Essential Oils in Food Preservation, Flavor and Safety

Edited by

Victor R. Preedy
Department of Nutrition and Dietetics,
King's College London, London, UK
Contents

Contributors xxiii
Biography xxxi
Preface xxxiii

Part I
General Aspects

1. Essential Oils: What They Are and How the Terms Are Used and Defined

José-Luis Ríos

Introduction 3
An Historical Overview 3
Concept and Definition 3
Variability of Essential Oils 4
Presence and Functions in the Vegetable Kingdom 4
Obtaining Essential Oils 4
Control and Analyses 5
Chemical Composition 5
Terpenes 6
Allyl phenols 6
Other Constituents 7
Use of Essential Oils 7
Cosmetics 8
Medicine and Pharmaceutics 8
Food 9
References 9


Tzi Bun Ng, Evandro Fei Fang, Alaa El-Din Ahmed Bekhit and Jack Ho Wong

Introduction 11
Methods of Authentication 11
Gas Chromatography–Mass Spectrometry (GC–MS) for Hyssopus cuspidatus Essential Oil 11
Determination of Enantiomeric Composition for Essential Oils of Indian Origin 12

Supercritical Fluid Extraction GC–MS (SFE GC–MS) Involving Use of Multidimensional GC to Resolve Enantiomers for Essential Oils of Lavandula 12
Enantioselective Capillary Gas Chromatography and Online Methods of Isotope Ratio Mass Spectrometry 13
Enantioselective Capillary Gas Chromatography and Isotope Ratio Mass Spectrometry, Coupled Online with Capillary Gas Chromatography on an HPS Column for Various Essential Oils 13
Isotope Ratio Mass Spectrometry Online Coupled with Capillary Gas Chromatography (GC-Py-IRMS) 14
Gas Chromatography–Combustion–Isotope Ratio Mass Spectrometry (GC–C–IRMS), in Combination with GC–MS and GC Flame Ionization Detector (FID) for Rosa damascene Essential Oil 14
Headspace–Solid Phase Microextraction Coupled to GC–C–IRMS for Citrus Oils 14
Multi Dimensional Gas Chromatography (MDGC) and GC–C–IRMS for Bitter Orange Flower Oil (or Neroli) and Lime Oils 14
GC–FID and GC–MS for Zanthoxylum armatum Leaf Essential Oil 15
Near Infrared (NIR) Spectroscopy for Sandalwood Oil 15
NIR Spectroscopy for Various Essential Oils 15
Simple Sequence Repeat (SSR) 16
3. Cultivation of Essential Oils
Sanjib Bhattacharya

Introduction
Important Species for Essential Oil Cultivation
Factors Influencing Cultivation of Essential Oils
   Environmental Factors
   Harvesting-Related Factors
   Fertilizers
   Cultivars
Cultivation of Selected Essential Oil-Bearing Plants
   Turpentine Oil
   Peppermint/Mentha Oil
   Caraway Oil
   Cardamom Oil
   Coriander Oil
   Ajowan Oil
   Dill Oil
   Fennel Oil
   Orange Peel Oil
   Nutmeg Oil
   Cinnamon Oil
   Garlic Oil
   Black Pepper Oil
   Vetiver Oil
   Rosemary Oil
   Palmarosa Oil
   Citronella Oil
   Clove Oil
   Ginger Oil
   Lemon Grass Oil

Summary Points
References

4. Methods for Extracting Essential Oils
Alexandros Ch Stratakos and
Anastasios Koidis

Introduction
Conventional Essential Oil Extraction Methods
   Cold Expression
   Solvent Extraction
   The “Enfleurage” Method
   Distillation
   Extraction with Supercritical Gases
   Benefits of Supercritical Fluid Extraction
   Comparison of Supercritical Fluid Extraction to Conventional Methods/Factors Affecting Extraction Conditions
   Novel “Green” Extraction Methods
      Microwave-Assisted Extraction
      Controlled Pressure Drop Process
      Ultrasound-Assisted Extraction
      Effects of Extraction Methods on Essential Oil Characteristics

Summary Points
References

5. Biologically Active Essential Oils against Stored Product Pests
Kaan Polatoglu and Omer Cem Karakoç

Introduction
Active Essential Oils against Sitophilus granarius (L.)
Active Essential Oils against Sitophilus oryzae (L.)
Active Essential Oils against Sitophilus zea mays Motschulsky
Essential Oils as Stored Product Pest Control Agents
Conclusions
References

6. Essential Oils for Arthropod Pest Management in Agricultural Production Systems
Yong-Lak Park and Jun-Hyung Tak

Introduction
Essential Oils as Pesticides
   Modes of Action of Essential Oils
   Essential Oils for Arthropod Pest Management
   Advantages and Disadvantages of Essential Oils as Pesticides
      Ecotoxicology of Essential Oils
      Nontarget Effects of Essential Oils in Pest Management
      Major Disadvantages of Using Essential Oils in Pest Management

Summary Points
References

7. Use of Essential Oils in Food Preservation
Oluyemisi Elizabeth Adelakun, Olusegun James Oyelade and Bosede Folake Olanipekun

Introduction
   Definition
   Preservative Effects of Essential Oils
## 8. Use of Essential Oils as a Preservative of Meat

_Elinton Chivandi, Rachael Dangarembizi, Trevor T. Nyakudya and Kennedy H. Erlwanger_

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>85</td>
</tr>
<tr>
<td>Methods and Principles of Meat Preservation</td>
<td>85</td>
</tr>
<tr>
<td>Meat Preservation: An Historical Review</td>
<td>85</td>
</tr>
<tr>
<td>Use of Essentials Oils in the Preservation of Meat</td>
<td>87</td>
</tr>
<tr>
<td>Benefits of the Use of Essential Oils in Meat Preservation</td>
<td>87</td>
</tr>
<tr>
<td>Specific Examples: Essentials Oils Currently Used in the Preservation of Meat</td>
<td>88</td>
</tr>
<tr>
<td>Mechanisms of Action of Essential Oils in the Preservation of Meat</td>
<td>89</td>
</tr>
<tr>
<td>Preservation against Microbial Spoilage</td>
<td>89</td>
</tr>
<tr>
<td>Preservation against Lipid Oxidation</td>
<td>89</td>
</tr>
<tr>
<td>Current Challenges: EOs in Meat Preservation</td>
<td>89</td>
</tr>
<tr>
<td>Future Prospects of Using EOs in Meat Preservation</td>
<td>90</td>
</tr>
<tr>
<td>Summary Points</td>
<td>90</td>
</tr>
<tr>
<td>References</td>
<td>91</td>
</tr>
</tbody>
</table>

## 9. Essential Oil-Based Nanoemulsion Formation by Low- and High-Energy Methods and Their Application in Food Preservation against Food Spoilage Microorganisms

_Saranya Sugumar, Vijayalakshmi Ghosh, Amitava Mukherjee and Natarajan Chandrasekaran_

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>93</td>
</tr>
<tr>
<td>Methods of Nanoemulsion Formation</td>
<td>94</td>
</tr>
<tr>
<td>Low-Energy Emulsification Methods</td>
<td>94</td>
</tr>
<tr>
<td>Spontaneous Emulsification</td>
<td>94</td>
</tr>
<tr>
<td>Phase Inversion Temperature (PIT)</td>
<td>95</td>
</tr>
<tr>
<td>Phase Inversion Composition (PIC)</td>
<td>95</td>
</tr>
<tr>
<td>Emulsion Inversion Point (EIP)</td>
<td>95</td>
</tr>
<tr>
<td>High-Energy Methods</td>
<td>95</td>
</tr>
<tr>
<td>High-Pressure Homogenizers</td>
<td>96</td>
</tr>
<tr>
<td>Microfluidizer</td>
<td>96</td>
</tr>
<tr>
<td>Ultrasonic Generators</td>
<td>96</td>
</tr>
<tr>
<td>Antimicrobial Activity of Nanoemulsion Using Essential Oils in Food Preservation</td>
<td>97</td>
</tr>
<tr>
<td>Summary Points</td>
<td>100</td>
</tr>
<tr>
<td>References</td>
<td>100</td>
</tr>
</tbody>
</table>

## 10. Use of Essential Oils in Poultry Production

_Ahmed M. Amerah and Arthur C. Ouwehand_

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>101</td>
</tr>
<tr>
<td>Essential Oils Definition and Mechanisms</td>
<td>101</td>
</tr>
<tr>
<td>Antimicrobial Mechanisms</td>
<td>101</td>
</tr>
<tr>
<td>Antioxidant Properties</td>
<td>102</td>
</tr>
<tr>
<td>Effect of Essential Oils on Poultry Performance</td>
<td>102</td>
</tr>
<tr>
<td>Effect of Essential Oils on Gut Health in Poultry</td>
<td>106</td>
</tr>
<tr>
<td>Effects of Essential Oils on Carcass Quality and Taste</td>
<td>107</td>
</tr>
<tr>
<td>Effect of Essential Oils on Poultry Red Mite (Dermanyssus gallinae)</td>
<td>107</td>
</tr>
<tr>
<td>Regulatory Perspective</td>
<td>107</td>
</tr>
<tr>
<td>Summary Points</td>
<td>109</td>
</tr>
<tr>
<td>References</td>
<td>109</td>
</tr>
</tbody>
</table>

## 11. Essential Oils as Flavorings in Carbonated Cola and Citrus Soft Drinks

_Sunday J. Ameh and Obiageri Obodozie-Ofoegbu_

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>111</td>
</tr>
<tr>
<td>Essential Oils, Spices, and Aromatic Plants</td>
<td>111</td>
</tr>
<tr>
<td>Carbonated Soft Drinks</td>
<td>111</td>
</tr>
<tr>
<td>History of Spices and the Political Economy of the Soda Industry Worldwide</td>
<td>112</td>
</tr>
<tr>
<td>Industrial Production of Sodas</td>
<td>113</td>
</tr>
<tr>
<td>Essential Oils in Cola and Citrus Soda Concentrates</td>
<td>114</td>
</tr>
<tr>
<td>Essential Oils as Flavorings in Sodas Concentrates</td>
<td>114</td>
</tr>
<tr>
<td>Essential Oils Used in Cola and Citrus Soda Concentrates</td>
<td>114</td>
</tr>
<tr>
<td>Formulation of Essential Oils into Soda Concentrates</td>
<td>116</td>
</tr>
<tr>
<td>Advanced Equipment and Techniques Used in Flavor Research and Soda Technology</td>
<td>118</td>
</tr>
<tr>
<td>Typical Concentrations of Essential Oil Molecules in Sodas</td>
<td>118</td>
</tr>
<tr>
<td>Conclusion</td>
<td>118</td>
</tr>
<tr>
<td>Summary Points</td>
<td>119</td>
</tr>
<tr>
<td>References</td>
<td>120</td>
</tr>
</tbody>
</table>
12. Microencapsulation Technology and Essential Oil Pesticides for Food Plant Production

Vera Krimer Malešević, Žužana Vaštag, Ljiljana Radulović-Popović, Mađarev-Popović Senka and Ivana Perićin-Starčević

Introduction 123
Essential Oils 123
Essential Oils as Pesticides 125
Summary Points 128
References 128

13. Effect of Essential Oils on Organoleptic (Smell, Taste, and Texture) Properties of Food

Abdalbasit Adam Mariod

Introduction 131
Physical and Chemical Properties of EOs 131
Effect of EOs on Food Organoleptic Properties (OLP) 132
Summary Points 136
References 136

14. Use of Essential Oils in Food Packaging

Irene Dini

Introduction 139
Antimicrobial Packaging Systems 139
Systems for Delivering Antimicrobials 140
Encapsulation of EOs 140
Essential Oils Combined with Paper 141
Essential Oils Combined with Edible Film 141
Essential Oil Vapor and Negative Air Ions 142
Legal Aspects of the Use of EOs in Foods 142
Food Packaging Projected to Extending Shelf-Life of Main Food Categories 142
Antimicrobial Activity of EOs in Food Systems Proposed to Enhance Meat Quality 142
Antimicrobial Activity of EOs in Food Systems Proposed to Enhance Fish Quality 143
Antimicrobial Activity of EOs in Food Systems Proposed to Enhance Dairy Product Quality 145
Antimicrobial Activity of EOs in Food Systems Proposed to Enhance Minimally Processed Fruit and Vegetable Quality 145
Antimicrobial Activity of EOs in Food Systems Proposed to Enhance Juice Quality 145
Antimicrobial Activity of EOs in Food Systems Proposed to Enhance Cereal-Based Food Quality 145
Summary Points 146
References 146

15. Essential Oils Added to Edible Films

Raúl Avila-Sosa, Enrique Palou and Aurelio López-Malo

Introduction 149
General Aspects of Edible Films 149
Edible Film Formation and Functional Properties 150
Essential Oils Used in Edible Films 150
In vitro Studies 151
In vivo Studies 152
Concluding Remarks 153
Summary Points 153
Acknowledgments 153
References 153

16. Essential Oils in Food Applications: Australian Aspects

Yasmina Sultanbawa

Introduction 155
Australian Native Essential Oils 155
Antimicrobial Agents in Food Applications 155
Insect Repellents in Agriculture 157
Flavoring Agents in Food and Beverages 159
Issues and Challenges of Using EOs in Food Production 159
Summary Points 159
References 159

Part II

Named Essential Oils

17. African Cardamom (Aframomum danielli) Oils

Gabriel Olaniran Adegoke, Felix O. Evwiehurhoma and M.O. Afolabi

Introduction 163
Botanical Aspects 163
Species and Geographical Distribution 163
Description 163
Cultivation and Harvesting 164
Usage and Applications 165
Chemical Composition 165
Usage and Applications in Food Science 166
Control of Foodborne Pathogens 166
Synergistic Activities 166
Antibrowning Effects 166
Food Preservation 168
Summary Points 169
References 170
18. Agarwood (Aquilaria malaccensis) Oils

Nor Azah Mohamad Ali, Chee Beng Jin and Mailina Jamil

Introduction 173
Botanical Aspects 173
Usage and Applications 174
Usage and Applications in Food Science 175
Herbal Tea 178
Wine 179
Noodles and Biscuits 179
Herbal Infusions and Beverages 179
Research on Agarwood by Forest Research Institute Malaysia 179
Summary Points 180
References 180

22. Aniseed (Pimpinella anisum, Apiaceae) Oils

Leandro Rocha and Caio P. Fernandes

Introduction 209
Botanical Aspects 209
Usage and Applications 210
Usage and Applications in Food Science 211
Summary Points 212
References 213

23. Anise Myrtle (Syzygium anisatum) Oils

Yasmina Sultanbawa

Introduction 215
Botanical Aspects 215
Usage and Applications 216
Antimicrobial Properties 217
Flavoring Agent 217
Safety of Anise Myrtle Essential Oils 218
Summary Points 218
References 218


Suzana Vieira Rabelo, Jullyana de Sousa Siqueira Quintans, Emmanoel Vilaça Costa, Jackson Roberto Guedes da Silva Almeida and Lucindo José Quintans Júnior

Introduction 221
Botanical Aspects 222
Usage and Applications 223
Usage and Applications in Food Science 223
Annona atemoya Aubl. 224
Annona cherimolia Mill. 224
Annona coriacea Mart. 224
Annona foetida Mart. 224
Annona glabra L. 225
Annona muricata L. 225
Annona pickellii (Diels) H. Rainer 225
Annona reticulata L. 226
Annona salzmannii A. DC. 226
Annona senegalensis Pers. 227
Annona squamosa L. 227
Annona vepretorum Mart. 227
<table>
<thead>
<tr>
<th>25. Basil (Ocimum basilicum L.) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Qing X. Li and Chiou L. Chang</strong></td>
</tr>
</tbody>
</table>

| Introduction | 231 |
| Botanical Aspects of Basil | 231 |
| Extraction, Compositions and Usage of Basil Oil | 232 |
| Basil Oil Extraction | 232 |
| Chemical Composition and Usage of Basil Oil | 232 |

| Applications of Basil Oil in Food Science | 233 |
| Culinary Flavoring | 233 |
| Food Preservation and Food Safety | 233 |
| Antimicrobial Activities | 234 |
| Preservatives for Processed Foods | 234 |
| Stored Grain Protection against Insect Pests | 234 |
| Postharvest Preservation of Fresh Fruits and Vegetables | 235 |
| Postharvest Preservation of Grains | 235 |
| Usages of Basil Oil as Preservatives in Food Packaging and Processing | 235 |
| Applications of Basil Oil and its Main Components to Livestock, Aquaculture, and Seafood | 236 |
| Applications of Basil Oil as Insecticides in Food Production | 236 |
| Disinfection of Seeds with Basil Oil | 236 |
| Safety of Basil Oil Components | 236 |

| Summary Points | 237 |
| References | 237 |

<table>
<thead>
<tr>
<th>26. Bay Laurel (Laurus nobilis) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>António Marques, Bárbara Teixeira and Maria Leonor Nunes</strong></td>
</tr>
</tbody>
</table>

| Introduction | 239 |
| Botanical Aspects | 239 |
| Usage and Applications | 240 |
| Usage and Applications in Food Science | 240 |
| Meat Products | 241 |
| Seafood Products | 243 |
| Agriculture Products | 243 |

| Summary Points | 244 |
| References | 245 |

<table>
<thead>
<tr>
<th>27. Bergamot (Citrus bergamia) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raúl Avila-Sosa, Addi Rhode Navarro-Cruz, Maria E. Sosa-Morales, Aurelio López-Malo and Enrique Palou</strong></td>
</tr>
</tbody>
</table>

| Introduction | 247 |
| Botanical Aspects | 247 |

<table>
<thead>
<tr>
<th>28. Bitter Gourd (Momordica charantia) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Evandro Fei Fang and Tzi Bun Ng</strong></td>
</tr>
</tbody>
</table>

| Introduction | 253 |
| Botanical Aspects | 253 |
| Usage and Applications of Bitter Gourd | 253 |
| Usage and Applications of Bitter Gourd Oils in Food Science | 254 |
| Composition | 254 |
| A Candidate in Solid Fat Application | 255 |
| Conclusions and Future Perspectives | 256 |
| Disclaimer | 257 |
| Acknowledgment | 257 |
| References | 257 |

<table>
<thead>
<tr>
<th>29. Bitter Orange (Citrus aurantium L.) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sirajudheen Anwar, Nafees Ahmed, Antonio Speciale, Francesco Cimino and Antonella Saija</strong></td>
</tr>
</tbody>
</table>

| Introduction | 259 |
| Botanical Aspects | 259 |
| Usages and Applications | 260 |
| Usage and Application in Food Sciences | 261 |
| Rationale and Limits | 261 |
| Bitter Oil and Antibacterial Activity for Food Preservation | 261 |
| Antimicrobial Action Mechanisms of Citrus Essential Oils | 264 |
| Bitter Oil and Antifungal Activity for Food Preservation | 265 |
| Bitter Oil and Antioxidant Activity for Food Preservation | 265 |
| Bitter Oil and Food Spoilage | 266 |
| Summary Points | 267 |
| References | 267 |

<table>
<thead>
<tr>
<th>30. Black Cumin (Nigella sativa) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mohamed F. Ramadan</strong></td>
</tr>
</tbody>
</table>

| Introduction | 269 |
| Botanical Aspects | 269 |
| Usage and Applications | 270 |
| Usage and Applications in Food Science | 272 |
| Antimicrobial Activity | 272 |
| Antioxidant Activity | 273 |
| Summary Points | 274 |
| References | 274 |
31. Black Pepper (Piper nigrum L.) Oils

Mansurah A. Abdulazeez, Ibrahim Sani, Bolanle D. James and Abdulmalik S. Abdullahi

Introduction 277
Botanical Aspects 277
Historical Cultivation 279
Present Day Cultivation 280
Usage and Applications 281
Historical Usage and Applications 281
Traditional Usage and Applications 281
Usage and Applications in Food Science 282
Essential Oil of Black Pepper as Preservative 282
Antibacterial Activities of Essential Oil of Piper nigrum 282
Antioxidant Activities of Essential Oil of Piper nigrum 283
Essential Oil of Black Pepper for Preservation of Orange Juice 283
Extraction of Essential Oil of Black Pepper 283
Effect of Radiation and Heat Treatment on Composition of EO of Black Pepper 284
Summary Points 284
References 284

32. Caraway (Carum carvi L.) Essential Oils

Iraj Rasooli and Abdolamir Allameh

Introduction 287
Botanical Aspects 287
Usage and Applications of Caraway 288
Usage and Applications in Food Science 288
Extraction and Purification Technologies for the Extraction of Essential Oils 291
Safety Issues of Drying and Storage of Caraway Seeds 291
Summary Points 292
References 292

33. Cardamom (Elettaria cardamomum Maton) Oils

Farooq Anwar, Ali Abbas, Khalid M. Alkharfy and Anwar-ul-Hassan Gilani

Introduction 295
Botanical Aspects 295
Flowers and Fruit 295
Uses and Applications 297
Usage and Applications in Food Science 297
Essential Oil Yield and Chemical Composition 298
Summary Points 300
Acknowledgments 300
References 301

34. Carrot (Daucus carota) Oils

Tzi Bun Ng, Evandro Fei Fang, Xiaolin Li, Qiu Lu, Jack Ho Wong and Hongwei Guo

Introduction 303
Botanical Aspects 303
Usage and Applications 303
Usage and Applications in Food Science 304
Composition 304
Antimicrobial Activity 306
Metabolic Effects 306
Adverse Effects of Excessive Intake of Carrots 306
Summary Points 307
Disclaimer 307
Acknowledgments 307
References 307

35. Carvone (Mentha spicata L.) Oils

Caterina Morcia, Giorgio Tumino, Roberta Ghizzoni and Valeria Terzi

Introduction 309
Botanical Aspects 309
Usage and Applications 310
Usage and Applications in Food Science 311
Summary Points 312
References 315

36. Cedar (Cryptomeria japonica) Oils

Yoshiyuki Mizushina and Isoko Kuriyama

Introduction 317
Botanical Aspects 317
Usage and Applications 318
Usage and Applications in Food Science 318
Preparation of EOs from USBs and the Xylem Tissue of Japanese Woods 318
Suppressive Effects of EOs from Japanese Woods on the Food Decay-Related Microbial Growth 318
Effects of EOs from Japanese Wood on in vitro DNA Polymerase Activity from Escherichia coli 319
Chemical Composition of EOs from Japanese Cedar 320
Suppressive Effects of Sesquiterpenes from EO–USB on Escherichia coli Growth 321
Inhibitory Effects of Sesquiterpenes from EO–USB on the Activities of the DNA Metabolic Enzymes in Escherichia coli 322
Summary Points 323
Acknowledgments 323
References 323
<table>
<thead>
<tr>
<th>37. Celery (Apium graveolens var. dulce (Mill.) Pers.) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adam Kokotkiewicz and Maria Luczkiewicz</td>
</tr>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Botanical Aspects</td>
</tr>
<tr>
<td>Usage and Applications</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
</tr>
<tr>
<td>Summary Points</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>38. Cinnamon (Cinnamomum zeylanicum) Essential Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gabriel A. Cardoso-Ugarte, Aurelio López-Malo and María E. Sosa-Morales</td>
</tr>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Botanical Aspects</td>
</tr>
<tr>
<td>Usage and Applications</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
</tr>
<tr>
<td>Antioxidant</td>
</tr>
<tr>
<td>Antifungal</td>
</tr>
<tr>
<td>Antibacterial</td>
</tr>
<tr>
<td>Packaging</td>
</tr>
<tr>
<td>Summary Points</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>39. Clove (Syzygium aromaticum) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>María G. Gohi, Sara I. Roura, Alejandro G. Ponce and María R. Moreira</td>
</tr>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Botanical Aspects</td>
</tr>
<tr>
<td>Usage and Applications</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
</tr>
<tr>
<td>Effects on the Native Microflora of Organic Swiss Chard</td>
</tr>
<tr>
<td>Inhibitory Parameters of Essential Oils to Reduce Food-Borne Pathogens</td>
</tr>
<tr>
<td>Clove Essential Oil Application on Lettuce Seeds</td>
</tr>
<tr>
<td>Preharvest Application of Clove Essential Oil Solutions in Lettuce Plants</td>
</tr>
<tr>
<td>Different Methods for the Technological Application in Lettuce Leaves</td>
</tr>
<tr>
<td>Effects of Clove Oil on Escherichia coli O157:H7 in Blanched Spinach and Cooked Minced Beef</td>
</tr>
<tr>
<td>Clove Essential Oil as Reducing Agent of Peroxidase Activity in Leafy Vegetables</td>
</tr>
<tr>
<td>Summary Points</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>40. Coriander (Coriandrum sativum) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alam Zeb</td>
</tr>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Botanical Aspects</td>
</tr>
<tr>
<td>Usage and Applications</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
</tr>
<tr>
<td>Antioxidant and Food Preservation</td>
</tr>
<tr>
<td>Food Flavoring Agent</td>
</tr>
<tr>
<td>Antibacterial and Antifungal Applications</td>
</tr>
<tr>
<td>Summary Points</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>41. Costmary (Chrysanthemum balsamita) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petras Rimantas Venskutonis</td>
</tr>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Botanical Aspects</td>
</tr>
<tr>
<td>Usage and Applications</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
</tr>
<tr>
<td>Costmary Essential Oil Yield and Composition</td>
</tr>
<tr>
<td>Bioactivities of Costmary Essential Oil and Its Main Constituents</td>
</tr>
<tr>
<td>Conclusion</td>
</tr>
<tr>
<td>Summary Points</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>42. Cumin (Cuminum cyminum L.) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manisha Mandal and Shyamapada Mandal</td>
</tr>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Botanical Aspects</td>
</tr>
<tr>
<td>Usage and Applications</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
</tr>
<tr>
<td>Nutritional Value</td>
</tr>
<tr>
<td>Antispoilage Activity</td>
</tr>
<tr>
<td>Antibacterial Activity</td>
</tr>
<tr>
<td>Antifungal Activity</td>
</tr>
<tr>
<td>Antioxidant Activity</td>
</tr>
<tr>
<td>Cuminin Chemistry</td>
</tr>
<tr>
<td>Safety and Toxicity</td>
</tr>
<tr>
<td>Summary Points</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>43. Curry Leaf (Murraya koenigii) Oils</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.R. Rajeswara Rao</td>
</tr>
<tr>
<td>Introduction</td>
</tr>
<tr>
<td>Botanical Aspects</td>
</tr>
<tr>
<td>Usage and Applications</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
</tr>
<tr>
<td>Summary Points</td>
</tr>
<tr>
<td>Acknowledgments</td>
</tr>
<tr>
<td>References</td>
</tr>
</tbody>
</table>
44. Curry Plant (Helichrysum sp.) Oils
D. Ben Hassine, D. Khilifi, H. Ferhout, E.G. Raoelison and J. Bouajila

45. Dill (Anethum graveolens L.) Oils
Zahra Tayarani Najaran, Mohammad K. Hassanzadeh, Maryam Nasery and Seyed Ahmad Emami

46. Eucalyptus (Eucalyptus citriodora Hook., Myrtaceae) Oils
Buniyamin A. Ayinde

47. Fenugreek (Trigonella foenum-graecum L.) Oils
Shyamapada Mandal and Manisha Deb Mandal

48. Frankincense (Boswellia) Oils
Hidayat Hussain, Ahmed Al-Harrasi and Ivan R. Green

49. Garlic (Allium sativum Linn.) Oils

50. Ginger (Zingiber officinale Rosc.) Oils
Ramakrishna Pai Jakribettu, Rekha Boloor, Harshith P. Bhat, Andrew Thaliath, Raghavendra Haniadka, Manoj P. Rai, Thomas George and Manjeshwar Shrinath Baliga

51. Grape Seed (Vitis vinifera) Oils
Tzi Bun Ng, Alaa El-Din Ahmed Bekhit, Evandro Fei Fang and Jack Ho Wong
## Adsorption of Mycotoxins

456

## Cosmetic Applications

456

## Usage and Applications in Food Science

457
- Chemical Composition
  - Use as Replacement in Food Products
  - Antimicrobial Activity
  - Use as Carrier for Essential Oils
  - Antioxidant Activity and Inhibitory Effects on Generation of Heterocyclic Aromatic Amines during Frying of Beef Patties

460

Summary Points
461

Disclaimer
461

Acknowledgments
461

References
461

## 52. Grapefruit (Citrus paradisi) Oils

Tzi Bun Ng, Alaa El-Din Ahmed Bekhit, Evandro Fei Fang, Xiaolin Li, Qiu Lu, Hongwei Guo and Jack Ho Wong

Introduction
463

Botanical Aspects
463

Usage and Applications
463
- As Gutta-perch Solvent
  - Insecticidal Activity and Antifeedant
  - Anti-elastase Activity

464

Usage and Applications in Food Science
464
- Composition
  - Flavoring Agent
  - Antimicrobial Activity
  - 1,1-Diphenyl-2-Picryl-Hydrazyl Radical-scavenging Activity

468

Summary Points
469

Disclaimer
469

Acknowledgments
469

References
469

## 53. Hyssop (Hyssopus officinalis L.) Oils

Asta Judžentienė

Introduction
471

Botanical Aspects
471

Usage and Applications
472

Usage and Applications of Hyssop in Food Science
472

Summary Points
478

References
478

## 54. Iris (Iris germanica) Oils

Hidayat Hussain, Ahmed Al-Harrasi, Ivan R. Green and Najeeb U. Rehman

Introduction
481

Botanical Aspects
481

Usage and Applications
482
- Antimicrobial Activity
- Antioxidant Activity
- Chemical Composition of Essential Oils from I. germanica

484

Summary
485

References
486

## 55. Jasmine (Jasminum sambac L., Oleaceae) Oils

Nafees Ahmed, Yousef A. Hanani, Shabana Y. Ansari and Sirajudheen Anwar

Introduction
487

Botanical Aspects
488

Usage and Applications
488

Usage and Applications in Food Industries
489
- As Antimicrobial for Food Preservation
- As Antioxidant
- As Flavoring Agent

491

Summary Points
493

References
494

## 56. Juniper (Juniperus communis L.) Oils

Kristina Ložienė and Petras Rimantas Venskutonis

Introduction
495

Botanical Aspects
495

Usage and Applications
496

Usage and Applications in Food Industries
497

Summary Points
499

References
499

## 57. Lavender (Lavandula angustifolia) Oils

Lauren A.E. Erland and Soheil S. Mahmoud

Introduction
501

Botanical Aspects
501

Usage and Applications
503

Usage and Applications in Food Science
504

Summary Points
507

References
507

## 58. Lemongrass (Cymbopogon spp.) Oils

Mansurah A. Abdulazeez, Abdulmalik S. Abdullahi and Bolanle D. James

Introduction
509

Botanical Description
509

Usage and Application of Lemongrass
511
59. Lemon Myrtle (*Backhousia citriodora*) Oils

Yasmina Sultanbawa

Introduction 517
Botanical Aspects 517
Usage and Applications 518
Usage and Applications in Food Science 518
Antimicrobial Properties 519
Flavoring Agent 519
Safety of Lemon Myrtle Essential Oils 520
Summary Points 520
References 520

60. Licorice (*Glycyrrhiza glabra* Linn.) Oils


Introduction 523
Botanical Aspects 523
Usage and Applications 524
Usage and Application in Food Science 525
Application and Safety-Quality Uses in Food 529
Summary Points 529
References 530

61. Lime (*Citrus aurantifolia*) Oils


Introduction 531
Botanical Aspects 531
Usage and Applications 532
Usage and Applications in Food Science 532
Summary Points 536
References 536

62. Lovage (*Levisticum officinale* Koch.) Oils

Petras Rimantas Venskutonis

Introduction 539
Botanical Aspects 539
Usage and Applications 540

63. Mexican Oregano (*Lippia berlandieri* and *Poliminthia longiflora*) Oils

Teresa Soledad Cid-Pérez, Guadalupe Virginia Nevárez-Moorillón, José Vinicio Torres-Muñoz, Enrique Palou and Aurelio López-Malo

Introduction 551
Botanical Aspects 551
Usage and Applications 553
Chemical Composition of Mexican Oregano Extracts 553
Usage and Applications in Food Science 557
Antimicrobial Activity of Mexican Oregano 557
Antioxidant Activity of Mexican Oregano 558
Summary Points 559
Acknowledgments 559
References 559

64. Mint (*Mentha spicata* L.) Oils

Om Prakash, Mahesh Chandra, A.K. Pant and D.S. Rawat

Introduction 561
Botanical Aspects 561
Usage and Applications 562
Usage and Applications in Food Science 563
Summary Points 568
Acknowledgment 571
References 572

65. Mugwort (*Artemisia vulgaris*) Oils

Farooq Anwar, Naveed Ahmad, Khalid M. Alkharfy and Anwar-ul-Hassan Gilani

Introduction 573
Botanical Aspects 573
Uses and Applications 574
Uses and Applications in Food Sciences 574
Essential Oil Production 575
Chemical Composition of Mugwort Essential Oil 575
Summary Points 578
References 578
66. Myrtle (Myrtus communis L.) Oils
Sirajudheen Anwar, Nafees Ahmed, Nasir Al Awad, Shabana Y. Ansari and Mohamed E. Wagih

Introduction 581
Botanical Aspects 581
Usage and Applications 582
Usage and Applications in Food Sciences 582
Myrtle Oil and Antibacterial Activity for Food Preservation 582
Myrtle Oil and Antifungal Activity for Food Preservation 583
Myrtle Oil and Antioxidant Activity for Food Preservation 583
Myrtle Oil and Food Spoilage 585
Summary Points 591
References 591

67. Neem (Azadirachta indica) Oils
Vijayalakshmi Ghosh, Saranya Sugumar, Amitava Mukherjee and Natarajan Chandrasekaran

Introduction 593
Botanical Aspects 593
Usage and Applications 594
Usage and Applications in Food Sciences 594
Antibacterial Activity 595
Antibacterial Activity In Vivo 597
Antifungal Activity 597
Antioxidant Activity 598
Agricultural Use 598
Summary Points 598
References 598

68. Negundo Chastetree (Vitex negundo) Oils
Cheng-jian Zheng and Lu-ping Qin

Introduction 601
Botanical Descriptions 601
Usage and Applications 602
Usage and Applications in Food Science 603
Chemistry of Volatile Oils 603
Insecticidal Bioactivity 604
Antimicrobial Activity 605
Safety 605
Summary Points 605
References 605

69. Nutmeg (Myristica fragrans Houtt.) Oils
Gomathi Periasamy, Aman Karim, Mebrahtom Gibrelianos, Gereziher Gebremedhin and Anwar-ul-Hassan Gilani

Introduction 607
Botanical Aspects 607
Uses and Applications 608
Uses and Applications in Food Sciences 608
Essential Oil Production 611
Chemical Composition of Nutmeg Essential Oil 611
Summary Points 614
References 615

70. Onion (Allium cepa) Essential Oils
F.J. Vazquez-Armenta, M.R. Cruz-Valenzuela and J.F. Ayala-Zavala

Introduction 617
Botanical Aspects 617
Usage and Applications 618
Usage and Applications in Food Science 618
Summary Points 622
References 622

71. Oregano (Origanum spp.) Oils

Introduction 625
Botanical Aspects 625
Usage and Application 625
Usage and Application in Food Science 626
Applications and Quality Issues 626
Application in Safety Issues 628
Summary Points 629
References 629

72. Patchouli (Pogostemon Cablin Benth) Oils
Kuntal Das

Introduction 633
Botanical Aspects 633
Plant Profile 633
Usage and Applications 636
Usage and Applications in Food Science 637
Patchouli cablin EO in Food Flavoring and Food Preservations 637
Patchouli cablin EO in Bakery Products 637
Patchouli cablin EO in Alcoholic and Nonalcoholic Beverages 638
73. Pune-sa (Nepeta) Oils

Hidayat Hussain, Ahmed Al-Harrasi and Ivan R. Green

Introduction 641
Botanical Aspects 641
Usage and Applications 641
Usage and Applications in Food Science
Antimicrobial Activity 642
Antioxidant Activity 647
Summary 647
References 647

74. Rockroses (Cistus sp.) Oils

Enrique Barrajon-Catalán, Laura Tomás-Menor, Aranzazu Morales-Soto, Nuria Martí Bruñá, Domingo Saura López, Antonio Segura-Carretero and Vicente Micol

Introduction 649
Botanical Aspects 649
Usage and Applications 650
Usage and Applications in Food Science
Cistus ladanifer L 651
Cistus incanus L 652
Cistus albidus L 655
Cistus salviifolius L 655
Cistus monspeliensis L 655
Cistus laurifolius L 655
Cistus libanotis L 656
Cistus parviflorus 656
Summary Points 656
Acknowledgments 656
References 656

75. Rose (Rosa × damascena Mill.) Essential Oils

Maryam Nasery, Mohammad K. Hassanzadeh, Zahra Tayarani Najaran and Seyed Ahmad Emami

Introduction 659
Botany 659
Usages and Applications 660
Usage and Applications in Food Science
As an Antimicrobial for Food Preservation 663
As an Antioxidant 663
As Flavoring Agent 664

76. Rose Hip (Rosa canina L.) Oils

Naveed Ahmad, Farooq Anwar and Anwar-ul-Hassan Gilani

Introduction 667
Botanical Aspects 667
Uses and Applications 667
Uses and Applications in Food Sciences 670
Chemical Composition of Rose Hips
Essential Oil 673
Summary Points 674
Acknowledgment 674
References 674

77. Rosemary (Rosmarinus officinalis L.) Oils

María Dolores Hernández, Jose Antonio Sotomayor, Ángel Hernández and María José Jordán

Introduction 677
Botanical Aspects 677
Usage and Applications 678
Usage and Applications in Food Science
Preservatives 681
Growth Promoters 683
Applications in Food Matrices
Meat 683
Fish 685
Processed Food 685
Technological Applications 685
Summary 685
References 686

78. Rose Pepper (Schinus molle L.) Oils

María S. Guala, Matias O. Lapissonde, Heriberto V. Elder, Catalina M. van Baren, Arnaldo L. Bandoni and Eduardo Dellacassa

Introduction 689
Botanical Aspects 690
Usage and Applications 691
Usage and Applications in Food Science
In Vivo and In Vitro Assays Performed on Ticks (Rhipicephalus microplus) 691
In Vivo Experiments Carried Out in Apiaries with the Oily Solution of the Essential Oil of Shinus molle Against Varroa (Varroa destructor) 693
Summary Points 694
References 695
79. Rose-Scented Geranium (*Pelargonium* sp.) Oils

*Ram Swaroop Verma, Rajendra Chandra Padalia and Amit Chauhan*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>697</td>
</tr>
<tr>
<td>Botanical Aspects</td>
<td>697</td>
</tr>
<tr>
<td>Usage and Applications</td>
<td>700</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
<td>701</td>
</tr>
<tr>
<td>Summary Points</td>
<td>702</td>
</tr>
<tr>
<td>Acknowledgment</td>
<td>703</td>
</tr>
<tr>
<td>References</td>
<td>703</td>
</tr>
</tbody>
</table>

80. Saffron Crocus (*Crocus sativus*) Oils

*Nafees Ahmed, Sirajudheen Anwar, Saeed S. Al-Sokari, Shabana Y. Ansari and Mohamed E. Wagih*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>705</td>
</tr>
<tr>
<td>Botanical Aspects</td>
<td>706</td>
</tr>
<tr>
<td>Usage and Applications</td>
<td>706</td>
</tr>
<tr>
<td>Usage and Applications in Food Industries</td>
<td>707</td>
</tr>
<tr>
<td>Saffron Oil as an Antimicrobial for Food Preservation</td>
<td>708</td>
</tr>
<tr>
<td>Saffron Oil as an Antioxidant</td>
<td>709</td>
</tr>
<tr>
<td>Summary Points</td>
<td>712</td>
</tr>
<tr>
<td>References</td>
<td>712</td>
</tr>
</tbody>
</table>

81. Sage (*Salvia officinalis*) Oils

*Demet Altindal and Nüket Altindal*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>715</td>
</tr>
<tr>
<td>Botanical Aspects</td>
<td>715</td>
</tr>
<tr>
<td>Botany</td>
<td>715</td>
</tr>
<tr>
<td>Harvesting</td>
<td>717</td>
</tr>
<tr>
<td>Usage and Applications</td>
<td>717</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
<td>718</td>
</tr>
<tr>
<td>Summary Points</td>
<td>720</td>
</tr>
<tr>
<td>References</td>
<td>720</td>
</tr>
</tbody>
</table>

82. Sandalwood (*Santalum album*) Oils

*Kuntal Das*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>723</td>
</tr>
<tr>
<td>Botanical Aspects</td>
<td>723</td>
</tr>
<tr>
<td>Plant Profile</td>
<td>723</td>
</tr>
<tr>
<td>Usage and Applications</td>
<td>726</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
<td>726</td>
</tr>
<tr>
<td>Summary Points</td>
<td>729</td>
</tr>
<tr>
<td>References</td>
<td>729</td>
</tr>
</tbody>
</table>

83. Shirazi thyme (*Zataria multiflora Boiss*) Oils

*Afsin Akhondzadeh Basti, Hassan Gandomi, Negin Noori and Ali Khanjari*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>731</td>
</tr>
<tr>
<td>Botanical Aspects</td>
<td>732</td>
</tr>
<tr>
<td>Usage and Applications</td>
<td>732</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
<td>732</td>
</tr>
<tr>
<td>Summary Points</td>
<td>735</td>
</tr>
<tr>
<td>References</td>
<td>735</td>
</tr>
</tbody>
</table>

84. Spiked Ginger Lily (*Hedychium spp.*) Oils

*Om Prakash, Mahesh Chandra, H. Punetha, A.K. Pant and D.S. Rawat*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botanical Aspects</td>
<td>737</td>
</tr>
<tr>
<td>Introduction</td>
<td>738</td>
</tr>
<tr>
<td>Usage and Applications</td>
<td>739</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
<td>739</td>
</tr>
<tr>
<td>Summary Points</td>
<td>749</td>
</tr>
<tr>
<td>Acknowledgment</td>
<td>749</td>
</tr>
<tr>
<td>References</td>
<td>749</td>
</tr>
</tbody>
</table>

85. Staranise (*Illicium verum Hook*) Oils

*Leandro Rocha and Luis Armando Candido Tietbohl*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>751</td>
</tr>
<tr>
<td>Botanical Aspects</td>
<td>751</td>
</tr>
<tr>
<td>Usage and Applications</td>
<td>753</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
<td>753</td>
</tr>
<tr>
<td>Summary Points</td>
<td>755</td>
</tr>
<tr>
<td>References</td>
<td>755</td>
</tr>
</tbody>
</table>

86. Summer Savory (*Satureja hortensis L.*) Oils

*Mohammad K. Hassanzadeh, Zahra Tayarani Najaran, Maryam Nasery and Seyed Ahmad Emami*

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>757</td>
</tr>
<tr>
<td>Botanical Aspects</td>
<td>757</td>
</tr>
<tr>
<td>Usage and Applications</td>
<td>758</td>
</tr>
<tr>
<td>Usage and Applications in Food Science</td>
<td>759</td>
</tr>
<tr>
<td>As Antimicrobial for Food Preservation</td>
<td>760</td>
</tr>
<tr>
<td>As an Antioxidant</td>
<td>762</td>
</tr>
<tr>
<td>Summary Points</td>
<td>763</td>
</tr>
<tr>
<td>References</td>
<td>763</td>
</tr>
<tr>
<td>Chapter</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>87.</td>
<td>Sweet Fennel (Ocimum gratissimum) Oils</td>
</tr>
<tr>
<td>88.</td>
<td>Sweet Flag (Acorus calamus) Oils</td>
</tr>
<tr>
<td>89.</td>
<td>Sweet Orange (Citrus sinensis) Oils</td>
</tr>
<tr>
<td>91.</td>
<td>Tangerine (Citrus reticulata L. var.) Oils</td>
</tr>
</tbody>
</table>
92. Tarragon (Artemisia dracunculus L.) Oils

Mohammad K. Hassanzadeh, Zahra Tayarani
Najaran, Maryam Nasery and Seyed Ahmad Emami

Introduction 813
Botanical Aspects 813
Usage and Applications 813
Usage and Applications in Food Science 815
  Tarragon as an Antimicrobial for Food Preservation 816
  Tarragon as an Antioxidant 816
Summary Points 817
References 817

93. Tasmanian Pepper Leaf (Tasmannia lanceolata) Oils

Yasmina Sultanbawa

Introduction 819
Botanical Aspects 819
Usage and Applications 819
Usage and Applications in Food Science 820
Antimicrobial Properties 820
Flavoring Agent 822
Safety of Tasmanian Pepper Leaf Essential Oils 822
Summary Points 822
References 823

94. Thyme (Thymus vulgaris L.) Oils

Shyamapada Mandal and Manisha DebMandal

Introduction 825
Botanical Aspects 825
Usage and Applications 826
Usage and Applications in Food Science 826
  Food Preservation and Antispoilage Activity 826
  Antibacterial Activity 827
  Antifungal Activity 829
  Antioxidant Activity 829
  Thyme Chemistry and Biological Activity 830
  Safety and Toxicity 831
Summary Points 831
References 832

95. Turmeric (Curcuma longa) Oils

Kuntal Das

Introduction 835
Botanical Aspects 835
  Plant Profile 835
Usage and Applications 838
Usage and Applications in Food Science 838
  TO in Food Flavoring and Food Preservations 839
  TO in Bakery Products 839
TO in Seltzers, Mineral, or Carbonated Beverages 840
TO in Other Food Products 840
TO in Alcoholic and Nonalcoholic Beverages 840
Summary Points 840
References 840

96. Vetiver Grass (Vetiveria zizanioides) Oils

Su-Tze Chou, Ying Shih and Chih-Chien Lin

Introduction 843
Botanical Aspects 843
  Plant Profile 843
  Botany 843
  Habits and Range 844
  Propagation 844
Usage and Applications 844
Usage and Applications in Food Science 845
  Safety 845
  Chemical Composition 845
  Usage and Applications in Food Flavor 846
  Usage and Applications in Food Preservation 847
Conclusions 848
Summary Points 848
Acknowledgment 848
References 848

97. Wormwood (Artemisia absinthium L.) Oils

Asta Judžentiene

Introduction 849
Botanical Aspects 849
Usage and Applications 850
Usage and Applications of Wormwood in Food Science 850
Summary Points 855
References 855

98. Yellow or White Mustard (Sinapis alba L.) Oils

Athula Ekanayake, Robert J. Strife, Gerhard N. Zehentbauer and Jairus R.D. David

Introduction 857
Botanical Aspects 857
Usage and Applications 857
  Characterization of WMEO 859
Usage and Applications in Food Science 860
Summary Points 862
References 862