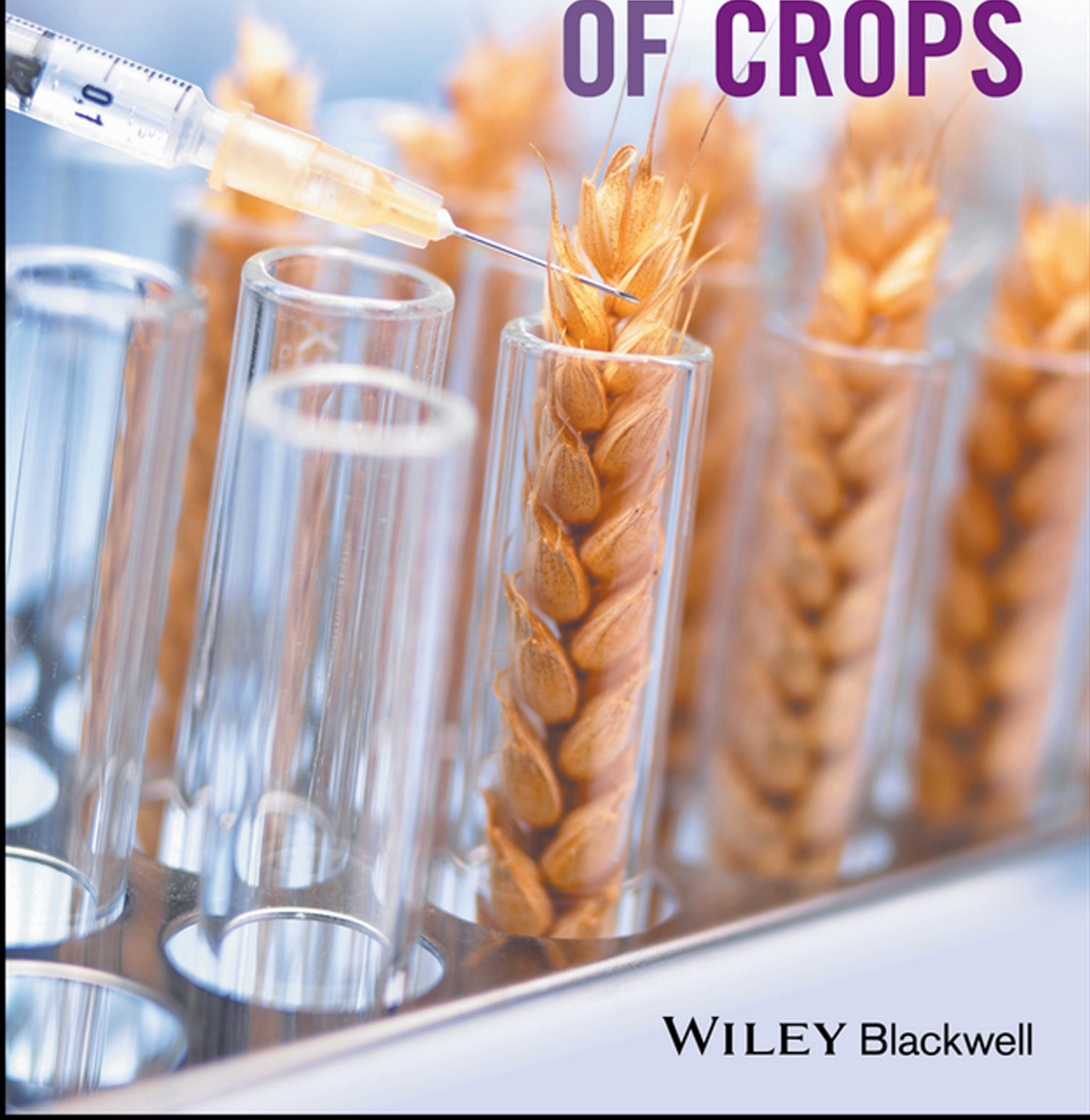


EDITED BY NOUREDDINE BENKEBLIA

PHYTONUTRITIONAL IMPROVEMENT OF CROPS



WILEY Blackwell

Phytonutritional Improvement of Crops

Phytonutritional Improvement of Crops

Editor

Noureddine Benkeblia

The University of the West Indies

Mona Campus

Kingston, Jamaica

WILEY Blackwell

This edition first published 2017

© 2017 John Wiley & Sons Ltd

All rights reserved. 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 Nouredine Benkeblia to be identified as the author 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

Editorial Office

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.

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. 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. 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. 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

Names: Benkeblia, Nouredine, editor.

Title: Phytonutritional improvement of crops / edited by Nouredine Benkeblia.

Description: Hoboken, NJ : Wiley, [2017] | Includes bibliographical references and index. |

Identifiers: LCCN 2017013212 (print) | LCCN 2017016709 (ebook) | ISBN 9781119079989 (ePub) | ISBN 9781119079941 (cloth)

Subjects: LCSH: Food crops--Biotechnology. | Phytonutrients. | Plant biotechnology.

Classification: LCC SB175 (ebook) | LCC SB175 .P498 2017 (print) | DDC 631.5/6--dc23

LC record available at <https://lcn.loc.gov/2017013212>

Cover Design: Wiley

Cover Image: © Science Photo Library - ADAM GAULT/Gettyimages

Set in 10/12pt WarnockPro by SPi Global, Chennai, India

Contents

List of Contributors *xv*

Foreword *xxi*

1	Important Plant-Based Phytonutrients	1
	<i>Avik Basu, Saikat Kumar Basu, Ratnabali Sengupta, Muhammad Asif, Xianping Li, Yanshan Li, Arvind Hirani, Peiman Zandi, Muhammad Sajad, Francisco Solorio-Sánchez, Ambrose Obongo Mbuya, William Cetzal-Ix, Sonam Tashi, Tshitila Jongthap, Danapati Dhungyel and Mukhtar Ahmad</i>	
	List of Abbreviations	1
1.1	Introduction	2
1.2	Nutraceuticals and Functional Foods in Human Health	3
1.3	Plants with Potential for Use as Nutraceutical Source and Functional Food Component	49
1.4	Nutraceutical Values of Fenugreek	49
1.4.1	Fenugreek Possesses the Following Medicinal Properties	50
1.4.1.1	Antioxidant Activity	50
1.4.1.2	Anti-leukemic Effect	50
1.4.1.3	Anti-Hyperglycemic Effect	50
1.4.1.4	Hypocholesterolemic Effect	51
1.4.1.5	Neuroprotective Effect	51
1.4.1.6	Anticarcinogenic Effect	51
1.5	Coloured Potatoes as Functional Food	51
1.6	Red Wine as Functional Food	54
1.7	Tea as Functional Food	54
1.8	Cereals as Nutraceuticals	55
1.9	Nutraceutical Properties of Wheat Bran and Germ	58
1.9.1	Wheat Bran	58
1.9.2	Wheat Germ	59
1.10	Barley and Oat as Nutraceuticals	59
1.11	Value-Added Products	59
1.12	Conclusion	61
	Acknowledgements	61
	References	61

2 Biotechnological Interventions for Improvement of Plant Nutritional Value: From Mechanisms to Applications 83

Rajan Katoch, Sunil Kumar Singh and Neelam Thakur

- 2.1 Introduction 83
- 2.2 Improvement of Food Nutrition 84
- 2.3 Improvement of Nutritional Value Through Crop Improvement 85
- 2.4 Identification of Genes With the Potential to Improve the Nutritional Quality 86
- 2.5 Genetic Engineering for the Introduction of Nutritionally Potential Genes 90
- 2.6 Nutritional Improvement Through Recent Biotechnological Advances 92
- 2.7 Production of Health Care Products 94
 - 2.7.1 The Development of Oral Vaccines in Plant System 95
 - 2.7.2 Advantages of Plant System in the Development of Oral Vaccines 96
 - 2.7.3 Edible Vaccine against Hepatitis B Virus 98
 - 2.7.3.1 Expression of Immunogenic S1 Glycoprotein of Infectious Bronchitis Virus in Transgenic Potatoes 98
 - 2.7.3.2 Immunisation against Rabies with Plant-Derived Antigen 99
 - 2.7.3.3 Immunisation with Potato Plants Expressing VP60 Protein Protects against Rabbit Hemorrhagic Disease Virus 99
 - 2.7.3.4 Oral Immunisation with Hepatitis B Surface Antigen Expressed in Transgenic Plants 99
 - 2.7.3.5 Oral Immunogenicity of Human Papillomavirus-Like Particles Expressed in Potato 99
- 2.8 Major Biotechnological Advances in Nutritional Improvement of Plants 99
- 2.9 Conclusion 100
- References 100

3 Nutrient Biofortification of Staple Food Crops: Technologies, Products and Prospects 113

Chavali Kameswara Rao and Seetharam Annadana

- 3.1 Introduction 113
- 3.2 The Concepts of Nutrition and Malnutrition 114
 - 3.2.1 Nutrition, Macronutrients, Micronutrients and Balanced Diets 114
 - 3.2.1.1 Macronutrients and Energy Requirement 115
 - 3.2.1.2 Micronutrients 115
 - 3.2.1.3 The Balanced Diets 115
 - 3.2.2 Hunger, Nutritional Security, Undernutrition and Malnutrition 116
 - 3.2.3 The Metabolic Syndrome 116
- 3.3 Strategies to Enhance Nutrient Intake and Nutrient Content of Plant Foods 118
 - 3.3.1 Interventions to Enhance Nutrient Intake 118
 - 3.3.2 Technologies for Biofortification 119
 - 3.3.3 Common Genetic Engineering Technologies 120
 - 3.3.4 Alternative Genetic Engineering Technologies 122
 - 3.3.5 Recent Genetic Engineering Technologies 123

3.3.6	Moral and Ethical Arguments Against Genetic Engineering Technologies	124
3.4	Quantitative and Qualitative Modification of Dietary Carbohydrates	125
3.4.1	The Carbohydrates	125
3.4.2	Modifying Levels of Components of Starch	128
3.4.3	Engineering Levels of Fructans	129
3.4.4	Quantitative and Qualitative Enhancement Dietary Fibre	130
3.5	Quantitative and Qualitative Enhancement of Proteins and Amino Acids	131
3.5.1	The Proteins and Amino Acids	131
3.5.2	Enhancement of Total Protein	132
3.5.3	Enhancement of Levels of Lysine	132
3.5.4	Enhancement of Levels of Methionine	133
3.5.5	Simultaneous Enhancement of levels Several Amino Acids	133
3.5.6	Artificial Storage Protein	133
3.5.7	Alternate Interventions	134
3.5.8	Non-Proteinogenic Amino Acids	135
3.6	Quantitative and Qualitative Enhancement of Fatty Acids in Oil Seed Crops	136
3.6.1	Lipids, Fats and Oils	136
3.6.2	Cholesterol	136
3.6.3	Characterisation of Fatty Acids, Dietary Fats and Oils	136
3.6.4	Quantitative and Qualitative Improvement of Oil Seed Crops	137
3.6.5	The New Shift in Fat Paradigm and Its Implications	140
3.7	Enhancement of Levels of Vitamins	141
3.7.1	The Vitamins	141
3.7.2	Retinoids (Vitamin A)	142
3.7.2.1	The Golden Crops	143
3.7.2.2	Golden Rice	144
3.7.2.3	Golden Sorghum	145
3.7.2.4	Orange Maize	145
3.7.3	Folate (Vitamin B ₉)	145
3.7.4	Ascorbic Acid (Vitamin C)	146
3.7.5	Tocopherols (Vitamin E)	147
3.7.6	Multi-vitamin Corn	148
3.8	Enhancement of Levels of Mineral Elements	148
3.8.1	Role of Mineral Elements in Human Health	148
3.8.2	Iron (Fe)	150
3.8.3	Zinc (Zn)	152
3.8.4	Calcium (Ca)	154
3.8.5	Selenium (Se)	155
3.8.6	Iodine (I)	156
3.8.7	Fluoride (F)	157
3.9	Enhancement of Antioxidants	157
3.9.1	The Antioxidants	157
3.9.2	Lycopene	158
3.9.3	Flavonoids	159

- 3.9.4 Carotenoids 159
- 3.9.5 Other Antioxidants 160
- 3.9.6 Thermal Stability of Antioxidants 160
- 3.10 Mitigation of Levels of Antinutritional Factors 160
- 3.10.1 The Antinutritional Factors 160
- 3.10.2 Phytate 160
- 3.10.3 Inhibitors of Digestive Enzymes 162
- 3.10.4 Reducing Levels of Allergens 162
- 3.10.5 Other Significant Antinutritional Factors 163
- 3.11 Conclusions and Recommendations 163
- Acknowledgement 167
- References 167

4 Applications of RNA-Interference and Virus-Induced Gene Silencing (VIGS) for Nutritional Genomics in Crop Plants 185

Subodh Kumar Sinha and Basavaprabhu L. Patil

- 4.1 Introduction 185
- 4.2 RNA Interference 186
- 4.2.1 RNAi in Modification of Primary Metabolism 186
- 4.2.1.1 Amino Acids/Protein 186
- 4.2.1.2 Carbohydrate 187
- 4.2.1.3 Lipid 187
- 4.2.1.4 Food Allergens 188
- 4.2.2 RNAi for Modification of Secondary Metabolism 188
- 4.2.2.1 Prolongation of Fruit Shelf-Life 190
- 4.2.2.2 Seedless Fruit Development 192
- 4.3 Virus-Induced Gene Silencing (VIGS) for Biofortification 192
- 4.4 Conclusions 195
- References 196

5 Strategies for Enhancing Phytonutrient Content in Plant-Based Foods 203

Carla S. Santos, Nouredine Benkeblia and Marta W. Vasconcelos

- 5.1 Introduction 203
- 5.2 What are Phytonutrients? 204
- 5.3 Which Plant-Based Foods are the Best Known Sources of Phytonutrients? 205
- 5.4 How Can We Enhance Phytonutrients? 207
- 5.4.1 Conventional Breeding 207
- 5.4.2 Molecular Breeding 208
- 5.4.3 Metabolic Engineering and Genetic Modification 208
- 5.5 Phenotyping for Phytonutrients at Different Levels 210
- 5.5.1 Low Throughput Techniques 210
- 5.5.2 High-Throughput Techniques 213
- 5.6 The Future Ahead/Concluding Remarks 216
- Acknowledgements 217
- References 217

6 The Use of Genetic Engineering to Improve the Nutritional Profile of Traditional Plant Foods 233

Marta R.M. Lima, Carla S. Santos and Marta W. Vasconcelos

- 6.1 Introduction 233
- 6.1.1 Nutrients in Plant Foods 233
- 6.1.2 Consequences of Malnutrition 235
- 6.1.3 Strategies to Overcome Malnutrition 235
- 6.2 What Are Genetically Engineered Crops? 236
- 6.2.1 Plant Genetic Transformation Technologies 236
- 6.2.2 Traditional Foods with Enhanced Nutritional Profiles: Case Studies 238
 - 6.2.2.1 Rice 238
 - 6.2.2.2 Potato 243
 - 6.2.2.3 Soybean 244
 - 6.2.2.4 Maize 245
- 6.3 GM Plant Foods Under Approval for Commercial Utilisation 245
- 6.4 Socioeconomic Impact and Safety of GM Foods 247
 - Acknowledgements 248
 - References 248

7 Carotenoids: Biotechnological Improvements for Human Health and Sustainable Development 259

George G. Khachatourians

- 7.1 Introduction 259
- 7.2 Occurrence 260
- 7.3 Discovery and Early History 260
- 7.4 Carotenoids Use in Human Foods and Biotechnology 262
- 7.5 Use of Carotenoids in Animal Feed 264
- 7.6 Global Market Situation and Sustainability 264
- 7.7 Carotenoid Biosynthesis and Function in Plants 266
- 7.8 Conclusion and Perspectives 268
 - References 268

8 Progress in Enrichment and Metabolic Profiling of Diverse Carotenoids in Tropical Fruits: Importance of Hyphenated Techniques 271

Bangalore Prabhashankar Arathi, Poorigali Raghavendra-Rao Sowmya, Kariyappa Vijay, Vallikannan Baskaran and Rangaswamy Lakshminarayana

- 8.1 Introduction 271
- 8.2 Trends in Biosynthesis of Carotenoids and their Profiling in Plants and Tropical Fruits 274
- 8.3 Biotechnological Approaches to Enrich Carotenoids in Tropical Fruits 281
 - 8.3.1 Conventional Approaches to Enrich Carotenoids in Tropical Fruits 283
 - 8.3.2 Pre- and Post-Harvest Technology to Improve Carotenoids Contents in Tropical Fruits 283
- 8.4 Bioaccessibility and Bioavailability of Carotenoids From Fruits and Their Products 285
- 8.5 Techniques to Characterise Carotenoids from Fruits 291

8.6	Conclusion	294
	Acknowledgements	294
	References	295
9	Improvement of Carotenoid Accumulation in Tomato Fruit	309
	<i>Lihong Liu, Zhiyong Shao, Min Zhang, Tianyu Liu, Haoran Liu, Shuo Li, Yuanyuan Liu and Qiaomei Wang</i>	
	List of Abbreviations	309
9.1	Introduction	310
9.2	Metabolism of Carotenoid in Tomato	312
9.2.1	Biosynthesis of Carotenoid	312
9.2.2	Catabolism of Carotenoid	315
9.3	The Biosynthetic Capacities of the Plastid	316
9.4	Hormonal Regulatory Network of Carotenoid Metabolism	317
9.4.1	Ethylene	317
9.4.2	Jasmonates	318
9.4.3	Brassinosteroids	319
9.4.4	Absciscic acid	319
9.4.5	Gibberellin	320
9.4.6	Auxin	320
9.5	Environmental Regulation of Carotenoid Metabolism	320
9.5.1	Light	320
9.5.2	Temperature	322
9.5.3	Carbon Dioxide (CO ₂)	322
9.5.4	Post-Harvest Regulation	322
9.6	Bioavailability of Carotenoid	322
9.7	Food Omics	324
	Acknowledgements	324
	References	327
10	Modern Biotechnologies and Phytonutritional Improvement of Grape and Wine	339
	<i>Atanas Atanassov, Teodora Dzhambazova, Ivanka Kamenova, Ivan Tsvetkov, Vasil Georgiev, Ivayla Dincheva, Ilian Badjakov, Dasha Mihaylova, Miroslava Kakalova, Atanas Pavlov and Plamen Mollov</i>	
10.1	Grape Genomics	339
10.1.1	Identifying Genes Behind the Main Secondary Metabolites	340
10.1.2	Identifying Disease Resistance Genes in <i>Vitis</i> sp.—a New Level of Grapevine Breeding	341
10.2	Marker Assisted Selection (MAS) and Genomic Selection (GS) of Grapevine	342
10.3	Engineered Resistance to Viruses	343
10.4	Diagnosis of Grapevine Viruses	350
10.4.1	Biological Assays	350
10.4.1.1	Woody Indexing	350
10.4.1.2	Herbaceous Indexing	350
10.4.2	Serological Assays	350

10.4.3	Molecular Assays	351
10.4.3.1	Nucleic Acid Hybridization	351
10.4.3.2	Polymerase Chain Reaction (PCR)	351
10.5	Phytonutritional Compounds with Biological Activity in Grape and Wine and Their Target Analyses	353
10.5.1	Biologically Active Substances Found in Grape and Wine	353
10.5.2	LC-MS and GC-MS Based Analysis and Metabolomics	358
10.5.2.1	Gas Chromatography–Mass Spectrometry (GC-MS)	359
10.5.2.2	Liquid Chromatography–Mass Spectrometry (LC-MS)	360
10.5.3	NMR–Based Metabolomic Analysis of Grape and Wine	360
10.6	Wine Quality	361
10.6.1	What is the Particular Meaning We Imply to the Term ‘Quality of Wine’?	361
10.6.2	How is the Wine Quality Created?	362
10.7	Grapevine Genetic Resources- Prospects in Management and Sustainable Use	367
10.7.1	European Policy, Regulation and Coordination Initiatives	367
10.7.2	Vitis Grapevine Genebanks, Collections and Databases	368
10.7.3	European Scientific Achievements	369
	References	370
11	Phytonutrient Improvements of Sweetpotato	391
	<i>Noureddine Benkeblia</i>	391
11.1	Introduction	391
11.2	Nutritional Qualities of Sweetpotato	393
11.3	Phytonutrient Improvements of Sweetpotato	396
10.3.1	Sweetpotato Improvement for β -Carotene	396
10.3.2	Sweetpotato Improvement for Anthocyanins and Phenolics	397
10.3.3	Other Nutrient Improvements	399
11.4	Conclusion and Future Perspectives	399
	Acknowledgements	400
	References	400
12	Improvement of Glucosinolate in Cruciferous Crops	407
	<i>Huiying Miao, Bo Sun, Yanting Zhao, Hongmei Qian, Congxi Cai, Jiaqi Chang, Mingdan Deng, Xin Zhang and Qiaomei Wang</i>	407
	List of Abbreviations	407
12.1	Introduction	408
12.2	Glucosinolate Breakdown	408
12.2.1	Glucosinolate Breakdown Upon Tissue Damage	409
12.2.2	Glucosinolate Breakdown in Living Plant Cell	410
12.2.3	Glucosinolate Hydrolysis in Mammalian	411
12.3	Biological Functions of Glucosinolates and Their Hydrolysis Products	411
12.3.1	Anticarcinogenic Mechanism	411
12.3.1.1	Detoxification	411
12.3.1.2	Cell Cycle Arrest and Apoptosis	412
12.3.1.3	Altered Oestrogen Metabolism	412

12.3.1.4	Histone Deacetylation Inhibition	413
12.3.2	Other Chemopreventive Effects	413
12.3.3	Adverse Effects	413
12.4	Glucosinolate Biosynthesis	414
12.4.1	Side-Chain Elongation	414
12.4.2	Formation of Core Glucosinolate Structure	414
12.4.3	Secondary Modifications	416
12.4.4	Regulators of Glucosinolate Biosynthetic Pathway	416
12.5	Metabolic Engineering of Glucosinolates in <i>Brassica</i> Crops	418
12.6	Glucosinolate Accumulation under Pre-Harvest and Post-Harvest Handlings	421
12.6.1	Effects of Light on Glucosinolate Accumulation	422
12.6.1.1	Photoperiod	422
12.6.1.2	Light Quality	422
12.6.2	Chemical Regulation of Glucosinolate Accumulation	423
12.6.2.1	Phytohormones	423
12.6.2.2	Sugars	424
12.6.2.3	Salinity	425
12.6.2.4	Fertilisation	426
12.6.3	Glucosinolate Changes upon Post-Harvest Handlings	427
12.6.3.1	Cooling	427
12.6.3.2	Controlled Atmosphere (CA) Storage	428
12.6.3.3	Modified Atmosphere Packaging	428
12.6.3.4	1-Methylcyclopropene (1-MCP) Treatment	429
12.6.3.5	Processing	430
12.6.3.6	Glucosinolate Changes under Different Cooking Methods	430
12.7	Conclusions and Future Prospects	432
	Acknowledgements	433
	References	433
13	Development of the Transgenic Rice Accumulating Flavonoids in Seed by Metabolic Engineering	451
	<i>Yuko Ogo and Fumio Takaiwa</i>	
13.1	Introduction	451
13.2	Production of Flavonoids in Rice Seed by Ectopic Expression of the Biosynthetic Enzymes	454
13.3	Production of Flavonoids in Rice Seed by Ectopic Expression of the Transcription Factors	458
13.4	Characterisation of Flavonoids in Transgenic Rice Seed by LC–MS-based Metabolomics	460
13.5	Future Prospects	461
	References	463
14	Nutrient Management for High Efficiency Sweetpotato Production	471
	<i>Yong-Chun Zhang, Ji-Dong Wang, Yan-Xi Shi and Dai-Fu Ma</i>	
14.1	Patterns of Growth and Development and Nutrient Absorption in Sweetpotato	471

14.1.1	Area under Sweetpotato	471
14.1.2	Growth Characteristics	471
14.1.3	Nutrient Requirements	472
14.1.4	Factors Affecting Nutrient Absorption	472
14.1.4.1	Soil Moisture Content	472
14.1.4.2	Genotype	472
14.1.4.3	Yield	474
14.1.4.4	Soil Aeration	474
14.2	Screening of High Efficient of Potassium Uptake and Utilised Genotypes	474
14.2.1	Potassium Deficiency	474
14.2.2	Potassium Use Efficiency and Utilisation Efficiency	476
14.2.3	Screening of High Uptake Efficiency Genotypes	476
14.2.4	Screening of High Use Efficiency Genotypes	478
14.3	Effect of Fertilisers	480
14.3.1	Effect of Nitrogen Application	480
14.3.1.1	Effect of Dose of Nitrogen on Yield	480
14.3.1.2	Effect of Dose of Nitrogen on Nitrogen Uptake and Utilisation Efficiency	480
14.3.1.3	Effect of Dose of Nitrogen on Root System Differentiation and Yield	481
14.3.2	Effect of Phosphorus Application	482
14.3.3	Effect of Potassium Application	482
14.3.4	Effect of Nitrogen, Phosphorus, and Potassium Application on Yield	483
14.4	Balanced Fertiliser Management in Sweetpotato at Sishui, Shandong: A Case Study	483
14.4.1	General Description of Area	483
14.4.2	Major Steps Towards Balanced Application of Fertilisers	485
14.4.2.1	Soil Sampling and Testing	485
14.4.2.2	Establishment of Abundance Index for Soil Nutrients	485
14.4.2.3	Determining Fertiliser Parameters	485
14.4.2.4	Recommended Dose of Fertilisers	488
14.4.2.5	A Customised Fertiliser Management Plan for the Region	490
14.4.2.6	Validating the Benefits of Balanced Application of Fertilisers	491
14.4.2.7	Demonstration and Promotion of the Technology of Balanced Application of Fertilisers to Sweetpotato	491
14.4.3	Establishment and Application of an Expert Consultation System	491
14.4.3.1	Structure and Design of Expert Consultation System	492
14.4.3.2	Functioning of the System	492
14.4.3.3	Characterising and Application of the System	492
14.5	Application of Fertilisers Through Drip Irrigation ('Fertigation')	493
14.5.1	Effect of Supplying Fertilisers Through Drip Irrigation on Sweetpotato	494
14.5.2	Input/output Ratio in Application of Fertilisers Through Drip Irrigation	495
	Acknowledgements	495
	References	495

List of Contributors

Mukhtar Ahmad

Department of Agronomy
PMAS-Arid Agriculture University
Rawalpindi
Punjab, Pakistan

Ilian Badjakov

Agrobiointitute
Sofia
Bulgaria

Seetharam Annadana

Technology Lead for an MNC
Krishi, 29, CR Layout
Sarakki Main Road
Bengaluru
India

Vallikannan Baskaran

Department of Biochemistry and
Nutrition
CSIR-Central Food Technological
Research Institute
Mysuru
India

Bangalore Prabhaskar Arathi

Department of Biotechnology
Jnana Bharathi Campus
Bangalore University
Bengaluru, India

Saikat Kumar Basu

Department of Biological Sciences
University of Lethbridge
Lethbridge, AB
Canada

Muhammad Asif

Department of Agricultural
Food and Nutritional Science
University of Alberta
Edmonton, AB, Canada

Avik Basu

Calcutta Medical College
Kolkata, WB
India

Atanas Atanassov

JGC, Sofia
Bulgaria

Noureddine Benkeblia

Laboratory of Crop Science
Department of Life Sciences
The University of the West Indies
Mona campus
Kingston
Jamaica

Congxi Cai

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

William Cetzal-Ix

Instituto Tecnológico de China
Calle 11 entre 22 y 28
Colonia Centro China 24050
Campeche
México

Jiaqi Chang

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Dai-Fu Ma

Xuzhou Sweetpotato Research Center
Xuzhou Academy of Agricultural Science
Xuzhou, Jiangsu
China

Mingdan Deng

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Danapati Dhungyel

Renewable Natural Resources Research
and Development Centre (RNR RDC)
Wengkhar
Mongar, Bhutan

Ivayla Dincheva

Agrobioinstitute
Sofia
Bulgaria

Teodora Dzhabazova

Agrobioinstitute
Sofia
Bulgaria

Vasil Georgiev

Center for Viticulture and Small Fruit
Research
College of Agriculture and Food Science
Florida A&M University
Tallahassee, FL
USA

Arvind Hirani

Department of Plant Science
University of Manitoba
Winnipeg, MB
Canada

Tshitila Jongthap

Medicinal and Aromatic Plants
Renewable Natural Resources Research
and Development Centre (RNR RDC)
Yusipang
Ministry of Agriculture and Forests
Government of Bhutan
Thimphu, Bhutan

Miroslava Kakalova

University of Food Technologies
Plovdiv
Bulgaria

Ivanka Kamenova

Agrobioinstitute
Sofia
Bulgaria

Rajan Katoch

Biochemistry Laboratory
Department of Crop Improvement
CSKHPKV, Palampur
India

George G. Khachatourians

Departments of Food and Bioproduct
Sciences
College of Agriculture and Bioresources
University of Saskatchewan
Saskatoon
Canada

Rangaswamy Lakshminarayana

Department of Biotechnology
Jnana Bharathi Campus
Bangalore University
Bengaluru
India

Xianping Li

Industrial Crop Research Institute
Yunnan Academy of Agricultural
Sciences
Kunming, Yunnan
China

Yanshan Li

Industrial Crop Research Institute
Yunnan Academy of Agricultural
Sciences
Kunming, Yunnan
China

Shuo Li

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Marta R.M. Lima

CBQF-Centro de Biotecnologia
e Química Fina
Escola Superior de Biotecnologia
Universidade Católica Portuguesa
Porto, Portugal

Yuanyuan Liu

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Lihong Liu

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Haoran Liu

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Tianyu Liu

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Ambrose Obongo Mbuya

Department of Theology
Great Lakes University of Kisumu
(GLUK)-Kenya
Kisumu
Kenya

Huiying Miao

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Dasha Mihaylova

University of Food Technologies
Plovdiv
Bulgaria

Plamen Mollov

University of Food Technologies
Plovdiv
Bulgaria

Yuko Ogo

National Institute of Agrobiological
Sciences
Transgenic Crop Research and
Development Center
Kannondai, Tsukuba, Ibaraki
Japan

Basavaprabhu L. Patil

Senior Scientists
National Research Center on Plant
Biotechnology
Pusa, New Delhi
India

Atanas Pavlov

University of Food Technologies
Plovdiv, Bulgaria

Hongmei Qian

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Chavali Kameswara Rao

Foundation for Biotechnology Awareness
and Education
Bangalore
India

Muhammad Sajad

Department of Plant Breeding and
Genetics
University College of Agriculture and
Environmental Sciences
The Islamia University of Bahawalpur
Punjab
Pakistan

Carla S. Santos

CBQF-Centro de Biotecnologia
e Química Fina
Escola Superior de Biotecnologia
Universidade Católica Portuguesa
Porto, Portugal

Ratnabali Sengupta

Department of Zoology
WB State University
Barasat, WB
India

Zhiyong Shao

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Yan-Xi Shi

Qingdao Agricultural University
Chengyang, Qingdao
Shandong, China

Sunil Kumar Singh

National Research Centre on Plant
Biotechnology
IARI, New Delhi
India

Subodh Kumar Sinha

Senior Scientists
National Research Center on Plant
Biotechnology
Pusa, New Delhi
India

Francisco Solorio-Sánchez

Campus de Ciencias Biológicas y
Agropecuarias
Universidad Autónoma de Yucatán
Mérida, Yucatán
México

Poorigali Raghavendra-Rao Sowmya

Department of Biotechnology
Jnana Bharathi Campus
Bangalore University
Bengaluru, India

Bo Sun

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Fumio Takaiwa

National Institute of Agrobiological
Sciences
Transgenic Crop Research and
Development Center
Tsukuba, Ibaraki
Japan

Sonam Tashi

College of Natural Resources
Royal University of Bhutan
Lobesa, Punakha
Bhutan

Neelam Thakur

Department of Zoology
PAU
Ludhiana, India

Ivan Tsvetkov

Agrobiointitute
Sofia
Bulgaria

Marta W. Vasconcelos

CBQF-Centro de Biotecnologia
e Química Fina
Escola Superior de Biotecnologia
Universidade Católica Portuguesa
Porto

Kariyappa Vijay

Department of Biotechnology
Jnana Bharathi Campus
Bangalore University
Bengaluru
India

Ji-Dong Wang

Institute of Agricultural Resources and
Environment
Jiangsu Academy of Agricultural Sciences
Scientific Observation and Experimental
Station of Arable Land Conservation of
Jiangsu Province, Ministry of Agriculture
Nanjing
China

Qiaomei Wang

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Peiman Zandi

Young Researchers and Elite Club
Takestan Branch
Islamic Azad University
Takestan
Iran

Xin Zhang

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Min Zhang

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Yong-Chun Zhang

Institute of Agricultural Resources and
Environment
Jiangsu Academy of Agricultural Sciences
Scientific Observation and Experimental
Station of Arable Land Conservation of
Jiangsu Province, Ministry of Agriculture
Nanjing, China
China

Yanting Zhao

Department of Horticulture
Zhejiang University
Hangzhou, Zhejiang
China

Foreword

From the twentieth century, modern agriculture is providing high quality foods, and 'classic' biotechnology has been used for centuries in breeding to produce improved food crops. However, with development of 'modern' biotechnology and the use of gene technology, much potential for further advances in crops improvement in nutritional qualities. At the end the twentieth century and the turn of the twenty-first century, interests in improving the nutritional and health benefits of crops became a priority aiming to improve diet, and control and prevent many other nutritional diseases particularly obesity, cardiovascular diseases, diabetes and cancers. During the last three decades and the better understanding of gene action and metabolic pathways, tremendous progress has been made in manipulating genes to enhance nutrients, phytochemicals and nutraceuticals of a large number of crops. Despite these developments, still a lot remains to be understood for example the interaction of genes and genomic environment, and/or genes with the environment. Nevertheless, the extensive existing genetic resources available including the wild relative species, and recombinant DNA methods are offering greatly expanded potential resources. Therefore, new options for improving the nutritional value of crops are open. This book is aiming to report recent advances and updated data on the use of molecular engineering to enhance the phytonutritional quality of crops. The different chapters are covering different molecular engineering techniques to increase phytonutrient levels in crops, as well as the potentials of improving specific crops.

Noureddine Benkebli
Professor of Crop Science
UWI Mona

Important Plant-Based Phytonutrients

Avik Basu¹, Saikat Kumar Basu², Ratnabali Sengupta³, Muhammad Asif⁴, Xianping Li⁵, Yanshan Li⁵, Arvind Hirani⁶, Peiman Zandi⁷, Muhammad Sajad⁸, Francisco Solorio-Sánchez⁹, Ambrose Obongo Mbuya¹⁰, William Cetzal-Ix¹¹, Sonam Tashi¹², Tshitila Jongthap¹³, Danapati Dhungyel¹⁴ and Mukhtar Ahmad¹⁵

¹ Calcutta Medical College, Kolkata, WB, India

² Department of Biological Sciences, University of Lethbridge, Lethbridge, AB, Canada

³ Department of Zoology, WB State University, Barasat, WB, India

⁴ Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, Canada

⁵ Industrial Crop Research Institute, Yunnan Academy of Agricultural Sciences, Kunming, Yunnan, China

⁶ Department of Plant Science, University of Manitoba, Winnipeg, MB, Canada

⁷ Young Researchers and Elite Club, Takestan Branch, Islamic Azad University, Takestan, Iran

⁸ Department of Plant Breeding and Genetics, University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpur, Punjab, Pakistan

⁹ Campus de Ciencias Biológicas y Agropecuarias, Universidad Autónoma de Yucatán, Carretera Mérida-Xmatkuil Km.15.5. C.P. 97100, Mérida, Yucatán, México

¹⁰ Department of Theology, Great Lakes University of Kisumu (GLUK)-Kenya, Kisumu, Kenya

¹¹ Instituto Tecnológico de Chíná, Calle 11 entre 22 y 28, Colonia Centro Chíná 24050, Campeche, México

¹² College of Natural Resources, Royal University of Bhutan, Lobesa, Punakha, Bhutan

¹³ Medicinal and Aromatic Plants, Renewable Natural Resources Research and Development Centre (RNR RDC) Yusipang,

Ministry of Agriculture and Forests, Government of Bhutan, Thimphu, Bhutan

¹⁴ Renewable Natural Resources Research and Development Centre (RNR RDC), Wengkharr, Mongar, Bhutan

¹⁵ Department of Agronomy, PMAS-Arid Agriculture University Rawalpindi, Punjab, Pakistan

List of Abbreviations

ALL	Acute Lymphoblastic Leukaemia
CAD	Coronary Artery Disease
CML	Chronic Myeloid Leukaemia
DNA	Deoxyribonucleic acid
FDA	Food and Drug Administration
HDL	High Density Lipoprotein
IDDM	Insulin Dependent Diabetes Mellitus
IHD	Ischemic Heart Disease
LDL	Low Density Lipoprotein
MDA	Malondialdehyde
NIDDM	Non-Insulin Dependent Diabetes Mellitus
UV	Ultraviolet

VLDL Very High Density Lipoprotein
SOD Superoxide dismutase

1.1 Introduction

Present-day consumers are more nutrition savvy. Each year, health magazines and articles in the newspapers are increasingly dedicated to the relationship between health and diet, especially to plant-based nutraceuticals, functional foods and value-added food products. Additionally, health-related research journals, magazines, books and television programmes tackle topics of treatment and prevention of diseases more than ever. The advent of the internet has acted as an active super highway for free information and has contributed significantly as one of the momentous events influencing communal knowledge and awareness across the planet (Wildman & Kelley 2007). In addition, powerful tools such as publicly available technical and non-technical search engines and social media have further strengthened the global community in the realm of knowledge empowerment. Several international food companies are also taking full benefit of the increasing health awareness and have contributed millions of dollar into the study of nutraceutical compounds, marketing and development of new products and have recognised a quickly developing new market with remarkable pledge. These products fall in the category of immense deemed functional foods. These manufactured food products or natural foods (vegetables and fruits) that can definitely influence human physiology action have bioactive compounds (Wildman 2001).

The term '*nutraceuticals*' was first coined by Stephen DeFelice, founder and chairman of the Foundation for Innovation in Medicine, in the United States in 1988. The definition given by the organisation was '*products isolated and purified from foods that are generally sold in medicinal forms and are usually associated with food.*' However, another definition was given by Health Canada in 1998. The same organisation coined a definition for the term '*functional foods*', which defined it as '*similar in appearance to, or may be, conventional foods that are consumed as part of a usual diet, and have demonstrated physiological benefits and/or reduce the risk of chronic diseases beyond the basic nutritional functions.*' Hence, there exists a fine line of demarcation between the two terms (Acharya *et al.* 2008).

The global market of nutraceuticals and functional foods is on the rise with the United States and Japan being the top two countries having the biggest share of it. However, in other countries, the expansion of the market is being restricted due to stringent laws governing food labelling, formulation, processing, packaging and marketing. Such issues need to be dealt with properly to facilitate the growth of functional food markets in every other country (Basu *et al.* 2007). Two more countries that are likely to emerge as promising markets for nutraceuticals in the near future are India and China. Both these countries have a rich source of herbs and trees, which have formed an essential part of traditional Indian and Chinese medicines. Even today, such traditional medicines play an important role in keeping the lives of a major part of the enormous population in both these countries. Moreover, the lion share of India's people live in the rural areas where there is almost no access to standard conventional health care centres providing modern day drugs. Hence, they depend on the local herbal products for cure of diseases (Basu *et al.* 2007). In both the countries, there are no strict government

regulations pertaining to the sale and consumption of these traditional medicines. They are available to the people as over-the-counter drugs without the need for any prescription. These facts point to their potential to grow as leaders in market for nutraceuticals and functional foods and thus contribute significantly to the export industry (Basu *et al.* 2007). This review aims at providing a detailed coverage of health as well as industrial aspects of plant-based nutraceuticals, functional foods and value-added food products to the readers as to understand: what they are and their applications in human health from a global perspective.

1.2 Nutraceuticals and Functional Foods in Human Health

Plants have always been a significant source of trace elements in our diet (Aberoumand 2012). They not only help us by meeting our optimum nutrient requirements but also provide an effective barrier to the occurrence of several morbid conditions (Aberoumand 2012). Many of these medicinal plants produce a number of different phytonutrients that play an important role in maintaining our very own physiological system. But most of those underlying biochemical processes still remain obscure (Thomas 2012). However, rapid development in the field of deoxyribonucleic acid (DNA) sequencing and other biotechnological *know-hows* are slowly paving the way to unlocking these secrets and will one day make plants a more indispensable part of human life than they were once thought to be (Thomas 2012).

With the growth of different pharmaceutical companies, the use of traditional medicinal plants has indeed received a severe blow. But in the last few decades, there has been a turn in the tide. Scientists and health experts have started to recognise the value of the plants in human health and this has thus led to the positive growth of nutraceuticals and functional food markets all over the globe. The National Centre for Traditional Medicine has been set up in Cambodia to provide medical care to people in traditional medicine yet with scientific means. Several medicinal plants (Tables 1.1–1.5) with nutraceutical values have been identified and the proper dosage forms have been prepared after carefully designed and repeated clinical trials. The use of traditional medicines in the country is under strict regulation of the Ministry of Health to ensure quality and safety of the products (Kraisintu 2003).

Community health study and investigation in metabolic syndrome of poor nutrition, dyslipidemia, hepatic derangement and associated cardiovascular risk factors are of immense importance in the present time. In concurrence with technological advancements, occupational and dietary lifestyles in all ages of both the sexes of men and women, irrespective of racial and ethnic differences are rapidly changing. Habitual changes of lifestyle of people in both urban and rural settings are also of no great difference like before. Adults (18 years and above) of both sexes are affected by this massive pathos of psychosomatic disorders. Clinical manifestation of early age of onset of atherosclerosis, ischemic heart disease along with hepatic derangements and dyslipidemia are the most common health disorders prevalent in every society. Data on health-related issues and nutrition from developed countries are easily available, but, unfortunately, the data from under developed and developing nations in Asia, Africa and Latin America are remarkably lacking. In addition, survey records and information are also less available from rural sectors and least from the tribal/aboriginal/first nation

Table 1.1 Medicinally important plants from Africa that are commonly used by local tribes as nutraceutical sources and as potential functional food components in their daily diets.

No	Local name	English name	Plant Family	Scientific name	Nutraceutical / Phytochemical	Habit	Part used	Medicinal properties	Tribes using the plant	References
1	Talamong	Blackthorn	Fabaceae	<i>Acacia mellifera</i> (Vahl) Benth	30-hydroxylup-20 (29)-en-3-one, 30-hydroxylup-20 (29)-en-3 β -ol, atranorin, methyl-2hydroxy-4-hydroxy-3, 6 dimethyl benzoate, β -stosterol-3 β -O-glucoside, linoleic acid, pentacyclic triterpenoids: (20R) 3-oxolupane-30al and (20S) 3-oxolupane-30al, (20R)-28-hydroxylupen-30-al-3-one, (20S)-3 β -hydroxylupan-30-al	Shrub	Stem bark	Treatment of pneumonia, malaria, primary infection of syphilis, sterility and stomach ache, skin diseases, coughs and gastrointestinal ailments	Pokot (Kenya)	Kokwaro (1993), Mutai <i>et al.</i> (2007), Mutai <i>et al.</i> (2009)
2	Iwongewonge	Indian liquorice, White thorn apple	Solanaceae	<i>Datura metel</i> L.	Alkaloids, tripenoid, steroids, flavonoid, triterpenes, phenolic compounds, tannins	Herb	Leaves, seeds	Tuberculosis, asthma, cough, convulsions, antibacterial, insanity, catarh, diarrhoea, hysteria, rheumatic pains	Sukuma (Tanzania)	Bharathi <i>et al.</i> (2010), Kokwaro (1993), Siva Sakthi <i>et al.</i> (2011)

3	Acak-acak	Asthma herb, pill bearing spurge	Euphorbia hirta L.	Flavonoids (Quercitrin, Myricitrin), Sterols (Cycloartenol, 24-methylene-cycloartenol, β -sitosterol, euphorbol hexacozonate, 1-hexacosanol, tinyaloxin, campesterol, stigmasterol), tannins (1,2,3,4, 6-penta-O-galloyl- β -D-glucose, 3,4-di-O-galloylquinic acid, gallic acid, 2,4, 6-tri-O-galloyl-D-glucose, euphorbin A,B,E), triterpenoids (α -amyrin, β -amyrin, taraxerone, taxerol, β -amyrin, acetate, taraxerone, 11 α , 12 α -oxidotaraxero)	Herb	Leaves, latex (whole plant)	Asthma, colic troubles, dysentery, cough, worms and vomiting, antibacterial, molluscicidal activity, anti-diarrhoeal, anti-inflammatory	Acholi (Uganda)	Chen (1991), Chitra <i>et al.</i> (2011), Kokwaro (1993), Lee (2011), Shih <i>et al.</i> (2010), Shih and Cherng (2012)
4	Magwagwa	Tick berry	Verbenaceae <i>Lantana camara</i> L.	Tannin, catechin, saponin, steroids, alkaloids, phenol, anthroquinone, protein and reducing sugar	Shrub	Leaves, roots, flowers	Coughs, antibacterial, antihypertensive, treatment of malaria, rheumatism, and skin rashes, anti- repellent, antiseptic, anti-inflammatory	Luo (Kenya)	Kokwaro (1993), Mary Kensa (2011), Patel <i>et al.</i> (2011)

(Continued)

Table 1.1 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical / Phytochemical	Habit	Part used	Medicinal properties	Tribes using the plant	References
5	Muvunza hukuma	African mistletoe, Dwarf red hibiscus, Poppy hibiscus	Malvaceae	<i>Hibiscus micranthus</i> L. f.	Steroids, flavonoids, carbohydrates, phenols, tannins and few compounds like phenolic acids, flavonoids, β -sitosterol, alkanes, fatty alcohols, acids	Shrub	Roots, stems	Bronchitis, antimicrobial, antiviral, antitumour, antipyretic, anti-inflammatory, haematological effects	Pokomo (Kenya)	Kokwaro (1993), Kumar <i>et al.</i> (2010a, 2010b), Kumar <i>et al.</i> (2011)
6	Lihululu	Yellow justicia, Sand Paper plant	Acanthaceae	<i>Justicia flava</i> (Forssk.) Vahl	Sterols, salicylic acid, lignans helioxanthin[(+)-isolariciresinol, justicidin, decanoic acid, β -sitosterol- β -D-glucoside], 1-aryl-2,3-naphthalide lignans [Orosunol, 8-demethylorosunol]	Herb	Leaves, root	Diarrhoea, fever, treatment of convulsions and feverish pains, yaws	Luhya (Kenya)	Kokwaro (1993), Johnson (2004), Olaniyi (1982), Olaniyi and Powell (1980),
7	Msalanga	Eastern cape resin tree	Anacardiaceae	<i>Ozoroa mucronata</i> (Bernh.) R. Fern. & A. Fern.	Anarcadic acid (LOX inhibition), maronic acid (olean-18-ene keto acid)	Tree	Roots	Dysentery, LOX inhibition, PG synthase inhibition, antimicrobial	Digo (Kenya)	Hostettmann-Kaldas and Nakanishi (1979), Kokwaro (1993), Kubo <i>et al.</i> (1987)

8	Mukonda kundi	Mozambique bitter apples	Solanaceae	<i>Solanum renschii</i> Vatke	Steroidal alkaloids, steroidal sapogenins	Shrub	Root	Typhoid fever, throat, wounds healing	Kamba (Kenya)	Bussmann (2006), Carle (1981), Heine <i>et al.</i> (1988), Kokwaro (1993)
9	Ng'owo	Bush fig, Broom cluster fig, Cape fig	Moraceae	<i>Ficus capensis</i> Thunb.	Flavanol, coumarins, steroids and triterpenes, alkaloids, balsams, tannins, resin, carbohydrates, phenolic	Tree	Roots, leaves, stem bark	Constipation, tonic, anti-rheumatic, fever, treatment of tuberculosis, antibacterial	Luo (Kenya)	Adebayo-Tayo and Odeniyi (2012), Dafalla (2005), Kokwaro (1993), Oyeleke <i>et al.</i> (2008)
10	Msahala	Alexandrian senna, East Indian senna	Fabaceae	<i>Cassia senna</i> L.	Alkaloids, saponins, tannins, phytosterols, naphthalene glycosides, 6-hydroxymusizin glycoside, tinnevellin glycoside, anthranoids (dianthrone, anthrone, anthraquinone)	Shrub	Leaflets, fruits (pods)	Indigestion, foot infections, subcutaneous parasitic infection	Swahili (Kenya)	Kokwaro (1993), Lemli <i>et al.</i> (1981), Mengers <i>et al.</i> (2004), Viswanathan and Nallamuthu (2012)
11	Segatet	Cape myrtle	Primulaceae	<i>Myrsine africana</i> L.	Saponins, tannins, flavonoids, amino acids, steroids and reducing sugar: embelin, rapanone (2,5 dihydroxy benzoquinone)	Shrub	Fruits, stem bark, leaves, root bark	Roundworm, tapeworm, remedy for chest pains and stiff joints	Marakwet (Kenya)	Kokwaro (1993), Midiwo <i>et al.</i> (2010), Vasudha <i>et al.</i> (2011)

(Continued)

Table 1.1 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical / Phytochemical	Habit	Part used	Medicinal properties	Tribes using the plant	References
12	Kemagugu	Flame lily, Creeping lily, Climbing lily, Fire lily, Tiger claw, Glory lily	Colchicaceae	<i>Gloriosa superba</i> L.	Alkaloids (colchicine and colchicoside), glycosides, steroids, terpenoids, tannins, phenols, saponin, flavonoids	Herb	Seeds, tubers	Abortion, antidote for snake bites, antibacterial, treatment of bruises, sprains and colic, wounds, fever	Marakwet (Kenya)	Kokwaro (1993), Rehana banu and Nagarajan (2012), Senthilkumar (2013a, 2013b)
13	Ol-erbat	Babul, Indian gum Arabic tree	Fabaceae	<i>Acacia nilotica</i> (L.) Willd. ex Delile	Tannins, saponin, saponin glycosides, volatile oils, phenols, triterpenes, flavonoids and alkaloid, resin, steroids, oleosins, D-glucuronic acid, 1-acetyl beta carboline, hydroxy citronellal, trans decalone, lavandulyl acetate, propionic acid-2-chloro, ethyl ester, 3-picoline-2-nitro	Tree	Whole plant	Gonorrhoea, cough, antibacterial, antimalarial, antifungal, anti-diarrhoea, anticancer, antimutagenic, spasmogenic, vasoconstrictor, anti -pyretic, anti-asthmatic, cytotoxic, anti-diabetic, anti-platelet aggregatory, antiplasmodial, molluscidal	Maasai (Kenya)	Ali <i>et al.</i> (2012), Hemamalini <i>et al.</i> (2013), Kokwaro (1993), Solomon-Wisdom and Shittu (2010)

14	Iravu	White caper brush, Woolly caper brush	Capparidaceae	<i>Capparis tomentosa</i> Lam.	Oxindole (3-Hydroxy-3-methyl-4-methoxyoxindole), glucocapparin, gluconorcappasalin, benzylglucosinolates, rutin, fatty acids, hydrocarbons, sitosterol, β -carotene	Shrub	Roots, fruits, leaves (aerial parts)	Syphilis, skin irritant, antibacterial, spices, cough, infertility, impotence, anti-convulsant	Chagga (Tanzania)	Dekker <i>et al.</i> (1987), Kokwaro (1993), Tlili <i>et al.</i> (2011)
15	Huhunga	Zambezi false-nettle	Euphorbiaceae	<i>Acalypha ornata</i> Hochst. ex A. Rich.	Isopulegly acetate, valenchi, vividiflorene, α -muurolene, 2-hexyne, 6-methyl- α -ionone, γ -elemene, (E)-2-methyl-4-undecene, ledol, cis-3-hexynyl benzoate, 2-methyl-1-octadecene, apiole, oplopanone, γ -endesmol, flavonoids, phenols, resins, sterols, tannins	Shrub	Leaves, roots	Leprosy, antiemetic, relief of postpartum pain, haemorrhoids, leprosy, scabies, antimicrobial	Sukuma (Tanzania)	Ahmed and Onocha (2013), Kokwaro (1993); Onocha <i>et al.</i> (2011a, 2011b)

Table 1.2 Medicinal plants from Central and West Asia with potential for use as nutraceutical and functional food.

No	Local name	English name	Plant Family	Scientific name	Nutraceutical	Habit	Part used	Medicinal Properties	References
1	Bumadaran-e-Sabzekoh	Achillea	Asteraceae	<i>Achillea keltaiensis</i> Bioss. & Hausskn.	Camphor, borneol, α -thujone, cineol, bornyl acetate and camphene	Herb	Flowers	Carminative, indigestion, edema, burns, skin infection gastric ulcer, antibacterial, anti-inflammatory, haemorrhage, dysmenorrhoea, enema, diarrhoea	Pirbalouti <i>et al.</i> (2010a), Rustaiyan <i>et al.</i> (1999), Zargari (1996)
2	Golnare-e-farsi	Pomegranate	Lythraceae	<i>Punica granatum</i> L.	Pomegranate, ellagic acid, 3,3',4'-tri-O-methyl ellagic acid, ethyl brevifolincarboxylate, urolic and maslinic acids, daucosterol	Tree	Flowers	Wound healing, antiviral, antibacterial, antifungal, remedy for cut wound, bronchitis, diarrhoea, digestive problems, man sex power reconstituent, dermal infected wounds, diabetes	Pirbalouti <i>et al.</i> (2010a, 2010b), Wang <i>et al.</i> (2006)
3	Panirak	Common Mallow	Malvaceae	<i>Malva sylvestris</i> L.	Phenolics, flavonoids, carotenoids, ascorbic acid	Herb	Flowers, leaves, mature fruits and leafy flowered stems	Treatment of various ailments, including cold, cough and burn, and cut wound-healing	Zargari (1996)

4	Zarrin giah	-	Lamiaceae	<i>Dracocephalum multicaule</i> Montbr. & Auch. ex Bentham	Limonene, α -pinene, methyl fgeraniate	Herb	Leaves, flowers (aerial parts)	Foot pain, sedative, analgesia, inflammatory, antibacterial, antiseptic	Mojab <i>et al.</i> (2002), Pirbalouti <i>et al.</i> (2010a)
5	Khosharizeh	-	Apiaceae	<i>Echinophora platyloba</i> DC.	Trans- β -ocimene, 2-furanone, myrcene, linalool and cis- β -ocimene	Shrub	Aerial parts	Antifungal, spice and culinary	Entezari <i>et al.</i> (2009), Pirbalouti <i>et al.</i> (2010a)
6	Golpar	-	Apiaceae	<i>Heracleum lasiopetalum</i> Boiss.	Flavonoids, tannins, saponins	Herb	Fruit	Antiseptic, spice, and condiment	Pirbalouti (2009), Pirbalouti <i>et al.</i> (2010a); Rohi Boroujeni <i>et al.</i> (2012)
7	Bakhtyari karafs	Wild clery	Apiaceae	<i>Kelussia odoratissima</i> Mozaff.	E-ligustilide Phthalide, 3- e - butyldiene phthalide and z-ligustilide	Herb	Leaves	Edible as vegetable, flavouring, indigestion, rheumatism, also used to cure some rheumatism disorders, common cold, cough, blood pressure, blood lipid and stomachache	Pirbalouti <i>et al.</i> (2010a, 2010c); Rohi Boroujeni <i>et al.</i> (2012), Sedighi <i>et al.</i> (2012), Sultana <i>et al.</i> (2005)

(Continued)

Table 1.2 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical	Habit	Part used	Medicinal Properties	References
8	Pooneh	Spearmint	Lamiaceae	<i>Mentha longifolia</i> (L.) Hudson.	Carvone, cis- piperitone epoxide, piperitenone oxide, menthone, flavonoids: 5,7,4'-trihydroxy-6,2',3'-trimethoxyflavone	Herb	Leaves, flowers	Edible as vegetable, flavouring, indigestion, cough, anti-inflammatory, carminative, antienetic, diaphoretic, anti spasmodic, analgesic, stimulant, emmenagogue, and anticatharral activities	Džamić <i>et al.</i> (2010), Ghoulami <i>et al.</i> (2001), Pirbalouti <i>et al.</i> (2010a), Sharopov <i>et al.</i> (2012a)
9	Marzeh Koochi	Bakhtiari <i>savory</i>	Lamiaceae	<i>Satureja bachtiarica</i> Bunge	Thymol, γ -terpinene, p-cymene, β -caryophyllene and borneol	Herb	Leaves, flowers	Edible as vegetable, flavouring, indigestion, cough, antibacterial	Pirbalouti (2009), Pirbalouti <i>et al.</i> (2010a, 2010c), Sefidkon and Jamzad (2000)
10	Lolopashmak (Chay-e-kohi)	Betony	Lamiaceae	<i>Stachys lavandulifolia</i> Vahl.	α -thujone, α -pinene, myrcene, β -phellandrene, germacrene D, Δ -cadinene, and 1, 4-methano-1 H-indene	Herb	Leaves, flowers	Green tea, antibacterial, skin diseases, menorrhagia, sedative, antispasmodic, diuretic, ulcers, fevers and diarrhoea	Pirbalouti and Mohammadi (2013), Pirbalouti <i>et al.</i> (2010a), Rohi Boroujeni <i>et al.</i> (2012), Zargari (1996)

11	Avishan	Deanaie thyme	Lamiaceae	<i>Thymus daenensis</i> Celak.	Geraniol, geranyl acetate, Herb β -caryophyllene, thymol, p-cymene, methyl carvacrol,	Leaves, flowers	Green tea, spice, culinary, cough, antibacterial, carminative, anti-inflammatory, expectorant, treatment of colds, antifungal, antiviral, anti-parasites Zargari (1996)	Nickavar <i>et al.</i> (2005), Pirbalouti <i>et al.</i> (2010a, 2010c), Pirbalouti <i>et al.</i> (2011), Sabahi <i>et al.</i> (2013), Zargari (1996)
12	Kakouti	–	Lamiaceae	<i>Ziziphora tenuior</i> L.	Pulegone, limonene, piperitenone	Leaves, flowers	Green tea, spice, culinary, antibacterial, carminative, antiasthmatic	Ebrahimi <i>et al.</i> (2012), Meral <i>et al.</i> (2002), Pirbalouti <i>et al.</i> (2010a), Sezik <i>et al.</i> (1991)
13	Khakeshir	Flixweed	Brassicaceae	<i>Descurainia sophia</i> (L.) Webb ex Prantl	Cis- β -ocimene, menthol, Herb neoisomenthyl acetate	Seeds	Laxative, gasteralgia, fever, treatment of some cancers, cough	Li <i>et al.</i> (2010), Pirbalouti (2009)
14	Gavzaban-e- koohi	Bugloss	Boraginaceae	<i>Anchusa italica</i> Retz.	Saponins, pyrrolizidine alkaloids, γ - α -linoleic acid, stearidonic acid	Flowers, leaves	Green tea, antidepressant, nerve system relaxant, antianxiety, cold, chest pain, sore throat, antibacterial, asthma, neurasthenia	Mojab <i>et al.</i> (2003), Pirbalouti (2009), Safa <i>et al.</i> (2012), Zaurov <i>et al.</i> (2013)

(Continued)

Table 1.2 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical	Habit	Part used	Medicinal Properties	References
15	Sorya	Ratanjot	Boraginaceae	<i>Arnebia euchroma</i> (Royle) I.M. Johnston.	Naphthoquinone red pigments: ethyl 9-(2',5'-dihydroxyphenyl) nonanoate, octyl ferulate, arnebiabinone and isohexenylnaphthazarins (e.g. acetylshikonin)	Herb	Roots, rhizome	Burn wound, anti-eczema, antimicrobial, anti-inflammatory, anti-viral, anti-tumour, cardiotonic and contraceptive properties	Damianakos <i>et al.</i> (2012), Kumar <i>et al.</i> (2011), Liu <i>et al.</i> (2010), Pirbalouti <i>et al.</i> (2010c)
16	Golraye dayhimi	–	Hypericaceae	<i>Hypericum scabrum</i> L.	α -pinen, thymol, carvacrol, spathulenol, <i>p</i> -Cymene	Herb	Flowers, aerial parts	Green tea, sedative, headache, analgesic, trauma, rheumatism, neuralgia, anti-inflammatory, antiseptic, gastroenteritis, ulcers, hysteria, bedwetting	Baser <i>et al.</i> (2002), Pirbalouti <i>et al.</i> (2010c)
17	Mort	Myrtle	Myrtaceae	<i>Myrtus communis</i> L.	Acylphloroglucinols, phenolic compounds: phenolic acids, flavonol glycosides, volatile components: 1,8-cineole, α -terpineol, methyl eugenol, linalool	Tree	Leaves	Skin discords, digestive discords, astringent, good hair condition, bronchodilator, anti-inflammatory	Messaoud <i>et al.</i> (2012), Pirbalouti (2009), Pirbalouti <i>et al.</i> (2010c)

18	Pesteh Koochi (baneh)	Persian turpentine tree	Anacardiaceae	<i>Pistacia atlantica</i> Desf.	Sterols (betasitosterol), triacylglycerol tocopherols (α - tocopherol), phenols (caffeic acid)	Tree	Fruit, resin	Indigestion, tonic, toothache, astringent	Pirbalouti (2009), Pirbalouti <i>et al.</i> (2010c), Pirbalouti <i>et al.</i> (2012), Saber-Tehrani <i>et al.</i> (2013)
19	Gol-e Arooneh, (aruone)	–	Lamiaceae	<i>Salvia hydrangea</i> DC. ex Bentham	β -caryophyllene, caryophyllene oxide, spathulenol, 1,8-cineole, α -pinene	Herb	Flowers, leaves	Cough, emollient, sore throat, antibacterial, antispasmodic, carminative and sedative	Barazandeh (2004), Pirbalouti <i>et al.</i> (2010c), Rustaiyan <i>et al.</i> (1997), Sonboli <i>et al.</i> (2009)
20	Zalzalak	Hawthorn	Rosaceae	<i>Crataegus curvisepala</i> Lindm. (= <i>Crataegus oxyacantha</i> L.)	Sobutylamine, ursolic acid, oleanolic acid, crategolic acid, adenosine, adenine, guanine, caffeic acid, quercetin, hyperoside, rutin, vitexin-4'- rhamnoside, tyramine, flavonoglycosyls, epicatechol, saponins, tannins, o-ethoxy phenylethylamine	Tree	Fruits, flowers, leaves	Heart discords, edible as wild fruit, hypolipidaemic, anti-inflammatory, anxiety, antimicrobial	Kashyap <i>et al.</i> (2012), Pirbalouti (2009), Verma <i>et al.</i> (2007)

(Continued)

Table 1.2 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical	Habit	Part used	Medicinal Properties	References
21	Nakhonak	Southern Milk Vetch	Fabaceae	<i>Astragalus hamosus</i> L.	Flavonoids: rhamnocitrin 4'- β -D-galactopyranoside, flavonols hyperoside, isoquercitrin, astragalin, 3-O- gentiobioside, rutin rhamnetin 3-O- glucoside	Shrub	Whole plant	Carminative, astringent, good for ulcers, leucoderma and inflammation, treatment of nervous affections	Bratkov <i>et al.</i> (2016), Krasteva <i>et al.</i> (2007), Pirbalouti (2009)
22	Mousir	Persian shallot	Alliaceae	<i>Allium stipitatum</i> Regel (= <i>Allium hirtifolium</i> Boiss.)	Organosulphur, phenolic compounds, allacin, diallyl disulphide diallyl trisulphide, 9-hexadecenoic acid, 11,14-eicosadienoic acid, n-hexadecanoic acid, furostanol and spirostanol saponins, flavonol glycosides	Herb	Bulbs	Edible as vegetable, flavouring, antihypertensive, antibacterial, antioxidant	Barile <i>et al.</i> (2005), Ghahremani-Majd <i>et al.</i> (2012), Ismail <i>et al.</i> (2013), Pirbalouti (2009)
23	Spand	Syrian rue	Nitrariaceae	<i>Peganum harmala</i> L.	Alkaloids (β -carboline), reducing compounds, tannins, volatile oils, saponins, flavonoids, sterols (triterpenes), harmine, harmaline, anthraquinone	Shrub	Fruit, seed	Antimicrobial, anti-parasite, asthma, colic, anthelmintic, antiseptic, gastrointestinal, antispasmodic, antiperiodic,	Benbott <i>et al.</i> (2013), Dastagir <i>et al.</i> (2012), Pirbalouti (2009)

24	Spharzeh	Plantain (psyllium)	Plantaginaceae	<i>Plantago psyllium</i> L.	Polyphenolic acid, flavonoids, mucilages (anionic polysaccharide of L-arabinose, D-xylose and D-galacturonic acid), iridoid glycosides	Herb	Seeds	Cough, emollient, cough, sore throat	Naghdi <i>et al.</i> (2004), Pirbalouti (2009), Saeedi <i>et al.</i> (2010)
25	Rivas	Syrian Rhubarb	Polygonaceae	<i>Rheum ribes</i> L.	Chrysophanol, physcion, rhein, aloe-emodin, physcion-8-O-glucoside, aloe-emodin-8-O- glucoside, Sennoside A, rhaponticin, flavonoids	Herb	Leaves, root	edible as vegetable, flavouring, jaundice, indigestion, skin discords, treatment of diabetes, haemorrhoids, ulcer, diarrhoea	Oktay <i>et al.</i> (2007), Pirbalouti (2009), Sayyah <i>et al.</i> (2009)

Table 1.3 Medicinal plants from the Himalayas with potential for use as nutraceutical source and as functional food component.

No	Local name	English name	Plant Family	Scientific name	Nutraceutical/Phytochemical	Habit	Part used	Uses/Medicinal properties	References
1	Bongkar	Aconite	Ranunculaceae	<i>Aconitum orochryseum</i> Stapf	Diterpenoid alkaloids [Hetisine-type (orochrine, 2-O-acetylorochrine, 2-O-acetyl-7 α -hydroxyorochrine), atisinium chloride and virescenine], flavonoids, flavonol glycosides, diterpenoid, norditerpenoid	Herb	Aerial parts	Antidote for poisons of scorpion and snake; cures contagious diseases and inflammation of intestines, common cough and cold, bilious fever, dysentery, febrifuge for fevers associated with malaria infection, kidney dysfunction and stomach ulceration, diarrhoea, dysentery, tonsillitis, headache, high altitude sickness, antimalarial	Gajalakshmi <i>et al.</i> (2011), Krug and Milliken (2008), Samten (2009), Wangchuk <i>et al.</i> (2007), Wangchuk <i>et al.</i> (2010)

2	Bongnag, Bikh	Indian Aconite	Ranunculaceae	<i>Aconitum heterophyllum</i> (Brühl) Stapf (= <i>Aconitum laciniatum</i> (Bruhl) Stapf)	Diterpene alkaloids	Herb	Tubers, leaves, roots, flowers	Anthelmintic, allays bone disease, mumps, gout, chronic infection and leprosy, analgesic, anti-inflammation, used for poison for arrows	Gajalakshmi <i>et al.</i> (2011), Krug and Milliken (2008), Samten (2009), Sarkar <i>et al.</i> (2012), Wangchuk <i>et al.</i> (2013)
3	Lug-mig	Weak violet Aster	Asteraceae	<i>Aster flaccidus</i> Bunge	Phenylpropanoids [(7'R, 8S)-9'-lariciresinol-(alpha-methyl)-butanoate, 5,9-dimethoxyl-7-(alpha-methyl)-butanoxyl-phenyl-2E-propenol-(alpha-methyl)-butanoate], 2-oxo-isocostic acid, musaenoside, kaempferol-3-O-β-D-glucopyranoside, 1β,6α-dihydroxyeudesm-4(15)-ene, 6β-propionyloxy-1,10-dehydrofuranoeeremophil-9-on, indaconitine, lupeol, liquiritigenin, apigenin, tricine, coniferyl aldehyde, friedelin, apigenin, p-hydroxybenzoic acid, 2-O-β-D-glucopyranoside-vicodiol, 10-O-β-D-glucopyranoside-oplopanone	Herb	Whole plant including flowers, roots, aerial part	Useful for treating affliction by evil spirits, antitumour, bronchitis, cramps, common cold and relieves pain	Gan <i>et al.</i> (2006), Gangwar <i>et al.</i> (2010), Krug and Milliken (2008), Liu <i>et al.</i> (2010), Miao <i>et al.</i> (2012), Samten (2009)

(Continued)

Table 1.3 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical/Phytochemical	Habit	Part used	Uses/Medicinal properties	References
4	Pangram	Red knotweed or Large leaved knotweed	<i>Polygonaceae</i>	<i>Bistorta macrophylla</i> (D. Don) Soják	(-)-epicatechin-5-O-beta-D-glucopyranoside, (+)-catechin-7-O-beta-D-glucopyranoside, 1-(3-O-beta-D-glucopyranosyl 4,5-dihydroxy-phenyl)-ethanone (-)-epicatechin, chlorogenic acid, gallic acid, anthraquinone glucoside 1-hydroxy-8-methoxy-3-methyl-6-O-β-D-glucopyranosyl-anthraquinone, 1, 6-dihydroxy- 8-methoxy-3-methyl-anthraquinone, quercitrin, kaempferol-3-O-α-rhamnoside, arborinol , β-sitosterol, β-sitosterol-D-glucoside	Herb	Rhizome, leaves	Allays diarrhoea, stomach pain, dysentery, wound healing	Krug and Milliken (2008), Phondani (2011), Samten (2009), Semwal <i>et al.</i> (2010), Wang <i>et al.</i> (2004)
5	Yakima	Gold saxifrage	<i>Saxifragaceae</i>	<i>Chrysosplenium nudicaule</i> Bunge	Triterpenoids, flavonol glycosides, volatile oil, hexadecanoic acid, ethyl ester; dibutyl phthate, (Z, Z, Z)-9, 12, 15-octadecatrienoic acid, ethyl ester, 2, 6-butylated hydroxytoluene, and 5, 6, 7, 7a-tetrahydro 4, 7a-trimethyl-2(4H)-benzofuranone	Herb	Whole plant including aerial parts	Anti-inflammatory and cholagogue; for headaches, gall bladder problem	Krug and Milliken (2008), Samten (2009), Yanli (2006), Yunshang <i>et al.</i> (2004)

6	Bashaka	Primrose, Climbing corydalis	Papaveraceae	<i>Corydalis crispa</i> Prain	Isoquinoline alkaloids (protopine, 13-oxoprotopine, 13-oxocryptopine, stylopine, coreximine, rheagenine, ochrobirine, sibiricine, bicuculline)	Herb	Whole plant including roots	Used as tonic, promotes vigour, treatment of infections in the blood, liver and bile, antiplasmodial, antimicrobial, anti-inflammatory	Krug and Milliken (2008), Samten (2009), Wangchuk <i>et al.</i> (2012a)
7	Re-skön	Corydalis	Papaveraceae	<i>Corydalis dubia</i> Prain	Dubamine, and isoquinoline alkaloids (cheilanthifoline sclerine, protopine, capnoidine, bicuculline, hydrastine, corydecumbine)	Herb	Whole plant including roots	Impure blood detoxifier and neuralgia, treatment of fever arising from affections of heart, lung, pancreas and kidney, antiplasmodial, antimicrobial, cytotoxicity and antiplasmodial activity	Krug and Milliken (2008), Samten (2009), Wangchuk <i>et al.</i> (2011), Wangchuk <i>et al.</i> (2012b)
8	Dbang-lag	Early Marsh Orchid	Orchidaceae	<i>Dactylorhiza hatagirea</i> (D. Don) Soó	Dactylorhins A-B-C-D-E, dactyloses A and B, lipids, glucoside	Herb	Tubers, roots	General tonic, promotes heat, dysentery, diarrhoea, chronic fever, cough, stomach ache, wounds, cuts, burns, fractures, general weakness, bone fracture,	Krug and Milliken (2008), Kizu <i>et al.</i> (1999), Pant and Rinchen (2012), Samten (2009)

(Continued)

Table 1.3 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical/Phytochemical	Habit	Part used	Uses/Medicinal properties	References
9	Bya-rgod-spos	Delphinium glaciale	Ranunculaceae	<i>Delphinium glaciale</i> Hook.f. & Thomson	Alkaloids	Herb	Aerial parts	For fever, loss of appetite, headache, dysentery, body swelling of wounds	Churyukanov (1986), Krug and Milliken (2008), Mashkovsky and Samten (2009)
10	Gongthogpa Tall Wormseed Mustard, Hawkweed-leaved Mustard, Wallflower		Brassicaceae	<i>Erysimum hieracifolium</i> L.f.	Glucosinolates (5-methylthiopentyl, (R)-5-methylsulphinylpentyl, 3-hydroxy-5-methylthiopentyl, 3-hydroxy-5-methylsulphinylpentyl, 3-hydroxy-5-methylsulphonylpentyl isothiocyanate, 3-hydroxypropyl isothiocyanate, erysinoside, helveticoside	Herb	Aerial parts including fruits, seeds	Useful for meat poisoning, lung problems and in reducing stress and insomnia	Daxenbichler <i>et al.</i> (1980), Kjær and Schuster (1970), Krug and Milliken (2008), Samten (2009)

11	Tseka	Fritillaria	Liliaceae	<i>Fritillaria delavayi</i> Franch.	Volatile oil, glycosides, sterol, triterpenes, polyoses, saponins, reducing compounds, quinones, flavonic glycosides, coumarins, isosteroidal alkaloids, delavine, delavinone, chuanbeinone, delafrinone, delafrine	Herb	Bulbs	Promotes vigour, counteract accumulation of fluids in joints, treatment of impotence, treatment of different lung diseases (bronchitis, tuberculosis, coughs), treatment of nervous system, antitussive and expectorant activity, anti-inflammatory	Krug and Milliken (2008), Maharjan <i>et al.</i> (2011), Saklani <i>et al.</i> (2011), Samten (2009)
12	Gangachung	Urn-shaped gentian.	Gentianaceae	<i>Gentiana urnula</i> Sm.	Iridoidal glycosides [gentiournosides A-C (<i>bis</i> -iridoidal glycosides), gentiournosides D-E (loganin)]	Herb	Entire plant including roots	Treat fever, dysentery and poisoning, antipyretic, treatment of thrombus, dysentery and sore throat	Krug and Milliken (2008), Liu <i>et al.</i> (1994), Samten (2009)
13	Parpata	Thinfruit Hypecoum	Papaveraceae	<i>Hypecoum leptocarpum</i> Hook. f. & Thomson	Alkaloids (leptocarpine, leptopine, leptopinine, leptopidine, leptopidinine), protopine, isohyperectine, oxohydrastinine (hypecoumine), cryptopine	Herb	Whole plant	Useful in treating common cough and cold, skin diseases, blood pressure and poisonings	Chen and Fang (1985), Krug and Milliken (2008), Samten (2009), Zhou <i>et al.</i> (1999)

(Continued)

Table 1.3 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical/Phytochemical	Habit	Part used	Uses/Medicinal properties	References
14	Ud-pel-sngon-po	<i>Himalayan Blue Poppy</i>	Papaveraceae	<i>Meconopsis simplicifolia</i> (D. Don) Walp.	Alkaloids (berberine, mecambridines)	Herb	Whole aerial part	Treat liver and lung inflammation and fever associated with cough and cold and malaria. Tétényi heals the blood, liver and the lung infections,	Krug and Milliken (2008), Samten (2009), Tétényi (2005), Wangchuk <i>et al.</i> (2011)
15	Pang poe	Spikenard	Caprifoliaceae	<i>Nardostachys jatamansi</i> (D. Don) DC. (= <i>Nardostachys grandiflora</i> DC.)	Pranocoumarin [E-2-methyl, 3-(5,9-dimethylbicyclo[4.3.0]nonen-9-yl)-2-propenoic acid and 2',2'-dimethyl-3'-methoxy-3',4'-dihydropyrancoumarin], sesquiterpenes, lignans, neo-lignans, coumarins, terpenoid ester (nardostachysin)	Herb	Whole plant (rhizomes, roots)	Used for its astringent, diuretic, digestive, carminative and laxative properties, as liver stimulant, antipyretic and tonic, antiseptic, high blood pressure, insomnia, antispasmodic, treatment of epilepsy, hysteria, convulsions, heart palpitations and round worm	Chatterjee <i>et al.</i> (2000), Chatterjee <i>et al.</i> (2005), Krug and Milliken (2008), Muliken and Crofton (2008), Samten (2009)

16	Tsher-sngon	Prickly Blue poppy	Papaveraceae	<i>Mecoropsis horridula</i> Hook. f. & Thomson	Alkaloids [8, 9- dihydroprotoxocryptochin, isoquinoline, protopine, (–)-reframoline, (–)- amurensinine], tricin, luteolin, apigenin, hydnocarpin, β-sitosterol, luteolin-7-O-β-D-glucopyranoside, kaempferol-3-O-β-D-glucopyranosyl(1→2)]-β-D-glucopyranoside, quercetin-3-O-β-D-galactopyranosyl(1→6)]-β-D-glucopyranoside, tricin-7-O-β-D-glucopyranoside, kaempferol-3-O-β-D-glucopyranoside, cinnamamide, N-p-hydroxyl-trans-coumaroyltyramine, quercetin, kaempferide, kaempferol, 3-(kaempferol-8-yl)-2,3-epoxyflavanone	Herb	Whole aerial part	Strong analgesic, strengthens bones and joints, treatment of headaches and fractures	Haifeng <i>et al.</i> (2009), Krug and Milliken (2008), Liu <i>et al.</i> (2014), Ming-Fang <i>et al.</i> (2009), Samten (2009)
17	Kutki, putishing	Figwort flower Picrorhiza	Plantaginaceae	<i>Neopicrorhiza scrophulariiflora</i> (Pennell) D.Y. Hong	Phenylpropanoid glycosides (scrophulosides A and B), androsin, picroside I, non-glycosidic iridoids, picrocins (D, E, F, G), iridoid glycosides (picrosides A and B)	Herb	Stolons, rhizomes, roots	Cold, cough and headache, also for problems related to bile, high blood pressure, sore throat, intestinal pain and conjunctivitis, fever	Kim <i>et al.</i> (2006), Krug and Milliken (2008), Rawal <i>et al.</i> (2009), Samten (2009), Wang <i>et al.</i> (2006)

(Continued)

Table 1.3 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical/Phytochemical	Habit	Part used	Uses/Medicinal properties	References
18	Drimug, muktsi	Tibetan Onosma	Boraginaceae	<i>Onosma hookeri</i> C.B. Clarke	Acetylshikonin, β , β -dimethylacrylshikonin, β , β -dimethylacrylalkannin or arnebin-1, shikonin, naphthaquinone pigments	Herb	Roots	To cure lung diseases, purify blood and stop vomiting of blood, also for tuberculosis, anti microbial, anticancer, antithrombotic, anti-inflammatory, wound healing, skin rashes	Krug and Milliken (2008), Ning and Cao (1996), Papageorgiou <i>et al.</i> (1999), Samten (2009)
19	Pangchidebo	-	Caprifoliaceae	<i>Pterocephalus hookeri</i> (C.B. Clarke) Diels	Loganin, triterpenoid saponins (hookerosides A–D), oleanolic and ursolic acids	Herb	Whole plant (roots)	Antidote, chronic inflammation, cold, cough	Krug and Milliken (2008), Samten (2009), Tian <i>et al.</i> (1993), Tan <i>et al.</i> (2011), Yang <i>et al.</i> (2006)

20	Domnag domthri	-	Plantaginaceae	<i>Veronica ciliata</i> Fisch.	Iridoid glycosides, benzoic acid	Herb	Entire plant including roots	Used as a substitute for bile, used to stop bleeding, wound treatment	Krug and Milliken (2008), Kun <i>et al.</i> (2003), Samten (2009)
21	A-bhi-sha, Xiao bai he	Dwarf lily	Liliaceae	<i>Lilium nanum</i> Klotzsch & Garcke	Not reported	Herb	Whole plant (bulbs as tonic)	Antidote and allays head injuries, heels bone fracture	Chen <i>et al.</i> (2000), Krug and Milliken (2008), Samten (2009)
22	Tsepara, lamichop	Bigflower Rhodiola	Crassulaceae	<i>Rhodiola crenulata</i> (Hook. f. & Thomson) H. Ohba	Salidroside (rhodioloside), rosavins, p-tyrosol, 2-Methyl-3-buten-2-ol, 3-Methyl-2-buten-1-ol, n-Octanol, geraniol, citronellol, myrtenol, linalool, 1-Octen-3-ol, pyrogallol, gallic acid, β -sitosterol, crenulatin, ellagic acid kaempferol,	Herb	Fleshy stems (rhizomes), roots	Alleviate depression, stimulation of nervous system, antioxidative	Krug and Milliken (2008), Qu <i>et al.</i> (2012), Samten (2009), Wang and Wang (1992)

Table 1.4 Medicinal plants from South Asia with potential for use as nutraceutical source and as functional food component.

No	Local name	English name	Plant Family	Scientific name	Nutraceutical /Phytochemical	Habit	Part used	Medicinal properties	References
1	Laasona	Garlic	Amaryllidaceae	<i>Allium sativum</i> L.	Saponins, sterols, tannins, proteins, carbohydrates, cardiac glycosides, sulphur compounds (trisulfide, di-2-propenyl; disulfide, di-2-propenyl; trisulfide, methyl 2-propenyl, diallyl disulfide)	Herb	Bulb and oil	Anticancer, antimicrobial, reduces blood pressure and blood cholesterol, antiviral, antifungal, anti-inflammatory, stimulant, carminative, antiseptic, anthelmintic, expectorant, diuretic, diaphoretic, diuretic, antisorbitic aphrodisiac, antiasthmatic, pulmonary diseases	Douiri <i>et al.</i> (2013), Kadam <i>et al.</i> (2013), Mikail (2010)
2	Ghee Kunwar, Ghritkumari	Aloe	Xanthorrhoeaceae	<i>Aloe vera</i> (L.) Burm. f.	Barbaloin (10- β -D-glucopyranosyl-1,8-dihydroxy-3-(hydroxymethyl)-9(10H)-anthracenone), tannins, flavonoids, lectins, terpenoids, carbohydrates, alkaloids, saponin, fatty acids, cholesterol, anthraquinones, chromones, mono and polysaccharides, sterols (lupeol, campesterol, and β -sitosterol), salicylic acid, organic acids, enzymes, saponins, vitamins, minerals, anthrone, aloe emodin, aloetic acid, choline, choline salicylate, saponinins	Herb	Leaves, stems	Laxative, anti-helminthic, skin disorders, , anti-inflammatory, cathartic, antiviral, wound healing, burns, antimicrobial, anticancer, antioxidant activity, dysentery, diarrhoea	Basu <i>et al.</i> (2007), Joseph and Raj (2010), Patel <i>et al.</i> (2012), Raphael (2012)

3	Balsana, Dendhu	St. John's wort	Hypericaceae	<i>Hypericum perforatum</i> L.	Dianthrone derivatives (hypericin, pseudohypericin, protohypericin), phloroglucinol derivatives (hyperforin, furohyperforin, adhyperforin), flavonoids (hyperoside, quercetin, quercetrin, rutin, biapigenin, kaempferol), flavonols (catechins), xanthones, n-Alkanols, Monoterpenes (α -pinene, β -Pinene, limonene), sesquiterpenes (caryophyllene, humulene)	Herb	Leaves, flowers	Analgesic, anti-viral, anti-censor, antidepressant and antiviral activity, treatment of traumas, burns, scabs and ulcers	Basu <i>et al.</i> (2007), Vatikuti and Ciddi (2005),
4	Shimla mirch	hot peppers, chili pepper	Solanaceae	<i>Capsicum annuum</i> L.	Capsaicin, carotenoids [capsanthin, zeaxanthin, provitamin A carotenoids : β -cryptoxanthin, α -carotene, β -carotene], flavonoids (quercetin and luteolin), total soluble reducing equivalents, phenolic acids, ascorbic acid	Herb	Fruit	Anticancer, anti-inflammatory, antiapoptotic, analgesic, carminative, rubefacient, anti oxidant, hypoglycemic, antifungal, antimicrobial, used as carminative, an appetiser and a stomachic. treatment of rheumatism, lumbago, neuralgia, and mental disorders	Howard <i>et al.</i> (2000), Laroche (2007), Sunil <i>et al.</i> (2012)

(Continued)

Table 1.4 (Continued)

No	Local name	English name	Plant Family	Scientific name	Nutraceutical /Phytochemical	Habit	Part used	Medicinal properties	References
5	Kali mirch	Black pepper	Piperaceae	<i>Piper nigrum</i> L.	Piperine, alkaloids, coumarins, phenols, tannins, β -Elemene, tricyclo[6.2.1.0(4,11)]undec-5-ene, 1,5,9-trimethyl- (isocaryophyllene-II), β -caryophyllene, (+)- β -Selinene, eremophilene, nonacosane, methyl hexadecanoate, ethyl hexadecanoate, methyl 14-methyl heptadecanoate, methyl trans-8-octadecanoate, ethyl cis-9-octadecanoate, hexadecanoic acid, octadecanoic acid	Herb	Fruit	Helps in digestion, antimicrobial, antiapoptotic, antibacterial, anti-Colon toxin, antidepressant, antifungal, anti-diarrhoeal, anti-inflammatory, antimutagenic, anti-metastatic activity, antioxidative, antirheumatic, antispasmodic, antispermatogenic, antitumour, antithyroid, ciprofloxacin potentiator, cold extremities, gastric ailments, hepatoprotective, insecticidal activity, intermittent fever, larvicidal activity	Ahmad <i>et al.</i> (2012), Krishnaswamy (2008), Siddiqui <i>et al.</i> (2005), Trivedi <i>et al.</i> (2011)

6	<i>Kala-dhatura</i>	Thorn apple, Downy datura	Solanaceae	<i>Datura metel</i> L.	Tropane alkaloids, flavonoids, glycosides, phenols, tannins, sterols saponins	Herb	All parts	In treatment of heart ailments, antibacterial, antifungal, asthma, cough, convulsion, insanity, anaesthetic, antispasmodic, bronchodilator and as hallucinogenic	Akharaiyi (2011), Dahanukar <i>et al.</i> (2000), Kiruthika and Sornaraj (2011)
7	Vilayati pudina	peppermint	Lamiaceae	<i>Mentha × piperita</i> L.	Menthol (Monoterpene), alkaloids, flavonoids, steroids, tannins, phenols	Herb	Leaves	Topical pain reliever & antipyretic, antibacterial, common cold, musculoskeletal pain, to calm pruritus and relieve irritation, anti-inflammation	Galeotti <i>et al.</i> (2002), Herro and Jacob (2010), Pramila <i>et al.</i> (2012), Sujana <i>et al.</i> (2013)
8	-	Scots pine (Pine oil)	Pinaceae	<i>Pinus sylvestris</i> L.	Borneol (Monoterpenes: α-pinene, car-3-ene, β-pinene, β-phellandrene, camphene, myrcene, limonene, terpinolene), glycerol, 3'-O-methylcatechin, phenolic compounds	Tree	Needles (leaves)	Disinfectant, antibacterial, antifungal, antiviral, antiseptic (pulmonary, urinary, hepatic), antineuralgic, cholagogue, choloretic, diuretic, expectorant, hypertensive, cough, catarrh	Basu <i>et al.</i> (2007), Maciag <i>et al.</i> (2007), Pan and Lundgren (1996)

(Continued)