Industrial Applications of Biosurfactants

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INTRODUCTION

Surfactants are amphiphilic compounds consisting of a hydrophobic and a hydrophilic domain. The presence of these two moieties within a molecule causes it to partition preferentially at the interface between fluids of different polarity and hydrogen bonding (Georgiou *et al.*, 1992). The formation of a micellar film at the interface lowers the interfacial energy, a unique effect of surfactants, and they find application in a wide variety of industries, involving the use of emulsifiers, detergents, wetting agents, dispensers and solubilizers *(Table 1)*.

A total of 7.5 million tonnes of surfactants were consumed world-wide in 1990 and there is clearly a potential for growth in the industry. In this respect, the application of biotechnology offers a new dimension for commercial development while knowledge and experience from the fermentation industry may be useful in producing specific formulations which are non-toxic and environmental-friendly.

BIOSURFACTANTS

Microbial compounds which exhibit high surface activity are classified as biosurfactants. Many of these are comparable to the synthetic ones in their ability to lower interfacial tension. In addition, the diversity of naturally produced amphiphilic compounds offers a wide choice of surface active agents for use in specific applications. However, for technical or economic reasons, biosurfactants are not used extensively in industry at present. This situation is expected to change with the increasing use of biosurfactants in bioremediation and the dispersion of oil spills (Harvey *et al.*, 1990).

Biosurfactants are produced by bacteria, yeasts, and moulds. Five major classes of biosurfactants have been identified. They are glycolipids, lipopeptides, lipopolysaccharides, substituted fatty acids and phospholipids. The most studied are two groups of glycolipids: the rhamnolipids of *Pseudomonas aeruginosa (Figure 1)* and the trehalose lipids of *Rhodococcus erythropolis* (Georgiou *et al.*, 1992).

Depending on the species of micro-organism, the synthesis of a biosurfactant may be growth associated, or enhanced by growth-limiting conditions or by the addition of precursors. The wide variety of biosurfactant structures indicates an equally diverse range of biosynthetic pathways. For simplicity, four main pathways are distinguished based on the synthesis of the hydrophobic, the hydrophilic and a combination of these depending on chain lengths. However, this classification does not adequately represent all the many different biosynthetic routes.

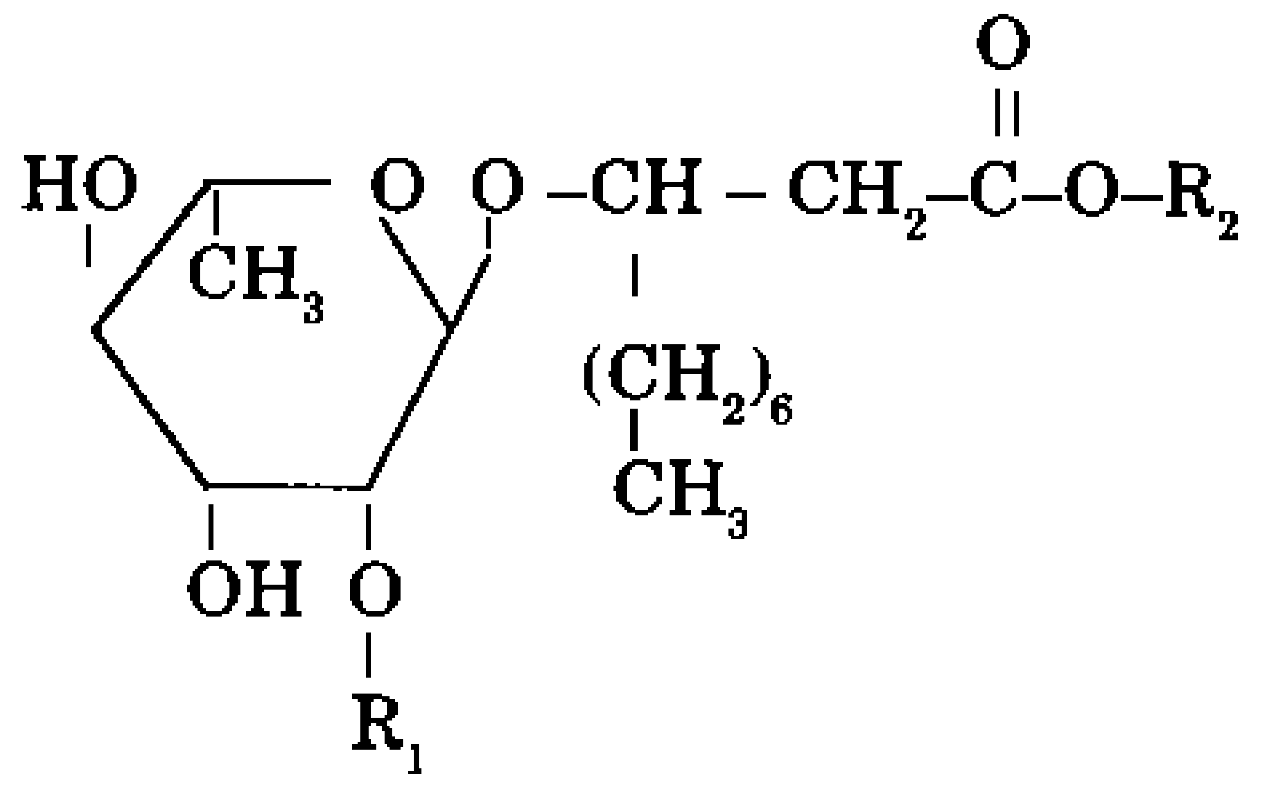
PHYSIOLOGY OF BIOSURFACTANTS

The main physiological role of biosurfactants is to permit micro-organisms to grow on water-immiscible substrates by reducing the surface tension at the phase boundary, thus making the substrate more readily available for uptake and metabolism (Ratledge, 1988). The molecular mecha-

TABLE 1. INDUSTRIAL APPLICATIONS OF BIOSURFACTANTS

Functions	Agriculture	Building and construction	Elastomers and plastics	Foods and beverages	Industrial cleaning	Leather	Metals	Paper	Paint and protective coating	Petroleum and petrochemical	Textiles
	Industrial users										
Emulsification	X		X	X		X	X		X	X	X
De-emulsification										X	
Wetting, spreading, penetration	X	X	X	X	X	X	X	X	X	X	X
Solubilization, solid dispersal	X		X	X						X	X
Air entrainment, foaming		X	X	X			X			X	
Defoaming				X				X			
Detergency				X	X	X		X		X	X
Antistatic			X						X		X
Corrosion inhibition					X					X	

Source: Kosaric et al., 1987.



RL 1: R_1= L –α–Rhamnopyranosyl– R_2= β–Hydroxydecanoic acid
RL 2: R_1= H R_2= β–Hydroxydecanoic acid
RL 3: R_1= L –α–Rhamnopyranosyl– R_2= H
RL 4: R_1= H R_2= H

Figure 1. Four rhamnose lipids from Pseudomonas *species*

nisms related to the uptake of these substrates are still not clear.

The effect of biosurfactants on alkane assimilation is similar. A synergistic effect of rhamnolipids from *P. aeruginosa* and a protein-like activator on the growth of the organism and the oxidation of alkanes had been described (Hisatsuka *et al.*, 1971). A peptido-glycolipid produced by a strain of *Pseudomonas* enabled the organism to grow on media containing alkanes (Koronelli *et al.*, 1983).

Another physiological role of biosurfactants is their antimicrobial activity towards various microorganisms. As a rule, different surfactants inhibit different taxonomy (Lang *et al.*, 1989). The antibiotic activity of biosurfactants produced by *Bacillus licheniformis* against yeasts, bacteria and fungi had been described (Jenny *et al.*, 1991). The inhibition of the growth of alkane utilizing yeasts, such as *Candida*, and *Pichia*, by safflower lipid and lactonic sophoroside had also been reported (Ito *et al.*, 1980).

PROPERTIES OF BIOSURFACTANTS

The properties of biosurfactants are similar to those of the synthetic surfactants. They can be described in terms of physico-chemical data such as critical micelle concentration (CMC), surface tension, interfacial tension, stability, and the type of emulsion formed. Several biosurfactants show low CMC values and reduce the surface tension of the fermentation broth to less than $30mNm^{-1}$. Lipopeptides and sophorose lipids also exhibit good thermal and chemical stability. In general the nonpolar glycolipids such as the dicorynomycolates are soluble in hydrophobic solvents, while the more polar glycolipids such as anionic trehalose tetraesters are soluble in chloroform/methanol mixtures.

APPLICATION OF BIOSURFACTANTS

Increasing interest in the application of biosurfactants arises from their broad range of functional properties, which include emulsification, de-emulsification, corrosion-inhibition and viscosity reduction (Fiechter, 1992). There are many areas of industrial applications where chemical surfactants could be replaced by biosurfactants. These include agriculture, the food and beverage industries, industrial cleaning, textile, cosmetic, pharmaceutical and petroleum industries (Kosaric *et al.* 1987).

Biosurfactants are technically important as they expand the range of available surfactants and exhibit surface-active properties differing from those of synthetic surfactants. Also, they can be produced from renewable substrates. Petroleum resources are being constantly depleted and at some point in the future surfactants made from renewable feedstocks may have a major role to play in supplying industry with its needs: biosurfactants may be produced from carbohydrates, fatty acids and agricultural by-products. Furthermore, biosurfactants are biodegradable, which reduces the potential for toxicity and pollution of the environment.

In the food industry, surface active compounds are used as emulsifiers in food additives for the processing of raw materials such as flavour oils (Kachholz and Schlingmann, 1977). Emulsification plays an important role in producing the right consistency and texture as well as in phase dispersion, particularly in dairy products.

In agriculture, surface active compounds are used for hydrophilization of heavy soils to obtain good wettability and to achieve even distribution of fertilizers in the soil. They also prevent the caking of certain fertilizers during storage, and promote wetting, spreading and penetration of the toxicants in pesticides (Kosaric *et al.*, 1987).

Surface active agents are used widely in household cleaning products and detergent, of which they form one of the most important constituents. Thus, the optimum choice of surfactants is important to ensure satisfactory performance, cost-effectiveness and environment safety. The most widely used anionic surfactant in detergents consists of linear alkylbenzene sulphonates (LAS). Recently, sulphonated methyl esters (SME), a new class of anionic surfactants derived from palm oil, have received attention as active ingredients for the production of washing and cleaning products (Ahmad, 1993). Until recently, the use of biosurfactants in detergents has received little attention although they show good surface active properties. However, it appears likely that they may find application in the detergent industry in the near future.

The production of surface active agents by microorganisms has been recognized for a long time, although a systematic characterization of such products has been slow to emerge, but interest in microbial surfactants has increased considerably in recent years, especially because of their potential application in enhanced oil recovery. The palm oil industry is in a position to make a significant contribution to the production of surfactants which would ultimately be high value-added materials. Biosurfactants produced from palm oil and its fractions could become a feasible alternative to chemically synthesized products of a similar nature.

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