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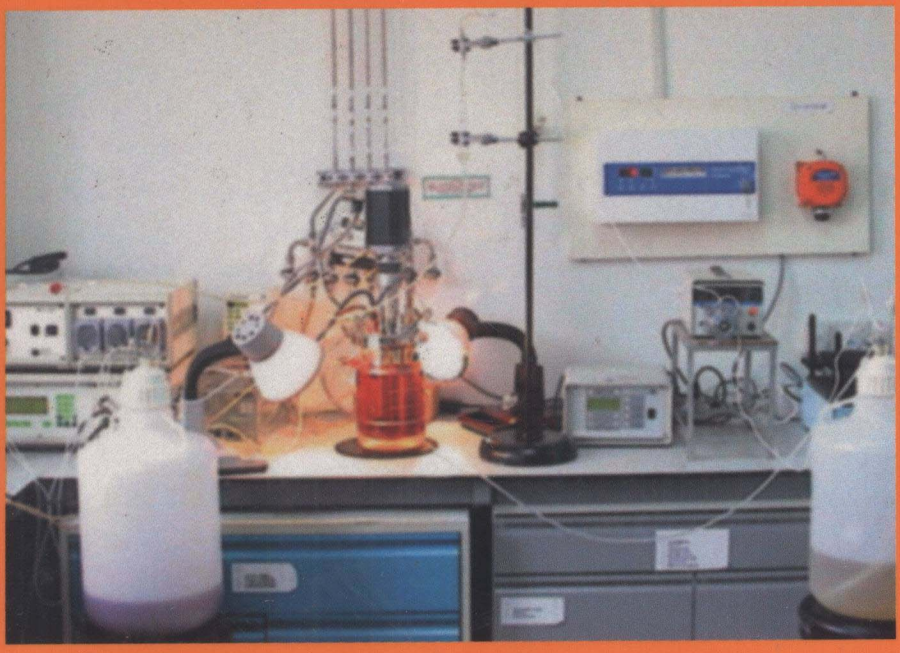

BIOCHEMICAL ENGINEERING AND BIOTECHNOLOGY

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BIOCHEMICAL ENGINEERING
AND BIOTECHNOLOGY

Preface

In the new millennium, extensive application of bioprocesses has created an environment for many engineers to expand knowledge of and interest in biotechnology. Microorganisms produce alcohols and acetone, which are used in industrial processes. Knowledge related to industrial microbiology has been revolutionised by the ability of genetically engineered cells to make many new products. Genetic engineering and gene mounting has been developed in the enhancement of industrial fermentation. Finally, application of biochemical engineering in biotechnology has become a new way of making commercial products.

This book demonstrates the application of biological sciences in engineering with theoretical and practical aspects. The seventeen chapters give more understanding of the knowledge related to the specified field, with more practical approaches and related case studies with original research data. It is a book for students to follow the sequential lectures with detailed explanations, and solves the actual problems in the related chapters.

There are many graphs that present actual experimental data, and figures and tables, along with sufficient explanations. It is a good book for those who are interested in more advanced research in the field of biotechnology, and a true guide for beginners to practise and establish advanced research in this field. The book is specifically targeted to serve as a useful text for college and university students; it is mostly recommended for undergraduate courses in one or two semesters. It will also prove very useful for research institutes and postgraduates involved in practical research in biochemical engineering and biotechnology.

This book has suitable biological science applications in biochemical engineering and the knowledge related to those biological processes. The book is unique, with practical approaches in the industrial field. I have tried to prepare a suitable textbook by using a direct approach that should be very useful for students in following the many case studies. It is unique in having solved problems, examples and demonstrations of detailed experiments, with simple design equations and required calculations. Several authors have contributed to enrich the case studies.

During the years of my graduate studies in the USA at the University of Oklahoma and the University of Arkansas, the late Professor Mark Townsend gave me much knowledge and assisted me in my academic achievements. I have also had the opportunity to learn many things from different people, including Professor Starling, Professor C.M. Sliepcevich and Professor S. Ellaison at the University of Oklahoma. Also, it is a privilege to acknowledge Professor J.L. Gaddy and Professor Ed Clausen, who assisted me at the University of Arkansas. I am very thankful for their courage and the guidance they have given me. My vision in research and my success are due to these two great scholars at the University of Arkansas: they are always remembered.

This book was prepared with the encouragement of distinguished Professor Gaddy, who made me proud to be his student. I also acknowledge my Ph.D. students at the University of Science Malaysia: Habibouallah Younesi and Aliakbar Zinatizadeh, who have assisted me in drawing most of the figures. I am very thankful to my colleagues who have contributed to some parts of the chapters: Dr M. Jahanshahi, from the University of Mazandaran, Iran, and Dr Nidal Hilal from the University of Nottingham, UK. Also special thanks go to Dr H. Younesi, Dr W.S. Long, Associate Professor A.H. Kamaruddin, Professor S. Bhatia, Professor A.R. Mohamed and Associate Professor A.L. Ahmad for their contribution of case studies.

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CHAPTER 1

Industrial Microbiology

1.1 INTRODUCTION

Microorganisms have been identified and exploited for more than a century. The Babylonians and Sumerians used yeast to prepare alcohol. There is a great history beyond fermentation processes, which explains the applications of microbial processes that resulted in the production of food and beverages. In the mid-nineteenth century, Louis Pasteur understood the role of microorganisms in fermented food, wine, alcohols, beverages, cheese, milk, yoghurt and other dairy products, fuels, and fine chemical industries. He identified many microbial processes and discovered the first principal role of fermentation, which was that microbes required substrate to produce primary and secondary metabolites, and end products.

In the new millennium, extensive application of bioprocesses has created an environment for many engineers to expand the field of biotechnology. One of the useful applications of biotechnology is the use of microorganisms to produce alcohols and acetone, which are used in the industrial processes. The knowledge related to industrial microbiology has been revolutionised by the ability of genetically engineered cells to make many new products. Genetic engineering and gene mounting have been developed in the enhancement of industrial fermentation. Consequently, biotechnology is a new approach to making commercial products by using living organisms. Furthermore, knowledge of bioprocesses has been developed to deliver fine-quality products.

Application of biological sciences in industrial processes is known as bioprocessing. Nowadays most biological and pharmaceutical products are produced in well-defined industrial bioprocesses. For instance, bacteria are able to produce most amino acids that can be used in food and medicine. There are hundreds of microbial and fungal products purely available in the biotechnology market. Microbial production of amino acids can be used to produce L-isomers; chemical production results in both D- and L-isomers. Lysine and glutamic acid are produced by *Corynebacterium glutamicum*. Another food additive is citric acid, which is produced by *Aspergillus niger*. Table 1.1 summarises several widespread applications of industrial microbiology to deliver a variety of products in applied industries.

The growth of cells on a large scale is called industrial fermentation. Industrial fermentation is normally performed in a bioreactor, which controls aeration, pH and temperature. Microorganisms utilise an organic source and produce primary metabolites such as ethanol,

TABLE 1.1. *Industrial products produced by biological processes*[12]

Fermentation product	Microorganism	Application
Ethanol (non-beverage)	*Saccharomyces cerevisiae*	Fine chemicals
2-Ketogluconic acid	*Pseudomonas* sp.	Intermediate for D-araboascorbic acid
Pectinase, protease	*Aspergillus niger, A. aureus*	Clarifying agents in fruit juice
Bacterial amylase	*Bacillus subtilis*	Modified starch, sizing paper
Bacterial protease	*B. subtilis*	Desizing fibres, spot remover
Dextran	*Leuconostoc mesenteroides*	Food stabilizer
Sorbose	*Gluconobacter suboxydans*	Manufacturing of ascorbic acid
Cobalamin (vitamin B_{12})	*Streptomyces olivaceus*	Food supplements
Glutamic acid	*Brevibacterium* sp.	Food additive
Gluconic acid	*Aspergillus niger*	Pharmaceutical products
Lactic acid	*Rhizopus oryzae*	Foods and pharmaceuticals
Citric acid	*Aspergillus niger* or *A. wentii*	Food products, medicine
Acetone-butanol	*Clostridium acetobutylicum*	Solvents, chemical intermediate
Insulin, interferon	Recombinant *E. coli*	Human therapy
	Baker's yeast	
Yeast and culture starter	*Lactobacillus bulgaricus*	Cheese and yoghurt production
	Lactic acid bacteria	
Microbial protein (SCP)	*Candida utilis*	Food supplements
	Pseudomonas methylotroph	
Penicillin	*Penicillium chrysogenum*	Antibiotics
Cephalosporins	*Cephalosparium acremonium*	Antibiotics
Erythromycin	*Streptomyces erythreus*	Antibiotics

which are formed during the cells' exponential growth phase. In some bioprocesses, yeast or fungi are used to produce advanced valuable products. Those products are considered as secondary metabolites, such as penicillin, which is produced during the stationary phase. Yeasts are grown for wine- and bread-making. There are other microbes, such as *Rhizobium*, *Bradyrhizobium* and *Bacillus thuringiensis*, which are able to grow and utilise carbohydrates and organic sources originating from agricultural wastes. Vaccines, antibiotics and steroids are also products of microbial growth.

1.2 PROCESS FERMENTATION

The term 'fermentation' was obtained from the Latin verb '*fervere*', which describes the action of yeast or malt on sugar or fruit extracts and grain. The 'boiling' is due to the production of carbon dioxide bubbles from the aqueous phase under the anaerobic catabolism of carbohydrates in the fermentation media. The art of fermentation is defined as the chemical transformation of organic compounds with the aid of enzymes. The ability of yeast to make alcohol was known to the Babylonians and Sumerians before 6000 BC. The Egyptians discovered the generation of carbon dioxide by brewer's yeast in the preparation