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Mapping of patents on bioemulsifier and biosurfactant: A review

A M Shete[1,**], G Wadhawa[2], I M Banat[3] and B A Chopade[4,*]

[1]Department of Microbiology, University of Pune, Pune 411 007

[2]Biotechnology Facilitating Cell, Department of Biotechnology, Govt of India, New Delhi

[3]School of Biomedical Sciences, University of Ulster, Coleraine BT52 1SA, N. Ireland, U K

[4]Department of Microbiology, Institute of Bioinformatics and Biotechnology, University of Pune, Pune 411 007

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Biosurfactant (BS) and bioemulsifier (BE) molecules have both hydrophilic and hydrophobic moieties that partition preferentially at the interface between fluid phases with different degrees of polarity and hydrogen bonding such as oil/water or air/water interfaces. Such characteristics enable excellent detergency, emulsifying, foaming and dispersing traits. Their low toxicity and environmental friendly nature and range of potential industrial applications in the oil, bioremediation, health care and food processing industries make them a highly sought after group of chemical compounds. Several patents have been issued on BE and BS produced by *Acinetobacter* spp., *Bacillus* spp., *Pseudomonas* spp. and sophorolipid producing yeasts like *Candida* spp. This review presents the result of a scan and mapping effort for 255 patents granted on these compounds worldwide highlighting the types of microorganisms, molecules produced, production process and their potential industrial applications.

Keywords: Bioemulsifier, Biosurfactant, Patents, Patent sites

Introduction

Chemical surfactants and emulsifiers assemble at the interface between water and a polar fluid, where they form interfacial films. Surfactants are soluble compound that reduces the surface tension of liquids, or reduces interfacial tension between two liquids or a liquid and a solid whereas, an emulsifier does not necessarily decrease the surface tension or interfacial tension but helps in dispersion of droplets of one immiscible liquid within another and prevents them from coalescing[1]. Among the desirable characteristics of these compounds are solubility, surface tension reduction, low critical micelle concentration, detergency power, wetting ability and foaming capacity, which make them highly useful for many industries. Chemical surfactants and emulsifiers have been used in various industries like detergents and soaps, petroleum, textile, agriculture, medicine and food[2]. However, most of these chemicals have hazardous environmental impact and therefore availability of a less or non-toxic alternative such as bioemulsifiers (BE) and biosurfactants (BS) was desirable.

BE and BS are surface active compounds that constitute the emulsion secreted by microorganisms to facilitate uptake of an insoluble substrate[3], and are amphipathic molecules containing proteins, polysaccharides or lipids capable of stabilizing oil in water emulsions[4,5]. These compounds have advantages over chemically synthesized surface active compounds as: i) Less or no toxicity[6]; ii) Biodegradability[7]; iii) Broad range of novel structural characteristics[8]; iv) Physical properties like low interfacial tensions and critical micelle concentrations[9,10]; v) High temperature stability and activity at extreme salinity and pH[11]; vi) Can be modified by genetically engineering the microorganism producing it using biological or biochemical techniques[12]; and vii) May be tailored to meet specific requirements[12].

Increasing interest in the potential applications of microbial surface-active compounds has been due to their broad range of functional properties that include emulsification, phase separation, wetting, foaming, solubilisation, de-emulsification, corrosion-inhibition and viscosity reduction of heavy crude oils. BS also plays an important role in microbial enhanced oil recovery[13,14]. They have also been reported to have some applications in the area of personal health

*Author for correspondence
Tel: (+91) 020 25690643; Fax: (+91) 020 25690087
E-mail: chopade@unipune.ernet.in
**Present address
Biochemical Science Division, National Chemical Laboratory, Pune 411 008

care[15,16], pulp and paper[17], coal, textiles and ceramics and uranium ore processing[18]. The industrial use of BE and BS is limited due to their high production cost compared to chemical surfactants. The main reasons for this include poor strain productivity, necessity to use expensive substrates, high production cost and inefficient downstream processing technologies. Thus, the ability to manipulate the metabolism of the producer strain to use cheaper substrates and improvement of process technology to facilitate product recovery may improve their economical competitiveness[2,3].

To date, the only BE/BS-produced on industrial scale and available in market are emulsan and rhamnolipids. Emulsan is polyionic lipopolysaccharide produced by *Acinetobacter calcoaceticus* RAG-1 ATCC 31012. It is marketed by Petroleum Fermentations (Netherlands) for use in cleaning oil-contaminated vessels, oil spills and microbially enhanced oil recovery (MEOR), besides to facilitate pipeline transportation of heavy crude oil. Rhamnolipids are produced by Jeneil Biosurfactants (http://www.biosurfactant.com/rhamnolipidproducts.html).

This review reports the main types of BS and BE, their chemical structure, producing microorganisms and potential industrial applications. In addition, mapping of 255 patents issued worldwide in relation to BE and BS has also been reported.

Patent search on BE and BS

The review mainly covers patents issued after 1975. The important patent sites include:

International Patent Sites

1 www.patents.com
2 US Patent and Trademark Office (www.uspto.gov)
3 European Patent Office (www.epo.co.at)
4 Canadian Patents Database (www.cipo.gc.ca)
5 Japanese Patent Office (www1.ipdl.jpo.go.jp)
6 The Surfip Portal (www.surfip.gov):
7 Intellectual Property Digital Library (www.ipdl.wipo.int)
8 Delphion Intellectual Property Network (www.delphion.com)

Indian Patent Sites

1 Indian Patent Office (www.patentoffice.nic.in and www.ipindia.nic.in)
2 Indian Patent database (www.patestate.com)
3 CSIR unit for research and development of information products (URDIP)
4 www.urdip.res.in
5 Ekaswa

Patents on BE and BS

i) Genus *Acinetobacter*

Emulsans, extracellular microbial protein associated lipopolysaccharides produced by *Acinetobacter* spp. ATCC 31012, are the most efficient emulsifiers, which are widely used in cleaning oil contaminated vessels, oil spill management, and enhanced oil recovery by chemical flooding (Table 1). The patented derivatives of emulsan include α-emulsan, apo-β-emulsan, apo- α -emulsan, apo-psi-emulsan, proemulsans and psi-emulsan. α -Emulsans exhibit a high degree of specificity in the emulsification of hydrocarbons containing both aliphatic and aromatic or cyclic components, which are typical of the hydrocarbonaceous residues found in oil-contaminated vessels used to transport or store crude oil in petroleum fractions. These oil-contaminated vessels may be cleaned by washing the oil-contaminated surfaces of such vessels with an aqueous solution in sea water or fresh water containing α -emulsans (10 μg/ml - 20 mg/ml) and at least one divalent cation (5 m*M* or more), forming an oil-in-water emulsion from which the oil can be recovered for fuel value or for refining (Gutnick *et al*, 1981, US 4276094). BE compositions like an esterase protein (32.5 KD) and a polysaccharide polymer are useful for forming and stabilizing oil-in-water emulsions (Gutnick *et al*, 2002, US 20020143071). BE produced by *A. calcoaceticus* strains can be used to stabilize hydrocarbosols by a surfactant package, which promotes substantially stabilized emulsification of a hydrocarbon with API gravity (20°API or less), viscosity (>100 cP) at 150°F, paraffin content (50% by wt) and aromatic content (15% by wt) into an aqueous phase to form a hydrocarbon-in-water emulsion (90:10 v/v). (Murphy *et al*, 2000, 1340969).

A. calcoaceticus strains also produce nondialyzable, interfacially-active BE (Gutnick *et al*, 1989, 1993, US 4883757, CA 1316478; Tanaka *et al*, 1991, EP 401700, JP 3130073) including KCTC 0081BP, one produced by *A. calcoaceticus* CL (Hwang & Kim, 1997, KR 9706157) and a BS produced by *Acinetobacter* spp. KRC-K4 (Park *et al*, 1999, KR170107). *A. calcoaceticus* strain also produces lipopolysaccharide biosurfactant which has a high emulsifying capacity, promotes the biodegradation of hydrocarbons

Table 1—Patents on bioemulsifier and biosurfactant produced by the members of the genus *Acinetobacter*

Sr No	Organism	Title	Patent No	Publication date	Inventor
1	*Arthrobacter* spp. RAG-1 ATCC 31012*	Production of α-emulsans	US 4230801	28-10-1980	Gutnick D L, Rosenberg E
2	*Arthrobacter* spp. RAG-1 ATCC 31012*	Production of α-emulsans	US 4234689	18-11-1980	Gutnick D L, Rosenberg E, Shabtai Y
3	*Acinetobacter* spp. RAG-1 ATCC 31012	Cleaning oil-contaminated vessels with α-emulsans	US 4276094	30-6-1981	Gutnick D L, Rosenberg E
4	*Acinetobacter* spp. RAG-1 ATCC 31012	Apo β-emulsans	US 4311829	19-1-1982	Gutnick D L, Rosenberg E, Belsky I, Zosim Z
5	*Acinetobacter* spp. RAG-1 ATCC 31012	Apo α-emulsans	US 4311830	19-1-1982	Gutnick D L, Rosenberg E, Belsky I, Zosim Z
6	*Acinetobacter* spp. RAG-1 ATCC 31012	Apo psi emulsans	US 4311831	19-1-1982	Gutnick D L, Rosenberg E, Belsky I, Zosim Z
7	*Acinetobacter* spp. RAG-1 ATCC 31012	Proemulsans	US 4311832	19-1-1982	Gutnick D L, Rosenberg E, Belsky I, Zosim Z
8	*Acinetobacter* spp. RAG-1 ATCC 31012	Psi emulsans	US 4380504	19-4- 1983	Gutnick D L, Rosenberg E, Belsky I, Zosim Z
9	*Acinetobacter* spp. RAG-1 ATCC 31012	Emulsans	CA 1149302	5-7-1983	Gutnick D L, Belsky I, Shabtai Y, Rosenberg E, Zosim Z
10	*Acinetobacter* spp. RAG-1 ATCC 31012	Polyanionic heteropolysaccharide biopolymers	US 4395353	26-7-1983	Gutnick D L, Rosenberg E, Belsky I, Zosim Z
11	*Acinetobacter* spp. RAG-1 ATCC 31012	α-Emulsans	US 4395354	26-7-1983	Gutnick D L, Rosenberg E, Belsky I, Zosim Z
12	*A. calcoaceticus*	Bathing agent	JP 63156714	29-06-1988	Osugi T
13	*A. calcoaceticus* ATCC 31012, NRRL B-15616, NRRL B-15847, NRRL B-15848, NRRL B-15849, NRRL B-15850 and NRRL B-15860	Bioemulsified-containing personal care products for topical application to dermopathologic conditions of the skin and scalp	US 4870010	26-9-1989	Hayes M E
14	*A. calcoaceticus* NRRL B-15847, NRRL B-15848, NRRL B-15849, NRRL B-15850 and NRRL B-15860	Bioemulsifier production by *A. calcoaceticus* strains	US4883757	28-11-1989	Gutnick D L, Nestaas E, Rosenberg E, Sar N
15	*A. calcoaceticus* ATCC 31012, NRRL B-15616, NRRL B-15847, NRRL B-15848, NRRL B-15849, NRRL B-15850 and NRRL B-15860.	Soaps and shampoos containing bioemulsifiers	CA 1266238	27-2-1990	Hayes M E, Holzner G

(*Contd*)

Table 1—Patents on bioemulsifier and biosurfactant produced by the members of the genus *Acinetobacter*— *Contd*

Sr No	Organism	Title	Patent No	Publication date	Inventor
16	*A. calcoaceticus*	Novel *A. calcoaceticus* and novel biosurfactant.	EP0401700	12-12 -1990	Fukui T, Negi T, Tanaka Y
17	*A. calcoaceticus* 217 strain (FERM BP-2905)	Novel *A. calcoaceticus* and novel biosurfactant	JP 03130073	03-6-1991	Tanaka Y, Fukui T, Negi T
18	*A. calcoaceticus* ATCC 31012, NRRL B-15616, NRRL B-15847, NRRL B-15848, NRRL B-15849, NRRL B-15850 and NRRL B-15860.	Personal care products containing bioemulsifiers	US 4999195	12-3-1991	Hayes M E
19	*A. calcoaceticus* ATCC 31012, NRRL B-15616, NRRL B-15847, NRRL B-15848, NRRL B-15849, NRRL B-15850 and NRRL B-15860.	Personal care products containing bioemulsifiers	CA 1300512	12-5-1992	Hayes M E
20	*A. calcoaceticus* strains	Bioemulsifier production by *A. calcoaceticus* strains	CA1316478	20-4-1993	Gutnick D L, Nestaas E, Rosenberg E, Sar N
21	*A. calcoaceticus* ATCC 31012, NRRL B-15616, NRRL B-15847, NRRL B-15848, NRRL B-15849, NRRL B-15850 and NRRL B-15860.	Hydrophobically modified proteins	US 5212235	18-5-1993	Nestaas E, Hrebenar K R, Lewis J M, Whitesides G M
22	*A. radioresistens* strain KA53	Novel bioemulsifiers	WO 9620611	11-7-1996	Ron E Z, Rosenberg E
23	*A. calcoaceticus* CL(KCTC 0081BP)	Microorganism producing biosurfactant	KR9706157	24-4-1997	Hwang K A, Kim Y S
24	*A. radioresistens* strain KA53	Bioemulsifiers	US 5840547	24-11-1998	Ron E Z, Rosenberg E
25	*Acinetobacter* spp. KRC-K4	Novel microorganism *Acinetobacter* spp. KRC-K4 and process for preparing bioemulsifier using the same	KR170107	01-2-1999	Park Ae-R, Jung-Ill K, Chang-Ho J
26	*Acinetobacter* spp. KRC-K4	New lipopolysaccharide biosurfactant	JP 11269203	05-10-1999	Prosperi G, Camilli M, Crescenzi F, Fascetti E, Porcelli F, Sacceddu P
27	*A. calcoaceticus* CBS 962.97	Lipopolysaccharide biosurfactant	US6063602	23-6-1999	Crescenzi F, Sacceddu P, Prosperi G, Camilli M, Fascetti E, Porcelli F
28	*A. calcoaceticus*	New lipopolysaccharide biosurfactant	JP11269203	23-6-1999	Crescenzi F, Sacceddu P, Prosperi G, Camilli M, Fascetti E, Porcelli F
29	*A. calcoaceticus*	New lipopolysaccharide biosurfactant	EP0924221	23-6-1999	Crescenzi F, Sacceddu P, Prosperi G, Camilli M, Fascetti E, Porcelli F

(*Contd*)

Table 1—Patents on bioemulsifier and biosurfactant produced by the members of the genus *Acinetobacter*— *Contd*

Sr No	Organism	Title	Patent No	Publication date	Inventor
30	*A. calcoaceticus* ATCC 31012, NRRL B-15847, NRRL B-15848, NRRL B-15849, NRRL B-15850 and NRRL B-15860.	Bioemulsifier-stabilized hydrocarbosols	JP 1340969	25-4-2000	Murphy P L, Bolden P L Jr, Deal J, Frances I, Hayes M E, Futch L E Jr, Hrebenar KR
31	*A. lwoffi* RAG-1, *A. calcoaceticus* BD4, BD413	Compositions containing bioemulsifiers and a method for their preparation	US20020143 071 WO0248327 US 6512014	3-10- 2002 12-12-2001 28-1-2003	Gutnick D L, Bach H R
32	*A. calcoaceticus* CBS 962.97	New lipopolysaccharide biosurfactant	US2255157		
33	*A. radioresistens* KA53	Novel bioemulsifiers	CA 2184897	NI	Rosenberg, E, Ron, E Z
34	*A. calcoaceticus*	New lipopolysaccharide biosurfactant	CA 2255157	NI	Prosperi, G, Porcelli, F, Fascetti, E, Crescenzi, F, Camilli, M, Sacceddu, P
35	*Acinetobacter* Spp.	Helps to stabilize hydrocarbons, mineral oils, high viscosity hydrocarbons and/or high viscosity crude oil or emulsions and/or to disperse or remove unwanted hydrocarbons and oils from location(s).	US 6713062	30-3-2004	Merchant J L.

**Acinetobacter calcoaceticus* RAG-1 was previously identified as *Arthrobacter* spp. RAG-1

in water and favours the adhesion of microorganisms to the water/oil interface (Crescenzi *et al*, 1999, 11-269203, US6063602, JP11269203, EP0924221). BE produced by *A. radioresistens* strain KA53 is designated as alasan or E-KA53 (100-2,000KD). Its emulsifying activity increases at high temperature (60-90°C) and shows resistance to strong alkali (Ron & Rosenberg, 1996, WO 9620611).

BE produced by *A. calcoaceticus* strains have been used in shampoos and soaps against acne and eczema and in personal care products. It improves hair-degreasing abilities enhancing the cleansing power. The skin cleansing cream and skin cleansing lotion containing these BE have: (a) A specific emulsification activity of at least about 25 units/mg; (b) Ability to remove sebum; and (c) Ability to interfere with microbial adhesion on skin or hair (Hayes *et al*, 1989, 1990, 1991, 1992, US 487010, CA 1266238, US 4999195, CA 1300512). A lipopolysaccharide produced *Acinetobacter* strains make bathing agents effective and reduces the deposition of slime and fur to bath tub and bath furnace (Takao, 1988, 63-156714). The hydrophobically modified protein emulsifiers and emulsion stabilizers can be incorporated in other compounds, which may be used in paints, dyes and cosmetics (Nestaas *et al*, 1993, US 5212235).

ii) Genus *Bacillus*

Surfactin, a BS produced by *Bacillus* spp (Table 2) can be used for pharmaceutical, energy and environmental problems (Paolo *et al*, 1993, US 5264363, US 5227294). EB-162, a BS produced by *B. subtilis* EB-162 (FERN P-17319), has excellent surface activity and is useful as a biosystem surfactant (Keisoku *et al*, 2000-273100). Surfactin in combination with antifungal, antibacterial and insecticidal compounds have been used for preventing or treating fungal and bacterial infections of plants (Heins *et al*, 2000, 2001 US 6060051; US 6103228, US 6291426; Tsuzuki *et al*, 2002, WO 0029426; Jimenez *et al*, CA 2289916, CA 2350782). Lichenysin, an effective surfactant over a wide range of temperatures, pH's, salt and calcium concentrations, produced by *B. licheniformis* JF-2 has been speculated for use for the enhancement of oil recovery from subterranean formations (Mcinerney *et al*, 1985, US 4522261).

Table 2—Patents on bioemulsifiers and biosurfactants produced by the members of the genus B*acillus*

Sr No	Organism	Title	Patent No	Publication date	Inventor
1	*B.subtilis* ATCC 21331 or ATCC 21332	Not available	US 3687926	Not available	Arima K *et al*
2	*B. licheniformis* JF-2 (ATCC 39307)	Biosurfactant and enhanced oil recovery	US4522261	11-6-1985	Mcinerney M J, Jenneman G E, Knapp R M, Menzie D E
3	*B. subtilis* ATCC 53813	Enhanced production of biosurfactant through the use of a mutated *B subtilis* strain	US 5037758	6-8-1991	Mulligan C N, Chow T Y
4	*B. subtilis*	A mutant of bacillus subtiles and a method of producing surfactin with the use of the mutant.	EP0463393	2-1-1992	Carrera P, Cosmina P, Grandi G
5	*B. subtilis* ATCC 53813	Enhanced production of biosurfactant through the use of a mutated *B. subtilis* strain	CA2025812	21-3-1992	Mulligan C N, Chow T Y K
6	*B. subtilis* ATCC 55033	Mutant of *B. subtilis* and production of surfactin by use of the mutant	J04299981	23-10-1992	Carrera P, Cosmina P, Grandi G
7	*B. subtilis* ATCC 55033	Method of producing surfactin with the use of mutant of *B. subtilis*	US 5227294	13-7-1993	Carrera P, Cosmina P, Grandi G
8	*Bacillus* spp.	Method for concentrating biosurfactant	JP 05211876	24-08-1993	Sakurai S, Imanaka T, Morikawa M
9	*B. subtilis* ATCC 55033.	Mutant of *B. subtilis*	US 5264363	23-11-1993	Carrera P, Cosmina P, Grandi G
10	*B. subtilis*	Culture of microorganism and production of substance by microorganism	JP 06121668	6-5-1994	Okuda M, Saito K, Shoda M
11	*B. subtilis*	Controlling agent against plant disease and injury	JP 06135811	17-5-1994	Shoda M, Sato H
12	*Bacillus* spp. TY-8 (FERM P-13666) & TY-34 (FERM P-13665).	New microorganism assimilating petroleum and waste oil	JP 07008271	13-01-1995	Okura I, Kubo M, Hasumi F, Yamamoto E
13	*B. subtilis*	Gene encoding antimicrobial peptide and production thereof	JP 07203975	8-8-1995	Noguchi N, Sato H, Shoda M
14	*Bacillus* spp.	Straight-chain surfactin	J08092279	09-04-1996	Mohamado O, Ishigami Y, Ishizuka Y
15	*B. subtilis* ATCC 21332, ATCC 6051, *B. licheniformis* ATCC 39307, ATCC 14580, *B. circulans* ATCC 9500, *B. polymyxa* ATCC 842, *Clostridium cellulolyticum* ATCC 35319, *Cl. aerotolerans* ATCC 43524.	Bacterial preparation for agricultural use	US 5733355	31-3-1998	Hibino S, Minami Z
16	*Bacillus* spp.	Methods for producing polypeptides in surfactin mutants of bacillus cells	WO9822598	28-5-1998	Adams L F, Brown S, Sloma A, Sternberg D
17	*Bacillus* 60A, *Pseudomonas* 11C	Method for inhibiting eukaryotic protein kinases	WO 99/20792	16-10-1998	Davies J E, Waters B, Saxena G

(*Contd*)

Table 2—Patents on bioemulsifiers and biosurfactants produced by the members of the genus B*acillus* — *Contd*

Sr No	Organism	Title	Patent No	Publication date	Inventor
18	*B. subtilis* AQ713	A novel strain of bacillus for controlling plant diseases and corn rootworm	WO9850422	12-11-1998	Manker D C, Mccoy R J, Heins S D, Jimenez D R, Orjala J E
19	*B. alkalophilus, B. amyloliquefaciens, B. brevis, B. circulans, B. coagulans, B. firmus, B. lautus, B. lentus, B. licheniformis, B. megaterium, B. pumilus, B. stearothermophilus, B. subtilis, or B. thuringiensis.*	Methods for producing polypeptides in mutants of bacillus cells	US 5958728	28-10- 1999	Sloma A, Sternberg D, Adams L. F, Brown S
20	*B. subtilis* AQ713	Strain of bacillus for controlling plant diseases and corn rootworm	US 6060051	9-5-2000	Heins S D, Manker D C, Jimenez D R, McCoy R J, Marrone P G, Orjala J E
21	*B. subtilis* AQ713	Compositions and methods for controlling plant pests	WO0029426	25-5-2000	Jimenez D R, Mccoy R J, Heins S D, Manker D C, Orjala J E, Marrone P G
22	*B. subtilis* AQ713	Compositions and methods for controlling plant pests	US 6103228	15-8-2000	Heins S D, Manker D C, Jimenez D R, McCoy R J, Marrone P G, Orjala J E
23	*B. subtilis* EB-162 (FERN P-17319)	Eb-162 material and its production	JP 2000273100	03-10-2000	Negishi K, Matsuo N, Miyadera K, Yajima M, Esumi Y
24	*B. subtilis* AQ713	Strain of bacillus for controlling plant diseases and corn rootworm	US 6291426	18-9-2001	Heins S D, Manker D C, Jimenez D R, McCoy R J, Marrone P G, Orjala J E
25	*Bacillus* 60A, *Pseudomonas* 11C	Method for inhibiting eukaryotic protein kinases	US 6319898	20-11-2001	Davies J E, Waters B, Saxena G
26	*Bacillus* spp.	Production process of surfactin	WO0226961	4-4-2002	Tsuzuki T, Furuya K, Miyota Y, Yoneda T
27	*B. subtilis* AQ713	A novel strain of bacillus for controlling plant diseases and corn rootworm	CA 2289916	Not Issued	Jimenez D R, Mccoy R J, Heins S D, Manker D C, Orjala J E, Marrone P G
28	*B. subtilis* AQ713	Compositions and methods for controlling plant pests	CA 2350782	Not Issued	Jimenez D R, Mccoy R J, Heins S D, Manker D C, Orjala J E, Marrone P G
29	Surfactin producer	Water-thin emulsions with low emulsifier levels	CA 2375885	Not Issued	Cioca G, Bevacqua A J, George L, Matathia M, Tadlock C C
30	*Bacillus* spp.	It can be used to improve the efficiency and quality of compost.	CN 1431314	23-7-2003	Shi J, Zeng G, Huang G

iii) Genus *Pseudomonas*

Rhamnolipids, surfactants produced by *Pseudomonas* spp. (Table 3), have different uses in petroleum industry. BS produced by *P. aeruginosa* TY-29 (FERM P-13667) and *P. aeruginosa* TY-30 (FERM P-13668) can decompose and assimilate petroleum and waste oil (Ichiro *et al*, 1995, 07008270). *P. aeruginosa* (USB-CS1) produces BS, which can stabilize emulsions of high viscosity crude oil (Rocha *et al*, 1999, 2000, US 5866376, US 6060287, CA 2260576). Methods for biodegradation of hydrophobic organic compounds, particularly PCBS and its remediation using a BE has also been patented (Rothmel, 1996, US 5516688). Rhamnolipids can also be used as biological control products, for rapidly killing zoospores of plant pathogenic microorganisms, *Pythium aphanidernatum, Plasmopara lactucae-radicis*, and *Phytophthora capsici* (Stanghellini *et al*, 1998, US 5767090); control of corn seed rots and seedling blights using a culture of emulsifier and surfactant producing bacterial strains of 6519EO1, 6133DO2, 6109DO1 (Haefele *et al*, 1991, US 4996049) and use of viscosin and analogs as antibacterial, antiviral and antitrypanosomal therapeutic compounds that inhibit the growth of *Mycobacterium tuberculosis*, Herpes Simplex Virus 2 and/or *Trypanosoma cruzi* (Burke *et al*, 1999, US 5965524).

L-rhamnose can be recovered directly from the culture solution by hydrolysis of the rhamnolipids (Carlo *et al*, 1996, US 5501966, US 5658793). BS produced by *P. rubescens* has also been used for reduction in an amount of a cellulase added and shortening in a treating time by reacting a cellulosic fiber with a cellulase (Masuoka *et al*, 1998, 10-096174).

iv) Genus *Arthrobacter*

Arthrobacter spp. No. 38 (FERM BP-4435) produces a novel type of BS having individual amino acid residues added, substituted, or deleted without adversely affecting BS activity of the compound[19-22]. Water soluble or dispersed BS produced by *Arthrobacter* spp. have been used for the microbial decontamination of soils contaminated with mineral oils in which BS as such or mixed with chemical surfactants are metered into the contaminated soils directly or into the removed contaminated soil layers, in an amount such that the formation of toxic intermediates, which slow down or block microbial degradation, is prevented. The accessibility of mineral oils and their products for the microorganisms is simultaneously increased and, as a result, accelerated, virtually complete mineralization by respiration to CO_2 and H_2O is effected[23,24].

V) Genus *Cyanobacterium*

Cyanobacteria J-1, which excretes a material useful as an emulsifying agent, is patented for forming emulsions of hydrocarbons and oils in water. Extracellular polymeric material (mol wt 200,000 Da) contains sugar, fatty acid, and protein moieties, and amide, carboxylic and amino groups[25-27].

Utilization of BE and BS (Table 4)

i) Petroleum Industry

Hayes *et al* have patented BE stabilized hydrocarbasols and their utilization in combustion of viscous hydrocarbons. Theses patents include methods and compositions to facilitate the transportation and combustion of highly viscous hydrocarbons by forming reduced viscosity hydrocarbon-in-water emulsions, and in particular, BE-stabilized hydrocarbon-in-water emulsions. There are such 11 patents, all owned by Petroleum Fermentations (WO 8501889, AU 3556584, AU 574403, US 4793826, US 4821757, US 4943390, RE 36983, US 4684372, US 4666457, US 4618348, US 4684372). This group has also patented a method for reducing such emissions, wherein the combustible compound is mixed with an admixture of a water soluble and a water insoluble sulfur sorbent which reduce the oxidized sulfur compound (SOX) level far greater than each sorbent alone. Extremely viscous hydrocarbons can be burned as preatomized fuels, which can also be mixed with sorbent admixtures (Hayes *et al*, 1989, US 4886519). BS can be utilized for separating hydrocarbon values from mineral deposits that is a liquid paraffinic hydrocarbon (6-18 C atoms) e.g. bitumen from tar sands. A group of microorganisms utilized for this purpose include *Arthrobacter terregens, A. xerosis, Bacillus megaterium, Corynebacterium lepus, C. xerosis, Nocardia petrophilia, Pseudomonas asphaltenicus and Vibrio ficheri* (Zajik *et al* 1981, 1986, CA 1114759, US 4640767).

Crude oil can be recovered from a reservoir by MEOR method (Sheehy *et al*, 1992, US 5083610). Nutrient injection methods can also be used for microbially altering the permeability of subterranean formations (Clark & Jenneman, 1992, US 5083611). In other system essentially free of hydrogen sulfide, the denitrifying microorganisms act as agents which help in the release of oil by the mechanism known to release oil including water diversion, biopolymer and BS production, N_2 formation, gas production, pH

Table 3—Patents on bioemulsifiers and biosurfactants produced by the members of the genus *Pseudomonas*

Sr No	Organism	Title	Patent No	Publication date	Inventor
1	*P. aeruginosa* DSM 2659 (Rsan ver)	Process for the production of rhamnolipids	US 4628030	9-12-1986	Kaeppeli O, Guerra-Santos L
2	*P. aeruginosa* DSM 2659 (Rsan ver)	Process for the manufacture of tensides	CA 1223534	30-6-1987	Guerra-Santos L, Kaeppeli O
3	Not available	Emulsified composition	JP 63077535	7-4-1988	Ishigami Y, others: 04
4	Not available	Rhamnolipid liposomes	US 4902512	20-2-1990	Ishigami Y, Gama Y, Nagahora H, Hongu T, Yamaguchi M
5	*P. aeruginosa* UI 29791, UI 220-7, and UI 47074	Method for producing rhamnose	US 4933281	12-6-1990	Daniels L, Linhardt R J, Bryan B A, Mayerl F, Pickenhagen W
6	*P. fluorescens* 6519E01 ATCC 53860, 6133D02 ATCC 53859, and *Serratia plymuthica* 6109D01 ATCC 53858 and the genetic equivalents thereof	Biological control of corn seed rot and seedling blight	US 4996049	26-2-1991	Haefele D M, Lamptey J C, Marlow J L
7	*P. aeruginosa* SB1, SB-3, SB-30	Production of emulsifying agents and surfactants	US 5013654	7-5-1991	Banerjee S, Karns J S, Chakrabarty A M
8	*P. aeruginosa*	*P. aeruginosa* and use of the same in process for biotechnological preparation of L-rhamnose	JP 06070754	15-3-1994	Giani C, Wullbrandt D, Rothert R, Meiwes J
9	*P. aeruginosa* TY-29 (FERM P-13667) and TY-30 (FERM P-13668).	New microorganism assimilating petroleum and waste oil	JP07-008270	13-01-1995	Okura I, Kubo M, Hasumi F, Yamamoto E
10	*Pseudomonas* spec. DSM 2874	Process for the biotechnical production of rhamnolipids and rhamnolipids with only one β- hydroxydecane carboxylic acid residue in the molecule	CA 1247030	28-2-1995	Lindörfer W, Wagner F, Hofmann H J, Sewe K U, Matulowic U, Syldatk C
11	*Pseudomonas* strains	Pharmaceutical preparation based on rhamnolipid	US 5455232	3-10-1995	Piljac G, Piljac V
12	*P. aeruginosa*	Immunological activity of rhamnolipids	US 5466675	14-11-1995	Piljac G, Piljac V
13	*P. aeruginosa*	Immunological activity of rhamnolipids	WO9602233	1-2-1996	Piljac G, Piljac V
14	*P. aeruginosa* DSM 7107, DSM 7108 and their mutants	*P. aeruginosa* and its use in a process for the biotechnological preparation of L-rhamnose	US 5501966	26-3-1996	Giani C, Wullbrandt D, Rothert R, Meiwes J

(*Contd*)

Table 3—Patents on bioemulsifiers and biosurfactants produced by the members of the genus *Pseudomonas* — *Contd*

Sr No	Organism	Title	Patent No	Publication date	Inventor
15	*P. aeruginosa*	Immunological activity of rhamnolipids	US 5514661	7-5-1996	Piljac G, Piljac V
16	*P. cepacia* ATCC 55487	Method of biodegrading hydrophobic organic compounds, particularly PCBS, and remediation thereof using a bioemulsifier	US 5516688	14-5-1996	Rothmel R K
17	*P. fluorescens* R.sub.4	Microbially produced rhamnolipids (biosurfactants) for the control of plant pathogenic zoosporic fungi	WO 97/25866	17-1-1997	Stanghellini M E, Miller R M, Rasmussen S L, Kim D H, Zhang Y
18	*P. aeruginosa* DSM 7107, DSM 7108	*P. aeruginosa* and its use in a process for the biotechnological preparation of L-rhamnose	US 5658793	19-8-1997	Giani C, Wullbrandt D, Rothert R, Meiwes J
19	*P. rubescens*	Improvement in cellulosic fiber and composition	JP 10096174	14-04-1998	Masuoka K, Obata T, Fukuda Y, Taharu N
20	*P. aeruginosa* (USB-CS1)	Novel *Pseudomonas* spp. that produce biosurfactant	KR141065	01-7-1998	Kim S J, Shin J E, Lee K S
21	*P. fluorescens* R.sub.4	Microbially produced rhamnolipids (biosurfactants) for the control of plant pathogenic zoosporic fungi	US 5767090	16-6-1998	Stanghellini M E, Miller R M, Rasmussen S L, Kim D H, Zhang Y
22	*P. aeruginosa* (USB-CS1)	Production of oily emulsions mediated by a microbial tenso-active agent	US 5866376	2-2-1999	Rocha C A, Gonzalez D, Iturralde M L, Lacoa U L, Morales F A
23	*P. viscose*	Analogs of viscosin and uses thereof	US 5965524	12-10-1999	Burke Jr T, Chandrasekhar B, Knight M
24	*P. aeruginosa* (USB-CS1)	Production of oily emulsions mediated by a microbial tenso-active agent	US 6060287	9-5-2000	Rocha C A, Gonzalez D, Iturralde M L, Lacoa U L, Morales F A
25	*Pseudomonas* 11C, *Bacillus* 60A	Method for inhibiting eukaryotic protein kinases	US 6319898	20-11-2001	Davies J E, Waters B, Saxena G
26	*P. aeruginosa*	Immunological activity of rhamnolipids	CA 2195419	Not issued	Piljac G, Piljac V
27	*P. aeruginosa* (USB-CS1)	Production of oily emulsions mediated by a microbial tenso-active agent	CA 2260576	Not issued	Lacoa U L, Morales F A, Rocha C A, Iturralde M L, Gonzalez D
28	*P. fluorescens* KPM-018P	Used for controlling plant insect pests	JP 2005102510	21-4-2005	Mayama S, Tosa Y, OtsuY, Toyada H, Matsuda K, Nonomura T.
29	*P. aeruginosa*	Used for preparing compost from lift garbage to improve efficiency and quality of compost.	CN 1431036	23-7-2003	Shi J, Yuan X, Zeng G

Table 4—Other patents on bioemulsifiers and biosurfactants

Sr No	Organism	Title	Patent No	Publication date	Inventor
1	*Co. hydrocarboclastus* UWO 409	Emulsifying agents of microbiological origin	CA 990668	8-6-1976	Zajic J E, Knettig, E
2	*Co. hydrocarboclastus* UWO 409	Emulsifying agents of microbiological origin	US 3997398	14-12-1976	Zajic J E, Knettig, E
3	*Ar. terregens, Ar. xerosis, B. megaterium, Co. lepus, Co. xerosis, N. petrophilia, Ps. asphaltenicus, V. ficheri*	Hydrocarbon extraction agents and microbiological processes for their production	CA 1114759	22-12-1981	Gerson D F, Zajic J E
4	*Mycobacterium phlei, Nocardia* rhodochrous,	Method and installation for flooding petroleum wells and oil-sands	CA 1119794	16-3-1982	Wagner F, Rapp P, Bock H, Lindörfer, W, Gebetsberger W, Schulz W
5	*Corynebacteria Salvinicum* SFC	Microbiological production of novel biosurfactants	CA 1125683	15-6- 1982	Zajic, J E, Panchal, C, Gerson, R K, Gerson, D F
6	*Alcaligenes* species ATCC 31853	Heteropolysaccharide S-198.	EP 0064354	11-10-1982	Pickens P A, Steenbergen S M, Chang J H S, Shim J L, Hayden H R, Peik J A, Colegrove G T
7	*Corynebacteria Salvinicum* SFC	Microbiological production of novel biosurfactants	US 4355109	19-10-1982	Zajic, J E, Panchal C, Gerson R K, Gerson D F
8	*Clostridium, Pseudomonas, Bacillus, Achromobacter, Alcaligenes, Bacterium, Chromobacterium, Corynebacterium, Escchereschia, Lactobacillus, Methanomonas, Micrococcus Mycobacterium, Propionebacterium, Proteus, Sarcina, Vibrio, Desulfovibrio,* and mixtures thereof.	Enhanced oil recovery process using microorganisms	US 4450908	29-5-1984	Hitzman D O
9	*Methylomonas clara* ATCC31226	Lipotensides, process for their isolation and their use	DE3312166	10-10-1984	Kachholz T, Schlingmann M
10	Any bioemulsifier/biosurfactant producer	Bioemulsifier-stabilized hydrocarbosols	WO 8501889	09-5- 1985	Hayes M E, Hrebenar K R, Murphy P L, Futch L E Jr., Deal J, Frances I, Bolden P L
11	Any bioemulsifier/biosurfactant producer	Combustion of viscous hydrocarbons	US4618348	1986-10-21	Futch Jr L E, Murphy P L, Hayes M E, Deal I J F, Hrebenar K R
12	*Ar. terregens, Ar. xerosis, B. megaterium, Co. lepus, Co. xerosis, N. petrophilia, Ps. asphaltenicus, V.*	Hydrocarbon extraction agents and microbiological processes for their production	US 4640767	3-2-1987	Zajic J E, Gerson D F

Table 4—Other patents on bioemulsifiers and biosurfactants — *Contd*

Sr No	Organism	Title	Patent No	Publication date	Inventor
	ficheri				(*Contd*)
13	Any bioemulsifier/biosurfactant producer	Method for reducing emissions utilizing pre-atomized fuels	US 4666457 EP0479771	19-5-1987 4-8-1992	Hayes M E, Hrebenar K R, Deal I, James F, Bolden, Jr, Paul L
14	Any bioemulsifier/biosurfactant producer	Combustion of viscous hydrocarbons	US 4684372 AU3556584 WO8501889	4-8-1987	Hayes M E, Hrebenar K R, Murphy P L, Futch, Jr; Laurence E, Deal I, James F, Bolden, Jr; Paul L
15	*Rh. erythopolis* DSM 43215, *Arthrobacter* spec. DSM 2567 or *Corynebacterium* spec. DSM 2568	Trehalose-lipid-tetraesters	CA 1226545	8-9-1987	Li Zu-Yi, Lang, S, Egbert W, Lindörfer F, Walter, S, Kai-Udo S, Walther H H J
16	Any bioemulsifier/biosurfactant producer	Enzymatic degradation of lipopolysaccharide bioemulsifiers	US 4704360	3-11-1987	Shoham Y, Rosenberg E, Gutnick D L
17	Not available	Liposome	JP 63182029	27-07-1988	Ishigami Y, Gama Y, Nagahora H, Motomiya T, Yamaguchi M
18	*Rh. erythropolis* DSM 43215, *Arthrobacter* DSM 2567 of *Corynebacterium* DSM 2568.	Trehalose lipid tetraesters	US 4720456	19-1-1988	Wagner F, Ristau E, Li Zu-yi, Lang S, Schulz W, Hofmann H J, Sewe K U, Lindorfer W
19	Any bioemulsifier/biosurfactant producer	Bioemulsifier stabilized hydrocarbons	AU574403	07-7-1988	Hayes ME, Hrebenar KR, Murphy PL
20	Any bioemulsifier/biosurfactant producer	Bioemulsifier-stabilized hydrocarbosols	US4793826	27-12- 1988	Hayes ME, Hrebenar K R, Murphy P L, Futch Jr L E, Deal I J F, Bolden Jr P L
21	Not available	PCB decomposition method and PCB decomposable mixed cultured microorganism	JP 64068281	14-03-1989	Kanehara K, Hashimoto T, Oana T, Fukuda M, Takagi M, Yano K, Oishi M
22	Any bioemulsifier/biosurfactant producer	Enzymatic degradation of lipopolysaccharide bioemulsifiers.	US 4818817	4-4-1989	Shoham Y, Rosenberg E, Gutnick D L
23	Any bioemulsifier/biosurfactant producer	Bioemulsifier stabilized hydrocarbosols	US4821757	18-4-1989	Hayes M E, Hrebenar K R, Murphy P L, Futch Jr. Laurence E, Deal I, James F, Bolden Jr. Paul L
24	*Alcaligenes* spp. ATCC 31961	Method for reducing sox emissions during the combustion of sulfur-containing combustible compositions	US 4886519	12-12-1989	Hayes M E, Hrebenar K R, Minor J L, Woodworth LM
25	Any bioemulsifier/biosurfactant producer	Bioemulsifier-stabilized hydrocarbosols	US4943390	24-7-1990	Hayes M E, Hrebenar K R, Murphy P L, Futch Jr. Laurence E,

Table 4—Other patents on bioemulsifiers and biosurfactants

Sr No	Organism	Title	Patent No	Publication — *Contd*	Inventor
					Deal I, James F, Bolden Jr; Paul L
					(*Contd*)
26	Any bioemulsifier/biosurfactant producer	Bioemulsifier-stabilized hydrocarbosols	WO8501889		
27	*Ps. fluorescens* 6519E01 ATCC 53860, 6133D02 ATCC 53859, and *Serratia plymuthica* 6109D01 ATCC 53858 and the genetic equivalents thereof	Biological control of corn seed rot and seedling blight.	US 4996049	26-2-1991	Haefele D M, Lamptey J C, Marlow J L
28	Endogenous microoganisms in oil reservoir	Microbial decontamination of soils contaminated with hydrocarbons, in particular mineral oils by microbial oxidation.	US 5128262	7-7-1992	Lindoerfer W, Sewe K U, Oberbremer A, Mueller-Hurtig R, Wagner F
29	Endogenous microoganisms in oil reservoir	Recovery of oil from oil reservoirs	US 5083610	28-1-1992	Sheehy A
30	microorganisms endogenous to said subterranean formation.	Nutrient injection method for subterranean microbial processes	US 5083611	28-1-1992	Clark J B, Jenneman G E
31	Not specified	Detergent composition	JP 05059394	09-03-1993	Hall P J, Haverkamp J V, Kralingen C G, Mihiyaeru S
32	Any bioemulsifier/biosurfactant producer	Viscous hydrocarbon-in-water emulsions	CA 1318216	25-5-1993	Polanco D R, Rivas, H J G, Euler M, Humberto L R, Ignacio A, Chirinos, M L, Rojas, D C, Antonio S P, Jose Q, Lirio R M
33	Any bioemulsifier/biosurfactant producer	Bioemulsifier-stabilized hydrocarbon sols	JP 05230479	7-9-1993	Hayes M E, Hrebenar K R, Murphy P L, Futch Jr L E, Deal I J F, Paul L B Jr
34	Particular microorganism(s) not specified	System and method for decontamination of contaminated ground	US 5246309	21-9-1993	Hobby M M
35	Particular microorganism(s) not specified	Method of preparing composite particles comprising adhering wax particles to the surface of resin particles.	US 5368972	29-11-1994	Yamashita H, Kotsugai A, Watanabe Y, Katoh K, Kawase H
36	Perticular microorganism(s) not specified	Microbial decontamination of soils contaminated with hydrocarbons, in particular mineral oils by microbial oxidation	CA 1334582	28-2-1995	Lindoerfer W, Sewe K U, Oberbremer A, Müller-Hurtig R, Wagner F
37	Denitrifying bacteria	Method for reducing the amount of and preventing the formation of hydrogen sulfide in an aqueous system	US 5405531	11-4-1995	Hitzman D O, Sperl G T, Sandbeck K A
38	Particular microorganism(s) not specified	Laundry detergent composition containing synergistic combination of sophorose lipid and nonionic surfactant	US 5520839	28-5-1996	Hall P J, Haverkamp J, van Kralingen C G, Schmidt M

Table 4—Other patents on bioemulsifiers and biosurfactants

Sr No	Organism	Title	Patent No	Publication — *Contd*	Inventor
39	Any bioemulsifier/biosurfactant producer	Nutrient mixtures for the bioremediation of polluted soils and waters	US 5635392	3-6-1997	Kopp-Holtwiesche B, Weiss A, Boehme A (*Contd*)
40	Various organisms	Composition containing a surface active compound and glycolipids and decontamination process for a porous medium polluted by hydrocarbons	US 5654192	5-8-1997	Ducreux J, Ballerini D, Baviere M., Bocard C, Monin N
41	Not specified	Detergent compositions	CA 2060698	30-9-1997	Hall P J, Haverkamp J, van Kralingen C G, Schmidt M
42	*Pseudomonas* or *Moraxella*	Method for cleaning porous surfaces with a washing liquid containing bacteria having an enzymatic activity	EP 0808671	26-11-1997	Debord G, Dran M
43	Any biosurfactant producer	Extraction of bitumen from bitumen froth and biotreatment of bitumen froth tailings generated from tar sands	US 5968349	19-10-1999	Duyvesteyn W P C, Budden J R, Picavet M A
44	Rhamnolipid and sophorolipid producers	Production of sucrose ester by homogeneous solventless process	CN 1232036	20-10-1999	Li Z, Shi Y
45	Biosurfactant KshAS-M Producer	Composition for increase of oil recovery	RU 2143553	27-12-1999	Kalinskij B A, Simaev J M, Bazekina L V, Tujgunov M R, Tukhteev R M
46	Any bioemulsifier/biosurfactant producer	System and process for in tank treatment of crude oil sludges to recover hydrocarbons and aid in materials separation.	US 6033901	7-3-2000	Powell Jr, John E
47	*Lactobacillus* Spp.	*Lactobacillus* therapies	US 6051552	18-4-2000	Reid G, Bruce A W, Busscher H J, Van der Mei H C
48	Any bioemulsifier/biosurfactant producer	Bioemulsifier-stabilized hydrocarbosols	CA 1340969	25-4-2000	Murphy P L, Bolden P L Jr, Deal J F, Hayes, M E, Futch L E Jr, Hrebenar K R
49	Not available	Sulfated oligosaccharide compound	JP 2000143686	26-05-2000	Uzawa H, Usui Y
50	Not available	Sulfated oligosaccharide compound and intermediate thereof	JP 2000143687	26-05-2000	Uzawa H, Usui Y
51	Not available	System and process for in tank treatment of crude oil sludges to recover hydrocarbons and aid in materials separation	US 6069002	30-5-2000	Powell Jr, John E
52	Any biosurfactant producer	Biochemical treatment of bitumen froth tailings	US 6074558	13-6- 2000	Duyvesteyn W P C., Budden J R, Huls B J
53	Not available	Cleaning foliage of agricultural plants	FR2787439	23-6-2000	Lemarchand P, Mer-

Table 4—Other patents on bioemulsifiers and biosurfactants

Sr No	Organism	Title	Patent No	Publication date	Inventor
				— *Contd*	
		to improve photosynthesis and increase crop yields, by adding acid, alkylsulfonate and biosurfactant			Mercier J L
					(*Contd*)
54	Any biosurfactant producer	Germicidal composition	US 6262038	17-7-2001	Pierce D, Heilman TJ
55	Any biosurfactant producer	Dry cleaning system comprising carbon dioxide solvent and carbohydrate containing cleaning surfactant	US 6369014	9-4-2002	Murphy D S, Binder D A
56	Any biosurfactant producer	Surfactant process for promoting gas hydrate formation and application of the same	US 6389820	21-5-2002	Rogers R E, Zhong Y
57	Any biosurfactant producer	Carbohydrate containing cleaning surfactant and method for using the same	US 6475968	5-11-2002	Murphy D S, Binder D A
58	Not available	A biotechnological method for the regeneration of hydrocarbons from dregs and muds, on the base of biosurfactants	WO 02062495	15-8-2002	Pesce L
59	Any bioemulsifier/biosurfactant producer	Pre-atomized fuels and process for producing same	RE 36983	12-12-2000	Hayes M E, Hrebenar K R, Murphy P L, Futch Jr L E, Deal J F, Bolden Jr P L
60	Any biosurfactant producer	Biochemical treatment of bitumen froth tailings	CA 2350927	Not issued	Budden J R, Duyvesteyn W P C, Huls B J
61	Any biosurfactant producer	Extraction of bitumen from bitumen froth and biotreatment of bitumen froth tailings generated from tar sands	CA 2350907	Not issued	Duyvesteyn W P C, Picavet M A, Budden J R
62	Particular microorganism(s) not specified	A process for the simplified biological rehabilitation of land polluted with long-term contamination based on mineral oil	CA 2303413	Not issued	Kopp-Holtwiesche B, Lauer U
63	*Lactobacillus* spp.	Lactobacillus therapies	CA 2206674	Not issued	Reid G, Bruce A W, Busscher H J, Van Der Mei H C
64	Any biosurfactant producer	Germicidal composition	CA 2267678	Not issued	Heilman T J, Pierce D
65	*Streptococcus* spp., *Bifidobacterium* spp. and lactic acid bacteria	Possesses anti-microbial properties including the ability to selectively bind to collagen and inhibit infections around wounds and at the site of implants and biofilms associated with infections in mammals	US 6727223	27-4-2004	Howard J, Reid G, Gan B S
66	Any biosurfactant producer	For coating of medical devices adapted for long term implantations	US 6921390	26-7-2005	Bucay-Couto W, Li J
67	Biosurfactant producers	Enhance PAH degradation; also help in removal of heavy metal ions from soil and aquatic environment	US 2005106702	19-5-2005	Brigmon R L, Story S, Altman D, Berry C J

Table 4—Other patents on bioemulsifiers and biosurfactants

Sr No	Organism	Title	Patent No	Publication — *Contd*	Inventor
68	*Pseudzyma* sp. TM-453	Glycolipid containing mannose and mannitol	JP 2005104837	21-4-2005	Matsuura F, Ota M, Tamai M, Tamura K
69	Biosurfactant producers	Enhances oil recovery from oil reservoirs at 70-90°C	WO 2005005773	20-1-2005	(*Contd*) Banwari L, Reddy M, Ramajaneya V, Agnihotri A, Kumar A, Sarbhai M, Singh N, Khurana R, Khazanchi S K, Misra T R
70	Biosurfactant producers	Enhances oil recovery from oil reservoirs	IN 189459	22-2-2003	Deshpande M, Mishra K, Bal A S, Khanna P, Juwarkar A, Babu P S
71	Biosurfactant producers	Helps for treating a surface of an apparatus within an electrocoating operation to remove or prevent sessile microorganism growth on the apparatus	US 2004231982, WO 2004078222	25-11-2004	Contos M A, Bourdeau M J, Pillar L L
72	Any biosurfactant producer	Used in detergent	US 2004152613	5-8-2004	Develter D, Renkin M, Jacobs I
73	Biosurfactant producers	Helps in plastic degradation along with other enzymes	WO 2004038016	6-5-2004	Abe K, Gomi K, Yamagata Y, Hasegawa F, Maeda H, Nakajima T, Machida M
74	Biosurfactant producers	Used as liquid fuel additive for inducing improvement of octane value	KR 2003044969	9-6-2003	Fukunaga T, Kim H R, Nozawa M
75	Aeruginous pseudomonads, hay bacillus, *B. licheniformis* and aplanobicillus	It can be used for compost of life garbage to speed up the assimilation action of microbes, shorten period and improve fertility.	CN 1431312	23-7-2003	Fu H, Zeng G, Huang G
76	*Myroides odoratus* SM-1, *B. subtilis* SM-4, *B. pumilus* SM-9	Helps in emulsification of crude oil	JP 2004154090	3-6-2004	Kawai F, Maneraato S
77	Biosurfactant producers	Efficiently eliminates flammability and ignitability of the leaked oil in a short time and affecting no bad effect to the environment including traffics and helps in decomposition treatment of the leaked oil.	JP 2003183635	3-7-2003	Yoshida K, Tamiya E, Tsubouchi N, Ishio I
78	Biosurfactant producers	Inhibit bacterial plaque formation, sterilizes and suppresses pathogenic bacteria in the bacterial plaque adhered in the oral cavity, and can effectively prevent or cure stomatopathy	JP 2003246717	2-9-2003	Morishima S
79	Biosurfactant producers	Helps in cleaning of petroleum contaminated soils	JP 2003320367	11-11-2003	Shimizu Y, Yasukagawa T, Tashiro E
80	*Rhodococcus ruber* Em	Increase the solubility of paraffin and polycyclic arylhydrocarbon in water,	CN 1519312	11-8-2004	Liu Z, Li X, Liu S

Table 4—Other patents on bioemulsifiers and biosurfactants

Sr No	Organism	Title	Patent No	Publication date	Inventor
		so it can be used for treating the oil-contained sewage and repairing the petroleum polluted soil.			

change, and the like which will result in diversion of water in the high permeability zones directing the water to be preferentially diverted into lower permeability zones, causing the enhanced displacement of oil during MEOR (Hitzman *et al*, 1995, US 5405531).

BS has been utilized in methods for the formation, processing, transportation and end use of a hydrocarbon-in-water emulsion (Rodriguez *et al*, 1993, CA 1318216). Bitumen froth is extracted from tar sands using a water process, which involves biotreatment of bitumen froth tailings resulting in a reduced amount of waste products and waste byproducts. Biotreatment involves microorganisms, *Pseudomonas* spp., *Comebactellum* spp., *Flavobacterium* spp., *Nocardia* spp., *Arthrobacter* spp., *Micrococcus* spp., *Mycobacterium* spp., *Streptomyces* spp., *Achromobacter* spp., *Rhodococcus rhodochrous* and *Bacillus sphaeiicus* (Duyvesteyn *et al*, 1999, 2000, US 5968349, US 6074558, CA 2350907, CA 2350927).

ii) Detergent

The detergent compositions show enhanced oily soil detergency in fabric washing even when the glycolipid BS used individually are poor detergents (Hall *et al*, 1993, 1995, 1996, 1997, 05-059394, US 5417879, US 5520839, CA 2060698). A BS comprising a carbohydrate group results in superior cleaning in a dry cleaning system of fabric like clothing or garments. The surfactant has a hydrocarbon group that is more solvent-philic than a carbohydrate group, and can result in reverse micelle formation in a densified gas like densified carbon dioxide (Murphy *et al*, 2002, US 6,369,014, US 6,475,968).

iii) Antimicrobial Compounds

BS produced by *Lactobacillus* are used for preventing urogenital infection in mammals. These BS inhibit microbial biofilm formation and displace adherent biofilm-forming bacteria from surfaces of urinary or vaginal endothelia caused due to insertion of urinary catheters, diapers, intravenous lines, dialysis tubes, stents, peritoneal tubes, tampons, diaphragms and endotracheal tubes. *Lactobacillus* BS inhibits adherence and colonization of *Candida albicans, Enterococcus faecalis, E. coli, Klebsiella, Proteus mirabilis, P. stuartii, Pseudomonas aeruginosa* (Reid *et al*, 2000, US 6051552, CA 2206674).

BS peptides possess anti-microbial properties including the ability to selectively bind to collagen and inhibit infections around wounds and at the site of implants and biofilms in mammals. These peptides are derived from human microorganism isolates and therefore are non-immunogenic, non-pathogenic, non-carcinogenic and non-invasive when administered to humans. BS producing bacteria include *Lactobacillus, Staphylococcus epidermidis, Streptococcus* spp. and *Bifidobacterium* spp. (Howard *et al*, 2002, US 20020120101).

A germicidal composition suitable for cleaning fruits, vegetables, skin and hair, includes a mixture of fruit acids (citric, glycolic, lactic, malic and tartaric acid) and a surfactant, which may be an anionic surfactant (sodium lauryl sulfate), a sophorose lipid BS, or a combination of the two surfactants. The compositions are germicidal, and are sufficient to kill 100% of *E. coli*, *Salmonella* and *Shigella* in 30 sec after application to the surface of the object (Pierce & Heilman, 2001, US 6262038). BS in combination with acid, alkylsulfonate can be used for cleaning foliage of agricultural plants. BS comprising liposaccharides having a strong enzymatic action, added to irrigation water, improves photosynthesis and increases crop yields (Lemarchand & Mercier, 2000, FR 2787439).

iv) Bioremediation

Microorganisms, which are capable of degrading hydrocarbon compounds, can treat polluted soils and waters. The actual process includes addition of a nutrient concentrate for stimulation of growth for the accelerated cultivation and growth of hydrocarbon-consuming microorganisms. The concentrate is an admixture of water-soluble and/or oil-soluble compounds of phosphorus (P) and nitrogen (N) and other components. The concentrate is in the form of a liquid water-based preparation and contains an ester of phosphoric acid as both an emulsifier and a P source.

Urea (10-40% by wt) is contained in the concentrate as an N source. This concentrate can be used for the treatment of polluted soils, waters, and articles using a diluted aqueous solution of the concentrated admixture (Kopp-Holtwiesche *et al*, 1997, US 5635392, CA 2303413). Use of BS for decontamination of contaminated ground has been patented (Hobby *et al*, 1993, US 5246309).

v) Other Areas

An anionic, surface-active trehalose lipid produced by *Rhodococcus erythopolis* DSM 43215, *Arthrobacter* spp. DSM 2567 or *Corynebacterium* spp. DSM 2568 when grown aerobically on hydrocarbons under limiting conditions but with no limitation of oxygen are useful as oil-field chemicals or in other applications where surfactants are needed (Li *et al*, 1987, CA 1226545). Use of BS for preparing composite particles comprising adhering wax particles to the surface of resin particles has been patented (Yamashita *et al*, US 5368972).

Patents on BE and BS produced by Yeast

Sophorolipid (SL) is an extracellular product of group of yeasts belonging to genus *Torulopsis* or *Candida* (Table 5). The principal carbon skeleton of SL is a L-[(2'-O-β-D-glucopyranosyl-β-D-glucopyranosyl)-oxy]alkane acid or alkene acid, which is formed by combining sophorose with a hydroxy fatty acid via a glycosyl ether bond and is chemically stable. Various secondary derivatives of SL, which are of good and stable quality and performance, have been produced. These compounds are useful as cleansers and emulsifiers having both excellent hygroscopic and hydrophilic properties due to their sophorose groups and hydrophobic properties arising from the fatty acid. Particularly, the hygroscopic property provides a wetting agent with excellent properties, which in addition, support skin physiology.

i) SL Preparation and its Derivatives

A hydroxyalkyl-etherified glycolipid ester represented by the formula (I), ##STR1## and (II), ##STR2## and prepared from SL possesses excellent surface activity (Inoue *et al*, 1980, US 4195177). A dehydrating purification process for a fermentation product, which comprises adding at least one polyhydric alcohol represented by the formula (III) or (IV) to hydrated SL or a secondary derivative, which is a fermentation product of *Torulopsis bombicola*, distilling off water with heating under reduced pressure, and obtaining a solution of SL or a secondary derivative having a lowered viscosity (Inoue *et al*, 1979, 1980, JP 54028895, US 4197166). The final product of this process is subjected to an alcoholysis reaction by adding an acid catalyst to the mother liquor to get hydroxy fatty acid ester (Inoue *et al*, 1980, US 4201844). SLs are subjected to methanolysis and using methanol in the presence of a strong acid to produce methyl 1-[(2'-O- β-D-glucopyranosyl -β -D-glucopyranosyl)oxy]-alkanoate and -alkenoate, and then resulting mixture is subjected to ester interchange by reaction with an alcohol to get glycolipid ester and glycolipid methyl ester (Inoue *et al*, 1979, JP 54109913, JP 54109914, 1980, US 4215213, US 4216311). Besides these, different methods have been developed for production and purification of SL derivatives (Shoji *et al*, 1980, JP 5504344, Yutaka *et al*, 1994, 1995, JP 06100581, JP 07118284).

A fed batch production process has been used for production of sophorosides. In this process, culturing takes place of at least one *Candida bombicola* or *C. apicola* strain and the cultured strain is exposed in a reaction zone to an excess sugar supply and a continuous supply of at least one appropriate substrate (0.01-4 g/h/l) and for a supply time such that the residual concentration of the substrate (18 g/l) in the reaction zone is maintained (Marchal *et al*, 1993, 1997, FR 2691975, US 5616479). In another fed batch process for production of SLs, the substrate essentially consists of at least one animal oil and at least one vegetable and/or at least one ester of said oil; both oils and ester incorporating an aliphatic linear chain with 10-24 C atoms (Marchal *et al*, 1994, 1999, DE 4319540, JP 06-062877, US 5900366). Using similar substrates, SLs are produced by cyclic fermentation with feed of fatty acid esters or oils (Marchal *et al*, 1999, US 5879913). In a new method for production of SLs, a yeast capable of secreting a sophoroselipid is fermented in a culture medium containing a glycerin, a succinate, a mono-, di- and/or tri-saccharide and a lipid precursor (Lang *et al*, 2002, US 6433152). The inventive method is characterized in that the lipid precursor contains one or more 3-alkanols, 4-alkanols or an alkanone with a chain length from 6-30 C atoms or mixtures of said alkanoistalkanone and the culture medium is maintained during fermentation under a reduced oxygen concentration

ii) SLs in Cosmetics

SL converted to glycolipid ester has been used as

an essential component in a cosmetic composition. Glycolipid ester acts as an excellent moisturizer, imparts a pleasant finishing touch to the skin and hair and eliminates the adverse properties attributable to the known moisturizer (Abe *et al*, 1981, US 4297,340). Glycolipid or its ester, converted to hydroxypropyl-etherified glycolipid ester (POSL) has been used in the pencil-shaped lip rouge, pencil-shaped lip cream and pencil-shaped eye shadow (Kawano *et al*, 1981, US 4305929). POSL is used in a powdered compressed cosmetic material, which has good and stable quality and performance and also doesn't crack even when dried or given a shock (Kawano *et al*, 1981, US 4305931). POSL has also been used in an aqueous cosmetic composition for the treatment of skin and hair. These products impart a

Table 5—Patents on bioemulsifiers and biosurfactants produced by yeast

Sr No	Organism	Title	Patent No	Publication date	Inventor
1	*Torulopsis bombicola*	Not available	US 3205150	1965	Spencer J F T, Tullich A P, Gorin P A J
2	*T. bombicola*	Not available	US 3312684	1967	Spencer *et al*
3	*T. bombicola*	Not available	S 3445337	1969	Spencer *et al*
4	Sophorolipid producers	Dehydration purification of fermentation products	JP 54028895	3-3-1979	Inoue S, Kimura Y, Kinta M
5	*T. bombicola*	Preparation of glycolipid ester	JP 54109913	29-8-1979	Inoue S, Kimura Y, Kinta M
6	*T. bombicola*	Preparation of glycolipid methyl ester	JP 54109914	29-8-1979	Inoue S, Kimura Y, Kinta M
7	Sophorolipid producers	Purification of sophorolipid derivatives	JP 55004344	12-1-1980	Shoji O, Toshinao U, Koichi Y
8	*T. bombicola*	Hydroxyalkyl-etherified glycolipid ester	US 4195177	25-3-1980	Inoue S, Kimura Y, Kinta M
9	*T. bombicola*	Dehydrating purification process for a fermentation product	US 4197166	8-4-1980	Inoue S, Kimura Y, Kinta M
10	*T. bombicola*	Process for producing a hydroxyfatty acid ester	US 4201844	6-5-1980	Inoue S, Miyamoto N
11	*T. bombicola*	Process for producing a glycolipid ester	US 4215213	29-6-1980	Inoue S, Kimura Y, Kinta M
12	*T. bombicola*	Process for producing a glycolipid methyl ester	US 4216311	5-8-1980	Inoue S, Kimura Y, Kinta M
13	*T. bombicola*	Cosmetic composition for skin and hair treatment	US 4297340	27-10-1981	Abe Y, Inoue S, Ishida A
14	*T. bombicola*	Stick-shaped cosmetic material	US 4305929	15-12-1981	Kawano J, Suzuki T, Inoue S, Hayashi S
15	*T. bombicola*	Powdered compressed cosmetic material	US 4305931	15-12-1981	Kawano J, Suzuki T, Inoue S, Hayashi S
16	*T. bombicola*	Cosmetic composition	US 4305961	15-12-1981	Tsutsumi H, Kawano J, Inoue S, Hayashi, S
17	*T. bombicola*	Skin-protecting cosmetic composition	US 4309447	5-1-1982	Tsutsumi H, Abe Y, Inoue S, Ishida A

Table 5—Patents on bioemulsifiers and biosurfactants produced by yeast

Sr No	Organism	Title	Patent No	Publication date	Inventor
18	*T. bombicola*	Hair cosmetic composition	US 4318901	9-3-1982	Ishida A, Homma I, Inoue S
19	Sophorolipid producers	Method of modifying quality of wheat flour product	JP 61205449	11-9-1986	Akira S, Akira Y
				— *Contd*	
20	*Candida* spp.	Use of sophoroselipid-lactone for the treatment of dandruffs and body odour.	EP0209783, B1	28-1-1987	Rothlisberger R, Mager H, Wagner F
					(*Contd*)
21	*T. bombicola* KSM-36 (FERM BP-799)	Novel microorganism	US 4782025	1-11-1988	Inoue S, Kimura Y
22	*Candida bombicola or C. apicola*	Fed batch prodn. of sophorolipid(s) from Candida - including pre-culture step, giving prod. in acetylated acid form, useful as emulsifier e.g. in sec. oil recovery	FR 2691975	10-12-1993	Marchal R, Lemal J, Sulzer C, Davila A
23	*C. bombicola or C. apicola*	Production of acetylated sophorolipid in acid form from substrate composed of oil or ester	JP 06062877	8-3-1994	Marchal R, Lemal J, Sulzer C, Davila A
24	*C. bombicola* CBS 6009	Fermentative production of sophorolipid composition	DE 4319540	3-2-1994	Lemal J, Marchal R, Davila A, Sulzer C
25	*C. bombicola* 22214	Sophorolipid derivative	JP 06100581	12-4-1994	Yutaka I, Yasuo G, Masaru K
26	*C. bombicola.*	Process for washing solid particles comprising a sophoroside solution	US 5326407	5-7-1994	Baviere M, Degouy D, Lecourtier J
27	*Micropolyspora*	Tetraglucose and its partial fatty acid ester	JP 06298784	25-10-1994	Ishigami Y, Gama Y, Someya J, Takamori Y, Ito T
28	Sophorolipid producers	Sophorose derivative	JP 07118284	9-5-1995	Yutaka I, Makoto S, Yasuo G, Yoshihiro K, Kuranari M
29	*Candida* spp.	Synergistic dual-surfactant detergent composition containing sophoroselipid	US 5417879	23-5-1995	Hall P J, Haverkamp J, Van Kralingen C G, Schmidt M
30	Sophorolipid producers	Preservative of cut flowers	US 5536155	16-7-1996	Futaki K, Shigeno K, Hoshi K
31	Sophorolipid producers	Utilization of sophorolipids as therapeutically active substances or cosmetic products, in particular for the treatment of the skin	WO 97/01343	25-6-1996	Maingault M
32	*C. bombicola*, *C. apicola*	Method of production of sophorosides by fermentation with fed batch supply of fatty acid esters or oils	US 5616479	1-4-1997	Marchal R, Lemal J, Sulzer C
33	Sophorolipid producers	Not available	FR 2740779	9-5-1997	Guerin G, Guillou V, Joubert D

Table 5—Patents on bioemulsifiers and biosurfactants produced by yeast

Sr No	Organism	Title	Patent No	Publication date	Inventor
					Joubert D
34	Sophorolipid producers	Use of sophorolipids and cosmetic and dermatological compositions	CN 1155240	23-7-1997	Hillion G, Marchal R, Stoltz C
35	Sophorolipid producers	Composition containing a surface active compound and glycolipids and decontamination process for a porous medium polluted by hydrocarbons	US 5654192	5-8-1— *Contd*	ucreux J, Ballerini D, Baviere M, Bocard C, Monin N
					(*Contd*)
36	*C. bombicola*	Process for the production of sophorose by *Candida bombicola*	ES 2103688	16-9-1997	Casas P J A, Garcia-Ochoa S F
37	*C. bombicola*	Process for the production of sophorolipids from sugars and oil using deenergized cells of *Candida bombicola*	ES 2103687	16-9-1997	Casas P J A., Garcia-Ochoa S F
38	*T. magnoliae*, *C.bombicola, C. apicola or C. bogoriensis.*	Use of a sophorolipid to provide free radical formation inhibiting activity or elastase inhibiting activity	US 5756471	26-5-1998	Hillion G, Marchal R, Stoltz C, Borzeix F
39	Sophorolipid producer	Glucose- and sophorose-lipids, a process for their preparation and their use	US5767255 DE19518982	16-6-1998	Wullbrandt D, Giani C, Lang S, Wagner F, Brakemeier A
40	C. bombicola	Process for the production of sophorolipids by cyclic fermentation with feed of fatty acid esters or oils	US 5879913	9-3-1999	Marchal R, Warzywoda M, Chaussepied B
41	*C. bombicola* CBS 6009	Production of sophorolipid acetate acids from oils or esters	US 5900366	4-5-1999	Marchal R, Lemal J, Sulzer C, Davila A
42	*C. bombicola or apicola*	Process for the production of sophorolipids by cyclic fermentation with feed of fatty acid esters or oils	US 5879913	9-5-1999	Marchal R, Warzywoda M, Chaussepied B
43	Sophorolipid producers	Utilization of sophorolipids as therapeutically active substances or cosmetic products, in particular for the treatment of the skin	US 5981497	9-11-1999	Maingault M
44	Sophorolipid producers	Not available	FR 2779057	3-12-1999	Borzeix C F
45	Sophorolipid producers	Use as agent for stimulating skin fibroblast metabolism	WO 99/62479	27-5-1999	Borzeix C F
46	Sophorolipid producers	Sophorolipids as stimulating agent of dermal fibroblast metabolism	US 6057302	2-5-2000	Borzeix F
47	Sophorolipid producers	Composition for high-density cold storage transportation	JP 2001131538	15-05-2001	Masaru K, Takashi N, Yoji A, Kazuo N, Tatsu N, Sumiko T, Jotaro N
48	*C. antarctica* T-34	Method for treating soy sauce oil	JP 2002101847	09-04-2002	Furubayashi M, Nakahara T, Nomura N, Okada K, Nakajima
49	*C. bombicola, C. bogoriensis, C. magnoliae, C. gropengiesseri or*	Sophoroselipids, method for their production and use	US 6433152	13-8- 2002	Lang S, Brakemeier A, Wullbrandt D, Seiffert-Storicko A

Table 5—Patents on bioemulsifiers and biosurfactants produced by yeast

Sr No	Organism	Title	Patent No	Publication date	Inventor
	C. apicola				
50	Sophorolipid producer	Process for the production of sophorosids by fermentation with continuous fatty acids ester or oil supply	CA 2075177	28-5-2002	Marchal R, Lemal J, Sulzer C
				— *Contd*	
51	Sophorolipid producer	Low-foaming detergent compositions	WO 03/002700	26-6-2002	Furuta T, Igarashi K, Hirata Y
					(*Contd*)
52	Sophorolipid producer	Use of sophorolipids comprising diacetyl lactones as agent for stimulating skin fibroblast metabolism	CA 2333787	Not issued	Borzeix C F
53	Sophorolipid producer	Use of sophorolipids as an agent to stimulate the metabolism of dermal fibroblasts	CA 2223740	Not issued	Borzeix C F
54	Sophorolipid producer	Utilization as therapeutically active substances or cosmetic products, for treatment of the skin	CA 2222273	Not issued	Maingault M
55	Sophorolipid producer	Use of sophorolipids and cosmetic and dermatological compositions	CA 2192595	Not issued	Hillion G, Marchal R, Stoltz C, Borzeix F
56	Sophorolipid producer	Stimulates skin dermal fibroblast cell metabolism, particularly collagen neosynthesis	US 6596265	22-7-2003	Borzeix C.
57	*C. bombicola*	Acts as an spermicidal and/or antiviral agent and/or anti-spermidical agents	WO 2005089522, US 2004242501, US 2005164955, AU 2003299557	29-9-2005	Gross R A, Shah V, Doncel G F
58	Sophorolipid producer	Can be use as slimming agents and/or active agents stimulating the leptin synthesis through adipocytes, in the manufacture of a cosmetic composition for reducing the subcutaneous fat overload	WO 2004108063	16-12-2004	Pellicier F, Andre P
59	Sophorolipid producer	Biodegradable low-foaming detergent compositions, which sustain favorable detergency over a wide temperature range	WO 03002700	9-1-2003	Furuta T, Igarashi K, Hirata Y

pleasant finishing touch or good performance to the skin, coupled with an excellent moisture-retaining activity (Tsutsumi *et al*, 1981, 4305961, Hillion, CA 2192595). POSL is useful in skin-protecting cosmetics like hand creams, cold creams, vanishing creams, milky lotions, beauty washes and hair cosmetics like set lotions, hair sprays and similar cosmetics for women. These compounds have added advantage since they have excellent barrier ability but are not liable to remain deposited on the skin/hair even after washing (Tsutsumi *et al*, 1982, US 4309447, Ishida *et al*, 1982, US 4318901). SL lactone has also been used for treatment of dandruffs and body odour (Rothlisberger *et al*, 1987 EP 0209783).

SLs have anti-radical and anti-elastasic properties, desirable in compositions for cosmetic, hygienic or pharmaco-dermatological use, in particular for the protection and care of hair or skin (Hillion *et al*, 1998, US 5756471). SLs are also used for the treatment of skin, as an activator of macrophages, and as agent in fibrinolytic healing, desquamating and depigmenting process (Maingault, 1999, US 5981497, CA

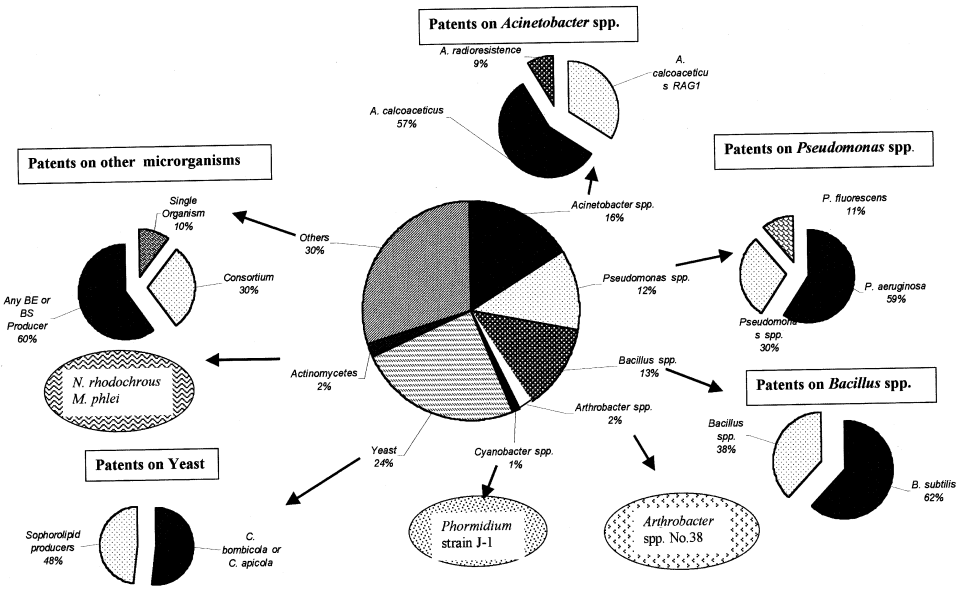

Fig. 1—Summary of patents on bioemulsifiers and biosurfactants produced by different microorganisms.

2222273). SL can be used in cosmetics as an agent for stimulating the metabolism of fibroblasts of the dermis of the skin, particularly as an agent that restructures the skin, agent that repairs the skin, and/or an agent that tones up the skin (Borzeix, 1999, FR 2779057, 2000, US 6057302, US 6596265).

iii) SLs in Other Fields

SLs have been used for modifying quality of wheat flour product. Production of bread from the wheat flour containing the SL promotes dough formation during mixing, improves gas retention power during baking, enlarges bread volume, and provides bread with good appearance and aging preventing properties (Akira & Akira, 1986, JP 61205449). *Candida antarctica* T-34 decomposes soy sauce oil to produce mannosyl erythritol lipid (MEL), which is used as a BS (Makio *et al*, 2002, 2002-101847). Sophorosides have been used in a process for cleansing solid particles like drill cuttings impregnated with a polluting fluid comprising hydrocarbons. They have advantage over other surfactants since they are not toxic, completely biodegradable and stable notably in alkaline medium (Baviere *et al*, 1994, US 5326407). Glycolipid like SL or its derivatives along with surface-active compounds can be used for decontamination of a porous medium like soils and groundwater tables polluted by hydrocarbons (Ducreux *et al*, 1997, US 5654192). SLs have been used to enhance oily soil detergency in fabric washing in combination with other anionic or nonionic surfactants (Hall *et al*, 1995, US 5417879) and for high-density cold storage transportation (Masaru *et al*, 2001, JP 2001131538)

Patents on BE and BS produced by Actinomycetes

Oil pollution, which occurs on riverbanks and beaches as a result of tanker accidents or human error, poses an important ecological problem. For separating oils or petroleum hydrocarbons, the soil, sand or oil-containing residues which contain the oils or petroleum hydrocarbons are impregnated with a quantity of a solution or dispersion of microbially-produced glycolipids produced by *Nocardia rhodochrous* such that the oil phase or emulsion thereof leaving the capillaries rises out of the aqueous phase and is separated from the aqueous phase and from the solid phase[28]. Glycolipid produced by *Nocardia rhodochrous* and *M. phlei* in water can be used for the flooding medium for the flooding of petroleum deposits and oil shale[29,30]. An oligosaccharide fatty acid ester produced by actinomycete of genus *Micropolyspora* and a partial ester of the tetraglucose can be used as a surfactant[31].

Conclusions

This review presents 255 patents related to BE and BS issued worldwide. Highest number of patents are issued for use of BE and BS in petroleum industry (33%), followed by cosmetics (15%), as an antimicrobial agent and medicine (12%) and for bioremediation (11%) (Fig. 1). Earliest literature about this

biomolecule has been published in 1965 and patents related to their utilization in petroleum industry were issued from 1980-81 onwards. At the same time its use in cosmetic industry has been explored. Utilization of these biomolecules for bioremediation started in 1990s. Similarly, replacement of chemical surfactants/emulsifiers by BE and BS in medicines is a relatively newer trend. In all these cases, non-toxicity, biodegradability and ecofriendliness nature of these biomolecules played an important role.

Patents based on producer organism are classified as follows: SLs, 24; emulsan, 16; surfactin, 13; and rhamnolipids, 12%. There are many patents, which do not specify the producer organism, but describe specific use of BS or BE. Some of the patents quote consortium for the production of BE or BS and its use. *Corynebacterium* spp., *Acaligene* spp., *Methylomonas* spp. are the organisms, which are rarely patented for production of BS. The last three categories cover 30 percent of all the patents on BS or BE.

The commercial production of BE and BS is a costly affair. However, in some cases, this problem has been solved by using the crude product or the direct fermentation broth (with one or two chemical processes done on it) without affecting the activity and potency of the actual product. Out of total 255 patents covered in this review, 50 percent are US patents. Other patents have been filed in Japan (16%), Canada (15%) and patents filed through PCT and filed in other countries cover 19 percent of the total patents. However, unfortunately there is not a single patent filed by an Indian inventor and owned by Indian institute, organization or a commercial company. Similarly, not a single invention includes an organism isolated from Indian Ocean or other potential sites like oil resources and refineries. A US patent was filed in 2002 on BE produced by *Acinetobacter* isolated from healthy human skin. This is perhaps the first patent of this kind from India[32]. Thus, there is a large scope to isolate novel bacterial, fungal and yeast strains, which can produce effective BE or BS. There is huge scope to speculate that one can invent totally novel microorganisms from above mentioned sites which can produce a novel BE or BS which can be utilized in the fields like petroleum industry, detergents, pharmaceutical companies, agriculture and personal health care products.

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