

Advanced Structured Materials

Dilipkumar Pal

Amit Kumar Nayak *Editors*

Bioactive Natural Products for Pharmaceutical Applications

 Springer

Editors

Dilipkumar Pal

Institute of Pharmaceutical Sciences
Guru Ghasidas Vishwavidyalaya
(A Central University)
Bilaspur, Chhattisgarh, India

Amit Kumar Nayak

Department of Pharmaceutics
Seemanta Institute of Pharmaceutical
Science
Mayurbhanj, Odisha, India

ISSN 1869-8433

Advanced Structured Materials

ISBN 978-3-030-54026-5

<https://doi.org/10.1007/978-3-030-54027-2>

ISSN 1869-8441 (electronic)

ISBN 978-3-030-54027-2 (eBook)

© The Editor(s) (if applicable) and The Author(s), under exclusive license to Springer Nature Switzerland AG 2021

This work is subject to copyright. All rights are solely and exclusively licensed by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, expressed or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Contents

1	Elicitor Signal Transduction Leading to the Production of Plant Secondary Metabolites	1
	Supriyo Saha and Dilipkumar Pal	
1.1	Introduction	2
1.2	Types of Plant Metabolites	3
1.3	Elicitor and Its Type	5
1.4	Application of Elicitors on the Production of Secondary Metabolites	6
1.4.1	Production of Secondary Metabolites Using Abiotic Elicitors	6
1.4.2	Production of Secondary Metabolites Using Biotic Elicitors	16
1.4.3	Production of Secondary Metabolites Using Abiotic-Biotic Dual Elicitors	24
1.5	Conclusion	31
	References	36
2	An Introduction to Bioactive Natural Products and General Applications	41
	Tijjani Ahmadu and Khairulmazmi Ahmad	
2.1	Introduction	42
2.2	Bioactive Natural Compounds: Distribution and Geographical Sources	44
2.3	Phytochemistry of Bioactive Natural Compounds	64
2.4	General Applications of Bioactive Natural Products	71
2.4.1	Traditional Medicine	71
2.4.2	Plant Based Pesticides and Agrochemical Industry	72
2.4.3	Pharmacological Applications in Drugs Development	74
2.4.4	Cosmetics	75

2.5	Delivery Technology for Bioactive Natural Products	76
2.5.1	Components of Nanoemulsion	77
2.6	Conclusions	78
	References	78
3	Plant Polysaccharides in Pharmaceutical Applications	93
	Amit Kumar Nayak, Md Saquib Hasnain, Amal Kumar Dhara, and Dilipkumar Pal	
3.1	Introduction	94
3.2	Classifications and Sources of Plant Polysaccharides	95
3.2.1	Plant Gums	95
3.2.2	Plant Mucilages	95
3.2.3	Plant Starches	97
3.3	Applications of Plant Polysaccharides in Pharmaceutical Dosage Forms	98
3.3.1	Emulsions	98
3.3.2	Suspensions	100
3.3.3	Tablets	101
3.3.4	Capsules	104
3.3.5	Beads	104
3.3.6	Microparticles	108
3.3.7	Nanoparticles	110
3.3.8	Liposomes	112
3.3.9	Transdermal Formulations	112
3.3.10	Buccal Formulations	113
3.3.11	Nasal Formulations	115
3.3.12	Ophthalmic Formulations	116
3.3.13	Colon-Targeting Formulations	116
3.3.14	Dental Formulations	117
3.4	Conclusion	118
	References	118
4	The Role of Phytochemicals in Cancer Prevention and Cure	127
	Braganza Cilwyn, Soundararajan Vijayarathna, Shanmugapriya, Rameshwar Naidu Jegathambigai, Subramaniam Sreeramanan, Yeng Chen, and Sreenivasan Sasidharan	
4.1	Introduction	128
4.2	Role of Phytochemicals in Cancer Prevention via Antioxidant Activity	129
4.3	Role of Phytochemicals in Cancer Prevention Via Pro-Oxidant Activity	130
4.4	Role of Phytochemicals in Cancer Cure Via Apoptosis Induction	132
4.5	Role of Phytochemicals in Cancer Cure Via Necrosis Induction	135

4.6	Role of Phytochemicals in Cancer Cure Via Autophagy Induction	138
4.7	Role of Phytochemicals in Cancer Cure Via Regulation of miRNA	139
4.8	Conclusions	144
	References	144
5	Role of Stress and Defense in Plant Secondary Metabolites Production	151
	Humberto Aguirre-Becerra, Ma Cristina Vazquez-Hernandez, Diana Saenz de la O, Aurora Alvarado-Mariana, Ramon G. Guevara-Gonzalez, Juan Fernando Garcia-Trejo, and Ana Angélica Feregrino-Perez	
5.1	Introduction	152
5.2	Abiotic Stress	153
5.2.1	Electromagnetic Sources	154
5.2.2	Acoustic Emissions	160
5.2.3	Nanoparticles	166
5.2.4	Metals and Salt Metals	172
5.2.5	Volatile Organic Compounds	173
5.2.6	Nutrient Deficiency	174
5.3	Biotic Stress	176
5.3.1	Bacteria and Viruses	176
5.3.2	Fungi	177
5.3.3	Phytohormones	179
5.3.4	miRNA	179
5.4	Future Perspectives	182
	References	184
	Natural Compounds Extracted from Medicinal Plants and Their Immunomodulatory Activities	197
	Vinod Kumar Gurjar and Dilipkumar Pal	
6.1	Introduction	199
6.2	Immunomodulators	200
6.2.1	Plant-Derived Bioactive as Immunomodulators	214
6.2.2	Classification of Immunomodulators	220
6.2.3	Low Molecular Weight Immunomodulators	222
6.2.4	High Molecular Weight Immunomodulators	223
6.2.5	High Throughput Screening (HTS) for Plants and Bioactive Compounds	226
6.3	Immunomodulatory Plants	235
6.3.1	<i>Acacia Catechu/Senegalia Catechu</i> (Family: (Fabaceae)).	235
6.3.2	<i>Acorus Calamus</i> (Family: Acoraceae)	236

6.3.3	<i>Allium Sativum</i> (Family: Amaryllidaceae)	237
6.3.4	<i>Andrographis Paniculate</i> (Family: Acanthaceae)	238
6.3.5	<i>Azadirachta Indica</i> (Family: Meliaceae)	239
6.3.6	<i>Boerhavia Diffusa</i> (Family: Nyctaginaceae)	240
6.3.7	<i>Clerodendrum Splendens</i> (Family: Lamiaceae)	241
6.3.8	<i>Curcuma Longa</i> (Family: Zingiberaceae)	241
6.3.9	<i>Cynodon Dactylon</i> (Family: Poaceae)	242
6.3.10	<i>Ficus Benghalensis</i> (Family: Moraceae)	242
6.3.11	<i>Glycyrrhiza Uralensis</i> Fisch (Family: Fabaceae)	242
6.3.12	<i>Murraya Koenigii</i> (Family: Rutaceae)	243
6.3.13	<i>Ocimum Sanctum</i> (Family: Lamiaceae)	243
6.3.14	<i>Panax Ginseng</i> (Family: Araliaceae)	244
6.3.15	<i>Picrorhiza Scrophulariiflora</i> (Family: Scrophulariaceae)	245
6.3.16	<i>Syzygium Aromaticum</i> (Family: Myrtaceae)	246
6.3.17	<i>Terminalia Arjuna</i> (Family: Combretaceae)	246
6.3.18	<i>Tinospora Cordifolia</i> (Family: Menispermaceae)	247
6.4	Conclusion and Future Perspective	247
	References	248
7	Antibacterial and Antifungal Plant Metabolites from the Tropical Medicinal Plants	263
	Luiz Everson da Silva, Camila Confortin, and Mallappa Kumara Swamy	
7.1	Introduction	264
7.2	Target for Antimicrobial Agents and Resistance Mechanisms	265
7.3	Tropical Plants with Relevant Antibacterial Activities	269
7.4	Synergisms of Phytochemicals and Conventional Antimicrobial Drugs	270
7.5	Antibiotic Resistance—Combination Therapy (Antibiotic + Phytochemical/Plant Extract)	273
7.6	Essential Oils with Antimicrobial Activity from Tropical Medicinal Plants	275
7.7	Plant-Derived Natural Products with Antifungal Activity	276
7.8	Fungal Resistance and Modulatory Potential of Extracts, Fractions and Essential Oil from Tropical Medicinal Species	278
7.9	Conclusions and Future Prospects	280
	References	281

8	Capillary Electrophoresis: A New Evolutionary Platform of Plant Secondary Metabolites	287
	Dilipkumar Pal and Souvik Mukherjee	
8.1	Introduction	288
8.1.1	Principle of the Technique	289
8.1.2	Nature of S_{pt}	290
8.2	Factors Effecting S_{pt}	291
8.2.1	I.P	291
8.2.2	Esp	292
8.3	Instrumentation	292
8.4	Difference Between C.e and Others S_{pt} Technique	293
8.5	Application	293
8.5.1	Quaternary Alkaloidal Compounds	295
8.5.2	Flavonoid	295
8.5.3	Terpenoids	297
8.5.4	Coumarin Derivatives	299
8.5.5	Quinones	301
8.5.6	Polyamine	302
8.6	Capillary Electrophoresis Non Aquas (C.e _N) for Bioactive Compound	303
8.7	Online C.e Concentration	303
8.8	C.e Versus C.e _{MS}	303
8.9	Conclusion	304
	References	305
9	Camptothecin: Occurrence, Chemistry and Mode of Action	311
	Mallappa Kumara Swamy, Boregowda Purushotham, and Uma Rani Sinniah	
9.1	Introduction	311
9.2	Camptothecin Discovery and Its Chemistry	313
9.3	Natural Sources of Camptothecin	316
9.3.1	Camptothecin from Plants	316
9.3.2	Camptothecin from Endophytes	317
9.4	Mode of Action of Camptothecin	320
9.5	Conclusions	322
	References	322
10	Secondary Metabolites from Plant Sources	329
	Chandi Charan Kandar	
10.1	Introduction	330
10.1.1	Comparison of Secondary Metabolites with Primary Metabolites	332
10.2	Alkaloids	333
10.3	Saponins	336

10.4	Phenolic Compounds	34
10.4.1	Simple Phenolics	34
10.4.2	Coumarins	34
10.4.3	Flavonoids	34
10.4.4	Chromones and Xanthenes	34
10.4.5	Tannins	34
10.4.6	Stilbenes	35
10.4.7	Lignans	35
10.5	Terpenes and Terpenoids	35
10.5.1	Hemiterpenes	35
10.5.2	Monoterpenes	35
10.5.3	Sesquiterpenes	35
10.5.4	Diterpenes	35
10.5.5	Sesterterpenes	35
10.5.6	Triterpenes	36
10.5.7	Sesquaterpenes	36
10.5.8	Tetraterpenes	36
10.5.9	Polyterpenes	36
10.6	Carbohydrates	36
10.7	Lipids (Fixed Oil, Fats, Waxes and Phospholipids)	36
10.7.1	Fixed Oils	36
10.7.2	Waxes	36
10.7.3	Phospholipids	36
10.7.4	Fatty Acids	37
10.8	Glycosides	37
10.9	Conclusion	37
	References	37
11	Pharmaceutical and Therapeutic Applications of Fenugreek Gum	379
	Purusottam Mishra, Amit Kumar Srivastava, Tara Chand Yadav, Vikas Pruthi, and Ramasare Prasad	
11.1	Introduction	379
11.1.1	Natural Gums	380
11.1.2	Fenugreek Gum	381
11.1.3	Chemical Composition of Fenugreek Seed	382
11.2	Galactomannan: The Chief Constituent of Fenugreek Gum	383
11.2.1	Structural Properties	383
11.2.2	Physicochemical Properties	383
11.2.3	Biosafety and Toxicological Studies	386
11.3	Drug Delivery Applications of Fenugreek Gum	387
11.3.1	Ophthalmic Drug Delivery	387
11.3.2	Gastroretentive Drug Delivery	388

11.3.3	Colon Drug Delivery	389
11.3.4	Vaginal Drug Delivery	389
11.3.5	Aerogels	390
11.4	Fenugreek Gum as a Pharmaceutical Excipient	391
11.4.1	Retarding Agent	391
11.4.2	Super-disintegrating Agent	391
11.4.3	Mucoadhesive and Bioadhesive Agent	392
11.4.4	Matrix Forming Agent	393
11.4.5	Bioavailability Enhancer	394
11.4.6	Microencapsulation of Probiotic	394
11.5	Therapeutic Applications of Fenugreek Gum	395
11.5.1	Antidiabetic Property	395
11.5.2	Hypolipidemic Potential and Role in Fat Accumulation	399
11.5.3	Anti-inflammatory Potential	400
11.5.4	Anticancer Potential	400
11.5.5	Hepatoprotective Potential	401
11.6	Conclusion and Future Perspectives	401
	References	402
12	Antimicrobial Application Potential of Phytoconstituents from Turmeric and Garlic	409
	Shiv Kumar Prajapati, Gaurav Mishra, Akanksha Malaiya, Ankit Jain, Nishi Mody, and Ashok M. Raichur	
12.1	Introduction	410
12.2	Turmeric	411
12.2.1	Phytochemistry of Turmeric	412
12.2.2	Antimicrobial Mechanism of Curcuminoids	412
12.3	Garlic	414
12.3.1	Phytochemistry of Garlic	415
12.3.2	Antimicrobial Mechanism of Phytochemicals of Garlic	416
12.4	Applications	418
12.4.1	Antimicrobial Applications of Phytoconstituents from Turmeric	418
12.4.2	Antimicrobial Applications of Phytoconstituents of Garlic	419
12.4.3	Nanoformulation Based Applications	421
12.4.4	Nanoparticles	422
12.5	Conclusion	428
	References	429

13 Carvacrol (<i>Origanum vulgare</i>): Therapeutic Properties and Molecular Mechanisms	437
Arijit Mondal, Sankhadip Bose, Kamalika Mazumder, and Ritu Khanra	
13.1 Introduction	438
13.2 Literature Search Methodology	439
13.3 Extraction and Isolation of Carvacrol	439
13.4 Biosynthesis of Carvacrol	440
13.5 Physical Properties	441
13.6 Metabolism and Excretion of Carvacrol	441
13.7 Acute Toxicity of Carvacrol	443
13.8 Antioxidant Activity	444
13.9 Antimicrobial Effect	445
13.10 Anticancer Effect of Carvacrol and the Related Mechanism of Actions	447
13.11 Carvacrol Derivatives with Pharmacological Activities	452
13.12 Conclusion and Future Perspectives	455
References	456
14 Pharmaceutical Application of Bio-actives from <i>Alstonia</i> Genus: Current Findings and Future Directions	463
Atish T. Paul, Ginson George, Nisha Yadav, Arjun Jeswani, and Prashant S. Auti	
14.1 Introduction	464
14.2 Botanical Description	466
14.3 Phytochemistry and Pharmacological Activities	466
14.3.1 Phytochemistry and Pharmacological Activities of <i>A. Scholaris</i>	466
14.3.2 Phytochemistry and Pharmacological Activities of <i>A. Macrophylla</i>	489
14.3.3 Phytochemistry and Pharmacological Activities of <i>A. Angustifolia</i>	498
14.3.4 Phytochemistry and Pharmacological Activities of <i>A. Boonei</i>	501
14.3.5 Phytochemistry and Pharmacological Activities of <i>A. Venenata</i>	505
14.3.6 Phytochemistry and Pharmacological Activities of <i>A. Yunnanensis</i>	508
14.3.7 Phytochemistry and Pharmacological Activities of <i>A. Spatulata</i>	511
14.3.8 Phytochemistry and Pharmacological Activities of <i>A. Rupestris</i>	513
14.3.9 Phytochemistry and Pharmacological Activities of <i>A. Rostrata</i>	515

14.3.10	Phytochemistry and Pharmacological Activities of <i>A. Pneumatophora</i>	516
14.3.11	Phytochemistry and Pharmacological Activities of <i>A. Penangiana</i>	518
14.3.12	Phytochemistry and Pharmacological Activities of <i>A. Mairei</i>	519
14.3.13	Phytochemistry and Pharmacological Activities of <i>A. Congensis</i>	519
14.3.14	Phytochemistry and Pharmacological Activities of <i>A. Angustiloba</i>	519
14.3.15	Phytochemistry and Pharmacological Activities of <i>A. Actinophylla</i>	522
14.4	Pharmacokinetics and Metabolite Identification	522
14.5	Intellectual Property Rights (IPR) Values of <i>Alstonia</i> Genus	524
14.6	Conclusion and Future Perspective	528
	References	529
15	Role of Natural Bio-active Compounds as Antidiabetic Agents	535
	Sandra N. Jimenez-Garcia, Lina Garcia-Mier, Moises A. Vazquez-Cruz, Xochitl S. Ramirez-Gomez, Ramon G. Guevara-Gonzalez, Juan Fernando Garcia-Trejo, and Ana Angélica Feregrino-Perez	
15.1	Introduction	536
15.2	Mechanisms of Action of Antidiabetic Substances	537
15.3	α -Amilase Inhibitors	538
15.4	α -Glucosidase Inhibition	541
15.5	Activation of Glucose Transporters	545
15.6	Activation of Insulin Secretion	547
15.7	Future Perspective and Conclusion	553
	References	553
16	An Overview of the Bioactivities of Gedunin	563
	Yong Sze Ong, Kooi Yeong Khaw, Loh Teng-Hern Tan, Peng-Nian Yew, Kai-Boon Tan, Wei Hsum Yap, Siah Ying Tang, Liang Ee Low, Learn-Han Lee, and Bey-Hing Goh	
16.1	Introduction	564
16.2	Bioactivities of Gedunin	565
16.2.1	Anti-Cancer Properties of Gedunin	565
16.2.2	Anti-neurological Disorders and Cryoprotective Effects of Gedunin	577
16.2.3	Anti-inflammatory Effects of Gedunin	578
16.2.4	Anti-parasitic Effects of Gedunin and Derivatives	579

16.2.5	Antimicrobial Effects of Gedunin and Derivatives . . .	580
16.2.6	Insect Growth Inhibition Effects of Gedunin and Derivatives	580
16.3	Commercial Potential of Gedunin	581
16.4	Conclusion and Gaps of Knowledge	581
	References	582
17	Biological Activities of Marine Products and Nutritional Importance	587
	Dilipkumar Pal and Khushboo Raj	
17.1	Introduction	588
17.2	Marine Organisms: Source of Nutrition	588
17.2.1	Proteins	588
17.2.2	Lipids and Fatty Acids	589
17.2.3	Sterols	591
17.2.4	Carbohydrates	594
17.2.5	Antioxidants	596
17.2.6	Vitamins and Minerals	597
17.3	Marine Sources for Pharmacological Effect	598
17.3.1	Anti-cancer	598
17.3.2	Anti-Cardiovascular Effect	603
17.3.3	Anti-coagulant Activity	604
17.3.4	Anti-obesity	604
17.3.5	Bone Growth and Healing	606
17.3.6	Anti-inflammatory Activities	607
17.3.7	Neuroprotective Agents	608
17.4	Summary	609
17.5	Conclusion	610
	References	611
18	Cardiac Tissue Engineering: A Role for Natural Biomaterials	617
	Pallavi Pushp and Mukesh Kumar Gupta	
18.1	Introduction	618
18.2	Approaches for CTE Using Natural Biomaterials, Cell-Sheet and Decellularized Tissues	619
18.3	Natural Biomaterials Used in 'Classical' CTE	620
18.3.1	Collagen I	621
18.3.2	Gelatin	623
18.3.3	Fibrin	624
18.3.4	Alginate	624
18.3.5	Chitosan	625
18.3.6	Fibroin/Silk Fibroin	625
18.3.7	Decellularized ECM	627
18.3.8	Other Natural Biomaterials	627

18.4	Enhancing the Elasticity and Electrical Conductivity of Natural Biomaterials for CTE	629
18.5	Enhancing the Mechanical Properties of Natural Polymers for CTE	630
18.6	Natural Biomaterials as Coating Materials	630
18.7	Types of Scaffolds for CTE from Natural Biomaterials	631
18.7.1	Fibrous Scaffolds	631
18.7.2	Porous Scaffolds/sponges	632
18.7.3	Hydrogels	632
18.7.4	Bio-Fabricated/Micro-Fabricated Scaffolds	633
18.8	Conclusion and Future Direction	634
	References	634
19	The Importance of Natural Products in Cosmetics	643
	Nagarjuna Reddy Desam and Abdul Jabbar Al-Rajab	
19.1	Introduction	644
19.2	Background	645
19.3	From Past to Future	647
19.4	Source of Natural Products	647
19.5	Extraction and Isolation of Natural Products or Essential Oils	648
19.6	Plants-Derived Cosmetics and Cosmeceuticals	648
19.6.1	Manufacture of Plant-Derived Cosmetics and Cosmeceuticals	649
19.6.2	Substances of Plant-Based Cosmetics and Cosmeceuticals	651
19.7	Applications of Natural Products in Cosmetics	662
19.7.1	Natural Products as Skin Care Agents	662
19.7.2	Natural Products as Hair Care Agents	667
19.7.3	Essential Oils Used as Cosmetics	669
19.8	New Trends in Cosmetics (Plant Origin of By-Products)	672
19.8.1	By-Products from Citrus Fruits	673
19.8.2	By-Products from Tomato and Olive	674
19.8.3	By-Products Processing from Coffee	674
19.9	Future Prospects and Conclusions	675
	References	676
20	Encapsulation of Bioactive Compound and Its Therapeutic Potential	687
	Lalduhsanga Pachuau, Laldinchhana, Probin Kumar Roy, James H. Zothantluanga, Supratim Ray, and Sanjib Das	
20.1	Introduction	688
20.2	Rationale for Encapsulation of Bioactive Compounds	690

20.3	Encapsulation of Bioactive Compounds	691
20.3.1	Microencapsulation	691
20.3.2	Nano-based Encapsulation Platforms for Bioactive Compounds	694
20.4	Conclusion	705
	References	705
21	Tannins and Polyphenols Extracted from Natural Plants and Their Versatile Application	715
	Suvadeep Mal and Dilipkumar Pal	
21.1	Introduction	716
21.2	Tannin Occurrence: Plants Containing Tannins	717
21.3	Classification of Tannins	723
21.3.1	Gallotannins	723
21.3.2	Ellagitannins	724
21.3.3	Condensed Tannins	724
21.3.4	Complex Tannins	725
21.4	Biosynthetic Pathways of Tannins	726
21.4.1	Biosynthesis of Hydrolysable Tannins	727
21.4.2	Biosynthesis of Condensed and Complex Tannins	728
21.5	Extraction Process of Tannins	731
21.6	Physical and Chemical Properties of Tannins	732
21.7	Chemical Tests of Tannins	733
21.7.1	Qualitative Tests	733
21.7.2	Quantitative Tests	735
21.8	Activities of Tannins	736
21.8.1	Anti-oxidant Properties	736
21.8.2	Anti-microbial Properties	738
21.9	Anti-viral Properties	738
21.9.1	Cardioprotective Activity	739
21.9.2	Anti-histaminic Property	740
21.9.3	Cytotoxic and Anticancer Activity	740
21.9.4	Anti-diabetic Property	743
21.9.5	Anti-obesity Action	744
21.9.6	Anti-inflammatory Action	744
21.9.7	Anti-aging Properties	745
21.9.8	Other Therapeutic Activities of Tannins	745
21.10	Tannins in Industry	746
21.11	Tannins in Cosmeceuticals	746
21.12	Tannins in Nutraceuticals	747
21.13	Conclusion	748
	References	748

22	Piperine: Sources, Properties, Applications, and Biotechnological Production	759
	Neetu Sachan, Dilipkumar Pal, and Phool Chandra	
22.1	Introduction	760
22.2	Biosynthesis of Piperine	760
22.3	Extraction Techniques	760
22.4	Effect on Heart	760
22.5	Effect on Pentobarbitone Sleeping Time	762
22.6	Bioavailability of Drugs	763
22.7	Effect on Enzymes	763
22.8	Effects on Antioxidant Pathways in Tissues from Diabetic Rats	764
22.9	Effect on the CNS	765
22.10	Effect on Acute Kidney Injury	766
22.11	Anticonvulsant Mechanisms of Piperine	767
22.12	Immunomodulatory and Antitumor Activity	768
22.13	Larvicidal Effects	769
22.14	Inhibits B Lymphocyte Activation and Effector Functions	769
22.15	The Anti-tumor Effectiveness and Mechanisms Accompanied with the Combination of Docetaxel-Piperine	769
22.16	Allergic Encephalomyelitis	770
22.17	Memory Enhancer and Restoration of Myelin Damage	770
22.18	Effect on Carbamazepine Metabolism	770
22.19	Bioenhancer Effects	773
22.20	Ayurvedic Formulations	773
22.21	Death of Cerebellar Granule Neurons Induced by Piperine is Distinct from that Induced by Low Potassium Medium	775
22.22	KV Channel as Therapeutic Target for Prostate Cancer Treatment	776
22.23	Piperine Impairs the Migration and T Cell-Activating Function of Dendritic Cells	776
22.24	Piperine-Laden Nanoparticles with Increased Dissolving and Improved Bioavailability for Controlling Epilepsy	780
22.25	In Vitro Cytotoxic and In Silico Activity	782
22.26	Conclusion	783
	References	784
23	Protein and Enzymes Isolated from Plant Sources and Their Utilization in Pharmaceutical Field	793
	Om Prakash Panda, Sitansu Sekhar Nanda, Dong Kee Yi, Dilipkumar Pal, and Souvik Mukherjee	
23.1	Introduction	794
23.1.1	Classification of p^R_t	794
23.1.2	Elemental Composition of Proteins	796

	23.1.3	Classification A_m^a	798
	23.1.4	Properties of p_t^R	799
23.2		p_t^R Sources: Animals and P_T^I	802
23.3		Some Important p_t^R , Their Characteristics and Uses	804
	23.3.1	Soybean	804
	23.3.2	Wheat	805
	23.3.3	Corn Zein	805
	23.3.4	Pea p_t^R	806
	23.3.5	Rice p_t^R	806
	23.3.6	Sunflower p_t^R	806
23.4		Isolation of p_t^R	807
	23.4.1	Selective Precipitation Methods	807
	23.4.2	Isoionic Precipitation	807
	23.4.3	Reversed-Phase High-Performance Liquid Chromatography (RP-HPLC)	808
	23.4.4	Mass Spectrometry of p_t^R	808
23.5		Application of p_t^R	809
23.6		Introduction of E_m^Z	809
	23.6.1	Nomenclature and Classification of E_m^Z	809
	23.6.2	Chemical Nature and Properties of E_m^Z	810
	23.6.3	Mechanism of E_m^Z Action	811
	23.6.4	Important Industrial E_m^Z and Their Sources	811
	23.6.5	E_m^Z Derived from P_T^I Sources	813
23.7		Pharmaceutical Applications	815
23.8		Conclusion	816
		References	816
24		Advances and Perspectives of Gamma-Aminobutyric Acid as a Bioactive Compound in Food	819
		Priti Jain and Mangesh S. Ghodke	
	24.1	Introduction	819
		24.1.1 Why is GABA Important?	821
		24.1.2 Alternative Synthetic Methods of GABA	821
	24.2	Pharmaceutical Properties of GABA	823
		24.2.1 Anti-Hypertensive Effect of GABA	823
		24.2.2 GABA as Neuroprotective Compound and for Neurological Disorders	824
		24.2.3 GABA as Anti-obesity Agent	825
		24.2.4 Antimutagenic and Antimicrobial Activities of γ -Aminobutyric Acid	825
		24.2.5 GABA as Anti-stress Compound	826
		24.2.6 Gamma-Aminobutyric Acid in Thyroid Dysfunction	827
		24.2.7 GABA as Renoprotective	827

24.3	GABA as Bioactive Compound in Food	828
24.3.1	Microorganisms as Sources of GABA/GAD	829
24.3.2	Plants as a Source of GABA and GABA Enriched Food	829
24.3.3	Dairy Products and Beverages as GABA Sources	830
24.3.4	Marine Sources of GABA	831
24.4	Techniques for GABA Enrichment and Advances in GABA Production	832
24.4.1	GABA Production by LAB	832
24.4.2	GABA Production by Other Microorganisms	833
24.4.3	Factors Affecting GABA Levels	833
24.4.4	Advances in GABA Production Techniques	837
24.5	Conclusion	839
	References	839
25	Medicinal Attribution of Ginsenoside: A Huge Source of Plant Bioactive Compound	845
	Dilipkumar Pal, Souvik Mukherjee, Satish Balasaheb Nimse, and K. K. Chandra	
25.1	Introduction	846
25.2	Biosynthesis of G_N^D	847
25.3	Biotransformation of G_N^D	849
25.4	Medicinal and Nutraceutical Applications	852
25.4.1	Anti-carcinogenic Effects	852
25.4.2	Cytotoxic and Anti T_U^m Activity	852
25.4.3	Inhibition of $T_U^m C_e^L$ Invasion and M_a^T	854
25.4.4	Inhibition of T_U^m Angiogenesis	854
25.4.5	Immunomodulatory Effects	855
25.4.6	Anti-inflammatory Activity	856
25.4.7	Antistress Activity	858
25.4.8	Memory, Learning, and N_E^{ur} Protection	858
25.4.9	Anti-diabetic Activity	859
25.5	Conclusions	859
	References	860

17. D Pal A P. Saha

Chapter 3

Plant Polysaccharides in Pharmaceutical Applications

Amit Kumar Nayak, Md Saquib Hasnain, Amal Kumar Dhara,
and Dilipkumar Pal

Abstract Plant polysaccharides are the by-products of photosynthesis within the plants and are being extracted from different parts of the plants, such as leaves, pods, fruits, seeds, cereals, stems, roots, rhizomes, corms, exudates, etc. The important advantages for the uses of plant polysaccharides include easy availability from the nature as plant resources are abundant, sustainable and low cost production, biodegradability, biocompatibility, water solubility, swelling ability, etc. Since long, numerous plant polysaccharides have already been explored and exploited as excipients in a variety of common pharmaceutical dosage forms, such as suspensions, emulsions, gels, tablets, capsules, beads, microparticles, nanoparticles, liposomes, transdermal formulations, buccal formulations, nasal formulations, ophthalmic formulations, etc. The current chapter presents a brief review on the pharmaceutical applications of various plant polysaccharides.

Keywords Plant polysaccharides · Biopolymers · Excipient · Pharmaceutical applications · Drug delivery

A. K. Nayak

Department of Pharmaceutics, Seemanta Institute of Pharmaceutical Sciences, Mayurbhanj, Odisha 757086, India

Md. S. Hasnain

Department of Pharmacy, Shri Venkateshwara University, Gajraula, Amroha, UP, India

A. K. Dhara

Department of Pharmacy, Contai Polytechnic, Darua, Contai, Purba Medinipur, West Bengal 721406, India

D. Pal (✉)

Department of Pharmaceutical Sciences, Guru Ghasidas Vishwavidyalaya (A Central University), Koni, Bilaspur, C.G 495009, India
e-mail: drdilip2003@yahoo.co.in

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2021

93

D. Pal and A. K. Nayak (eds.), *Bioactive Natural Products for Pharmaceutical Applications*, Advanced Structured Materials 140, https://doi.org/10.1007/978-3-030-54027-2_3

3.1 Introduction

An inspiring array of plant-derived materials and products have already been revealed for the uses in many applications including pharmaceuticals, cosmetics, ticals, biomedical, foods, textiles, paints, paper-making, etc. (Ali et al. 2019; George and Suchithra 2019; Hasnain et al. 2019a; Nayak et al. 2020; Pal et al. 2019a; Sinha Mahapatra et al. 2011; Xie et al. 2016). Amongst the different plant-derived materials, plant polysaccharides have already been demonstrated as a useful group of polymeric biomacromolecules possessing some outstanding merits over the synthetic polymers and these merits include easy availability from the nature as plant resources are abundant, sustainable and low cost production, biodegradability, biocompatibility, water solubility, swelling ability, etc. (Nayak and Hasnain 2019a; Nayak et al. 2018a). The most important reason for the rising interest for the uses of various plant polysaccharides is the advantages of easy cultivation and harvesting to offer a constant supply of raw plant materials for the polysaccharide extractions. Plant polysaccharides are the by-products of photosynthesis within the plants and are being extracted from different parts of the plants, such as leaves, pods, fruits, seeds, cereals, stems, roots, rhizomes, corms, exudates, etc. (Prajapati et al. 2013). These are high molecular weight biopolymers possessing many monosaccharidic units as building blocks, which are linked each other by O-glycosidic linkages in different patterns (Nayak and Pal 2016). Similar or different monosaccharidic units are arranged as extremely complex molecular structures with the variations in sequences, linkages, branching patterns and distributions of side chains. In addition, the molecular structural features of plant polysaccharides possess the presence of many functional groups, which can be modified or tailored to produce polysaccharides of desirable quality (Nayak and Pal 2018; Nayak et al. 2018b). During past few decades, an extensive volume of research efforts have been directed to use various plant polysaccharides in many biomedical and medical applications including their pharmaceutical uses as the dosage formulation excipients and dosage performance enhancers in terms of desired pattern of drug releasing, improved drug stability, enhanced bioavailability, desired target specificity, etc. (Nayak and Hasnain 2019a; b; Pal and Nayak 2017).

Various useful plant polysaccharides have already been explored and exploited as biopolymeric agents in many healthcare area including pharmaceutical industry and researches. Some of the widely used plant polysaccharides as efficient excipients in various kinds of pharmaceutical dosage forms are gum Arabic (Nayak and Hasnain 2019c), gum tragacanth (Dhupal et al. 2019), pectin (Nayak and Pal 2016), guar gum (Jana et al. 2019), locust bean gum (Hasnain et al. 2019b; Nayak and Hasnain 2019d), sterculia gum (Bera et al. 2019; Nayak and Hasnain 2019e), tamarind gum (Dey et al. 2019; Nayak, 2016; Nayak and Hasnain 2019f), cashew gum (Nayak et al. 2019), okra gum (Nayak and Hasnain 2019g; Nayak et al. 2018b), gum odina (Samanta et al. 2019), fenugreek seed mucilage (Nayak and Hasnain 2019h; Pal et al. 2019b), linseed polysaccharides (Nayak and Hasnain 2019i), ispaghula mucilages (Guru et al. 2018), plant starches (Nayak and Pal