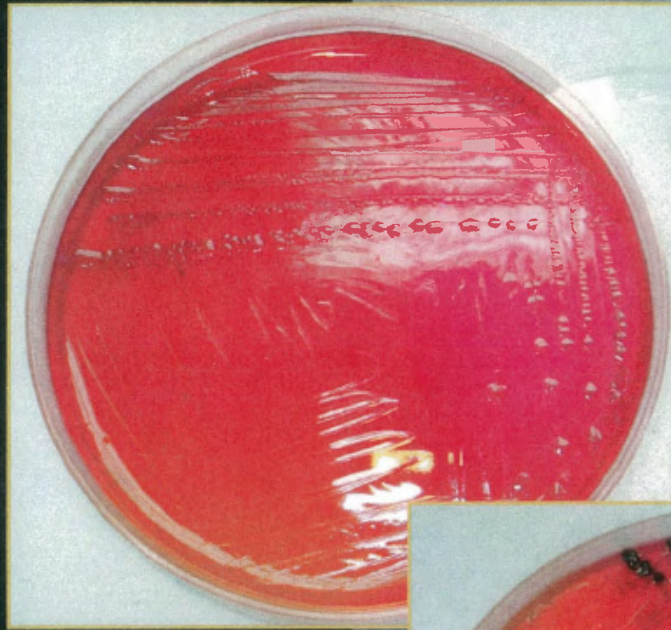


BIOSURFACTANTS

Research Trends and Applications



Edited by
Catherine N. Mulligan
Sanjay K. Sharma

CRC Press

BIOSURFACTANTS

Research Trends and Applications

Edited by
Catherine N. Mulligan
Sanjay K. Sharma
Ackmez Mudhoo



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

© 2014 by Taylor & Francis Group, LLC
CRC Press is an imprint of Taylor & Francis Group, an Informa business

No claim to original U.S. Government works

Printed on acid-free paper
Version Date: 20131108

International Standard Book Number-13: 978-1-4665-1823-0 (Hardback)

This book contains information obtained from authentic and highly regarded sources. Reasonable efforts have been made to publish reliable data and information, but the author and publisher cannot assume responsibility for the validity of all materials or the consequences of their use. The authors and publishers have attempted to trace the copyright holders of all material reproduced in this publication and apologize to copyright holders if permission to publish in this form has not been obtained. If any copyright material has not been acknowledged please write and let us know so we may rectify in any future reprint.

Except as permitted under U.S. Copyright Law, no part of this book may be reprinted, reproduced, transmitted, or utilized in any form by any electronic, mechanical, or other means, now known or hereafter invented, including photocopying, microfilming, and recording, or in any information storage or retrieval system, without written permission from the publishers.

For permission to photocopy or use material electronically from this work, please access www.copyright.com (<http://www.copyright.com/>) or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of users. For organizations that have been granted a photocopy license by the CCC, a separate system of payment has been arranged.

Trademark Notice: Product or corporate names may be trademarks or registered trademarks, and are used only for identification and explanation without intent to infringe.

Visit the Taylor & Francis Web site at
<http://www.taylorandfrancis.com>

and the CRC Press Web site at
<http://www.crcpress.com>

6 Characterization, Production, and Applications of Lipopeptides

Catherine N. Mulligan

CONTENTS

Introduction.....	147
Lipopeptide Biosurfactants	148
Surfactin	151
Surfactin Production.....	151
Lipopeptide Production Reactor Design and Optimization.....	154
Measurement and Characterization Techniques	155
Genetics of Lipopeptide Production	156
Extraction of Lipopeptides.....	157
Membrane Lipopeptide Recovery	159
Strain Isolation.....	160
Properties and Applications of Lipopeptides	164
Conclusion	166
References.....	167

INTRODUCTION

Surfactants are amphiphilic compounds that reduce the free energy of the system by replacing the bulk molecules of higher energy at an interface. They contain a hydrophobic portion with little affinity for the bulk medium and a hydrophilic group that is attracted to the bulk medium. Surfactants have been used industrially as adhesives; flocculating, wetting, and foaming agents; deemulsifiers; and penetrants (Mulligan and Gibbs, 1993). They are used for these applications based on their abilities to lower surface tensions and increase solubility, detergency power, wetting ability, and foaming capacity. Petroleum users have traditionally been the major users, as in enhanced oil removal applications by increasing the solubility of petroleum components (Falatko, 1991). They have also been used for mineral flotation and in the pharmaceutical industries. Typical desirable properties include solubility enhancement, surface tension reduction, the critical micelle concentrations (CMCs), wettability, and foaming capacity.

Surfactants are classified as cationic, anionic, zwitterionic, and nonionic and are made synthetically from hydrocarbons, lignosulfonates, or triglycerides. Some common synthetic surfactants include linear alkyl benzenesulfonates, alcohol sulfates, alcohol ether sulfates, alcohol glyceryl ether sulfonates, α -olefin sulfonates, alcohol ethoxylates, and alkylphenol ethoxylates (Layman, 1985). Surfactants have many applications industrially with multiphase systems. Sodium dodecyl sulfate (SDS, $C_{12}H_{25}SO_4^- Na^+$) is a widely used anionic surfactant. The effectiveness of a surfactant is determined by surface tension lowering, which is a measure of the surface free energy per unit area or the work required to bring a molecule from the bulk phase to the surface (Rosen, 1978). These amphiphilic compounds (containing hydrophobic and hydrophilic portions) concentrate at solid-liquid, liquid-liquid, or vapor-liquid interfaces. An interfacial boundary exists between two immiscible phases. The hydrophobic portion concentrates at the surface while the hydrophilic is oriented toward the solution. A good surfactant can lower the surface tension of water from 72 to 35 mN/m and the interfacial tension (tension between nonpolar and polar liquids) for water against n-hexadecane from 40 to 1 mN/m. Efficient surfactants have a low CMC (i.e., less surfactant is necessary to decrease the surface tension) as the CMC is defined as the minimum concentration necessary to initiate micelle formation (Becher, 1965). In practice, the CMC is also the maximum concentration of surfactant monomers in water and is influenced by pH, temperature, and ionic strength.

An important factor in the choice of surfactant is the product cost (Mulligan and Gibbs, 1993). In general, surfactants are used to save energy and consequently energy costs (such as the energy required for pumping or mixing). Charge type, physico-chemical behavior, solubility, and adsorption behavior are some important selection criteria for surfactants.

Some surfactants, known as biosurfactants, are biologically produced from yeast or bacteria (Lin, 1996). They can be potentially as effective with some distinct advantages over the highly used synthetic surfactants due to high specificity, biodegradability, and biocompatibility (Cooper, 1986).

Biosurfactants are grouped as glycolipids, lipopeptides, phospholipids, fatty acids, and neutral lipids (Bierman et al., 1987). Most of these compounds are either anionic or neutral, with only a few cationic ones. The hydrophobic parts of the molecule are based on long-chain fatty acids, hydroxy fatty acids, or α -alkyl- β -hydroxy fatty acids. The hydrophilic portion can be a carbohydrate, amino acid, cyclic peptide, phosphate, carboxylic acid, or alcohol. A wide variety of microorganisms can produce these compounds. The CMCs of the biosurfactants generally range from 1 to 200 mg/L and their molecular weights (MWs) from 500 to 1500 amu (Lang and Wagner, 1987).

LIPOPEPTIDE BIOSURFACTANTS

Lipopeptides are produced by a variety of microorganisms, including *Bacillus*, *Lactobacillus*, *Streptomyces*, *Pseudomonas*, and *Serratia* (Cameotra and Makkar, 2004; Georgiou et al., 1992). The lipopeptides are cyclic peptides with a fatty acyl chain. Various lipopeptides include surfactin (Roongsawang et al., 2003; Youssef et al., 2007), lichenysin A (Yakimov et al., 1995) or C (Jenny et al., 1991), B (Folmsbee et al., 2006), D (Zhao et al., 2010), bacillomycin (Roongsawang et al., 2003), fengycin

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.