D-Xylitol

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Editors

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Fermentative Production, Application and Commercialization

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Sugar, xylitol, honey and buffalo's milk are all sweet, but incomparable is the sweetness of the Lord*

Sheikh Farid

*Added by the editors related to the context of this book

About the Editors

Professor Silvio Silvério da Silva was born on 31 December 1959. He is a professor at the Department of Biotechnology, Engineering School of Lorena, University of São Paulo, Brazil. He completed his doctorate in Biochemical and Pharmaceutical Technology from the University of São Paulo (USP) and GBF German Research Centre for Biotechnology, Germany in 1994. Prof. Silva is a reviewer of several reputed scientific journals and also offers ad hoc consulting services to various institutions. He has published more than 130 papers in peer reviewed international journals and presented more than 455 scientific papers in international conference proceedings. He has also 18 book chapters to his credit. He has recorded two patents on technological processes for xylitol production. Prof. Silva has guided 10 doctoral students, 25 masters' dissertations and 55 scientific initiation students in the area of Applied Microbiology, Biochemical Engineering and Food Science and Technology. He has successfully completed 19 research projects funded by the Brazilian Government and private funding agencies. Prof. Silvio has been actively working on fermentative production of xylitol for 24 years.

His area of research is Microbial Technology harnessing the potential of lignocellulosic feedstock for the production of xylitol and bioethanol. He has visited several international research institutions and universities of various countries for the exchange of scientific knowledge on the production of value-added products from lignocellulose feedstock.

Dr. Anuj K. Chandel completed his doctorate in 2009 from Jawaharlal Nehru Technological University, Hyderabad, India. After receiving his masters in 2000 in biotechnology from the Indian Institute of Technology Roorkee, he joined Dalas Biotech Ltd. Bhiwadi for three years for the large-scale production of penicillin acylase and antibiotic intermediates. Subsequently, he worked at the University of Delhi in a nationwide research project on development of a bioethanol production process from lignocellulosic feedstock funded by the Department of Biotechnology (DBT), Ministry of Science and Technology, Govt. of India. He worked on this

project for 3 years. Later he joined Celestial Labs Ltd., Hyderabad as a research associate and pursued his doctoral studies on ethanol production from *Saccharum spontaneum* (wild sugarcane) using thermotolerant yeasts. After this, he did post doctoral studies at the University of Stellenbosch, South Africa working on development of fermentative processes for vaccine production from recombinant yeasts. Currently he is working with Prof. S. S. Silva, Engineering School of Lorena, University of São Paulo as a post doctoral researcher for the development of a fuel ethanol production process from sugarcane bagasse in a thematic project funded by FAPESP. He is the author of 35 articles in peer-reviewed journals and 12 book chapters.

Preface

Hemicellulose, the second most abundant polysaccharide in nature, is well suited for the production of value-added products like xylitol, ethanol, protein rich food and fodder due to its enormous availability, low cost and environmentally benign process. In general, the major fraction in hemicellulose is pentosans (xylan), and the microbial conversion of xylan into xylitol is now possible on an industrial scale. D-Xylitol is found in low content as a natural constituent of many fruits and vegetables. It is a five-carbon sugar polyol and has been used as a food additive and sweetening agent to replace sucrose, especially for non-insulin dependent diabetics. It has multiple beneficial health effects such as the prevention of dental caries, osteoporosis and acute otitis media. In industries, it has been produced by chemical reduction of D-xylose, presented in xylan. Advancements in biotechnology such as screening of microorganisms, manipulation of pentose-utilizing microorganisms by molecular biology-based approach modifications, developments in fermentation processes and downstream processing could enhance the production of xylitol. Commercially, cheaper sources of carbohydrates, derived from photosynthetic biomass and modified fermentation conditions, could lead to more cost-effective production of xylitol. These methodologies would open new markets and create new applications of xylitol. This book was written keeping in mind the fundamental aspects of hemicellulose break-down into its monomeric constituents: D-xylose utilization for xylitol production by different bioconversion methods, xylitol recovery and its analysis in laboratories, economic evaluation and diverse applications of xylitol.

This book has been divided into five parts. Part I deals with the different kinds of hydrolytic methods applied to different kinds of biomass sources for xylose recovery and detoxification of xylose rich hydrolysates. In this part, three chapters are included. Chapters 1 and 2 highlight the hydrolytic methods for hemicellulosic fraction of various lignocellulosic materials. For depolymerisation of the hemicellulosic fraction of the plant cell wall, generally acid-catalysed processes are employed at high temperature and pressure. During the deconstruction of hemicelluloses, other unwanted products such as furans, phenolics and weak acids are also generated in addition to sugars. It is necessary to eliminate these inhibitors

from the hydrolysates prior to fermentation in order to get satisfactory product yields and productivities. Chapter 3 summarizes the different methods explored for detoxification of lignocellulose hydrolysates. Part II aims to explore the microorganisms, media formulations, and fermentation methods, as well as the enzymatic production of xylitol and bioenergetics analysis for xylitol production. This part constitutes the major part of the book and contains six chapters. Microbial strains, particularly yeasts used for xylitol production, metabolic pathways, physiological pathways, strain improvement methods, statistical optimization of various influential parameters, fermentation strategies and enzymatic production of xylitol have been discussed in detail in Chaps. 4–8, respectively. In addition, bioenergetic analysis of xylitol production (carbon balance and xylitol yields, and productivities from different kind of substrates adopting various fermentative strategies) employing different microorganisms has been summarized in Chap. 9. Part III describes the xylitol recovery and the analytical methods explored for xylitol quantification. Chapter 10 is concerned with xylitol recovery and crystallization from chemical synthesis and biotechnologically-based production strategies. Chapter 11 presents an appraisal on the analytical methods for xylitol quantification. Analysis on economic feasibility of biotechnological production of xylitol and market demand has been summarized in Part IV. Chapter 12 describes the key factors which influence the large-scale production of xylitol. This chapter concludes the technological barriers and methods to overcome for successful xylitol production on an industrial scale. Chapter 13 provides an overview on commercialization of xylitol, economic analysis of fermentative production of xylitol and recovery and a brief research on market demands of xylitol in future. Finally, Part IV is dedicated to the applications (medical and non-medical) of xylitol. Chapter 14 describes the application of xylitol in food/feed-based industrial sectors and summarizes the health benefits of xylitol. Chapter 15 provides an overview on the medical applications of xylitol in addition to promising future applications which may have impact on increased xylitol demands.

We sincerely believe that this book should cater to the needs of graduate and post graduate students, researchers of the biochemistry, microbiology, biotechnology, biochemical engineering, pharmacy, medicine, scientists and engineers both in academia and industry and business entrepreneurs. We would like to thank our colleagues MGA Felipe, Ines C. Roberto, Walter de Carvalho, Attilio Converti, M. Vitolo, Hou-Rui Zhang, Om V. Singh, Ricardo de Freitas Branco, R. C. L. B Rodriguez, Larissa Canilha, Solange I. Mussatto and Felipe F. A. Antunes for their constant help and encouragement. We also appreciate the timely help of our departmental staff (Nicanor, Paulo Roberto, Nadir, Walkiria, Isnaldi and Cibele) for the completion of this book. We are also thankful to doctoral and masters students of our department for their necessary help. We are grateful to the publishers for their necessary help and cooperation. Anuj would like to express sincere thanks to his wife, Meenakshi, and son, Abhay, for their patience and immense support during editing of this book. Silvio Silvério is also thankful to his wife, Deyse, and daughter, Isabela, for their cooperation while editing this book.

Editors are also thankful to EEL/USP for providing necessary facilities and basic infrastructure. We are grateful to the Government funding agencies of Brazil, particularly FAPESP, CNPq and CAPES, for the financial assistance to our lab to carry out the research work on various aspects of lignocellulose biotechnology. Last, but certainly not least, we welcome the reader's opinions and suggestions to improve future editions. Readers' benefits will be the best reward for the authors.

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