
ESSENTIAL OILS

Extraction Methods and Applications

Edited By
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Contents

Preface	xxvii
1 A Methodological Approach of Plant Essential Oils and their Isolated Bioactive Components for Antiviral Activities	1
<i>Kunal Sharma, Vivek Mishra, Kumar Rakesh Ranjan, Nisha Yadav and Mansi Sharma</i>	
1.1 Introduction	1
1.2 General Chemical Properties and Bioactivity	2
1.3 Antiviral Mechanisms	3
1.3.1 Time of Addition Assay	4
1.3.1.1 Pretreatment of Host Cells	5
1.3.1.2 Pretreatment of Virions	5
1.3.1.3 Co-Treatment of Host/Cultured Cells and Virions During Virus Inoculation	5
1.3.1.4 Post-Entry Treatment	6
1.3.2 Thermal Shift Assays	6
1.3.2.1 Viral Attachment Assay	6
1.3.2.2 Viral Fusion Assay (Entry Assay)	6
1.3.3 Morphological Study	6
1.3.4 Protein Inhibition	7
1.3.5 Other Metabolic Anti-Viral Mechanisms	9
1.4 Assessment of Antiviral Activities <i>via In Vitro</i> Assays	9
1.4.1 Determination of Cytotoxicity (Cytopathogenic Reduction Assay)	9
1.4.2 <i>In Vitro</i> Activities on Different Viruses	12
1.4.2.1 Human Herpes Virus	12
1.4.2.2 Influenza Virus	15
1.4.2.3 Non-Enveloped Viruses	15
1.4.2.4 Other Viruses	16
1.5 Activities of Essential Oils in Relation to Their Bioactive Components	16
1.6 Antiviral Activities as Compared to the Polarity of Bioactive Components	17
1.7 <i>In Vivo</i> Studies of Essential Oils for its Antiviral Effect	18
1.7.1 Herpes Simplex Virus	18
1.7.2 Influenza Virus	18
1.7.3 West Nile Virus	20
1.8 Activities In-Respect to the Available Antivirals	21

1.9	Antiviral Essential Oils and Their Bioactive Components Loaded in Nanosystems	22
1.10	Conclusion	23
	References	24
2	Essential Oils Used to Inhibit Bacterial Growth in Food	31
	<i>Luiza Helena da Silva Martins, Sabrina Baleixo da Silva, Adilson Ferreira Filho, Andrea Komesu, Johnatt Allan Rocha de Oliveira and Debora Kono Taketa Moreira</i>	
2.1	Introduction	31
2.2	Chemistry of Essential Oils	32
2.3	Essential Oils Against Microorganisms in Food Products	35
2.4	Application of Essential Oils in the Food Industry	37
2.5	Essential Oil Extraction Techniques	40
2.6	Conclusions	42
	References	43
3	Industrial Application of Essential Oils	49
	<i>S. Kiruthika and S. Vishali</i>	
3.1	Introduction	49
3.2	Essential Oils	50
3.2.1	Sources and Chemical Composition	51
3.2.2	Extraction Methods	52
3.2.2.1	Conventional Extraction Methods	52
3.2.2.2	Innovative Extraction Methods	53
3.2.3	Industrial Applications of Essential Oils	54
3.2.3.1	Food Preservation and Active Packaging Systems	54
3.2.3.2	Aromatherapy	56
3.2.3.3	Pharmaceutical and Medicinal Application	57
3.2.3.4	Biopesticide in Insect Pest Management	60
	Conclusion	63
	Declaration about Copyright	63
	References	64
4	Influence of Biotic and Abiotic Factors on the Production and Composition of Essential Oils	69
	<i>Sandra Gonçalves, Inês Mansinhos and Anabela Romano</i>	
4.1	Introduction	69
4.2	Essential Oil Characteristics	70
4.3	Factors Influencing Essential Oils Production and Composition	70
4.4	Abiotic Factors	72
4.4.1	Drought	81
4.4.2	Salinity	82
4.4.3	Temperature	83
4.4.4	Light	83
4.4.5	Nutrients	84
4.4.6	Heavy Metals	85

4.5	Biotic Factors	86
4.6	Concluding Remarks	91
	Acknowledgements	91
	References	92
5	Investigation of Antiviral Effects of Essential Oils	99
	<i>Ahmad Mustafa, Dina H. El-Kashef, Miada F. Abdelwahab, Alshymaa Abdel-Rahman Gomaa, Muhamad Mustafa, Nada M. Abdel-Wahab and Alyaa H. Ibrahim</i>	
5.1	Introduction	99
5.2	Viruses: Structure, Characteristics, and Replication	101
5.3	<i>In Vitro</i> Antiviral Activity and Mechanism of Action Investigations of Essential Oils and Essential Oil Components	103
5.3.1	Investigation of <i>In Vitro</i> Antiviral Activities	103
5.3.1.1	Plaque Reduction Assay	103
5.3.1.2	The Inhibition of Viral Cytopathogenic Effect	103
5.3.2	Mechanisms of Action	104
5.3.2.1	Time-of-Drug-Addition Assay	104
5.3.2.2	Temperature-Shift Assay	105
5.3.2.3	Morphological Alteration	105
5.3.2.4	Protein Inhibition	105
5.3.2.5	Other Mechanisms of Action	106
5.3.3	Selectivity Index (SI)	106
5.4	The Antiviral Efficacy of Essential Oils on Viruses Affecting Different Body Systems	106
5.4.1	Respiratory System	106
5.4.1.1	Influenza Virus	106
5.4.1.2	Adenovirus and Rhinovirus	111
5.4.1.3	Severe Acute Respiratory Syndrome Coronavirus 1 (SARS-COV-1)	111
5.4.1.4	Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-COV-2)	111
5.4.2	GIT System	113
5.4.2.1	Coxsackie Virus	113
5.4.2.2	Dengue Virus	113
5.4.2.3	Yellow Fever Virus	113
5.4.2.4	Murine Norovirus Type 1	113
5.4.3	Nervous System	113
5.4.3.1	West Nile Virus	113
5.4.4	Immune System	114
5.4.4.1	HIV	114
5.4.5	Reproductive System	114
5.4.5.1	Human Papilloma Virus (HPV)	114
5.4.6	Other Viruses	114
5.4.6.1	Human Herpes Virus	114
5.4.6.2	Orf Virus	115

5.5	The Antiviral Efficacy of Essential Oils on Phyto-Pathogenic Viruses	115
5.6	The Antiviral Efficacy of the Essential Oils on Animal-Infecting Viruses	115
5.6.1	Virus Affecting Cattle (Bovine Viral Diarrhea Virus)	115
5.6.2	Virus Affecting Cats (Feline Calicivirus F9)	115
5.6.3	Virus Affecting Pigs (Porcine Parvovirus)	115
5.7	Synergistic Effect of Essential Oil Components with Known Antiviral Drugs	116
5.8	Aromatherapy and its Role as an Antiviral Agent	116
5.9	Route of Essential Oil Administration	116
5.10	Nano-Formulated Essential Oils: A Promising Approach to Enhance Antiviral Activity	117
5.11	Safety of Essential Oils	117
5.12	Antiviral Essential Oils: Drawbacks versus Future Perspectives	118
5.13	Summary	118
	References	118
6	<i>Mentha</i> sp. Essential Oil and Its Applicability in Brazil	125
	<i>Daniele de Araujo Moysés, Hanna Patricia dos Santos Martins, Margoula Soares Ribeiro, Natasha Costa da Rocha Galucio, Raquel Ribeiro de Souza, Regianne Maciel dos Santos Correa, José de Arimateia Rodrigues do Rego, Maria Fani Dolabela and Valdicley Vieira Vale</i>	
	Introduction	126
6.1	Ethnobotany of the <i>Mentha</i> in Brazil	127
6.2	Chemical Constituents of <i>Mentha</i> Oil	135
6.3	Evaluation of Biological Activities of <i>Mentha</i> Essential Oils	139
6.4	Toxicity of Essential Oils from <i>Mentha</i> Used in Folk Medicine	144
6.5	Final Considerations and Perspectives	147
	References	148
7	Microbial Influence on Plants for Enhanced Production of Active Secondary Metabolites	157
	<i>Naushin Bano, Mohammad Amir, S. Nabilah Jawed and Roohi</i>	
7.1	Introduction	157
7.2	Classes of Plants Secondary Metabolites	159
7.2.1	Terpenes	159
7.2.2	Phenolic Compounds	159
7.2.3	Nitrogen-Containing Secondary Metabolites	160
7.2.4	Sulphur Containing Secondary Metabolites	160
7.3	Secondary Metabolites Production from Plants	160
7.3.1	<i>In Vivo</i> Production of Secondary Metabolites	161
7.3.2	<i>In Vitro</i> Secondary Metabolites Production	161
7.4	Interaction of Microorganisms in the Rhizosphere	161
7.5	Influence of Bacteria and Fungi on Plants	164
7.5.1	Plant Growth Promoters	164

7.5.1.1	Plant Growth-Promoting Bacteria (PGPR)	164
7.5.1.2	Plant Growth-Promoting Fungi (PGPF)	164
7.5.2	Production of Plant Biomass	165
7.5.3	Bacteria and Fungus as Biofertilizers	166
7.5.4	Role of Bacteria and Fungi as a Phytostimulator	166
7.5.5	Role of Bacteria and Fungi as a Biopesticides	166
7.5.6	Stress Tolerant Activity of Bacteria and Fungi	167
	Conclusion and Future Perspectives	168
	References	168
8	Valorization of Limonene Over Acid Solid Catalysts	173
	<i>José E. Castanheiro</i>	
8.1	Introduction	173
8.2	Limonene Reactions with Alcohols	176
8.3	Hydration and Acetoxylation	177
8.4	Conversion of Limonene into <i>p</i> -Cymene	179
8.5	Conclusions	181
	References	181
9	Elucidating the Role of Essential Oils in Pharmaceutical and Industrial Applications	185
	<i>Sundaresan Bhavaniramy, Selvaraju Vishnupriya, Kumanan Vijayarani and Ramar Vanajothi</i>	
9.1	Introduction	185
9.2	Extraction of Volatile Oils from Various Sources	186
9.2.1	Terpenes	188
9.2.2	Hydrocarbons	188
9.3	Role of Essential Oils in Industry	190
9.3.1	Role in Cosmetics and Aromatherapy	190
9.3.1.1	Cosmetic Industry	191
9.3.1.2	Immortelle Essential Oil	191
9.3.1.3	Lavender Essential Oil	192
9.3.1.4	German Chamomile Oil	193
9.3.1.5	Neroli Essential Oil	194
9.3.1.6	Peppermint Essential Oil	195
9.3.1.7	Rosemary Essential Oil	196
9.3.2	Application in Food Industry	196
9.3.2.1	Food Preservation	196
9.3.2.2	Food Packaging	197
9.4	Pharmacological Effects of Essential Oils	198
9.5	Concluding Remarks	199
	Acknowledgment	200
	References	200

10	Uses of Essential Oils in Different Sectors	207
	<i>Sumeyra Gurkok and Selma Sezen</i>	
10.1	Introduction	207
10.2	Food and Beverage	210
10.3	Packaging	212
10.4	Cosmetic and Perfumery	213
10.5	Aromatherapy	214
10.6	Medical	217
10.7	Agriculture	219
10.8	Textile	220
10.9	Cleaning Household	221
10.10	Safety of Essential Oils	221
	Conclusion	223
	References	223
11	Chemical Composition and Pharmacological Activities of Essential Oils	229
	<i>V. Chandrakala, Valmiki Aruna, Gangadhara Angajala and Pulikanti Guruprasad Reddy</i>	
11.1	Introduction	229
11.2	Anticancer	235
	11.2.1 Role of Terpenes in Anticancer Activity	235
	11.2.2 Role of Aromatic Compounds in Anticancer Activity	235
	11.2.3 Mode of Action	236
	11.2.4 The Effect of EOs in Different Types of Cancers	236
	11.2.5 Multi-Drug Resistance (MDR)	238
11.3	Anti-Inflammatory	239
	11.3.1 Terpenoids for Anti-Inflammatory	239
	11.3.2 Phenylpropanoids for Anti-Inflammatory	239
	11.3.3 Role of Essential Oil for Anti-Inflammatory	240
11.4	Anti-Viral	243
	11.4.1 Terpenoids for Anti-Viral Activity	244
	11.4.2 Essential Oils for Coronavirus	245
	11.4.3 Essential Oil for Anti-Viral Activity	247
11.5	Anti-Fungal	248
	11.5.1 Mode of Action	249
	11.5.2 Essential Oil for Anti-Fungal Activity	249
11.6	Antidiabetic	253
11.7	Larvicidal Activity	253
11.8	Anti-Bacterial	254
	Conclusion	255
	Conflicts of Interest	255
	Acknowledgements	255
	References	255

12 Augmented Stability and Efficacy of Essential Oils Through Encapsulation Approach	269
<i>Poonam Parashar and Kamla Pathak</i>	
12.1 Introduction	269
12.2 Various Strategies for Encapsulation of Essential Oils	270
12.2.1 Essential Oils Encapsulated in Liposomes	270
12.2.2 Essential Oils Encapsulated in Cyclodextrin Complexes	276
12.2.3 Essential Oils Encapsulated in Polymeric Complexes	278
12.2.4 Essential Oils Encapsulated in Electrospun Fibers	279
12.2.5 Essential Oils Encapsulated in Microemulsion/Nanoemulsions	281
12.2.6 Essential Oils Encapsulated in Mesoporous Silica Nanoparticles	283
12.3 Conclusions	284
References	284
13 Antimicrobial Effect of Essential Oils for Food Application	291
<i>Larissa Morais Ribeiro da Silva, Jorge Alberto Sanchos-Burgos, Eveline de Alencar Costa, Maria Jaiana Gomes Ferreira, Cicero C. Pola, Carmen Luiza Gomes and Celli Rodrigues Muniz</i>	
13.1 Introduction	291
13.2 Biotechnological Strategies for Extracting Essential Oils for Food Application	292
13.3 Methods for Evaluating the EO Inhibitory Activity <i>In Vitro</i>	295
13.3.1 Factors Affecting Method Susceptibility	295
13.3.2 Resources Used to Improve Halo Diameter Reading in the Agar Diffusion Method	295
13.4 Influence of Extraction Methods on the Antimicrobial Compounds in Essential Oils	297
13.5 Inhibition of Bacteria by Essential Oils in Food	299
13.6 Use of Essential Oils in Packaging or Food Contact Surfaces	302
13.6.1 Embedded Films of Nanocapsules with EO	303
13.6.2 Packaging Reinforced with Nano-Incorporations and Added with EO	303
13.6.3 Bioactive Films Added EO	304
13.7 Effect of Encapsulation of Essential Oils on the Inhibitory Activity against Bacteria	305
13.8 Conclusions	306
References	306
14 Antioxidant or Antimicrobial Nature of Essential Oils to Minimize Food Waste	315
<i>Dipak Subhash Sali, Vishal Gokul Beldar, Alok Kumar Panda and Manojkumar Jadhao</i>	
14.1 Introduction	315
14.2 Essential Oils Chemical Composition	317
14.3 Essential Oils: Their Antimicrobial Activity and Mode of Action	317

14.4	EO Used in Food Packaging	319
14.5	Application of EO in Different Food Products	322
14.5.1	Fruits and Vegetables	322
14.5.2	Meat and Meat Products	328
14.5.3	Fish	328
14.5.4	Dairy Products	329
14.5.5	Bakery Products	329
14.6	Legal Aspects of the Use of EO in Food	330
14.7	Conclusion	330
	References	331
15	Application of Essential Oils to Biofilms	339
	<i>Sumeyra Gurkok and Selma Sezen</i>	
15.1	Introduction	339
15.2	Definition of Biofilm	340
15.3	Principles of Biofilm Formation	340
15.4	Benefits of Biofilm to Microorganism	342
15.5	Mechanisms of Resistance to Antimicrobial Agents	342
15.6	Global Threat of Biofilms	344
15.7	Essential Oils	345
15.8	Antimicrobial and Antibiofilm Effects of EOs	346
15.9	Antibacterial Mechanism of Action	349
15.10	Strategies for Improving the Antibiofilm Efficacy of EOs	350
15.11	Common Methods for Determination of Antimicrobial and Antibiofilm Activities of EOs	351
15.12	Limitations of EOs Usage	352
	Conclusion	353
	References	353
16	Biological Applications of Essential Oil	361
	<i>D. Jini</i>	
16.1	Introduction	361
16.2	Sources of Essential Oil	362
16.3	Extraction of Essential Oil	363
16.4	Phytochemistry of Essential Oil	363
16.5	Biological Applications	364
16.5.1	Applications of Essential Oil on the Treatment of Cancer	365
16.5.2	Applications of Essential Oil on the Treatment of Respiratory Tract Diseases	367
16.5.3	Applications of Essential Oil on the Treatment of Cardiovascular Diseases	367
16.5.3.1	Anti-Inflammatory Activity	368
16.5.4	Applications of Essential Oil on the Treatment of Obesity	368
16.5.5	Applications of Essential Oil on the Treatment of Diabetes	368
16.5.5.1	Antioxidant Activity	369

16.5.6	Applications of Essential Oils Against Infectious Diseases	369
16.5.6.1	Antibacterial Activity	370
16.5.6.2	Antifungal Activity	371
16.5.6.3	Antiviral Activity	371
16.5.7	Applications of Essential Oil on Dandruff	371
16.6	Essential Oil Safety Issue	372
16.7	Conclusion	372
	Acknowledgment	372
	References	372
17	Current Status and Advancement of Biopesticides from Essential Oil for Agriculture, Food Storage, and Household Applications	381
	<i>Masrina Mohd Nadzir, Salfarina Ramli, Farhana Nazira Idris and Faiznur Mohd Fuad</i>	
17.1	Introduction	381
17.1.1	Essential Oil Extraction	383
17.2	Application of Essential Oil Biopesticides in Agriculture	383
17.2.1	Agriculture Pest	384
17.2.2	Types of Essential Oils for Agricultural Pest Management	385
17.3	Application of Essential Oil Biopesticides for Food Storage	385
17.3.1	Food Storage Pests	395
17.3.2	Types of Essential Oils for Food Storage Pest Management	396
17.4	Application of Essential Oil Biopesticides for Household Pests	406
17.4.1	Household Pests	406
17.4.2	Types of Essential Oils for Household Pest Management	407
17.5	Delivery of Biopesticides	412
17.6	Pesticidal Action of Biopesticides	413
17.7	Conclusion and Constraints	415
17.8	Acknowledgement	415
	References	416
18	Essential Oil Used as Larvicides and Ovicides	427
	<i>Gurleen Kaur, Rajinder Kaur and Sukhminderjit Kaur</i>	
18.1	Introduction	427
18.2	Important Aspects of Essential Oils	428
18.3	Larvicides and Ovicides	430
18.3.1	Larvicides Against <i>Aedes aegypti</i>	431
18.3.2	Larvicidal Activity Against <i>Anopheles stephensi</i>	433
18.3.3	Larvicide Against <i>Aedes albopictus</i>	434
18.3.4	Ovicidal Activity Against <i>Pediculus humanus capitis</i>	435
18.3.5	Ovicidal Activity Against <i>Haemonchus contortus</i>	437
18.3.6	Ovicidal Activity Against <i>Helicoverpa armigera</i> Hubner	438
18.4	Conclusion	439
	References	439

19 Essential Oil-Based Biopesticides	443
<i>Nishant Sharma, Kunal Sharma, Sachchidanand Soaham Gupta, Kumar Rakesh Ranjan, Vivek Mishra and Maumita Das Mukherjee</i>	
19.1 Introduction	443
19.2 Phytochemistry and Sources of Essential Oils	445
19.3 Biological Activity of Essential Oil Biopesticides	447
19.3.1 Efficacy of Essential Oils to Insects	447
19.3.2 Essential Oils as Insect Repellents	449
19.3.3 Bactericidal Properties of Essential Oils	450
19.3.4 Antifungal and Anti-Oomycete Properties of Essential Oils	450
19.3.5 Herbicidal/Weedicide Properties of Essential Oils	452
19.4 Synergistic Formulations of Essential Oils	454
19.5 Toxic Effects of Essential Oils on Mammals and Non-Target Organisms	454
19.6 Advantages, Current Constraints and Long-Term Prospects	455
19.7 Conclusion	457
References	458
20 Essential Oils Obtained from Algae: Biodiversity and Ecological Importance	465
<i>Deprá, M. C., Dias, R. R., Nascimento, T. C., Silva, P. A., Zepka, L. Q. and Jacob-Lopes, E.</i>	
20.1 Introduction	465
20.2 What are Essential Oils?	466
20.3 Chemical Structure and Biological Activity from Algal Essential Oils	467
20.4 Ecological Importance of Essential Oils in Marine System	470
20.5 Conclusion and Future Perspectives	472
References	472
21 Gas Chromatography-Olfactometry (GC-O) of Essential Oils and Volatile Extracts	477
<i>Eduardo Dellacassa and Manuel A. Minteguiaga</i>	
21.1 Introduction	477
21.2 Historical Aspects	479
21.3 GC-O Methodologies	481
21.3.1 Detection Frequency Methods	482
21.3.2 Dilution Analysis	482
21.3.2.1 Aroma Extraction Dilution Analysis (AEDA)	483
21.3.2.2 Combined Hedonic Aroma Response Measurements (CHARM Analysis)	483
21.3.3 Posterior Intensity Methods (PI)	485
21.3.4 Time-Intensity Methods	485
21.3.4.1 Odor-Specific Magnitude Estimation (OSME, Direct Intensity)	486
21.4 Different GC-O Application to Assess for Essential Oils' Odorants	486
21.4.1 <i>Citrus</i> spp. (Rutaceae)	487
21.4.2 <i>Mentha</i> spp. (Lamiaceae)	488
21.4.3 <i>Thymus</i> spp. (Lamiaceae)	490

21.4.4	<i>Foeniculum</i> spp. (Apiaceae)	491
21.4.5	<i>Coriandrum</i> spp. (Apiaceae)	492
21.4.6	<i>Pinus</i> spp.	493
21.4.7	GC-O Applied to Characterize <i>Baccharis dracunculifolia</i> DC. Odorants	494
	Acknowledgements	497
	Funding	497
	References	497
22	<i>In Vitro</i> and <i>In Vivo</i> Methods Used to Assess the Biological Potential of Essential Oils	501
	<i>Syed Ali Raza Naqvi, Sadaf Ul Hassan, Tauqir A. Sherazi, Amjad Hussain, Muhammad Rehan Hasan Shah Gilani and Tanvir Hussain</i>	
22.1	Introduction	501
22.2	Chemistry of EOs	502
22.3	<i>In Vitro</i> Methods Used to Assess the Biological Potential of EOs	503
22.4	Evaluation of Antioxidant Potential	504
22.4.1	What are Antioxidants?	504
22.4.2	Antioxidant Potential of Botanical Materials	504
22.4.3	Modes of Action	505
22.4.4	<i>In Vitro</i> Methods for Antioxidant Activities	505
22.4.5	DPPH Scavenging Assay	506
22.4.6	2,2-Azinobis-(3-Ethylbenzothiazoline-6-Sulfonate) Assay	507
22.4.7	Bleachability of β -Carotene in Linoleic Acid System	510
22.5	Antimicrobial Activities of Essential Oils	511
22.5.1	Disk Diffusion Assay	512
22.5.2	Agar Well Diffusion Method	512
22.5.3	Determination of Minimal Inhibitory Concentration (MIC)	513
22.6	Essential Oils as Natural Antimicrobial Agents	514
22.7	Anticancer Activity of Essential Oils	515
22.8	Cell Culture and Treatment	515
22.9	Determination of Cell Viability	515
22.10	Conclusion	515
	Acknowledgement	515
	References	516
23	Biological Potential of Essential Oils: Evaluation Strategies	521
	<i>Santanu Chakraborty, Manami Dhibar, Aliviya Das, Kalpana Swain and Satyanarayan Pattnaik</i>	
23.1	Introduction	521
23.2	Biological Activities of Essential Oils	523
23.2.1	EOs as Antibacterial Agents	524
23.2.2	EOs as Antifungal Agents	525
23.2.3	EOs as Anti-Inflammatory Agents	526
23.2.4	EOs as Antioxidants	526
23.2.5	EOs as Anticancer Agents	526

23.2.6	EOs as Anti-Diabetic Agents	528
23.2.7	EOs as Antispasmodics	528
23.3	<i>In Vitro</i> Assessment of Biological Activities	529
23.3.1	Antimicrobial Assay	529
23.3.2	Antibacterial Assay	529
23.3.3	Antifungal Assay	530
23.3.4	Antioxidant Assay	530
23.3.5	Anticancer Assay	532
23.3.6	Anti-Diabetic Assay	532
23.4	<i>In Vivo</i> Assessment of Biological Activities	532
23.4.1	Antimicrobial Assay	532
23.4.2	Antidermatophytic Assay	533
23.4.3	Antifungal Assay	533
23.4.4	Anti-Inflammatory Assay	533
23.4.5	Antioxidant Assay	534
23.4.6	Anticancer Assay	535
23.4.7	Anti-Diabetic Assay	535
23.4.8	Mosquito Repellent Assay	537
23.5	Conclusion	537
	References	537
24	Algal Essential Oils and Their Importance in the Ecosystem	551
	<i>S.Z.Z. Cobongela</i>	
24.1	Introduction	551
24.2	Algal Essential Oils	552
24.3	Factors Affecting Algae Essential Oil Production	553
24.3.1	Temperature	553
24.3.2	Light	554
24.3.3	Nutrients	554
24.3.4	Chemical Stress	554
24.4	Ecological Importance of Algal Essential Oils	554
24.5	Pheromone Properties of Algal Essential Oils	556
24.6	Algal Essential Oils in “Beach-Odor”	557
24.7	Algal Essential Oils in “Off-Odor”	557
24.8	Antibacterial Activities of Algal Essential Oils	558
24.9	Antifungal Activities of Algal Essential Oils	558
24.10	Conclusion	559
	References	559
25	Classical Methods for Obtaining Essential Oils	565
	<i>Syed Raza Ali Naqvi, Hiba Shahid, Ameer Fawad Zahoor, Muhammad Saeed, Muhammad Usman, Ali Abbas, Mamoon Ur Rasheed and Tanvir Hussain</i>	
25.1	Introduction	565
25.2	Classical Methods for Extracting Essential Oils	568
25.2.1	Maceration	568

25.2.2	Mechanical Treatment	568
25.2.3	Hydro Distillation	570
25.2.4	Water Distillation	570
25.2.4.1	Steam Distillation	574
25.2.5	Cold Pressing Method	574
25.2.6	Solvent Extraction	576
25.2.7	Soxhlet Extraction	577
25.3	Chromatographic Technique for Analysis of Essential Oil	578
	Conclusion	578
	Acknowledgement	579
	References	579
26	A Comprehensive Guide to Essential Oil	
	Determination Methods	583
	<i>Payel Dhar, Urbashi Neog, Biplab Roy, Nishithendu Bikash Nandi, Sankar Chandra Deka and Pinku Chandra Nath</i>	
	Abbreviations	584
26.1	Introduction	584
26.2	Chemical Composition of EOs	585
26.2.1	Hydrocarbons Derived from Terpenes	587
26.2.2	Oxygenated Compounds	587
26.3	EO and Its Group	588
26.4	Biological Activity: Pathway Cell	588
26.4.1	Osmophores	589
26.4.2	Trichomes	589
26.5	Classical Methods for Extraction of Essential Oils	590
26.5.1	Steam Distillation	590
26.5.2	Hydro-Distillation Method	591
26.5.3	Steam Explosion Method	591
26.5.4	Solvent Extraction Method	592
26.5.5	Cold Press (CP) Method	592
26.6	Contemporary Extraction Methods	592
26.6.1	Supercritical Fluid (SCF) Extraction	592
26.6.2	High Pressure Extraction	593
26.6.3	Microwave-Assisted Hydro-Distillation	593
26.6.4	Hydrodistillation with Pretreatment of Enzyme	593
26.6.5	Microwave-Assisted Steam Distillation	594
26.6.6	Ultrasound-Assisted Extraction	595
26.6.7	Solvent-Free Microwave Extraction	595
26.6.8	Microwave Hydro-Diffusion and Gravity	595
26.6.9	Oil Extraction by Solar Energy	596
26.6.10	Pulse Electric Field	596
26.7	Conclusion	596
	References	597

27 Encapsulation of Essential Oils	603
<i>Ádina L. Santana and M. Angela A. Meireles</i>	
27.1 Introduction	603
27.2 Encapsulation	605
27.2.1 Chemical	605
27.2.1.1 Molecular Inclusion Complexation	605
27.2.1.2 Interfacial Polymerization	606
27.2.1.3 <i>In Situ</i> Polymerization	606
27.2.2 Physical-Chemical	606
27.2.2.1 Coacervation	606
27.2.2.2 Emulsification	606
27.2.3 Physical	607
27.2.3.1 Spray Drying	607
27.2.3.2 Freeze Drying	608
27.2.3.3 Electrospaying and Electrospinning	608
27.2.3.4 Supercritical Technology	609
27.3 Process Simulation and Economic Evaluation	613
Concluding Remarks and Prospects	614
References	614
28 Encapsulated Essential Oils: Main Techniques to Increase Shelf-Life	619
<i>Fernanda Wariss Figueiredo Bezerra, Lucas Cantão Freitas, Vânia Maria Borges Cunha, Giselle Cristine Melo Aires, Rafael Henrique Holanda Pinto and Raul Nunes de Carvalho Junior</i>	
28.1 Introduction	619
28.2 Coating Materials	620
28.3 Techniques for Essential Oil Encapsulation	623
28.3.1 Coacervation	623
28.3.2 Extrusion	624
28.3.3 Nanoprecipitation	625
28.3.4 Emulsification	626
28.3.5 Spray Drying	626
28.3.6 Thin Film Hydration Method	627
28.3.7 Supercritical Fluid Technology	628
28.4 Concluding Remarks	629
Acknowledgment	629
References	630
29 Encapsulation Technologies of Essential Oils for Various Industrial Applications	635
<i>Tuyen C. Kha and Phuong H. Le</i>	
29.1 Introduction	635
29.2 Encapsulation Technique	636
29.2.1 Essential Oil as the Core Material	637
29.2.1.1 Chemical Composition and Physical Properties of EOs	637
29.2.1.2 Biological Activities of EOs	641

29.2.2	Wall Materials	642
29.2.3	Encapsulation Method and Release Mechanism	643
29.2.4	Applications of Encapsulated EOs	649
29.2.4.1	Preservative in Foods	649
29.2.4.2	Baked Foods	649
29.2.4.3	Beverages	656
29.2.4.4	Fresh Fruit and Vegetables	657
29.2.4.5	Raw Meat and Meat Products	657
29.2.4.6	Milk and Dairy Products	658
29.2.4.7	Cosmetic and Health Care	659
29.2.4.8	Cotton and Textile	660
29.2.4.9	Pharmaceutical	661
29.3	Conclusions	662
	References	663
30	Extraction of Essential Oils with Supercritical Fluid	671
	<i>Ádina L. Santana and M. Angela A. Meireles</i>	
30.1	Introduction	671
30.2	Why Use Supercritical Carbon Dioxide to Extract Essential Oils?	672
30.3	Commercial Equipment Used for Supercritical Fluid Extraction of Essential Oils: Bench and Industrial Scale	676
30.3.1	Bench Scale	676
30.3.2	Pilot and Commercial Scale	677
30.4	Patent Survey	678
30.5	Economic Evaluation	678
30.6	Life Cycle Assessment	679
30.6.1	Goal and Scope Definition	680
30.6.2	Life Cycle Inventory	680
30.6.3	Life Cycle Impact Assessment (LCIA)	681
30.6.4	Interpretation	681
30.6.5	Recent Studies on LCA of SFE of Essential Oils and the Main Results	681
30.7	Current Outlook and Prospects	681
	References	682
31	Advantages of Essential Oil Extraction Using Supercritical Fluid: Process Optimization and Effect of Different Processing Parameters on Extraction Efficiency	685
	<i>Shaziya Manzoor, Rubiya Rashid, Mudasir Ahmad, F.A. Masoodi, Pir Mohammad Junaid and Sadaf Parvez</i>	
31.1	Introduction	685
31.2	Essential Oils	686
31.3	Supercritical Fluid Extraction	687
31.4	Superiorities of SFE over Other Extraction Methods	688
31.5	Extraction of EOs by Supercritical Fluid	689

31.5.1	Effects of Temperature	695
31.5.2	Effect of Pressure	695
31.5.3	Effect of Particle Size	696
31.5.4	Effect of Flow Rate	697
31.5.5	Use of a Co-Solvent	697
31.5.6	Extraction Time	698
31.6	Antimicrobial and Antioxidant Properties of Essential Oils Extracted via SFE	698
31.7	Optimization	699
31.7.1	Optimization Using RSM and BBD, Taguchi Model	699
31.7.2	Artificial Neural Networks (ANNs)	700
31.8	Conclusion	701
	References	701
32	Supercritical Fluid Extraction of Essential Oils from Natural Sources: Mathematical Modeling and Applications	707
	<i>Carina Contini Triques, Edson Antônio da Silva, Kátia Andressa Santos, Elissandro Jair Klein, Veronice Slusarski-Santana, Márcia Regina Fagundes-Klen and Mônica Lady Fiorese</i>	
32.1	Introduction	707
32.2	Essential Oils	708
32.3	Conventional Extraction Methods	710
32.4	Supercritical Fluid Extraction	711
32.4.1	Cosolvent Addition	713
32.5	Typical Behavior and Mathematical Modeling	714
32.6	Parameters Affecting the CO ₂ -Supercritical Fluid Extraction	723
32.6.1	Pressure and Temperature	723
32.6.1.1	Pressure	726
32.6.1.2	Temperature	728
32.6.2	Pre-Treatment – Moisture and Particle Size	729
32.6.3	Extraction Time and Apparent Solubility	730
32.6.4	Solvent Flow	732
32.7	Scale-Up and Economic Analysis	733
32.8	Applications	734
32.9	Final Considerations	734
	References	735
33	Fundamentals, Mathematical Models, and Extraction Processes with Supercritical Fluids	741
	<i>Facundo Mattea, Nicolás Gañán and Marcelo Ricardo Romero</i>	
33.1	Introduction: Background	741
33.2	Fundamentals of Supercritical Fluid Extraction	743
33.2.1	Supercritical Fluids	743
33.2.2	Solubility and Phase Equilibria	745
33.3	The Extraction Process	747
33.3.1	Process Scheme	747

33.3.2	Process Parameters	749
33.3.2.1	Temperature and Pressure	749
33.3.2.2	Flow Rate	751
33.3.3	Mathematical Modeling of the Extraction Process	751
33.3.4	Scale-Up	752
33.4	Separation	753
33.4.1	Extract Recovery Strategies	753
33.4.2	Essential Oil Fractionation	754
33.4.3	Solvent Regeneration and Recycling	755
33.5	Recent Application of Supercritical Extraction of Essential Oils and Industrial Application of Supercritical Fluid Extraction Processes	756
33.6	Novel and Future Perspectives of Supercritical Fluid Extraction for Essential Oils	758
33.6.1	Supercritical Fluid Extraction Coupled with Other Green Extraction Technologies	758
33.6.2	Future Perspectives	760
	References	760
34	Supercritical CO₂ Extraction as a Clean Technology Tool for Isolation of Essential Oils	767
	<i>T. P. Krishna Murthy, R. Hari Krishna, M. N. Chandra Prabha, Priyadarshini Dey, Blessy Baby Mathew and C. Manjunatha</i>	
34.1	Introduction	767
34.2	Essential Oils	768
34.3	Applications of EOs	769
34.3.1	Antibacterial and Antifungal Activity	769
34.3.2	Antioxidant and Anticancer Activity	769
34.3.3	Antiviral Activity	770
34.3.4	Food Preservative and Packaging	770
34.3.5	Aromatherapy	770
34.3.6	Dairy Products	771
34.3.7	Biocontrol Agents	771
34.4	Extraction Methods	771
34.4.1	Distillation	772
34.4.2	Cold Pressing/Expression	772
34.4.3	Hydrodiffusion	772
34.4.4	Solvent Extraction	772
34.4.5	Microwave-Assisted Extraction (MAE)	773
34.4.6	Ultrasound-Assisted Extraction (UAE)	773
34.5	Supercritical Fluid Extraction (SCFE)	773
34.6	Parameters Influencing SCFE of EOs	776
34.6.1	Pressure	776
34.6.2	Temperature	777
34.6.3	CO ₂ Flow Rate	777
34.6.4	Moisture	777
34.6.5	Cosolvent	777

34.6.6	Particle Size of Plant Material	778
34.6.7	Extraction Time	778
34.7	Optimization of SCFE Process	780
34.8	Mathematical Modeling of Extraction Curves	785
34.9	Coupled or Assisted SCFE	786
34.9.1	Enzyme-Assisted SCFE	786
34.9.2	Ultrasound-Assisted SCFE	786
34.10	Conclusion	786
	References	787
35	Classical Techniques for Extracting Essential Oils from Plants	795
	<i>Yogesh Murti, Sonia Singh and Kamla Pathak</i>	
35.1	Introduction	795
35.2	Market Value of Essential Oils	796
35.3	Sources of Essential Oils	796
35.4	Chemical Nature of Essential Oils	796
35.5	Extraction of Essential Oils	803
35.5.1	Distillation Methods	804
35.5.1.1	Hydrodistillation	804
35.5.1.2	Steam Distillation	806
35.5.2	Hydrodiffusion	839
35.5.3	Solvent Extraction	839
35.5.4	Soxhlet Extraction	843
35.5.5	Cold Pressing Method/Expression	844
35.5.6	Cohobation	847
35.5.7	Enfleurage	848
35.5.8	Maceration	849
35.6	Conclusion	850
	References	851
36	Acquisition of Essential Oils Through Traditional Techniques	859
	<i>Lucas Cantão Freitas, Vinicius Sidonio Vale Moraes, Sabrina Baleixo da Silva and Raul Nunes de Carvalho Junior</i>	
36.1	Introduction	859
36.2	Obtaining Essential Oils	860
36.2.1	Cold Pressing	861
36.2.2	Steam Distillation	862
36.2.3	Hydrodistillation	863
36.2.4	Enfleurage	864
36.2.5	Solvent Extraction	864
36.3	Concluding Remarks	866
	Acknowledgment	866
	References	866

37 Essential Oils: Chemical Composition and Methods of Extraction	871
<i>Arshi Gupta, Kumar Rakesh Ranjan, Nisha Yadav, Deeksha and Vivek Mishra</i>	
37.1 Introduction	871
37.2 Chemical Assemblage of Essential Oils	873
37.2.1 Terpenes	874
37.2.1.1 Monoterpenes	874
37.2.1.2 Sesquiterpenes	874
37.2.1.3 Diterpenes	875
37.2.2 Heteroatomic Metabolites	875
37.2.2.1 Ketones	875
37.2.2.2 Acids	876
37.2.2.3 Aldehydes	876
37.2.2.4 Alcohols	876
37.2.2.5 Lactones	876
37.3 Extraction of Essential Oils Key Factors are Involved in Determining the Extraction Method	876
37.3.1 Conventional Extraction Methods	879
37.3.1.1 Hydro Distillation	879
37.3.1.2 Enfleurage Method	879
37.3.1.3 Hydro Diffusion	880
37.3.1.4 Cold Pressing	880
37.3.1.5 Steam Distillation	881
37.3.2 Green Extraction Methods	881
37.3.2.1 Supercritical Fluid Extraction (SFE)	881
37.3.2.2 Microwave-Assisted Extraction (MAE)	882
37.3.2.3 Ultrasonication-Assisted Extraction (UAE)	883
37.3.2.4 Conclusion	884
37.4 Conclusion	884
References	885
38 Dental Applications of Essential Oils	891
<i>Aarati Panchbhai</i>	
38.1 Introduction	891
38.2 Background	892
38.3 Preparation of Essential Oils	892
38.4 Mechanism of Action of Essential Oils	893
38.5 Methods of Application of Essential Oil for Dental Uses	893
38.6 Therapeutic Actions of Essential Oil for Dental Uses	894
38.7 Dental/Oral Conditions Treated by Essential Oils	894
38.8 Dental Applications of Essential Oils	895
38.9 Safety Issues in Relation to Use of Essential Oils	897
38.10 Research	898
38.11 Conclusion	899
References	899

39	Essential Oil-Based Therapies	903
	<i>Syed Ali Raza Naqvi, Vaneeza Javed, Naseem Abbas, Muhammad Rehan Hasan Shah Gilani, Sadaf Ul Hassan, Muhammad Rizwan Javed and Mazhar Hussain</i>	
39.1	Introduction	903
39.2	Essential Oil-Rich Plants	905
39.2.1	Citronella	905
39.2.2	Peppermint	906
39.2.3	Lavender	907
39.2.4	Tea-Tree	908
39.2.5	Eucalyptus	910
39.2.6	Chamomile	911
39.2.7	Patchouli	912
39.2.8	Ylang-Ylang	913
39.2.9	Bergamout	914
39.2.10	Geranium	915
39.2.11	Lemon	916
39.3	How Essential Oil Therapy Works	917
39.3.1	Cosmetic Aromatherapy	918
39.3.2	Massage Aromatherapy	918
39.3.3	Medical Aromatherapy	918
39.3.4	Olfactory Aromatherapy	918
39.3.5	Psycho-Aromatherapy	918
39.4	Essential Oil-Based Therapies	918
39.4.1	Brainstorming Therapies	921
	39.4.1.1 In the Treatment of Dementia	921
	39.4.1.2 Stress Reduces Therapy Among Adolescents	921
39.4.2	Anti-Microbial Therapy	921
39.4.3	In Treatment of Eczema	921
39.4.4	Anti-Hair Fall Therapy	922
39.4.5	Anti-Tumor Therapy	922
39.4.6	Chemopreventive Therapy	923
39.4.7	Coronavirus Therapeutics	923
39.4.8	Essential Oil Helps in Epilepsy	923
39.4.9	Treatment of Cardiovascular Disorders	925
39.5	How to Use EOs?	925
	Conclusion	925
	References	926
40	Clinical Applications of Essential Oils	933
	<i>Laxmi Tripathi, Praveen Kumar, Kalpana Swain and Satyanarayan Pattnaik</i>	
40.1	Introduction	933
40.2	Aromatherapy	934
40.3	Mode of Action of Essential Oils in Aromatherapy	934
40.4	Classification of Aromatherapy	935

40.4.1	Cosmetic Aromatherapy	935
40.4.2	Massage Aromatherapy	935
40.4.3	Medical Aromatherapy	937
40.4.4	Olfactory Aromatherapy and Psycho-Aromatherapy	938
40.5	Essential Oils from Various Parts of the Plants Used in Aromatherapy	939
40.6	Essential Oil-Based Therapies	942
40.6.1	Pain and Inflammation	943
40.6.2	Hemodialysis	946
40.6.3	Psychological Disorders	946
40.6.4	Treatment of Nausea and Vomiting	947
40.6.5	Managing Menopause Symptoms	947
40.6.6	Treatment of Dermatological Problems	947
40.7	Safety Issues Related to Essential Oil-Based Therapy	948
40.8	Conclusion	948
	References	948
41	Therapeutic Role of Essential Oils	953
	<i>S. Vishali, E. Kavitha and S. Selvalakshmi</i>	
41.1	Introduction	953
41.2	Uses of Essential Oils	956
41.2.1	Nontherapeutic Uses of EOs	957
41.2.1.1	Pesticide	957
41.2.1.2	Food Preservative	957
41.2.1.3	Cosmetics and Home Care	957
41.2.1.4	Mosquito Repellent	958
41.2.1.5	Others	958
41.3	Classification of Aromatherapy	958
41.3.1	Cosmetic Aromatherapy	958
41.3.2	Massage Aromatherapy	958
41.3.3	Medical Aromatherapy	958
41.3.4	Olfactory Aromatherapy	959
41.3.5	Psycho-Aromatherapy	959
41.4	Role of Essential Oil in Clinical Practice	960
41.5	Applications of Edible Essential Oil on Therapy	964
41.5.1	Almond Oil	966
41.5.2	Avocado Oil	967
41.5.3	Canola Oil	968
41.5.4	Coconut Oil	968
41.5.5	Flaxseed Oil	969
41.5.6	Groundnut Oil	969
41.5.7	Sesame Oil	970
41.5.8	Sunflower Oil	970
41.6	Risky EOs to Children	970
41.6.1	Camphor Oil	970
41.6.2	Wintergreen Oil	971

41.7	Side Effects of EOs	971
41.8	Therapeutic Guidelines and Safety Precautions	972
41.9	Conclusions	973
	Declaration About Copyright	973
	References	973
42	Plant Essential Oils and Their Constituents for Therapeutic Benefits	977
	<i>Monika Rani, Simran Jindal, Ritesh Anand, Niharika Sharma, Kumar Rakesh Ranjan, Maumita Das Mukherjee and Vivek Mishra</i>	
42.1	Introduction	977
42.1.1	Concept and Definition	977
42.1.2	A Journey Through History	979
42.1.3	Composition	980
42.2	Biological Activities	983
42.2.1	Antimicrobial Activities: Mode of Action and Effects	984
42.2.1.1	Antibacterial Activities	984
42.2.1.2	Anti-Fungal Activities	987
42.2.1.3	Anti-Viral Activities	989
42.2.2	Antioxidant Activities	991
42.2.3	Antiphlogistic Activity	994
42.2.4	Anti-Cancer Activities	996
42.2.5	Miscellaneous Activities	998
42.2.5.1	Penetration Enhancement	998
42.2.5.2	EOs in Food	999
42.2.5.3	Antinociceptive Effects	999
42.2.5.4	Insect Repellent Activity	999
42.3	Conclusion	1000
	References	1000
43	Essential Oils Used in Packaging: Perspectives and Limitations	1009
	<i>Khadija El Bourakadi, Abou El Kacem Qaiss and Rachid Bouhfid</i>	
43.1	Introduction	1009
43.2	Essential Oils: Definition, Preparation, and Composition	1010
43.3	Essential Oils: Medicinal and Biological Functions	1012
43.4	Functional Application of Essential Oils	1013
43.5	Active Packaging Material Based on Essential Oils	1014
43.5.1	Composite and Nanocomposite Materials Based on Essential Oils	1014
43.5.2	Advantages	1017
43.5.3	Limitations	1018
43.6	Conclusion and Future Perspectives	1019
	References	1020
Index		1025

Preface

Essential oils have been used by global communities for centuries, for different purposes such as medicinal, flavoring, preservatives, perfumery, aromatherapy, dentistry, cosmetics, insecticide, fungicide, bactericide, among others. Essential oils are natural and biodegradable substances, usually non-toxic or with low toxicity to humans. Essential oils are botanical products with having volatile nature and are known for their special odor and are found effective in the treatment of oxidative stress, cancer, epilepsy, skin allergies, indigestion, headache, insomnia, muscular pain, and respiratory problems, etc. Essential oils principally enhance resistance to abiotic stress and protection against aquatic herbivores. They possess antimicrobial, antifungal, antitumor, and antioxidant activities. However, essential oils are easily lost or degraded under ambient conditions (temperature, air, light, and humidity), resulting in limited applications. So, their encapsulation is one of the proven techniques to successfully protect essential oils and enable various applications. The purpose of this book is to offer current knowledge on essential oils' chemical structure, therapeutic, and biological activities, to describe their functional uses, and to assess the benefits and drawbacks of their usage in many fields.

Essential Oils: Extraction Methods and Applications addresses the topics related to methods of extracting essential oils, biological and therapeutic applications, their uses in different sectors of the industry, and will also address methods and applications of encapsulated essential oils. In addition, we cover issues such as the latest biological applications of essential oils, as well as traditional and modern methods for extracting essential oils. This book should be useful for different industries like pharma, perfumery, flavoring, perfumery, aromatherapy, cosmetics, others and also useful for faculty, researchers, students from academics, and laboratories which are linked to essential oils and their useful properties, applications of the different paradigms. The summaries of the work reported in the following 43 chapters are as follows:

Chapter 1 discusses the plant essential oils and their isolated bioactive components for their potential antiviral activities in detail. The fundamental knowledge of antiviral properties of essential oil along with their mechanisms of actions, efficacy, and safety is needed for their targeted drug delivery systems, which are consequential to their further research, new drug design, and further applications.

Chapter 2 covers the use of essential oils derived from aromatic plants as a safer and more nutritious alternative to artificial preservatives. Essential oils' natural properties, extraction procedures, and activity against pathogenic and deteriorating microorganisms, as well as their uses in food preservation, are discussed.

Chapter 3 reviews the sources and composition of various essential oils and the variety of extraction methods. Primarily, it focuses on applying essential oils in different industrial sectors like chemicals, food preservation, pharmaceutical, and pesticides, etc.

Chapter 4 focuses on the effect of various abiotic and biotic factors (drought, temperature, salt, heavy metals, UV light, living organisms, etc.) on essential oils production and composition. The importance of these factors to adequate agricultural practices for aromatic plants cultivation and to obtain high-quality essential oils is also discussed.

Chapter 5 emphasizes the potential antiviral effect of essential oils by reviewing some recent literature. It illustrates the different methods implemented to investigate the *in vitro* antiviral activity of EOs and their components along with their mechanisms of action. Furthermore, the effectiveness of EOs against several viral illnesses that impact human body systems, as well as some plants and animals, are also highlighted.

Chapter 6 discusses *Mentha* species and their chemical compositions on account of their biological activity as reported by the scientists, with a focus on microbiological activity. *Mentha piperita* L. is judged to be the most promising of the species offered to be used as an herbal medication.

Chapter 7 describes the plant secondary metabolites that play a significant role as anti-oxidants, anti-cancerous, anti-microbial, and have medicinal properties. The influence of microbes on plants is elaborated in the context of the enhanced production of these secondary metabolites in various stress conditions, with mechanisms of contact briefly elaborated.

Chapter 8 details the valorization of limonene (an essential oil) into compounds with high commercial value by different reactions, such as alkoxylation, hydration, and acetalization over heterogeneous catalysts. Also, the conversion of limonene into p-cymene is studied. Different solid materials, like clays, zeolites, heteropolyacids, and silica with sulfonic groups towards the valorization of limonene are discussed.

Chapter 9 discusses the role of essential oils in various industrial applications, focusing on pharmaceutical, cosmetic manufacturing, food processing, and preservation industry. The major focus dealt with volatile bioactive compounds in essential oils that are responsible for altering synthetic additives with natural composites in food, cosmetics, and medicines.

Chapter 10 discusses the most common uses of essential oils in various sectors. It focuses on the increased use of essential oils in the food, beverage, packaging, cosmetics, perfumery, medical, agriculture, textile, and cleaning industries in line with the increasing awareness and demand of consumers for natural ingredients.

Chapter 11 deals with various pharmacological activities of essential oils and their major chemical components. The mechanism of action and pharmacological targets of various essential oils particularly anti-inflammatory, anticancer, antiviral, antifungal, larvicidal, antidiabetic, and antibacterial activities are discussed in the present chapter. Additionally, the potential efficacy of terpenoids and phenylpropanoids in the treatment of cancer, inflammation, and viral infections are illustrated in this chapter.

Chapter 12 reveals the stability and efficacy associated challenges that are often encountered by essential oils that led to compromised efficiency. Further, the chapter gives insight to overcome these challenges through various encapsulation techniques, their formulation aspect, and the advantages as per the reported literature.

Chapter 13 discusses the antimicrobial effect of essential oils and their food application. Additionally, the biotechnological strategies for extracting essential oils for food application

and the methods for evaluating the essential oil's inhibitory activity are discussed. Moreover, the influence of extraction methods on the antimicrobial compounds in essential oils is also presented.

Chapter 14 epitomizes the application of essential oils in food packaging and food products. Essential oils sources such as plants, fruit, and flowers and their chemical composition are presented in this chapter. The main focus of this chapter is to highlight the potential application of essential oils as an antimicrobial, antifungal, and antioxidant agent in different food packaging and products.

Chapter 15 discusses the use of essential oils against biofilm-forming bacteria. The formation and organization of biofilms and their role in acquiring antibiotic resistance are presented. The main focus is given to provide information on the nature of essential oils, their antimicrobial and antibiofilm activities, and their mechanism of action.

Chapter 16 discusses the biological applications of essential oils such as antibacterial, antifungal, antiviral, antioxidant, and anti-inflammatory activities and their usage in the treatment of various ailments such as cancer, respiratory tract diseases, cardiovascular diseases, obesity, and diabetes. Additionally, the sources and extraction process of essential oil are also discussed.

Chapter 17 details the various essential oils used as biopesticides in agriculture, food storage, and the household. The delivery and the pesticidal modes of action of biopesticides are discussed in detail. The target pest and the active ingredients responsible for the pesticidal action are also presented.

Chapter 18 explicitly describes the larvicidal and ovicidal potential of essential oils with special reference to potent larvicidal activity against mosquito vectors including *Aedes aegypti*, *Anopheles stephensi*, *A. Albopictus*, and the ovicidal activity against human head lice (*Pediculus humanus*), domestic animal gastrointestinal nematode (*Haemonchus contortus*) and American bollworm (*Armigera Helicoverpa Hubner*).

Chapter 19 discusses the primary applications of essential oils as pesticides and their biological activity with a different class of organisms and discusses potential directions for the use of essential oils as pesticides of the future. Additionally, the role of essential oils synergistic compositions and toxic effects of essential oils on non-target organisms are also studied. The main aim of this chapter is to explain the present state of knowledge and recent advances in the phytochemistry of plant essential oils, their biological activity in a variety of species, and their potential as biopesticides.

Chapter 20 details the scientific advancement and discoveries about the biological potential of essential oils from micro and macroalgae, which has been arousing interest in the most diverse industrial applications. The major focus is attributed to the ecological importance and biodiversity of micro and macroalgae under this new market perspective.

Chapter 21 explains how to comprehend the complexity of olfactory responses by developing instrumental ways for objectively analyzing them. Particularly, gas chromatography-olfactometry technology has been profusely employed. An overview of data that may be collected using several gas chromatography-olfactometry techniques on essential oils is described, along with the procedures and foundations involved.

Chapter 22 covers key *in vitro* and *in vivo* methods to assess essential oils with a brief description of different protocols. Essential oils are found effective in the treatment of oxidative stress, cancer, skin allergies, headache, insomnia, muscular pain, and respiratory problems.

Chapter 23 details the various evaluation strategies adopted to assess the biological potential of different essential oils. This chapter aims at bringing up a summary and critical appraisal of the reported methods, both *in vitro* and *in vivo*, for assessment of the biological activities of essential oils.

Chapter 24 discusses the importance of algal essentials in the ecosystem. It further details environmental factors affecting the production of essential oils and their organic volatile compounds by algae. Their interesting bioactivity that can offer significant benefits and biotechnological relevance are also presented.

Chapter 25 is a good set of classical methods of obtaining essential oils along with their merits and demerits in terms of efficiency, cost, handling, and compatibility. The classical methods, owing to their simplicity, handling, and cost-effectiveness are mostly preferred in all sectors of extracting essential oils.

Chapter 26 discusses different techniques for the extraction of essential oils from plant-based materials. The biological activity, different pathways, and chemical constituents are also discussed in the chapter to investigate the suitable treatment for the extraction purpose.

Chapter 27 reviews the physicochemical/physical methods used to encapsulate essential oils, and the recent application of capsules. Green and non-thermal methods, such as supercritical fluid-based technologies along with electro-spraying reduce processing time, hence enhance encapsulation efficiency, and prolong the shelf life of encapsulated essential oils when compared to conventional processes.

Chapter 28 accounts for general aspects about the techniques of coacervation, extrusion, nano-precipitation, emulsification, spray drying, thin-film hydration method, and supercritical fluid technology and their applications in the essential oils encapsulation.

Chapter 29 presents encapsulation technology of essential oils, including preparation of emulsions, the encapsulation methods, and the release of encapsulated products. Several examples of successful applications and recommendations for future investigations of the encapsulated essential oil products into various industries, such as foods, cosmetics, textiles, and pharmaceuticals are also discussed.

Chapter 30 reviews the advantages of the supercritical fluid extraction of essential oils and updates the readers on the current efforts to reduce the cost of products and the environmental impact provoked by SFE. Also, this chapter discussed in detail the advances in the manufacture of commercial supercritical fluid extraction equipment, the studies of economic feasibility, and the life cycle assessment of supercritical fluid extraction to improve the sustainability of this process.

Chapter 31 discusses the superiority of supercritical fluid extraction of essential oils over other conventional extraction techniques. Furthermore, the effect of different process parameters influencing the efficiency of supercritical fluid extraction is deliberated upon. Optimization of supercritical fluid extraction process is reviewed using different statistical experiments like Box-Behnken design, Central composite design, Taguchi design, and artificial neuron network.

Chapter 32 examines the benefits of using supercritical fluid to extract essential oils, including process parameters and their impacts, as well as examples from the literature. Information regarding industrial interest is also exemplified, such as the scale-up and economic analysis. The importance of mathematical modeling along with its applications are also discussed.

Chapter 33 summarizes the fundamentals of the extraction of essential oils with supercritical fluids at a laboratory, pilot, and industrial scale. The effects of process parameters are analyzed based on thermodynamics and available mathematical models. Finally, the combination of novel green technologies with supercritical fluids like ultrasound, microwave, or membrane separation is briefly discussed.

Chapter 34 provides a basic understanding of supercritical fluids and the role of supercritical CO₂ in essential oils extraction. The influence of process parameters in the supercritical fluid extraction process along with optimization using the design of experiments is explained. The applications of various mathematical models for describing extraction curves of supercritical fluid extraction are also presented.

Chapter 35 discusses the classical extraction methodologies of essential oils. The selection of extraction method affects the yield of essential oils as well as their effect on the physicochemical properties. The major focus is given to communicate the chemical composition of essential oils and their pharmaceutical applications.

Chapter 36 addresses the main traditional techniques for extracting essential oils from plant matrices. The advantages and disadvantages of each method are discussed, mainly in terms of their specificities and process parameters as reported in the specialized literature.

Chapter 37 discusses the chemical compounds and their structures in various essential oils from extracted aromatic and medicinal plants. The essential oils can be extracted by classical and green methods, e.g. solvent extraction and supercritical fluid extraction respectively. The contemporary techniques have proved beneficial as they involve little or no solvent, less time, and energy.

Chapter 38 focuses on properties and dental applications of essential oils that are being researched as a form of complementary therapy in dentistry, although few are included in the dental practices.

Chapter 39 is coverage of key flora used to extract essential oils, their major therapies, and different therapeutic aspects. According to reported literature, the last decades of the 20th century was the blooming era of essential oils-based therapy which now gaining ample intention particularly in the treatment of nervous systems.

Chapter 40 details the various clinical applications of essential oils. Therapeutic indications of essential oils obtained from various parts of plants in diverse disease conditions including psychological disorders, cancers, dermatological diseases, pain, and inflammation, etc. are discussed in fair detail.

Chapter 41 deals with the role of essential oils and edible essential oils in the therapeutic field. The significance of the essential oils in clinical studies is discussed exhaustively. The side effects of the use of essential oils and the safety precautions to be carried out are also detailed.

Chapter 42 discusses various biological activities of essential oils extracted from plants. The emphasis is on the mechanism of action, communicating the benefits, disadvantages, and future viability of various applications of the volatile oils to contribute to citizen science. Furthermore, the history of the benefits of essential oils is discussed.

Chapter 43 goals are to afford a summary of current knowledge about essential oils' chemical structure, therapeutic, and biological activities, to define their functional applications, and to evaluate the possibilities and limitations of their use in the food industry.

Highlights:

- Provides a broad overview of essential oils
- Explores different extraction methods of essential oils
- Elaborate potential applications of essential oils in varied fields hence realizing their broad significance
- Reveals potential properties of essential oils
- Highlights supercritical fluid extraction with CO₂ as an innovative method to obtain essential oils

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Biological Potential of Essential Oils: Evaluation Strategies

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Abstract

Among the different bioactive phytochemical constituents, essential oils are widely accepted, recognized, and used in food, cosmetic, chemical industries, pharmaceutical industries as well as even in our daily life. They are the complex mixtures of volatile organic compounds which are characterized by a strong odor produced in the form of secondary metabolites in plants. Since essential oils have exhibited diverse biological activities, there is an increasing trend of exploitation of these natural products in the cosmetic and pharmaceutical industries. Characterization and *in-vitro*, and *in-vivo* evaluation of these essential oils are very important owing to the regulatory requirements for use in drug and cosmetic product development. This chapter aims at bringing up a summary and critical appraisal of the reported methods, both *in-vitro* and *in-vivo*, for assessment of the biological activities of essential oils.

Keywords: Essential oil, biological activity, antibacterial, antimicrobial, antifungal, anti-inflammatory, antidiabetic, anticancer

23.1 Introduction

In the present era, natural products have gained much more interest as compared to their synthetic counterparts because of their safety profile, low adverse effects, eco-friendly nature, and easy availability [1]. From ancient times, plants or their specific parts are used for nutritional as well as for medicinal values [2–4]. Plant sources providing various classes of chemical compounds and they are termed phytochemicals. Some of the phytochemicals have medicinal values and are known as bioactive phytochemical constituents. The most important bioactive phytochemical constituents obtained from plant sources are tannins, terpenoids, alkaloids, phenolic compounds, flavonoids, saponins, essential oils, etc. [5]. Among the different bioactive phytochemical constituents, essential oils are widely accepted, recognized, and used in food, cosmetic, chemical industries, pharmaceutical

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