

Bioprocessing for Value-Added Products from Renewable Resources :

New Technologies and Applications

可再生资源增值产品的生物加工： 新技术及其应用

Shang-Tian Yang



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导 读

进入 21 世纪,现代社会的发展面临着能源和资源的短缺和环境污染等严重问题。全球经济显现出传统的石油基经济逐步向生物基经济的转变。在这一变迁和交替过程中,由于近年来石油价格的长期高位运行,生物基的经济,特别是生物炼制,受到了科学界、产业界和各国政府的高度重视。一个以工业生物技术为核心的、以可再生资源利用为特征的可持续发展的新型生物加工产业已经开始快速发展。近年来欧洲、美国和日本等发达国家针对目前自身面临的资源、能源和环境危机制定出今后几十年发展工业生物技术的计划。我国近年来非常重视工业生物技术的发展,国家中长期科学与技术规划、973 计划和 863 计划都将工业生物技术列为重点专题,工业生物技术产业得到了快速发展。

在以上背景下,2007 年由 Elsevier 出版的“Bioprocessing for Value-added Products from Renewable Resources: New technologies and Applications”是一本非常及时和全面反映可再生资源的生物加工生产价值增加产品的新技术和新应用的专著。该书主编为美国俄亥俄州立大学化工和生物分子工程系的杨尚天教授,他长期从事可再生资源生物加工方向的研究,为编写本书组织了强大的作者阵容,各章作者都是在活跃在各自领域中的第一流专家。

本书共分二十五章。第一章介绍了生物技术到生物炼制的发展和变迁,是本书其它章节所贯穿的主旨。接着介绍了生物加工工程基础的关键性现代技术,组成本书的第一部分“强有力的技术”,共由 6 章组成:基因组和蛋白质组数据应用于生物过程分析和优化(第二章);生物产品和生物过程发展中的定向进化工具(第三章);代谢工程的应用、方法和挑战(第四章);淀粉酶和纤维素酶的结构和功能(第五章);生物反应器工程(第六章);生物分离中的膜(第七章)。

本书第二部分是“生物加工中的培养”,主要介绍适合生物加工要求的各种生物和培养特性,共由 4 章组成:细菌和酵母培养—过程特性、产物和应用(第八章);丝状真菌的培养—过程特性、产物和应用(第九章);植物细胞和发根组织培养—过程特性、产物和应用(第十章);海洋微藻破囊壶菌生产高价值产品(第十一章)。

第三部分是“非传统和新型的生物加工过程”,共由 10 章组成:非传统生物催化在用生物质生产化学品和聚合物中的应用(第十二章);生物催化在手性合成的应用(第十三章);固定化细胞发酵生产化学品和燃料(第十四章);油包水型培养技术发酵生产高粘度黄原胶(第十五章);萃取发酵生产羧酸(第十六章);真菌发酵生产医药产品(第十七章);固体发酵及其应用(第十八章);藻类光合反应器生产叶黄素和玉米黄素(第十九章);从生物可再生资源到动力产生:生物燃料电池中的生物催化(第二十章);可再生资源的生物制氢(第二十一章)。

本书最后一部分是第四部分“原料利用”,主要介绍了可再生生物质作为大规模工业化生产的原料及其加工的一些例子,共由 4 章组成:生物转化乳清乳糖生产微生物细

胞外多糖（第二十二章）；微生物利用可再生资源生产生物塑料（第二十三章）；植物油脂的工业应用（第二十四章）；从动物粪便中生产价值增加产品（第二十五章）。

本书可认为是至今最为全面反映可再生资源的生物加工的研究进展的专著，全书内容非常新颖，编排具有很强的内在的逻辑性。很明显，其全面性、系统性和权威性将使得该书成为可再生资源的生物加工研究的百科全书式的参考书，是从事生物化工、生物工程、生物能源工程、生物材料工程、化工、轻工和农产品加工等领域或行业的师生和研发人员的重要参考书。

作为其中一章的作者，非常高兴看到在中国出版这本书，考虑到本书读者群的专业性以及更好地保持本书原貌和降低出版周期，以导读版形式引进也是非常令人欣慰的。衷心感谢科学出版社为本书出版所做的大量工作，相信本书的出版将对我国可再生资源生物加工领域的研究和开发产生重要的推动作用。

徐志南 教授
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2007年4月

序 言

石油储藏和化石燃料的快速消耗是全世界面临的一个挑战性难题，尤其对于严重依赖石油基原料的国家。一个新的工业趋势是从石油基的产品和制造过程向生物基的产品和制造过程变迁，从而能够保护地球上的自然资源和将地球从工业污染中解救出来。同时，许多工业化国家，例如美国，面临双重的难题：一是过剩的农产品供应导致农民的低回报；二是由于实行不断严格的环境法规从而需要高成本处理大量食品加工废弃物。针对以上各种难题，发展生物基产品的工业将提供一个既经济又环保的解决方法。

上世纪 70 年代发生的石油危机和 80 年代早期诞生的新型生物技术工业已经让人类社会看到利用可再生资源实现充分可持续发展的曙光。从此，涌现了很多生物基新产品和生物加工新技术。但是，直到最近，生物技术产业依然主要关注于重组蛋白质药物和转基因动植物，而很少关注大量的中等价值的工业产品，如含氧化合物，医药中间体，聚合物，工业溶剂，燃料，食品营养补剂和饲料添加剂等，尽管以上很多产品的传统生产方法或正在采用的方法都是基于碳水化合物原料的发酵生产。在过去的 20 到 30 年中，这些生物基产品的商业化进程缓慢，主要原因是生物加工过程的相对低效导致这一领域投资回报率低，来源于市场中处主导地位的石油基产品的激烈价格竞争，以及难以转变传统上化学工业与农产品工业相分离的企业文化。在过去的几年中，这一情况已经得到急剧的改变。传统的农业公司，包括 Cargill 和 ADM，已经从主要是食品和饲料的供应商扩展和转变为价值增加产品的主要制造者，其中包括特种化学品和燃料乙醇。同时，几个大型化学公司，包括杜邦、陶氏化学品和孟山都，已经在基于生物技术的制造过程上投入了主要的研发力量。两年之间原油价格成倍上涨和最近每桶 70 美元的高价也加速了这一向生物基经济的转变，使得很多生物基产品在经济上具有竞争性，对公司和私人投资者很有吸引力。

本书全面总结了生物技术和生物加工工程的基本原理、生物基新产品的工业化生产实例，以及对利用可再生资源进行可持续生产价值增加产品具有普遍意义的各种技术进展。结合实例，讨论了从基因组到代谢工程和生物过程工程的各种关键技术。本书非常详细地介绍了生物技术和生物加工工程的基本原理和新进展，以及它们在现有和新的生物基工业产品上的应用，从而帮助专家和非专家都能理解这一领域的最新进展。本书首先讨论了生物技术和生物加工工程领域中对建立一个新型的生物基产品的工业具有基石意义的现代技术。本书第二部分总结了从细菌到海藻的一系列不同类型的生物。这些生物由于各有特性，包括独特的加工过程要求、产生各种产品和具有多样用途，从而适合应用于生物加工过程。本书第三部分由各种正在研发的非传统和新型的生物加工过程组成。最后，本书提供了经济利用各种可再生资源为原料生产工业产品的例子。

两年前，我们开始本书的编写，从美国和其它国家被邀请的各位作者都是在各自领域中一流的专家，没有他们的贡献和杨凯文在文字编辑上的帮助，这本书将不可能及时完成和出版。

俄亥俄，都柏林

2006 年 9 月

(徐志南 译)

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Preface

The rapid depletion of petroleum reserves and fossil fuels presents a challenging problem to the world, especially to countries whose industries are heavily reliant on petroleum-based feedstocks. A new industrial trend is to move from petroleum-based to bio-based products and manufacturing processes that can conserve the earth's natural resources and save the planet from industrial pollution. Meanwhile, many industrialized countries, such as the United States, also face the dual problems of surplus agricultural commodities with low economic returns for farmers and large amounts of food processing wastes with high disposal costs because of increasingly tight environmental regulations. The development of a bio-based product industry will offer an economical and environmentally friendly solution to the aforementioned problems.

The oil crisis in the 1970's and the birth of a new biotechnology industry in the early 1980's have given society the hope of becoming fully sustainable by using renewable resources. Since then, many new bio-based products and bioprocessing technologies have been developed. Until recently, however, the biotechnology industry has focused its effort mainly on recombinant protein drugs and transgenic plants and animals. Much less attention has been given to high-volume medium-value industrial products such as oxychemicals, drug intermediates, polymers, industrial solvents, fuels, and food ingredients and feed supplements, although many of these have traditionally been or are currently produced by fermentation from carbohydrate-based feedstocks. The slow progress in commercial development of these bio-based products in the past 20 to 30 years can be attributed to low investment return due to relatively inefficient bioprocesses and steep price competition from the petroleum-based products that dominate the market, and the difficulty of changing the corporate cultures of the traditionally segregated chemical and agricultural industries. This situation has been drastically changed in the last few years. Traditional agricultural companies, including Cargill and ADM, have expanded and transformed from being primarily commodity food/feed suppliers to major manufacturers of value-added products, including specialty chemicals and fuel ethanol. During the same period, several large chemical companies, including DuPont, Dow Chemical, and Monsanto, have also made major R&D investments in biotechnology-based manufacturing processes. This shift toward a bio-based economy has further accelerated as the price of crude oil has been doubled in two years and recently reached US \$70 per barrel, making many bio-based products economically competitive and appealing to corporate and private investors.

This book provides a comprehensive review of the fundamentals of biotechnology and bioprocess engineering as well as industrial examples of new bio-based products and advancements in technology development that are important to the general field of sustainable bioprocessing for value-added industrial products from renewable resources. Critical enabling technologies, from genomics to metabolic and bioprocess engineering, are discussed, with some examples. Both fundamentals and novel developments in biotechnology and bioprocess engineering, and their applications to existing and new bio-based industrial products are described in sufficient

detail to allow both experts and non-experts to comprehend recent progress in this field. This book first discusses the modern technologies in the fields of biotechnology and bioprocess engineering that are the cornerstones for building a new bio-based products industry. The second part of the book reviews different organisms, ranging from bacteria to algae, that are suitable for bioprocessing because of their unique characteristics, process requirements, products, and applications. The third part of the book comprises a variety of unconventional and novel bioprocesses currently in development. Finally, the book provides examples of the economical use of different renewable resources as feedstocks to produce industrial products.

We started this book more than two years ago. The invited contributing authors are leading experts in their respective research field from the USA and other countries. Without their contribution and editorial assistance from Kevin Yang, this book would not have been finished in time for publication.

Dublin, Ohio
September, 2006

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