recovery, cleaning of oil tankers, transportation of crude oil, soil/sand bioremediation, remediation of organics and metals, used as emulsifiers, moistening agents, dispersing agents, foaming agents, beneficial food elements and detergents. (Banat *et al*., 2000; Perfumo*et al*., 2010).

They augment the biodegradation and removal of oil through mobilisation, solubilisation or emulsification. Recently they have been widely used in enhance oil recovery process by microbes which play an important role in clean-up of oil containers/storage tanks and formation of products from petrochemicals (Liu *et al*., 2011). Mulligan (2009) reported the application of biosurfactants in enhanced soil washing for hydrocarbon- and metal-contaminated soils.

The miscellaneous structures of biosurfactants award them the capability to exhibit versatile performance. By its structure, biosurfactants wields its toxicity on the cell membrane permeability bearing the resemblance of a detergent like effect (Sridhar *et al*., 2015). El-Sheshtawy and Doheim(2014) reported that biosurfactant produced by *Pseudomonas* sp. have strapping antibacterial and antifungal activity; these surfactant play the role of anti-adhesive agents to pathogens making them useful for treating many diseases as well as its use as therapeutic agent. Biosurfactant produced by *Stenotrophomonas* sp. was accounted for the antimicrobial and antioxidant activity, and also employed in the solubilization of phenanthrene (Gargauri*et al*., 2017).

Biosurfactants have been also used for diverse food processing application but they generally play a role as food formulation ingredient and anti-adhesive agents, as food formulation ingredient they support the formation and stabilization of emulsion due to their capability to reduce the surface and interfacial tension. Biosurfactants from *Saccharomycescerevisiae* and*Pseudomonasaeruginosa* were used in the fruit salad for dressing (Sridhar *et al*., 2010).

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