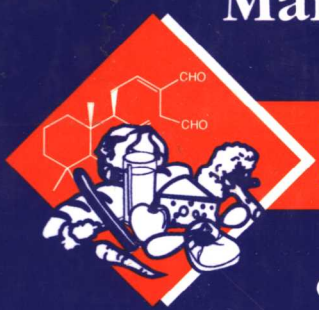
Volume 2

Functional Foods

Biochemical and Processing Aspects

EDITED BY

John Shi
G. Mazza
Marc Le Maguer



FUNCTIONAL FOODS AND NUTRACEUTICALS SERIES

CRC PRESS

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Foreword

The science of functional foods and nutraceuticals is at the confluence of two major factors in our society — food and health. The link between diet and disease has now been quite widely accepted, not only at the institutional level by organizations such as Health Canada, the U.S. Surgeon General and the Japan Ministry of Health and Welfare, but also by a large portion of the populace. In recent years, there appears to have been a growing desire by individuals to play a greater role in their own health and well-being rather than rely strictly on conventional medical practice. Much of this drive has been attributed to the aging of the "baby boomer" generation and their efforts to hold the inevitable effects of time on the body at bay. As a result, there has been a burgeoning market for a wide range of dietary supplements and nutraceutical products that are perceived by the consuming public to be beneficial in the maintenance of their health and in the prevention of disease.

This book continues a series of timely publications on functional foods under the editorship of Dr. G. Mazza and explores new sources of nutraceuticals and functional food ingredients as a logical step between foods and therapeutic drugs. Specifically, the book addresses the biochemical and processing aspects associated with the production of functional foods and nutraceutical products. By definition, a nutraceutical is a product isolated or purified from a biological material that is generally sold in medicinal form and is not usually associated with food. A nutraceutical is demonstrated to have a physiological benefit or provide protection against chronic disease. A functional food is similar in appearance to conventional foods, is consumed as part of a usual diet, and has demonstrated physiological benefits or reduces the risk of chronic disease beyond basic nutritional functions.* Based on these definitions, the book addresses the key factors associated with functional foods and nutraceuticals: the biochemistry of various bioactives, their physiological effects and the engineering and process technology associated with the isolation and purification of the desired compounds from the complex biological matrices in which they are found.

In the first book in the series, the biochemical and processing aspects of functional foods were examined in detail. This book now moves the topic forward in its study of the biochemistry and processing aspects of tocopherols and tocotrienols from oil and cereal grains, isoflavones from soybeans, flavonoids from berries, lycopene from tomatoes, limonene from citrus, phenolic diterpenes from rosemary and sage, organosulfur constituents from garlic, pectin from fruits, bioactives from *Echinacea* and omega-3 fatty acids from fish products. Many of these biologically active compounds appear regularly in articles in the popular press and take on almost a "folk medicine" aura. These products will benefit from the sound and thorough

* Nutraceuticals/Functional Foods and Health Claims on Foods. Policy Paper, Therapeutic Products Programme and the Food Directorate, Health Canada. November 1998.

approach taken in this book that will help them achieve recognized status in the lexicon of the medical and nutrition professionals.

While each product-specific chapter addresses the biochemical and processing of the subject compound and material from which it is being extracted, Chapter 11 addresses the engineering and technology associated with the extraction of the nutraceutical compounds from plant material from the technology side. Given that essentially all of the target biologically active compounds exist at very low levels in the source material, a suitable technique to extract and separate the compounds is vital to the economic feasibility and will help govern whether the product can be brought to the market at a realistic price.

The book ends with a more general chapter, albeit one that is critical to the success of the sector. Safety of the products is paramount and needs to be carefully addressed if the functional foods and nutraceutical products are to take their legitimate place in the kit of tools that can be used to maintain the health and well-being of the population. Anecdotal evidence of either safety or efficacy will not suffice to ensure the long-term impact that nutraceuticals and functional foods can bring to the quality of life in the general population. Market forces will continue to be a major driver for the industry, as many players ranging from small entrepreneurs to multinational food and pharmaceutical companies seek to enter the marketplace.

The contributors, coeditors and the series editor are to be congratulated on development of a very useful and timely book that serves to advance the science of functional foods and nutraceuticals. A thorough and complete understanding of the many aspects of functional foods and nutraceuticals, the biochemistry, physiological effects, impact of processing and the technologies required for the production, will all contribute to moving this exciting area ahead.

Brian Morrissey, Ph.D.
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and Research Director of Agriculture and Agri-Food Canada
Ottawa, Canada

Series Preface

The titles in the Functional Foods and Nutraceuticals Series offer food, nutrition and health professionals a comprehensive treatment of the emerging science and technology of functional foods and nutraceuticals. The first two books in the series, *Functional Foods: Biochemical and Processing Aspects, Volume 1* and *Herbs Botanicals and Teas*, have received worldwide acceptance by practitioners in these fields. This latest book and upcoming volumes present the state-of-the-science and technology of all aspects of functional foods and nutraceuticals, from chemistry and pharmacology to process engineering and clinical trials.

With over 2100 scientific references, *Functional Foods: Biochemical and Processing Aspects, Volume 2* provides readers with a comprehensive and up-to-date scientific publication. This volume discusses the occurrence, chemistry, bioavailability, health effects, processing and engineering aspects of tocopherols and tocotrienols from oil and cereal grain, isoflavones from soybeans and soy foods, flavonoids from berries and grapes, lycopene from tomatoes, limonene from citrus, phenolic diterpenes from rosemary and sage, organosulfur constitutes from garlic, phytochemicals from *Echinacea*, pectin from fruit, omega-3 fatty acids from fish products and safety aspects of botanicals.

The book also presents a detailed chapter on solid–liquid extraction technologies for manufacturing nutraceuticals and dietary supplements, and several chapters provide information on physical and chemical properties of bioactives. This information, which is seldom available, is essential for the reliable and economical scaleup of laboratory-based extraction and purification techniques for secondary plant metabolites.

A critical issue in the development of functional foods and nutraceuticals is product safety and efficacy. In Chapter 12, Safety of Botanical Dietary Supplements, a variety of safety issues related to dietary supplements are discussed. These include the complex issue of herb–drug interactions and inherent toxicity of some plants, such as comfrey, which has been used for inflammatory disorders including arthritis, thrombophlebitis and gout, and as a treatment for diarrhea. Recently, however, the U.S. Food and Drug Administration (FDA) has requested the withdrawal of dietary supplements containing the herb comfrey due to the potential danger of liver damage and its possible role as a cancer-causing agent. With respect to herb–drug interactions, the recent case reports that implicate St. John's wort herb–drug interactions with cyclosporine, warfarin, theophylline and ethinyl estrodiol are reviewed.

The present volume also addresses the issue of processing and its effects on the bioavailability of bioactives. It shows that processing of a functional food may have profound effects on specific health benefits it claims to deliver. As illustrated in Chapter 4, the physiological effects of lycopene are altered significantly during processing, primarily due to its isomerization and oxidation. Worth noting, however,

is the fact that the *cis*-isomers, which are produced in the processing of tomatoes, are better absorbed by the human body than the naturally occurring all-*trans* form.

Upcoming volumes of the series include methods of analysis for functional foods and nutraceuticals, and functional dairy products.

I hope that this work will be useful to all those interested in functional foods and nutraceuticals, especially food scientists and technologists, nutritionists, phytochemists, physiologists, food process engineers and public health professionals.

G. Mazza
Series Editor

Preface

During the past decade, functional foods and nutraceuticals have emerged as a major consumer-driven trend, serving the desire of aging populations to exercise greater control over health, delay aging, prevent disease and enhance well-being and performance. This trend is expected to continue, and the need for and interest in scientific information on all aspects of functional foods will continue to be vital to the advancement of this emerging sector.

The Functional Foods and Nutraceuticals Series, launched in 1998, was developed to provide a timely, comprehensive treatment of the emerging science and technology of functional foods and nutraceuticals that are shown to play a role in preventing or delaying the onset of diseases, especially chronic diseases. *Functional Foods: Biochemical and Processing Aspects, Volume 1*, the first volume of the series, is a bestseller devoted to functional food products from oats, wheat, rice, flaxseed, mustard, fruits, vegetables, fish and dairy products. In Volume 2, the focus is on presenting the latest developments in chemistry, biochemistry, pharmacology, epidemiology and engineering of tocopherols and tocotrienols from oil and cereal grain, isoflavones from soybeans and soy foods, flavonoids from berries and grapes, lycopene from tomatoes, limonene from citrus, phenolic diterpenes from rosemary and sage, organosulfur constitutes from garlic, phytochemicals from *Echinacea*, pectin from fruit and omega-3 fatty acids and docosahexanoic acid from fish products. Also covered is solid–liquid extraction technologies for manufacturing nutraceuticals and dietary supplements.

All chapters, especially the last two, contain information that has not been published previously. The chapter on solid–liquid extraction technologies, for example, presents and discusses both theoretical and practical aspects of these technologies, from fundamental concepts of equilibrium and mass transfer to equipment selection and design. Similarly, the chapter on safety of botanicals reviews safety issues of botanicals associated with misidentification of plant species, misuse of products, product adulteration and botanical/drug interactions.

The contributing authors are international experts on the subjects covered, and we are grateful to every one of them for their thoughtful and well-written contributions. We hope that this book will be of interest to a wide spectrum of food scientists and technologists, nutritionists, biochemists, engineers and entrepreneurs worldwide, and that it will serve to further stimulate the development of functional foods and nutraceuticals and contribute to providing consumers worldwide with products that prevent diseases and help to maintain a healthier life. We believe the scientific community will benefit from the overall summary of each area presented.

John Shi
G. Mazza
Marc Le Maguer

Acknowledgments

The editors would like to express sincere gratitude and appreciation to all those who reviewed chapters: Dr. Cathy Y. W. Ang (National Center for Toxicological Research/FDA); Dr. Joseph M. Betz (American Herbal Products Association); Professor Robert Shewfelt (University of Georgia); Professor Bor S. Luh (University of California at Davis); Professor Patricia Murphy (Iowa State University); Professor Bhimu S. Patil (Citrus Center, Texas A&M University); Drs. Steve Nagy and Steven Pao (Florida Department of Citrus Research Center); Dr. Keshun Lui (Monsanto Company); Dr. Marijan A. Boskovic (Kraft Foods); Dr. Matt Bernart (Om-Chi Herbs Company); Professors John DeMana, Yukio Kakuda and Gauri Mittal (University of Guelph, Canada); Drs. Akhtar Humayoun, John K. G. Kramer, Albert Liptay, Peter J. Wood and Chris J. Young (Agriculture and Agri-Food Canada). Support from Dr. Brian Morrissey (former Assistant Deputy Minister and Research Director of Agriculture and Agri-Food Canada) and Dr. Gordon Timbers (Food Research Coordinator Agriculture and Agri-Food Canada) is appreciated.

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Contents

1 Tocopherols and Tocotrienols from Oil and Cereal Grains

Anna-Maija Lampi, Afaf Kamal-Eldin and Vieno Piironen

CONTENTS

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1.1 INTRODUCTION

Because tocopherols and tocotrienols exhibit the biological activity of α-tocopherol, they belong to the group of compounds called vitamin E (VERIS, 1998). It was first discovered as a factor present in, for example, cereal grains to prevent reproductive failure in the rat, nutritional muscular dystrophy in the quinea pig and rabbit, and later other vitamin E deficiency symptoms. There is no specific reaction for which vitamin E is a cofactor. Instead, its role is to prevent a range of oxidation reactions of polyunsaturated lipids *in vivo* and to function as a biological antioxidant (Machlin, 1991; Combs, 1998; Traber, 1999). In the human body, vitamin E is the most important lipid-soluble antioxidant that provides an effective protective network against oxidative stress together with other antioxidants, such as vitamin C. For healthy people, it is relatively easy to get enough tocopherols and tocotrienols from the diet to prevent vitamin E deficiency, but higher daily intakes may provide other beneficial effects and may be needed when the diet contains large amounts of polyunsaturated fats (Horwitt, 1991).

Both tocopherols and tocotrienols are important antioxidants in foods, feeds and their raw materials, where they scavenge lipid radicals similarly as they do *in vivo* (Schuler, 1990; Combs, 1998). Tocopherols and tocotrienols improve storage and processing stability of many fat-containing materials and also are added as antioxidants to some foods and feeds during manufacturing. Protection needed in foods and feeds is, however, different from that of a living tissue, because these materials are subjected to a large variety of chemical and physical environments. Moreover, antioxidant activities of different tocopherols and tocotrienols vary depending on the conditions. Despite the fact that all E-vitamers are believed to be absorbed to the same extent in the human body, the bioavailability and bioactivity of α-tocopherol is much higher than that of the others.

This chapter deals with tocopherols and tocotrienols. It begins with a review of their chemical and physical properties and extends to their nutritional and health effects. The main focus is on tocopherols and tocotrienols in oil and cereal grains