Microbial Surfactants and Their Potential Applications: An Overview
Ashis K. Mukherjee* and Kishore Das

Abstract
Biosurfactant or microbial surfactants produced by microbes are structurally diverse and heterogeneous groups of surface-active amphipathic molecules. They are capable of reducing surface and interfacial tension and have a wide range of industrial and environmental applications. The present chapter reviews the biochemical properties of different classes of microbial surfactants and their potential application in different industrial sectors.

Introduction
Surfactants are amphipathic molecules that partition preferentially at the interface between fluid phases such as oil/water or air/water interfaces. These properties of surfactants capable them of reducing surface and interfacial tension and make surfactant an excellent detergency, emulsifier, foaming and dispersing agents.

With increasing environmental awareness and emphasis on a sustainable society in harmony with the global environment, during the recent years, natural surfactants produced by living cells are getting much more attention as compared to the synthetic chemical surfactants. Among the natural surfactants, those produced by microbial origin, known as microbial surfactants or biosurfactants are the most promising. They are defined as “structurally diverse/heterogeneous groups of surface-active molecules synthesized by microorganisms”. Considering the important properties and a wide range of applications of biosurfactants, during recent years much more attention has been given to understand the biochemical properties and physiological role of different classes of biosurfactant on the producing microorganism as well as commercial application of biosurfactants.

Classification of Biosurfactants
Based on their chemical composition and types of microbes producing them, biosurfactant are divided into five broad groups viz., glycolipids, lipopeptides and lipoproteins, phospholipids, hydroxylated and crossed-linked and fatty acids, polymeric surfactants and particulate surfactants.

Glycolipids
Glycolipids are carbohydrates like mono-, di-, tri- and tetrasaccharides that include glucose, mannose, galactose, glucuronic acid, rhamnose and galactose sulphate combined with long chain aliphatic acids or hydroxy aliphatic acids. The best examples of glycolipids include trehalose lipids.

*Corresponding Author: Ashis K. Mukherjee—Department of Molecular Biology and Biotechnology, Tezpur University, Tezpur-784 028, Assam, India. Email: akm@tezu.ernet.in

rhamnolipids, sophorolipids, diglycosyl diglycerides and mannosylerythritol lipids. Other types of glycolipids have been reported in the literature such as glycoglycerolipid,\textsuperscript{6} sugar-based emulsifiers,\textsuperscript{7,8} mannosylerythritol lipid A and many different hexose lipids.\textsuperscript{9}

**Trehalose Lipids**

Several structural types of microbial trehalose lipid biosurfactants have been reported. Disaccharide trehalose linked at C-6 and C-6' to mycolic acids is associated with most species of *Mycobacterium*, *Nocardia* and *Corynebacterium*.\textsuperscript{4,10} Mycolic acids are long-chain, \(\alpha\)-branched \(-\beta\)-hydroxy fatty acids. Trehalolipids from different organisms differ in the size and structure of mycolic acid, the number of carbon atoms and the degree of unsaturation.\textsuperscript{4,11} In 2002, Philp and his colleagues\textsuperscript{12} reported the production of trehalose lipids from alkanotrophic *Rhodococcus ruber* on gaseous alkanes propane and butane.

**Rhamnolipids**

Certain species of *Pseudomonas* are characterized to produce large amounts biosurfactant containing one or two molecules of rhamnose linked to one or two molecules of \(\beta\)-hydroxydecanoic acid.\textsuperscript{13-16} In 1965, Edward and Hayashi\textsuperscript{17} have reported formation of glycolipid, type R-1 containing two rhamnose and two \(\beta\) hydroxydecanoic units by *Pseudomonas aeruginosa*. A second kind of rhamnolipid (R-2) containing one rhamnose unit was reported by Itoh et al.\textsuperscript{18} Gas-chromatographic analysis of hydroxyl fatty acids rhamnolipid produced by *P. aeruginosa* DAUPE 614 showed that positions of the fatty acids in the lipid moiety were variable.\textsuperscript{16}

**Sophorolipids**

Sophorolipids consist of a dimeric carbohydrate sophorose attached with a long chain hydroxy fatty acid and are mainly produced by yeasts such as *Torulopsis bombicola*, *T. apicola*\textsuperscript{19} and *Wickerhamiella domericqiae*.\textsuperscript{20} Sophorolipids have the capacity to lower the surface tension of water from 72.8 mN/m to 40 to 30 mN/m, with a critical micelle concentration of 40 to 100 mg/l.\textsuperscript{21} It has been shown that *T. petrophilum* produces sophorolipids on water insoluble substrates such as alkanes and vegetable oil.\textsuperscript{22} Moreover, it has been reported that critical micelle concentration (CMC) and the solubilization ratio of the sophorolipids biosurfactant were found to be in a good range compared with synthetic surfactants.\textsuperscript{23}

**Mannosylerythritol Lipids**

This glycolipid biosurfactant consists of a sugar called mannosylerythritol and are synthesized by yeast like *Candida antarctica*\textsuperscript{24,25} and *Candida* sp. SY 16.\textsuperscript{26} The fatty acid component of biosurfactant was determined to be hexanoic, dodecanoic, tetradecanoic or tetradecenoic acids.\textsuperscript{26} Mannosylerythritol lipids synthesized by *Candida* sp. SY 16\textsuperscript{26} lowered the surface tension of water to 29 dyne/cm at critical micelle concentration of 10 mg/l and the minimum interfacial tension was 0.1 dyne/cm against kerosene.\textsuperscript{26} Fukuoka et al\textsuperscript{27} have characterized the surface active properties of a new glycolipid biosurfactant, mono acylated mannosylerythritol lipid produced by *Psdozyma antarctica* and *P. rugulosa*.

**Lipopeptides**

**Surfactin**

Surfactin, a cyclic lipopeptide is one of the most effective biosurfactants known so far, which was first reported in *B. subtilis* ATCC-21332.\textsuperscript{28} Because of its exceptional surfactant activity it is named as surfactin.\textsuperscript{29} Surfactin can lower the surface tension from 72 to 27.9 mN/m\textsuperscript{29} and have a critical micelle concentration of 0.017 g/l.\textsuperscript{31} The surfactin groups of compounds are shown to be a cyclic lipopeptatides which contain a \(\beta\)-hydroxy fatty acid in its side chain.\textsuperscript{32} Recent studies indicate that surfactin shows potent antiviral, antimycoplasma, antitumoral, anticoagulant activities as well as inhibitors of enzymes.\textsuperscript{30,33} Although, such properties of surfactins qualify them for potential applications in medicine or biotechnology, they have not been exploited extensively till date.