Volume I

Fermentation and Biochemical Engineering

The biochemical engineering approach to fermentation has been significant as the engineers have always been engaged in commercial fermentation operations. Perhaps the easiest way to assess and illustrate the role of biochemical engineering in fermentation technology is to first summarise its contributions in various aspects. Biochemical engineering contributions to fermentation technology can be looked at in many different ways. We can go through the characteristic fermentation process flowsheet and look at the main stages: (i) medium preparation and sterilisation, (ii) inoculum preparation, (iii) reaction (fermentation), and (iv) pretreatment for recovery. Alternatively we can adopt a unit operations approach and collectively examine all activities which have a common basis, heat sterilisation of media, aseptic transfer of fluids, mass transfer (aeration) and so forth.

This first volume discusses:

- Fermentation feedstocks
- Microbiological and engineering aspects of solid state fermentation
- Biological basis of productivity in fermentation
- Sterilisation techniques in fermentation processes
- Designing parameters of fermentor
- Biosensors and nanobiosensors
- Production of enzymes
- Recovery and purification of fermentation products. It also include microbial solid state fermentation for future biorefineries.

Diagrams, figures, tables and index supplement the text. All topics have been covered in a cogent and lucid style to help the reader grasp the information quickly and easily.

This reference textbook *Fermentation and Biochemical Engineering* is essential reading for BTech (Environmental Biotechnology/Microbiology/Food Microbiology/Biomedical and Biochemical Engineering) and students pursuing BSc/MSc course in Biotechnology and Microbiology. Besides students, this book will prove useful to industrialists and consultants in the respective fields.

QR code to access online CBS Catalogue

Dedicated to Education

CBS Publishers & Distributors Pvt Ltd

4819/XI, Prahlad Street, 24 Ansari Road, Daryaganj, New Delhi 110 002, India

E-mail: delhi@cbspd.com, cbspubs@airtelmail.in; Website: www.cbspd.com

New Delhi | Bengaluru | Chennai | Kochi | Kolkata | Mumbai

Bhopal | Bhubaneswar | Hyderabad | Jharkhand | Nagpur | Patna | Pune | Uttarakhand | Dhaka (Bangladesh)

ISBN: 978-93-89185-91-1

Volume I

Fermentation and Biochemical Engineering

Richard Durbia

CBS

Volume I

Fermentation and Biochemical Engineering

KM Richard

SR Durbia

CBS Dedicated to Education

CBS Publishers & Distributors Pvt Ltd

Fermentation and Biochemical Engineering

Volume I

Contents at a Glance

Fermentation and Biochemical Engineering

Volume I

K M Richard
S R Durbin

CBS

CBS Publishers & Distributors Pvt Ltd

New Delhi • Bengaluru • Chennai • Kochi • Kolkata • Mumbai

Bhopal • Bhubaneswar • Hyderabad • Jharkhand • Nagpur • Patna • Pune • Uttarakhand • Dhaka (Bangladesh)

Disclaimer

Science and technology are constantly changing fields. New research and experience broaden the scope of information and knowledge. The authors have tried their best in giving information available to them while preparing the material for this book. Although, all efforts have been made to ensure optimum accuracy of the material, yet it is quite possible some errors might have been left uncorrected. The publisher, printer and the authors will not be held responsible for any inadvertent errors, omissions or inaccuracies.

Fermentation
and
Biochemical Engineering

Volume I

ISBN: 978-93-89185-91-1

First Edition: 2020

Published by Satish Kumar Jain and produced by Varun Jain for

CBS Publishers & Distributors Pvt Ltd
4819/XI Prahlad Street, 24 Ansari Road, Daryaganj, New Delhi 110 002, India.
Ph: 23289259, 23266861, 23266867 Fax: 011-23243014 Website: www.cbspd.com
e-mail: delhi@cbspd.com; cbspubs@airtelmail.in.

Corporate Office: 204 FIE, Industrial Area, Patparganj, Delhi 110 092
Ph: 4934 4934 Fax: 4934 4935 e-mail: publishing@cbspd.com; publicity@cbspd.com

Branches

- **Bengaluru:** Seema House 2975, 17th Cross, K.R. Road, Banasankari 2nd Stage, Bengaluru 560 070, Karnataka
  Ph: +91-80-26771678/79 Fax: +91-80-26771680 e-mail: bangalore@cbspd.com
- **Chennai:** 7, Subbaraya Street, Shenoy Nagar, Chennai 600 030, Tamil Nadu
  Ph: +91-44-26680620, 26681266 Fax: +91-44-42032115 e-mail: chennai@cbspd.com
- **Kochi:** 42/1325, 1326, Power House Road, Opp KSEB Power House, Ernakulam 682 018, Kochi, Kerala
  Ph: +91-484-4059061-65 Fax: +91-484-4059065 e-mail: kochi@cbspd.com
- **Kolkata:** 6/B, Ground Floor, Rameswar Shaw Road, Kolkata-700 014, West Bengal
  Ph: +91-33-22891126, 22891127, 22891128 e-mail: kolkata@cbspd.com
- **Mumbai:** 83-C, Dr E Moses Road, Worli, Mumbai-400018, Maharashtra
  Ph: +91-22-24902340/41 Fax: +91-22-24902342 e-mail: mumbai@cbspd.com

Representatives

• **Bhopal**	0-8319310552	• **Bhubaneswar**	0-9911037372	• **Hyderabad**	0-9885175004
• **Jharkhand**	0-9811541605	• **Nagpur**	0-9421945513	• **Patna**	0-9334159340
• **Pune**	0-9623451994	• **Uttarakhand**	0-9716462459	• **Dhaka (Bangladesh)**	01912-003485

Printed at: Glorious Printers, Daryaganj, Delhi, India

Preface

In broader terms, biotechnology is defined as the use of biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use. Apart from referring to a type of energy metabolism, fermentation in the industrial sense is regarded as any process for the production of various chemical or pharmaceutical compounds by means of the mass cultivation of micro-organisms.

The biochemical engineering approach to fermentation has been significant as the engineers have always been engaged in commercial fermentation operations. Perhaps the easiest way to assess and illustrate the role of biochemical engineering in fermentation technology is to first summarise its contributions in various aspects. Biochemical engineering contributions to fermentation technology can be looked at in many different ways. We can go through the characteristic fermentation process flowsheet and look at the main stages: (i) medium preparation and sterilisation, (ii) inoculum preparation, (iii) reaction (fermentation), and (iv) pretreatment for recovery. Alternatively we can adopt a unit operations approach and collectively examine all activities which have a common basis, heat sterilisation of media, aseptic transfer of fluids, mass transfer (aeration) and so forth.

This reference textbook on *Fermentation and Biochemical Engineering* is divided in two volumes. First volume contains seven sections and 1 to 33 chapters.

Section I discusses general considerations and biological aspects. Chapter 1 is devoted to historical perspective of fermentation and discusses various chronological development from the early 1700 when wooden vats of 1500 barrel capacity was introduced. Chapter 2 deals with fermentation feedstocks such as micro-organisms and nutrient sources. Chapter 3 concentrates on fermentation biotechnology: an overview and discusses basic concept of fermetation. Chapter 4 focuses on microbial growth kinetics. Microbial growth is described as an orderly increase in all chemical components in the presence of suitable medium and the culture environment. There are four types of microbial growth: bacteria grow by binary fission, yeast divide by budding, fungi divided by chain elongation and branching and viruses grow intracellularly in host cells.

Section II discusses industrial fermentation and solid state fermentation. Chapter 5 is devoted to microbiological aspects of solid substrate fermentation. Solid state fermentations (SSF) have attracted a renewed interest and attention from researchers due to recent developments in the field of microbial biotechnology. Chapter 6 deal with solid state fermentation for bioconversion of biomass and agricultural. This chapter discusses some important aspects of solid-state cultivation system, including the variety of substrates and micro-organisms used in SSF for the production of various end products, and the performance control of system by regulation of important factors. Chapter 7 focuses on engineering aspects of solid state fermentation. This chapter discusses the various micro- and macro- level engineering problems associated with SSF and some possible solutions for its full commercial realisation. Chapter 8 concentrates on

microbial solid state fermentation for future biorefineries. Today's biorefinery technologies would be almost unthinkable without biotechnology. Novel biorefinery processes using solid state fermentation (SSF) technology have been developed as an alternative to conventional processing routes, leading to the production of added-value products from agriculture and food industry raw materials. Chapter 9 explains industrial fermentation processes.

Section III discusses biological basis of productivity in fermentation. Chapter 10 is devoted to isolation, preservation and improvement of important micro-organisms. The term isolation refers to the separation of a strain from a natural, mixed population of living microbes, as present in the environment, for example in water or soil flora, or from living beings with skin flora, oral flora or gut flora, in order to identify the microbe(s) of interest. Chapter 11 deal with industrial media and the nutrition of industrial organism. The use of a good, adequate, and industrially usable medium is as important as the deployment of a suitable micro-organism in industrial microbiology. Unless the medium is adequate, no matter how innately productive the organism is, it will not be possible to harness the organism's full industrial potentials. Chapter 12 focuses on sterilisation techniques in fermentation processes. Sterilisation is a technique to make anything free from organisms either by removing them or killing them. The removal or killing of all the organisms from fermentation medium is the main aim of the sterilisation process or else the contaminant will deteriorate the process. Chapter 13 concentrates on development of inocula for industrial fermentations. Inoculum is a small amount of material containing bacteria, viruses, or other micro-organisms that is used to start a culture.

Section IV discusses designing aspects of fermentator. Chapter 14 is devoted to fermentation monitoring and optimisation. Chapter 15 deals with designing parameters of fermentor. The function of the fermenter or bioreactor is to provide a suitable environment in which an organism can efficiently produce a target product—the target product might be cell biomass, metabolite and bioconversion product. It must be so designed that it is able to provide the optimum environments or conditions that will allow supporting the growth of the micro-organisms. Chapter 16 focuses on bioreactor design. In any fermentation process, the bioreactor plays a central role in determining the process efficiency. Even with recombinant products where stringent quality control implies that downstream processing is the major cost component, it is the bioreactor performance which determines product yields. Chapter 17 concentrates on aeration and agitation. The main function of aeration is to supply enough oxygen to the microbes in submerge culture technique for proper metabolism, while agitation provides proper mixing of the nutrient so that each and every organisms get proper nutrients. The main aim of the agitator is to provide homogenous environment all over the fermenter. It is also used for mixing of different phases, oxygen and heat transport.

Section V discusses biosensors and instrumentation and control systems. Chapter 18 provides information biosensors and nanobiosensors: design and applications. Biosensors are the device in which there is a coupling of biological sensing element with a detector system using a transducer. In comparison with any other currently available diagnostic device, biosensors are much higher in performance in terms of sensitivity and selectivity both. Advances in nanotechnology have led to the development of nanoscale biosensors that have exquisite sensitivity and versatility. The ultimate goal of nanobiosensors is to detect any biochemical and biophysical signal associated with a specific disease at the level of a single molecule or cell. They can be integrated into other technologies such as lab-on-a-chip to facilitate molecular diagnostics. Chapter 19 explains instrumentation and control systems and discusses the methods of measuring process variables along with on-line analysis of other chemical factors and control systems.

Section VI discusses enzymes and their importance in bioprocesses. Chapter 20 is devoted to characteristics of enzymes. Chapter 21 deals with production of industrial enzymes. Fermentation is a method of generating enzymes for industrial purposes. Fermentation involves the use of micro-organisms, like bacteria and yeast to produce the enzymes. Chapter 22 concentrates on fungal laccase enzyme for biotechnological application. Laccase belongs to the small group of enzymes called the blue multi copper oxidases. Chapter 23 focuses on enzymes in biosynthesis of nanoparticles. While a large number of microbial species are capable of producing metal nanoparticles (NPs), mechanism of nanoparticle biosynthesis is very important. Chapter 24 concentrates on nanoparticles in enzyme immobilisation. Chitosan nano-particles due to their highest specific surface area are much proper for immobilisation of higher amount of enzymes.

Section VII discusses recovery and purification of fermentation products. Chapter 25 is devoted to downstream processing: a review. Downstream processing refers to the recovery and purification of biosynthetic products, particularly pharmaceuticals, from natural sources such as animal or plant tissue or fermentation broth, including the recycling of salvageable components and the proper treatment and disposal of waste. Chapter 26 deals with solid-liquid separation which are used for clarification of liquids, solid recovery, dewatering of solids, thickening of slurries and washing of solids. Chapter 27 focuses on aqueous two-phase extraction systems which offers a suitable environment for protein separation because of the significant presence of water at all stages of the process, an important requirement for the maintenance of enzymic activity. Chapter 28 concentrates on chromatography which lies at the core of all biotechnology purification processes.

Chapter 29 explains membrane separation processes. Chapter 30 is devoted to affinity precipitation which is a relatively simple, convenient and reproducible technique that results in high target molecule recovery at high specificity. Chapter 31 deals with solvent extraction which is usually used to recover a component from either a solid or liquid. Chapter 32 concentrates on drying and crystallisation which involves removal of moisture from solids, solutions, slurries and pastes to give solid products, which often after drying are final products to be packed. Chapter 33 explains electrokinetic separation processes for biochemical products. The major recent developments in using electrokinetic processes for separation in biological system appear to have centred on the recovery and separation of high molecular weight, low volume, high value products such as therapeutic and diagnostic enzymes and proteins by some form of electrophoretic process.

Diagrams, figures, tables and index supplement the text. All topics have been covered in a cogent and lucid style to help the reader grasp the information quickly and easily.

It may not be wrong to hold that the present reference textbook of *Fermentation and Biochemical Engineering* is a complete treatise on this subject. It is essential reading for B Tech (environmental biotechnology/microbiology/food microbiology/biomedical and biochemical engineering) and students pursuing BSc/MSc course in Biotechnology and Microbiology. Besides students, this book will prove useful to industrialists and consultants in the respective fields.

This reference textbook also caters to the requirement of the syllabus prescribed by various universities for undergraduate and postgraduate courses in the above subjects. It has been prepared with meticulous care, aiming at making the book error-free. Constructive suggestions are always welcome from users of this book.

K M Richard
S R Durbin

Contents

Section V
BIOSENSORS AND INSTRUMENTATION AND CONTROL SYSTEMS

Section VI
ENZYMES AND THEIR IMPORTANCE IN BIOPROCESSES