



Herbal Nutraceuticals

Products and Processes

Edited by

Santosh Kumar Upadhyay

Sudhir Pratap Singh

WILEY

Herbal Nutraceuticals

Herbal Nutraceuticals

Products and Processes

Edited by

Santosh Kumar Upadhyay

Department of Botany

Panjab University

Chandigarh, India

Sudhir Pratap Singh

Department of Industrial Biotechnology

Gujarat Biotechnology University

Gandhinagar, India

WILEY

This edition first published 2025
© 2025 John Wiley & Sons Ltd

All rights reserved, including rights for text and data mining and training of artificial technologies or similar technologies. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

The right of Santosh Kumar Upadhyay and Sudhir Pratap Singh to be identified as the authors of the editorial material in this work has been asserted in accordance with law.

Registered Office(s)

John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, USA

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at www.wiley.com.

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

Trademarks: Wiley and the Wiley logo are trademarks or registered trademarks of John Wiley & Sons, Inc. and/or its affiliates in the United States and other countries and may not be used without written permission. All other trademarks are the property of their respective owners. John Wiley & Sons, Inc. is not associated with any product or vendor mentioned in this book.

Limit of Liability/Disclaimer of Warranty

While the publisher and authors have used their best efforts in preparing this work, they make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives, written sales materials or promotional statements for this work. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for your situation. You should consult with a specialist where appropriate. The fact that an organization, website, or product is referred to in this work as a citation and/or potential source of further information does not mean that the publisher and authors endorse the information or services the organization, website, or product may provide or recommendations it may make. Further, readers should be aware that websites listed in this work may have changed or disappeared between when this work was written and when it is read. Neither the publisher nor authors shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

Library of Congress Cataloging-in-Publication Data Applied for:

Hardback ISBN: 9781394241545

Cover Design: Wiley

Cover Image: © Lallapie/Shutterstock

Set in 9.5/12.5pt STIXTwoText by Straive, Pondicherry, India

Contents

About the Editors *xvii*

List of Contributors *xix*

Preface *xxv*

- 1 Plants Based Nutraceuticals: An Overview** *1*
Dheeraj Bisht, Vikas Bhatt, Rajeshwar Kamal Kant Arya, Shikha Yadav, Deepak Kumar, Sudhir Pratap Singh, and Santosh Kumar Upadhyay
- 1.1 Introduction *1*
- 1.2 Historical Background Behind Nutraceutical Investigations *2*
- 1.3 Pervasive Requisition for Nutraceuticals *3*
- 1.4 Classification of Nutraceuticals *3*
- 1.4.1 Traditional Nutraceuticals *4*
- 1.4.1.1 Prebiotics *4*
- 1.4.1.2 Dietary Fibers *4*
- 1.4.1.3 Antioxidant *5*
- 1.4.1.4 Spices *5*
- 1.4.1.5 Polyunsaturated Fatty Acids *6*
- 1.4.1.6 Polyphenols *6*
- 1.5 Popularly Found Herbs Utilized as Nutraceuticals *6*
- 1.5.1 Nontraditional Nutraceuticals *6*
- 1.5.2 Recombinant Nutraceuticals *8*
- 1.5.3 Fortified Nutraceuticals *8*
- 1.6 Utility of Nutraceuticals in Cure of Different Diseases *9*
- 1.6.1 Nutraceuticals for Cardiovascular Diseases *9*
- 1.6.1.1 Allicin and Allin *9*
- 1.6.1.2 Omega-3 Fatty Acids *10*
- 1.6.1.3 Soya Isoflavones *10*
- 1.6.1.4 Proteins, Peptides, and Amino Acids *10*
- 1.6.1.5 Antioxidants and Vitamins *10*
- 1.6.1.6 Phytosterols *11*
- 1.6.1.7 Alkaloids *11*
- 1.6.2 Nutraceuticals in Radiotherapy and Chemotherapy-based Cancer Treatment *11*
- 1.6.2.1 Curcumin *12*
- 1.6.2.2 Ginger and Genistein *12*
- 1.6.3 Nutraceuticals for Prostate Cancer Treatment *12*

- 1.6.3.1 Silibinin 13
- 1.6.3.2 Soy Isoflavones 13
- 1.6.4 Skincare Nutraceuticals 14
- 1.6.4.1 Peptides with Biological Activity 14
- 1.6.4.2 Biologically Active Polysaccharides 14
- 1.6.4.3 Botanical Extracts with Biological Activity 15
- 1.7 Current Status of Nutraceuticals 15
- 1.8 Challenges and Future Aspects 15
- 1.9 Conclusion 16
- References 16

2 Herbal Nutraceutical as Alternative Medicine 23

*Alok Sharma, Madhu, Sapna Avinash Kondalkar, Ajay Kumar Meena,
and Santosh Kumar Upadhyay*

- 2.1 Introduction 23
- 2.2 Classification of Nutraceuticals 24
 - 2.2.1 Traditional Nutraceuticals 24
 - 2.2.1.1 Probiotic Microorganisms 26
 - 2.2.1.2 Nutraceutical Enzymes 27
 - 2.2.2 Nonconventional Nutraceuticals 27
- 2.3 Types of Herbal Nutraceuticals Used as Alternative Medicine 27
 - 2.3.1 Herbal Nutraceuticals Based on Food Availability 27
 - 2.3.1.1 *Angelica* 27
 - 2.3.1.2 *Anise* 28
 - 2.3.1.3 *Allium sativum* 28
 - 2.3.1.4 *Artemisia annua* 28
 - 2.3.1.5 *Boswellia serrata* 28
 - 2.3.1.6 *Curcuma longa* 28
 - 2.3.1.7 *Foeniculum vulgare* 29
 - 2.3.1.8 *Glycyrrhiza glabra* 29
 - 2.3.1.9 *Medicago sativa* 29
 - 2.3.1.10 *Moringa oleifera* 29
 - 2.3.1.11 *Zingiber officinale* 29
 - 2.3.2 Herbal Nutraceuticals Based on Chemical Nature 30
 - 2.3.2.1 Carbohydrates-based Herbal Nutraceutical for Alternative Medicine 30
 - 2.3.2.2 Lipids and Fatty Acids Based Herbal Nutraceutical for Alternative Medicine 31
 - 2.3.2.3 Amino Acid-based Herbal Nutraceutical for Alternative Medicine 31
 - 2.3.2.4 Phenolic Compound-based Herbal Nutraceutical for Alternative Medicine 32
 - 2.3.2.5 Terpenes-based Herbal Nutraceutical for Alternative Medicine 32
 - 2.3.2.6 Mineral-based Herbal Nutraceutical for Alternative Medicine 33
 - 2.3.3 Herbal Nutraceuticals Based on Mode of Action 33
 - 2.3.3.1 Nutraceutical with Antioxidant Therapeutic Properties 33
 - 2.3.3.2 Nutraceutical with Antimicrobial Therapeutic Properties 34
 - 2.3.3.3 Nutraceutical with Anti-inflammatory Therapeutic Properties 34
- 2.4 Conclusions 35
- Acknowledgments 35
- References 35

- 3 Significance of Nutraceuticals in Modern Health Maintenance and Disease Prevention 47**
Mahra Mohammad Moosa Ali Alblooshi, Kok-Song Lai, Swee-Hua Erin Lim, and Shamshul Ansari
- 3.1 Introduction 47
- 3.1.1 Addressing Nutritional Gaps 47
- 3.1.2 Confluence of Nutrition and Medicine 48
- 3.2 Plant-based Nutraceuticals 48
- 3.3 Plant-based Nutraceuticals in the Middle East 49
- 3.4 Modified Versus Organic Plant-based Nutraceuticals 50
- 3.5 The Preventive Potency of Plant-based Nutraceuticals 50
- 3.6 Prospective Developments in Plant-based Functional Foods: Global and Middle Eastern Perspectives 53
- 3.7 Conclusions 54
References 54
- 4 Applications of Spices in Nutraceuticals 59**
Ashwini Prabhu
- 4.1 Introduction 59
- 4.2 Benefits of Spices as Nutraceuticals 60
- 4.2.1 Anticancer Potential of Spices 60
- 4.2.2 Spices and Antidiabetic Activity 66
- 4.2.3 Spices in the Prevention of Cardiovascular Disorders 67
- 4.3 Conclusions 68
References 69
- 5 Antioxidant Properties of Food Plants, Spices, Beverages, and Nutraceuticals—Health and Anti-aging Potentials 77**
Michael Wink
- 5.1 Introduction 77
- 5.2 Reactive Oxygen Species and Health Implications 79
- 5.3 Antioxidant Molecules from Nature 90
- 5.4 Antioxidant Activities in the Model System *Caenorhabditis elegans* 91
- 5.5 Potential Health Benefits of Herbal Products with Antioxidant Properties 93
- 5.6 Conclusions 94
Acknowledgments 95
References 95
- 6 Nutraceuticals with Antidiabetic Potentials from Plants 107**
Roman Lysiuk, Serhii Oliinyk, Andrii Boiko, Iryna Lozynska, Petro Oliinyk, and Andrian Boiko
- 6.1 Introduction 107
- 6.2 Types of Diabetes 108
- 6.3 Flavonoids in Ameliorating of Diabetes Mellitus Complications 109
- 6.4 Diabetic Cardiomyopathy 110
- 6.5 Diabetic Nephropathy 111
- 6.6 Diabetic Neuropathy 113

- 6.7 Diabetic Retinopathy 113
- 6.8 Diabetic Skin Ulcer 114
- 6.9 Improvement of Bioavailability of Flavonoids 114
- 6.10 Plant-derived Nutraceuticals with Antidiabetic Potentials 115
 - 6.10.1 Beetroot (*Beta vulgaris* L.) 115
 - 6.10.2 Cabbage (*Brassica oleracea* var. *capitata*) 116
 - 6.10.3 Onion (*Allium cepa* L.) 117
 - 6.10.4 Bilberry (*Vaccinium myrtillus* L.) 118
 - 6.10.5 Parsley (*Petroselinum crispum* (Mill.) Nym. ex Hill) 119
 - 6.10.6 Pumpkin (*Cucurbita pepo* L.) 120
- 6.11 Conclusions 123
 - References 124

- 7 Herbal Wine and Health Benefits 135**
Sonia Morya, Gopika S. Pillai, Abishek Dinesh, Amenah S. Alotaibi, Hanan A. Alatawi, and Farid Menaa
 - 7.1 Introduction 135
 - 7.2 Defining Concept of Herbal Wines 135
 - 7.3 Historical Roots 136
 - 7.4 Emerging Trends of Herbal Wine 136
 - 7.5 The Herbal Component 137
 - 7.6 Selection of Herbs 137
 - 7.6.1 Lavender 137
 - 7.6.2 Rosemary 138
 - 7.6.3 Thyme 139
 - 7.6.4 Chamomile 140
 - 7.6.5 Hibiscus 141
 - 7.6.6 Ginger 142
 - 7.6.7 Lemon Balm 143
 - 7.6.8 Peppermint 144
 - 7.7 Techniques for Incorporating Herbs into the Wine Matrix 145
 - 7.8 Significance of Herbal Wine in Human Health 147
 - 7.9 Future Prospective of Herbal Wine 148
 - 7.10 Conclusion 149
 - References 149

- 8 Plant-based Nutraceuticals with Anticarcinogenic Potential 155**
Omar S. Al-Odat, Gabriella Yao, Nicole K. Schmalbach, Daniel A. Guirguis, Osama Aloudat, Patrick A. Newport-Ratiu, Subash C. Jonnalagadda, and Manoj K. Pandey
 - 8.1 Journey of Nutraceuticals: From Folklores to Linchpins 155
 - 8.2 Therapeutic Nutraceuticals for the Treatment of Chronic Inflammation and Cancer 156
 - 8.2.1 Capsaicin 160
 - 8.2.2 Diallyl Sulfide 160
 - 8.2.3 Cinnamaldehyde 161
 - 8.2.4 6-Gingerol 161
 - 8.2.5 Eugenol 161

8.2.6	Diosgenin	162
8.2.7	Garcinol	162
8.2.8	Thymoquinone	162
8.2.9	Quercetin	163
8.2.10	Sulforaphane	163
8.2.11	α -Pinene	163
8.2.12	Piperine	163
8.2.13	1,8-Cineole (Cin)	163
8.3	A Cancer and Inflammation Savior: Curcumin	164
8.3.1	Curcumin Against Solid Cancers	164
8.3.2	Curcumin Against Hematological Malignancies	165
8.3.3	Development of Curcumin Clinical Trials	165
8.4	Conclusion and Future Direction	173
	Author's Contributions	173
	Financial Support and Sponsorship	173
	Abbreviations	174
	References	175
9	Nano-based Herbal Nutraceuticals Against Different Diseases	187
	<i>Priyanku Pradip Das, Mehak Thakur, Dheeraj Bisht, Rajeshwar Kamal Kant Arya, Shavkatjon Azizov, H. Lahlennawia, and Deepak Kumar</i>	
9.1	Introduction	187
9.2	Plant-mediated Nanoparticles as Antioxidant Agents	188
9.3	Plant-mediated Nanoparticles as Anti-inflammatory Agents	189
9.4	Plant-mediated Nanoparticles as Antimicrobial Agents	191
9.5	Plant-mediated Nanoparticles as Antidiabetic Agents	192
9.6	Plant-mediated Nanoparticles as Antihypertensive Agents	192
9.7	Plant-mediated Nanoparticles as Anti-obesity Agents	193
9.8	Conclusion and Future Direction	194
	References	194
10	The Flavorful World: Exploring the Applications of Spices in Nutraceuticals	201
	<i>Anuradha and Navneeta Bharadvaja</i>	
10.1	Introduction	201
10.2	Chemistry of Compounds Specific to Spices	202
10.2.1	Phenolic Compounds	203
10.2.2	Terpenes	204
10.2.3	Alkaloids	204
10.3	Role of Spices as Nutraceuticals	204
10.3.1	Digestion	206
10.3.2	Antidiabetic	206
10.3.3	Anti-inflammatory	206
10.3.4	Antioxidant Property	207
10.3.5	Anti-lithogenic Effect	207
10.3.6	Anticancer Effect	207
10.4	Conclusion	207
	References	208

11	Carotenoids: Their Sources, Bioactivity, and Application in Industry	211
	<i>Irwandi Jaswir, Dedi Noviendri, Mohd Aznan Md Aris, Soraya Ismail, Widya Lestari, Noraihan Mat Harun, and Ridar Hendri</i>	
11.1	Introduction	211
11.2	Sources of Carotenoid	213
11.2.1	α -Carotene and β -Carotene	214
11.2.2	β -Cryptoxanthin	214
11.2.3	Lycopene	214
11.2.4	Zeaxanthin	214
11.2.5	Astaxanthin	215
11.2.6	Fucoxanthin	215
11.3	Carotenoids Bioactivity	217
11.3.1	Provitamin A Activity	217
11.3.2	Antioxidant/Prooxidant Activity	217
11.3.3	Carotenoids as Anticancer	218
11.3.4	Carotenoids for Obesity	220
11.3.5	Anabolic Activity on Bone Components	220
11.4	Carotenoid Applications in Industry	221
11.5	Conclusions	223
	Acknowledgments	223
	References	223
12	Nutraceuticals in Legumes	229
	<i>Rajan Katoch, Ankur Tripathi, Neelam Thakur, and Kiran</i>	
12.1	Introduction	229
12.2	Legumes: A Superfood for Combating Malnutrition and Hunger	230
12.3	Nutritional Profile of Legumes	231
12.3.1	Proteins	231
12.3.2	Carbohydrates	231
12.3.3	Fat Content	232
12.3.4	Micronutrients	232
12.4	Nutraceutical Compounds in Legumes	232
12.4.1	Bioactive Peptides and Proteins	233
12.4.2	Resistant Starch, Dietary Fiber, and Oligosaccharide Content	233
12.4.3	Lipids, Phytosterols, and Phytoestrogens	233
12.4.4	Minerals and Vitamins	234
12.5	Nonnutritive Bioactive Compounds	234
12.5.1	Polyphenolic Content	234
12.5.2	Saponins	235
12.5.3	Lectins	236
12.5.4	Phytic Acid	237
12.5.5	Enzyme Inhibitors	237
12.6	Nutraceutical Activities of Bioactive Compounds Present in Legumes	240
12.6.1	Anticancer Activities	240
12.6.2	Protection from Cardiovascular Ailments	240
12.6.3	Antidiabetic Activities	241
12.6.4	Hepato-protective Activities	241

- 12.7 Nutraceutical Uses of Legumes in Traditional Medicine System 241
- 12.8 Legume-based Nutritionally Fortified Food 242
- 12.9 Conclusion 242
- References 243

13 Nutraceutical Potential of Herbal Beverages 251

Anoma Chandrasekara, Sashya Diyapaththugama, and Fereidoon Shahidi

- 13.1 Introduction 251
- 13.1.1 Herbal Beverages 251
- 13.2 Bioactive Compounds in Herbal Beverages 254
- 13.2.1 Phenolic Compounds 254
- 13.2.2 Phenolic Acids 254
- 13.2.3 Flavonoids 255
- 13.2.4 Tannins 255
- 13.2.5 Coumarins 255
- 13.2.6 Terpenes 255
- 13.2.7 Carotenoids 255
- 13.2.8 Polyacetylenes 256
- 13.3 Bioactivities of Herbal Beverages 256
- 13.4 Antioxidant Properties of Herbal Beverages 256
- 13.5 Herbal Beverages in Asia 257
- 13.5.1 Bael 257
- 13.5.2 Indian Pennywort 258
- 13.5.3 Tanner's Cassia 258
- 13.5.4 Jackfruit 258
- 13.5.5 Rang Jued 259
- 13.5.6 Heen Bovitiya 259
- 13.5.7 Moringa 259
- 13.6 Tropical Fruit Herbal Beverages 260
- 13.6.1 Wood Apple 260
- 13.6.2 Java Plum 260
- 13.6.3 June Plum 261
- 13.6.4 Carambola 261
- 13.7 Herbal Beverages in Africa 261
- 13.8 Herbal Beverages in South America 262
- 13.9 Herbal Beverages in Europe 263
- 13.10 Conclusions 263
- References 264

14 Nutraceuticals Present in Edible Oils 271

Rupasree Mukhopadhyay and Shruti Kabra

- 14.1 Introduction 271
- 14.2 Edible Oils and Their Uses 273
- 14.2.1 Coconut Oil 274
- 14.2.2 Cottonseed Oil 274
- 14.2.3 Groundnut/Peanut Oil 275
- 14.2.4 Olive Oil 275

14.2.5	Palm Oil	275
14.2.6	Rapeseed or Mustard Oil	276
14.2.7	Ricebran Oil	276
14.2.8	Sesame Oil	277
14.2.9	Soybean Oil	277
14.2.10	Sunflower Oil	277
14.3	Important Nutraceuticals Present in Edible Oils	278
14.3.1	Essential Fatty Acids	278
14.3.2	Vitamin E: Tocopherols and Tocotrienols	280
14.3.3	Phytosterols and Phytostanols	282
14.3.4	Oryzanol	283
14.3.5	Squalene	284
14.3.6	Carotenoids	286
14.3.7	Lecithin (Phospholipids)	287
14.3.8	Phenolic Compounds	289
14.3.8.1	Lignans	290
14.3.8.2	Isoflavones	290
14.4	Conclusion	291
	References	292
15	Nutraceuticals from Conventional and Nonconventional Fruits	309
	<i>Karishma Sebastian, Manjula Belagihalli Siddalingappa, Jeevitha Devaraju, and Panneer Selvam Ranchana</i>	
15.1	Introduction	309
15.2	Apple	310
15.3	Peach	310
15.4	Plum	310
15.5	Apricot	310
15.6	Sweet Cherry	310
15.7	Mango	311
15.8	Banana	311
15.9	Citrus	312
15.10	Grapes	312
15.11	Guava	312
15.12	Papaya	312
15.13	Pineapple	313
15.14	Sapota	313
15.15	Annona	313
15.16	Pomegranate	314
15.17	Dates	314
15.18	Avocado	314
15.19	Aonla	314
15.20	Strawberry	315
15.21	Kiwifruit	315
15.22	Rambutan	315
15.23	Mangosteen	316
15.24	Litchi	316

15.25	Longan	316
15.26	Blueberry	316
15.27	Raspberry	317
15.28	Walnut	317
15.29	Fig	317
15.30	Olive	318
15.31	Jamun	318
15.32	Passionfruit	318
15.33	Phalsa	318
15.34	Acerola	319
15.35	Mulberry	319
15.36	Prickly Pear	319
15.37	Sea Buckthorn	320
15.38	Bael	320
15.39	Conclusions	322
	References	322
16	Nutraceutical Potential of Staple Food Crops	329
	<i>Aroma Joshi, Arun Kumar Gupta, Avinash Kumar Jha, Bindu Naik, Vijay Kumar, and Sarvesh Rustagi</i>	
16.1	Introduction	329
16.2	Overview of Major Staple Food Crops and Their Nutritional Composition	330
16.3	Bioactive Compounds Present in Staple Cereal Crops	330
16.4	Health Benefits of Staple Food Crops	333
16.5	Emerging Trends in Staple Food Crop Research	335
16.5.1	The Trend of Plant-based Ingredients/Foods	335
16.5.2	Beyond Vegan and Vegetarian: Flexitarian Trend	335
16.5.3	New Generation in Plant-based Alternatives	335
16.5.4	Potential for Genetic Modification to Enhance Nutraceutical Content	336
16.5.5	Nutritionally Enhanced Food Crops to Improve Global Health	336
16.5.5.1	Biofortified Rice	336
16.5.5.2	Biofortified Maize and Cassava	336
16.5.5.3	Biofortified Wheat	336
16.5.5.4	Nutritionally Enhanced Feed Crops	337
16.5.5.5	Integrating Traditional and Modern Knowledge for Sustainable Nutrition	337
16.6	Importance of Educating Consumers About the Nutraceutical Potential	338
16.6.1	Significance of Consumer Education	338
16.6.2	Strategies for Effective Consumer Education	338
16.7	Importance of Promoting Staple Food Crops as Nutraceutical Sources	339
16.8	Future Scope and Conclusion	339
	References	340
17	Pseudocereals Nutraceuticals	347
	<i>Sonia Morya, Aniket More, Arno Neumann, and Shikha Chauhan</i>	
17.1	Introduction	347
17.2	Types and Classification of Pseudocereals	348
17.2.1	Amaranth	348

17.2.2	Quinoa	350
17.2.3	Buckwheat	353
17.3	Nutritional Composition of Pseudocereals	355
17.4	Health Benefits of Pseudocereals	355
17.4.1	Nutraceutical Properties of Amaranth	358
17.4.2	Nutraceutical Properties of Quinoa	358
17.4.3	Nutraceutical Properties of Buckwheat	359
17.5	Functional Properties and Nutraceutical Potential	360
17.6	Challenges and Opportunities	363
17.7	Conclusion	364
	References	364

18 Safety Concerns Associated with Microalgal Nutraceuticals 373

Freny Shah, Niranjana Mishra, Kanti Bhooshan Pandey, and Sandhya Mishra

Abbreviations 373

18.1	Introduction	373
18.2	Market Trends	374
18.3	Microalgal Source and Nutrient Profile	375
18.4	Functional Foods with Microalgae	376
18.4.1	Vitamins	376
18.4.2	Minerals	376
18.5	Safety Concerns and Measures to be Followed	376
18.6	Applications of Microalgal Nutraceuticals	377
18.6.1	Human Nutrition	377
18.6.2	Biomedical Applications	378
18.6.3	Nucleic Acids	379
18.6.4	As Anticancer Agents	379
18.6.5	Animal/Aquafeed	379
18.6.6	Aquaculture	380
18.7	Problems of Contamination	380
18.8	Future Scope	380
18.9	Conclusion	381
	Acknowledgments	381
	References	382

19 Toxicity Evaluation of Nutraceuticals 387

Sonia Morya, Farid Mena, and Sharvarya Arun Vichare

19.1	Introduction	387
19.1.1	Toxicity Evaluation Methods	388
19.1.1.1	In Vitro Methods	388
19.1.1.2	In Vivo Methods	390
19.1.2	Clinical Trials	393
19.1.2.1	Phase 0 Clinical Trials	393
19.1.2.2	Phase I Clinical Trials	394
19.1.2.3	Phase II Clinical Trials	394
19.1.2.4	Phase III Clinical Trial	394
19.1.2.5	Post-marketing Surveillance	394

19.1.3	Factors Influencing Toxicity of Nutraceuticals	394
19.1.3.1	Dosage and Exposure Levels	394
19.1.3.2	Interactions with Other Compounds	395
19.1.3.3	Genetic Variability and Individual Differences	397
19.1.3.4	Formulation and Manufacturing Processes	397
19.1.4	Ethical Considerations	398
19.2	Emerging Trends and Future Prospects	398
19.3	Conclusion	399
	References	399
	Index	405

About the Editors

Dr. Santosh Kumar Upadhyay is currently working as an assistant professor of Botany at the Panjab University, Chandigarh, India. He has been working in the field of Plant Biotechnology for more than 16 years. His present research focuses in the area of functional genomics for stress tolerance. He is involved in the bio-prospecting and characterization of various important proteins from plant biodiversity, and defense and stress signaling genes in bread wheat. His research group has developed a pool of vital genes and long noncoding RNAs associated with abiotic and biotic stress tolerance and signaling in plants. He has also established the method for genome editing in bread wheat using CRISPR-Cas system and developed a tool SSinder for CRISPR target site prediction. His research contribution led to the publication of more than 70 research papers in leading journals of international repute. Further, there are more than five national and international patents, 50 book chapters, and 12 books in his credit. In recognition of his substantial research record, he has been awarded NAAS Young scientist award (2017–2018) and NAAS-Associate (2018) from the National Academy of Agricultural Sciences, India, INSA-Associate Fellow (2023), and INSA Medal for Young Scientist (2013) from the Indian National Science Academy, India, NASI-Young Scientist Platinum Jubilee Award (2012) from the National Academy of Sciences, India, and Altech Young Scientist Award (2011). He has also been the recipient of the prestigious DST-INSPIRE Faculty Fellowship (2012) and SERB-Early Career Research Award (2016) from the Ministry of Science and Technology, Government of India. Dr. Upadhyay also serves as a member of the editorial board and reviewer of several peer-reviewed international journals.

Dr. Sudhir Pratap Singh is currently Professor at the Department of Industrial Biotechnology, Gujarat Biotechnology University, Gandhinagar, Gujarat, India. He has been working in the area of molecular biology and biotechnology for more than a decade. Currently, his primary focus of research is gene mining, biocatalyst engineering, and characterization of novel enzyme variants for the production of high-value functional biomolecules from low-cost feedstock. He has generated metagenomic data resources from diverse ecological niches and ethnic food samples and has characterized novel genes encoding enzyme variants with desirable catalytic properties for the biosynthesis of functional sugar molecules such as D-allulose, turanose, trehalose, and trehalulose. Further, he has achieved enzymatic production of prebiotic molecules, such as fructooligosaccharides, glucooligosaccharides, 4-galactosyl-Kojibiose, xylooligosaccharides, levan, dextran, type III resistant starch, etc. Prof. Singh has published more than 75 research articles (SCI) and 8 books (edited). Further, he has 12 patents (granted) to his credit as an inventor. He has been conferred the TATA Innovation Fellowship (DBT, Govt. of India), Professor SB Chincholkar Award (BRSI), Young Scientist Award (IBA), SBS-MKU Genomics Award (BRSI), and Professor Hira Lal Chakravarty Award (ISCA, DST, Govt. of India). His team was awarded Gandhian Young Technological Innovation Award (SRISTI) in 2019. He is a life member of the National Academy of Sciences, India. Further, Prof. Singh is the Fellow of the National Academy of Agricultural Sciences (FNAAS) and the Fellow of the International Society of Energy, Environment, and Sustainability (FISEES).

List of Contributors

Hanan A. Alatawi

Department of Biological Sciences, University
College of Haqel, Tabuk University, Tabuk
Saudi Arabia

Mahra Mohammad Moosa Ali Alblooshi

Health Sciences Division, Abu Dhabi
Women's College, Higher Colleges of
Technology, Abu Dhabi, UAE

Omar S. Al-Odat

Department of Biomedical Sciences, Cooper
Medical School of Rowan University
Camden, NJ, USA

Department of Chemistry and Biochemistry
Rowan University, Glassboro, NJ, USA

Amenah S. Alotaibi

Department of Biology, Faculty of Science
Genomic & Biotechnology, University of
Tabuk, Tabuk, Saudi Arabia

Osama Aloudat

Department of Biomedical Sciences, Cooper
Medical School of Rowan University
Camden, NJ, USA

Shamshul Ansari

Health Sciences Division, Abu Dhabi
Women's College, Higher Colleges of
Technology, Abu Dhabi, UAE

Anuradha

Plant Biotechnology Laboratory, Department
of Biotechnology, Delhi Technological
University, New Delhi, India

Mohd Aznan Md Aris

Faculty of Medicine, International Islamic
University Malaysia, Kuantan Campus
Kuantan, Pahang, Malaysia

Rajeshwar Kamal Kant Arya

Department of Pharmaceutical Sciences
Sir J. C. Bose Technical Campus
Bhimtal, Kumaun University, Nainital
Uttarakhand, India

Shavkatjon Azizov

Faculty of Life Sciences, Pharmaceutical
Technical University, Tashkent, Uzbekistan

Navneeta Bharadvaja

Plant Biotechnology Laboratory, Department
of Biotechnology, Delhi Technological
University, New Delhi, India

Vikas Bhatt

Devsthali Vidyapeeth College of Pharmacy
Rudrapur, Uttarakhand, India

Dheeraj Bisht

Devsthali Vidyapeeth College of Pharmacy
Rudrapur, Uttarakhand, India

Andrii Boiko

Department of Management and Economy
of Pharmacy and Drug Technology of
Postgraduate Faculty, Danylo Halytsky Lviv
National Medical University
Lviv, Ukraine

Andrian Boiko

Department of Therapeutic Dentistry
Periodontology and Dentistry FPDE, Danylo
Halytsky Lviv National Medical University
Lviv, Ukraine

Anoma Chandrasekara

Department of Applied Nutrition, Wayamba
University of Sri Lanka, Makandura
Gonawila, Sri Lanka

Shikha Chauhan

Department of Food Technology and
Nutrition, School of Agriculture, Lovely
Professional University, Phagwara
Punjab, India

Priyanku Pradip Das

Department of Pharmaceutical Chemistry
School of Pharmaceutical Sciences, Shoolini
University, Solan, Himachal Pradesh, India

Jeevitha Devaraju

Division of Horticulture, School of
Agricultural Sciences, Karunya Institute
of Technology and Sciences
Coimbatore, India

Abishek Dinesh

Department of Food Technology and
Nutrition, School of Agriculture, Lovely
Professional University, Phagwara
Punjab, India

Sashya Diyapaththugama

Department of Applied Nutrition, Wayamba
University of Sri Lanka, Makandura
Gonawila, Sri Lanka

Daniel A. Guirguis

Department of Biomedical Sciences, Cooper
Medical School of Rowan University
Camden, NJ, USA

Arun Kumar Gupta

Department of Food Science & Technology
Graphic Era (Deemed to be University)
Dehradun, Uttarakhand, India

Graphic Era Hill University
Dehradun, Uttarakhand, India

Noraihan Mat Harun

Faculty of Medicine, International Islamic
University Malaysia, Kuantan Campus
Kuantan, Pahang, Malaysia

Ridar Hendri

Faculty of Fisheries, Riau University
Pekanbaru, Indonesia

Soraya Ismail

Faculty of Medicine, International Islamic
University Malaysia, Kuantan Campus
Kuantan, Pahang, Malaysia

Irwandi Jaswir

Department of Chemistry, Padang State
University, Padang, Indonesia

International Institute for Halal Research and
Training, International Islamic University
Malaysia, Kuala Lumpur, Malaysia

Avinash Kumar Jha

Department of Food Technology and
Nutrition, School of Agriculture, Lovely
Professional University, Phagwara
Punjab, India

Subash C. Jonnalagadda

Department of Chemistry and Biochemistry
Rowan University, Glassboro, NJ, USA

Aroma Joshi

Department of Food Science & Technology
Graphic Era (Deemed to be University)
Dehradun, Uttarakhand, India

Shruti Kabra

Department of Food and Nutrition, Telangana
Mahila Viswavidyalayam, Koti, Hyderabad
Telangana, India

Rajan Katoch

Biochemistry Laboratory, Department of
Chemistry & Biochemistry, CSKHPKV
Palampur, Himachal Pradesh, India

Kiran

Department of Genetics & Plant Breeding
CSKHPKV, Palampur, Himachal
Pradesh, India

Sapna Avinash Kondalkar

Regional Ayurveda Research Institute
Gwalior, Madhya Pradesh, India

Deepak Kumar

Department of Pharmaceutical Chemistry
School of Pharmaceutical Sciences
Shoolini University, Solan, Himachal
Pradesh, India

Vijay Kumar

Himalayan School of Biosciences, Swami
Rama Himalayan University, Dehradun
Uttarakhand, India

Kok-Song Lai

Health Sciences Division, Abu Dhabi
Women's College, Higher Colleges of
Technology, Abu Dhabi, UAE

H. Lahlhenmawia

Department of Pharmacy, Regional Institute
of Paramedical and Nursing Sciences
Zemabawk, Aizawl, Mizoram, India

Widya Lestari

Faculty of Dentistry, International Islamic
University Malaysia, Kuantan Campus
Kuantan, Pahang, Malaysia

Swee-Hua Erin Lim

Health Sciences Division, Abu Dhabi
Women's College, Higher Colleges of
Technology, Abu Dhabi, UAE

Iryna Lozynska

Department of Biochemistry, Danylo
Halytsky Lviv National Medical University
Lviv, Ukraine

Roman Lysiuk

Department of Pharmacognosy and Botany
Danylo Halytsky Lviv National Medical
University, Lviv, Ukraine

Madhu

Department of Botany, Panjab University
Chandigarh, India

Ajay Kumar Meena

Regional Ayurveda Research Institute
Gwalior, Madhya Pradesh, India

Farid Mena

Department of Biomedical and
Environmental Engineering, California
Innovations Corporation, San Diego, CA, USA

Niranjan Mishra

Applied Phycology and Biotechnology
Division, CSIR-Central Salt and Marine
Chemicals Research Institute, Bhavnagar
Gujarat, India

Sandhya Mishra

Applied Phycology and Biotechnology
Division, CSIR-Central Salt and Marine
Chemicals Research Institute, Bhavnagar
Gujarat, India

Aniket More

Department of Food Technology and
Nutrition, School of Agriculture, Lovely
Professional University, Phagwara
Punjab, India

Sonia Morya

Department of Food Technology and Nutrition
School of Agriculture, Lovely Professional
University, Phagwara, Punjab, India

Rupasree Mukhopadhyay

Department of Genetics and Biotechnology
Telangana Mahila Viswavidyalayam, Koti
Hyderabad, Telangana, India

Bindu Naik

Department of Food Science & Technology
Graphic Era (Deemed to be University)
Dehradun, Uttarakhand, India

Arno Neumann

BET Bioscience Extraction Technologies Inc.
Abbotsford, British Columbia, Canada

Patrick A. Newport-Ratiu

Department of Biomedical Sciences, Cooper
Medical School of Rowan University
Camden, NJ, USA

Department of Chemistry and Biochemistry
Rowan University, Glassboro, NJ, USA

Dedi Noviendri

Bioprocess and Molecular Engineering
Research Unit, Kulliyah of Engineering
International Islamic University Malaysia
Kuala Lumpur, Malaysia

Serhii Oliinyk

Nobel – Ukraine Pharmaceutical Company
Kyiv, Ukraine

Petro Oliinyk

Department of Disaster Medicine and Military
Medicine, Danylo Halytsky Lviv National
Medical University, Lviv, Ukraine

Manoj K. Pandey

Department of Biomedical Sciences, Cooper
Medical School of Rowan University
Camden, NJ, USA

Kanti Bhooshan Pandey

BDIM Division, CSIR-Central Salt and Marine
Chemicals Research Institute, Bhavnagar
Gujarat, India

Gopika S. Pillai

Department of Food Technology and
Nutrition, School of Agriculture, Lovely
Professional University, Phagwara
Punjab, India

Ashwini Prabhu

Division of Cancer Research and Therapeutics
(CaRT), Yenepoya Research Centre, Yenepoya
(Deemed to be University), Mangalore
Karnataka, India

Panneer Selvam Ranchana

Division of Horticulture, School of
Agricultural Sciences, Karunya Institute of
Technology and Sciences Coimbatore, India

Sarvesh Rustagi

Department of Food Technology, SALS
Uttaranchal University, Dehradun
Uttarakhand, India

Nicole K. Schmalbach

Department of Biomedical Sciences, Cooper
Medical School of Rowan University
Camden, NJ, USA

Karishma Sebastian

Division of Horticulture, School of
Agricultural Sciences, Karunya Institute of
Technology and Sciences, Coimbatore, India

Freny Shah

Applied Phycology and Biotechnology
Division, CSIR-Central Salt and Marine
Chemicals Research Institute, Bhavnagar
Gujarat, India

Fereidoon Shahidi

Department of Biochemistry, Memorial
University of Newfoundland, St. John's
Newfoundland, Canada

Alok Sharma

Regional Ayurveda Research Institute
Gwalior, Madhya Pradesh, India

Manjula Belagihalli Siddalingappa

Division of Horticulture, School of
Agricultural Sciences, Karunya
Institute of Technology and Sciences
Coimbatore, India

Sudhir Pratap Singh

Department of Industrial Biotechnology
Gujarat Biotechnology University
Gandhinagar, India

Mehak Thakur

School of Biological and Environmental
Sciences, Shoolini University, Solan
Himachal Pradesh, India

Neelam Thakur

Biochemistry Laboratory
Department of Chemistry & Biochemistry
CSKHPKV, Palampur
Himachal Pradesh, India

Ankur Tripathi

College of Dairy & Food Technology
Agriculture University, Jodhpur
Rajasthan, India

Santosh Kumar Upadhyay

Department of Botany, Panjab University
Chandigarh, India

Sharvary Arun Vichare

Department of Food Technology and Nutrition
School of Agriculture, Lovely Professional
University, Phagwara, Punjab, India

Michael Wink

Institute of Pharmacy and Molecular
Biotechnology, Heidelberg University
Heidelberg, Germany

Shikha Yadav

Department of Pharmacy, Galgotias
University, Noida, Uttar Pradesh, India

Gabriella Yao

Department of Biomedical Sciences, Cooper
Medical School of Rowan University
Camden, NJ, USA

Preface

Nutraceuticals are nutritive pharmaceuticals of health significance. It could be fortified food product or dietary supplement. Nevertheless, the health benefits of nutraceuticals are over and above the basic nutritional function. The recommended level of consumption of nutraceuticals not only maintains good health but also functions against life-style-related acute and chronic metabolic disorders. Thus, nutraceutical bioactive molecules help in disease prevention and promote optimal health, quality, and longevity of life. The medical uses of nutraceuticals in disease like depression, stress, cardiovascular and gastrointestinal disorders, cancer, cholesterol, obesity, and diabetes have been intensively studied. These bioactive molecules of high value are obtained from natural biosphere resources. Nutraceuticals can be derived from animals, plants, microorganisms, and fungal sources. Herbal bioactives comprise a variety of phytochemicals like polyphenols, alkaloids, terpenoids, and derivatives thereof. Many traditional literatures support the utilization of herbs as natural remedies to handle the metabolic and physiological disorders. Herbs may be categorized into food, medicinal, and poisonous types, according to the active and functional constituents they harbour.

The current book entitled “Herbal Nutraceuticals: Products and Processes” enlisted the numerous important herbal nutraceuticals from different plants sources including horticultural and agricultural important crops, as well. The book started with the overview of herbal nutraceuticals and covered diverse aspects of their application for the human health. Various chapters included in the book described the medicinal importance of various herbal constituents as alternative medicines, their importance in health benefits in the modern day life style, their antidiabetic and anticarcinogenic potentials, and antioxidant properties. In addition, the nutraceutical potential of various cereals, pseudo cereals, legumes, fruits, and oils have been specifically discussed in various chapters. It is a well-known truth that nothing is absolutely beneficial in the world. The positive and negative implications are associated with each substance. And therefore, at the end chapters describing the safety concern and toxicity evaluation have been included. Overall, *Herbal Nutraceuticals: Products and Processes* is a comprehensive book for the diverse knowledge and application for human health benefits.

Santosh Kumar Upadhyay

Department of Botany
Panjab University, Chandigarh, India

Sudhir Pratap Singh

Department of Industrial Biotechnology
Gujarat Biotechnology University, Gandhinagar, India

1

Plants Based Nutraceuticals: An Overview

*Dheeraj Bisht¹, Vikas Bhatt¹, Rajeshwar Kamal Kant Arya²,
Shikha Yadav³, Deepak Kumar⁴, Sudhir Pratap Singh⁵, and Santosh Kumar Upadhyay⁶*

¹Devsthali Vidyapeeth College of Pharmacy, Rudrapur, Uttarakhand, India

²Department of Pharmaceutical Sciences, Sir J. C. Bose Technical Campus, Bhimtal, Kumaun University, Nainital, Uttarakhand, India

³Department of Pharmacy, Galgotias University, Noida, Uttar Pradesh, India

⁴Department of Pharmaceutical Chemistry, School of Pharmaceutical Sciences, Shoolini University, Solan, Himachal Pradesh, India

⁵Department of Industrial Biotechnology, Gujarat Biotechnology University, Gandhinagar, Gujarat, India

⁶Department of Botany, Panjab University, Chandigarh, India

1.1 Introduction

The term nutraceuticals evolved from a combination of nutrition and pharmaceuticals and was coined by Stephen De Felice in 1989. According to him, nutraceuticals are food commodities or fractions that grant health benefits and clinical advantages (Durazzo et al. 2020). The word nutraceuticals, is not so popular worldwide and is many of time it is confused by the term dietary supplements, which is an important need for the health of humankind. However, in-depth studies of both terms manifest some root differences, such as the fact that nutraceuticals are prominent in treating several illnesses besides being important dietary supplements (Bommakanti et al. 2023). US FDA is usually not in favor of the term nutraceuticals, which is generally denoted as food-emerged derivatives with some other values specified by the elementary nutritional fractions that exist in that specific food item. Another misleading term for nutraceuticals is functional food, which can be described as any food being synthesized or manufactured employing scientific intelligence, with or without competent information on why or how it is being used (Tsiaka et al. 2022).

Moreover, when functional food helps to manage and treat ailments other than anemia, it is categorized as a nutraceutical (Jalgaonkar et al. 2019). These incorporate a large variety of products, including dietary supplements, genetically altered products, isolated nutrients, plant products, and processed cereals. Modifications in lifestyle patterns bring about influential changes in the everyday dietary regime that may lead to the emergence of newly developed lifestyle abnormalities such as type-2 diabetes and obesity. Other than these, cardiac disorders, namely stroke and ischemic heart dysfunction, are the most common reasons for mortality in the entire world. Nutraceuticals are reported as appropriate medications for these factors to cure such lifestyle

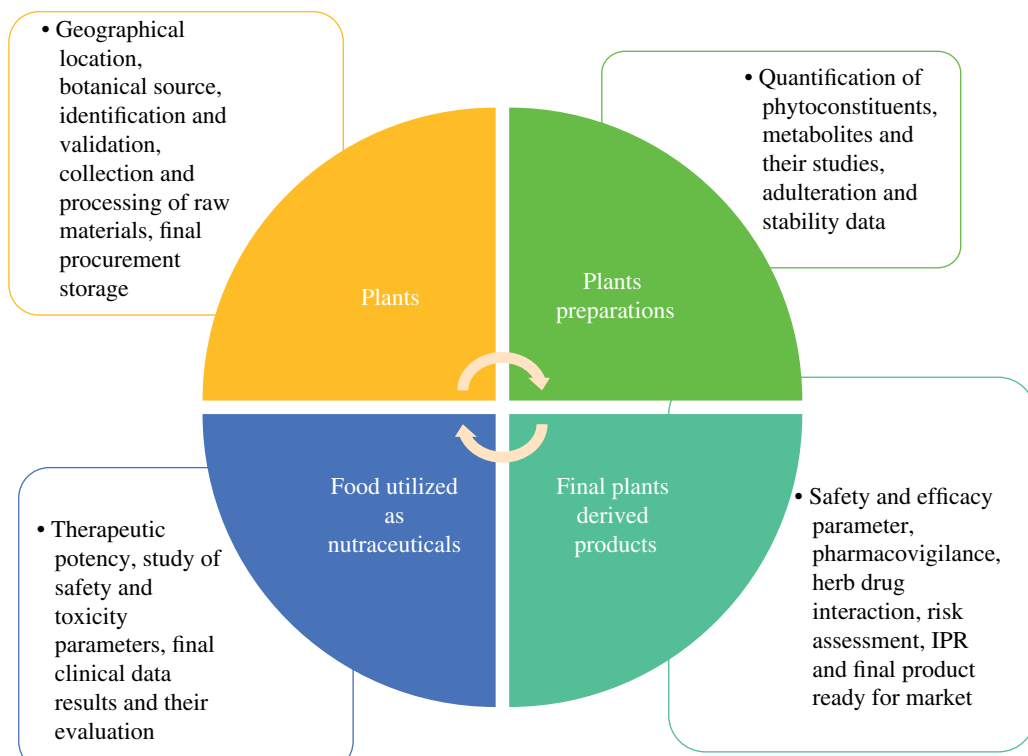


Figure 1.1 Identification and validation of plant-based nutraceuticals. *Source:* Mukherjee et al. (2016); Donno (2020).

abnormalities, hence attaining worldwide acceptability expeditiously. Besides these lifestyle abnormalities, nutraceuticals are utilized for the cure of various types of clinical manifestations, namely hypercholesterolemia, allergic problems, sleep disorders, inflammations, immunodeficiencies, depressive situations, malignancies conditions, hypertension, cardiovascular diseases (CVDs), and anemic disorders (Jalgaonkar et al. 2019; Tsiaka et al. 2022).

It can be suggested that nutraceuticals have very efficacious and potent outcomes and marvelous health benefits that make them crucially attractive to consumers. In the last few years, the significance and importance of plant-based nutraceuticals have evolved, and the development of nutraceutical has revealed that it is crucial for human beings to have sound health considerations for better wellness and fitness. This work focuses mainly on the therapeutically active medicinal phytoconstituents derived from various parts of plants worldwide to cure and prevent various ailments. These phytochemicals obtained from plants could be used as nutraceuticals, further exploring their numerous remedial benefits and the theme behind their remarkable and valuable impacts on human health (Figure 1.1) (Mohammad and Imran 2019; Shahidi 2012).

1.2 Historical Background Behind Nutraceutical Investigations

The father of current remedies, Hippocrates (460–377 BC), suggested the root stone for modern-time nutraceuticals via the fabled quote, “Let food be thy medicine and medicine by the food.” He was recognized as the founder of the idea that specific foods could also be a remedy for curing and controlling a disorder besides the drug moieties (Nwosu and Ubaoji 2020). Roman physician Galen