Biotechnology

edited by
H.-J. Rehm and G. Reed

Volume 6b

Special Microbial Processes

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This book contains 298 figures and 136 tables

Deutsche Bibliothek Cataloguing-in Publication-Data

Biotechnology: a comprehensive treatise in 8 vol. / ed. by H.-J. Rehm and G. Reed. – [Ausg. in 8 Bd.]. – Weinheim; Basel (Switzerland); Cambridge; New York, NY: VCH.
Teilw. mit d. Verl.-Angabe Verl. Chemie, Weinheim, Deerfield Beach, Florida, Basel. –
Teilw. mit d. Erscheinungsorten Weinheim, Deerfield Beach, FL. –
Teilw. mit d. Erscheinungsorten Weinheim, New York
NE: Rehm, Hans J. [Hrsg.]
[Ausg. in 8 Bd.]
Vol. 6b. Special microbial processes / Vol. ed.: Hans-Jürgen Rehm. – 1988
ISBN 3-527-26093-5 (Weinheim ...) Gewebe
ISBN 0-89573-413-3 (New York ...) Gewebe

Compositor and Printer: Zechnersche Buchdruckerei, D-6720 Speyer
Bookbinding: Klambt-Druck GmbH, D-6720 Speyer
Printed in the Federal Republic of Germany

Biotechnology
Volume 6b

Biotechnology

A Comprehensive Treatise in 8 Volumes

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Distribution
VCH Verlagsgesellschaft, P.O. Box 101161, D-6940 Weinheim (Federal Republic of Germany)
Switzerland: VCH Verlags-AG, P.O. Box, CH-4020 Basel (Switzerland)
Great Britain and Ireland: VCH Publishers (UK) Ltd., 8 Wellington Court, Wellington Street, Cambridge CB1 1HW (Great Britain)
USA and Canada: VCH Publishers, Suite 909, 220 East 23rd Street, New York, NY 10010-4606 (USA)

ISBN 3-527-26093-5 (VCH Verlagsgesellschaft)
ISBN 0-89573-413-3 (VCH Publishers)

Preface

This volume describes various fermentations and biotechnological processes which did not readily fit into the subject matter of preceding volumes.

The first three chapters deal with processes which have been developed in the past, and brings the reader up-to-date on newer developments. Plant cell and animal cell cultures have already been briefly described in Volume 1; the present volume covers the methodology in considerable more detail.

The chapter on poly-beta-hydroxybutyric acid is highly applications oriented, because PHB is a new microbial product with an excellent potential for successful commercial development.

The chapter "Coal in Biotechnology" also documents the opening of a new field in biotechnology.

The contribution on the microbial elimination of nitrogen and phosphorus supplements Volume 8. In the second edition of "Biotechnology" it will be included in the volume "Microbial Degradations".

Many other new fields – models for biotechnological photosynthesis, accumulation and leaching of metals, future perspectives of biotechnology in space and more earth-bound matters such as the microbial processing of tobacco, flax, and leather, for example – have been treated in this volume because of their potential for future developments. It is hoped that this will stimulate the interest of readers in these new areas of biotechnological research.

The authors of this volume have worked diligently to make their wide knowledge and expertise available to the reader. Their contributions in Volume 6b will supplement the subject matter of preceding volumes so that the reader will get a clearer understanding of the entire field of biotechnology.

I wish to thank Dr. G. Reed for his invaluable editorship, Dr. H. F. Ebel of the VCH Verlagsgesellschaft for his always helpful advice and Mrs. Christa Schultz, also of the VCH Verlagsgesellschaft, for her untiring and always friendly and constructive help in getting this volume into print.

Münster, October 1988

Hans-Jürgen Rehm

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Chapter 1

Microbial Production of Butanol/Acetone

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I. Introduction

It is fascinating that a few anaerobic microorganisms are able to ferment sugars to solvents such as *n*-butanol and acetone. This ability was already noticed by PASTEUR (1861), its industrial significance was recognized by FERNBACH and STRANGE (1911) and by WEIZMANN (1915), and from 1915 until about 1950 the acetone-butanol fermentation was the basis of an industrial process operated on a very large scale. With respect to fermenter volume it was only exceeded by the ethanol-producing industries. After 1950, the importance of this process declined rapidly, because the production of *n*-butanol and acetone from oil became economically more favorable. Only recently, a revival of the interest in this fermentation occurred. The acetone-butanol fermentation – as a result of the oil crisis – became again an appealing industrial process. So it was challenging to apply the achievements of modern biotechnology to it and to study in detail the reactions leading to acetone and butanol formation and their regulation. As a result, we have now a much better understanding of this fermentation as compared to the time when it was industrially operated. Following an excursion into the history of the process, focus of this chapter will be on these new developments.

A number of excellent reviews on the acetone-butanol fermentation have appeared in recent years (BARKER, 1956; BEESCH, 1953; ROOS, 1961; HASTINGS, 1978; SPIVEY, 1978; MOREIRA, 1983; ENNIS et al., 1986a; JONES and WOODS, 1986; MC NEIL and KRISTIANSEN, 1986; ROGERS, 1986); they should be consulted for additional information.

Some of the physical properties of acetone and butanol are summarized in Table 1. Acetone is an important intermediate in the manufacture of methacrylates and methyl isobutyl ketone and a solvent for resins, paints, varnishes, lacquers, and cellulose acetate; it is miscible in all proportions with water. *n*-Butanol is a precursor of butyl acetate and dibutyl phthalate and like acetone a good solvent. Its solubility in water is 8% (w/w).

II. History

The formation of butanol by fermentation was first noticed by PASTEUR in connection with his discovery of the butyrate fermentation (PASTEUR, 1861). The causative organism was named "vibrion butyrique", and the term "anaerobic" was coined, when it was found that the bacteria responsible for this fermentation were killed in air. Pure cultures of butyrate producers additionally forming small amounts of *n*-butanol were obtained by WINOGRADSKY in 1895, and a strain *(Granulobacter butylicum)* yielding appreciable quantities of butanol was first described by BEIJERINCK (1896).

Table 1. Physical Properties of Acetone and Butanol

Property	Acetone	*n*-Butanol
Melting point at 101.3 kPa	−94.6°C	−90.2°C
Boiling point at 101.3 kPa	56.1°C	117.7°C
Specific gravity	0.7899	0.8098
Heat of vaporation	502.7 J/g	593.5 J/g
Heat of combustion	5587 J/g	36296 J/g
Vapor pressure at 20°C	24.62 kPa	0.61 kPa