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John M. Walker
School of Life and Medical Sciences
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Hatfield, Hertfordshire, AL10 9AB, UK

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Natural Products From Marine Algae

Methods and Protocols

Edited by

Dagmar B. Stengel

Botany and Plant Science, School of Natural Sciences, Ryan Institute for Environmental, Marine and Energy Research, National University of Ireland Galway, Galway, Ireland

Solène Connan

Photobiotechnology, INTECHMER, Conservatoire National des Arts et Métiers, Cherbourg, Cedex, France; CNRS, GEPEA, UMR6144, Boulevard de l'Université, Saint Nazaire, Cedex, France

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Editors
Dagmar B. Stengel
Botany and Plant Science
School of Natural Sciences
Ryan Institute for Environmental
Marine and Energy Research
National University of Ireland Galway
Galway, Ireland

Solène Connan
Photobiotechnology, INTECHMER
Conservatoire National des Arts et Métiers
Cherbourg, Cedex, France

CNRS, GEPEA, UMR6144
Boulevard de l'Université
Saint Nazaire, Cedex, France

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Preface

Over the last decade or so, there has been an explosion in the global interest in marine algae including both seaweeds (macroalgae) and microalgae. This has commonly focused on their application as a source of bioenergy but also, more recently, on their potential as an "untapped" resource of natural products. In tandem with scientific and technological developments, public awareness of algae has increased considerably and their inclusion in our daily lives does not appear as alien anymore as it might have been, at least in the western world, a few years ago. Numerous algae-based products are on offer to the consumer, ranging from agri-horticultural to food and cosmetic products. Despite this enhanced presence, the general understanding of the diversity and complexity of what this unfortunate all-encompassing term "algae" entails is usually still underestimated by the public as well as some non-phycological researchers; however many scientists globally are currently engaged in unraveling the chemical and taxonomic richness of this diverse group of organisms. In parallel to working towards a better understanding of the basic biology of the many algal groups and their strategies to survive in the marine environments, considerable research efforts have resulted in significant advances in algal biotechnology. There has also been excellent progress in the field of chemical and structural identification of bioactive compounds as promising (marine-derived) natural products with potential in drug development in the long term. On the other hand, algal products also have the capability to be integrated in our daily lives as consumers for example as health-promoting foods.

Valuable compounds from marine algae include pigments, lipids, and fatty acids and sterols, polysaccharides, proteins and peptides, as well as many secondary metabolites such as mycosporine-like amino acids, phenolic compounds, and terpenes, all of which are highly specific to different algal groups and even to species within these. Bioactivities of algal compounds described to date range from antioxidant, anti-inflammatory, antidiabetic, anticancer, antiviral, antimicrobial, antifungal to anti-obesity and antidiabetic; more recently, high potencies of natural algal products against specific parasites have also been discovered.

Whilst of traditional and current economic value, and with high social acceptance as commodities in Asia, the western world is lagging in its appreciation of this marine resource, but this is about to change. For example, algae are anticipated to play an important role in the future within the European bioeconomy, with climate change, food security, and an aging population presenting global challenges; industry, researchers, politicians, and, increasingly, the public currently look towards the oceans as a source of novel and sustainable source of biomass to supply human food and support health and well-being. The provision of sustainable and safe biomass, together with more effective extraction of novel valuable compounds, is thus a growing concern and at the forefront of many national and international multidisciplinary research programs.

Regardless of the ultimate application, assuming that suitable algal biomass can be provided sustainably, the vast diversity and complexity of algal biomass demands reliable, fast, and efficient extraction techniques that allow safe provision of the target compound(s) and accurate but affordable analytical techniques. Also, rapid and reliable tests for bioactivities are required for the manifold applications that are known—and those yet to be discovered.

This volume aims to provide examples of the recent advances in extraction methodologies, analytical techniques, and commonly used bioactive assays currently applied to marine algae. Chapters include protocols for a suite of both routinely used standard procedures and newly developed, highly advanced and specialized techniques, which display currently available tools for characterizing algal chemical composition for the vast array of applications. Whilst the book cannot attempt to be complete (both due to the diversity and complexity of algal compounds, as well as ongoing technological developments), protocols were chosen to represent a range of extraction and analytical methods currently applied to both marine macro- and microalgae. They also cover a range of different compounds families that are of current and potential future interest, concentrating on high-value (i.e., non-bioenergy) applications in the food, agricultural, cosmetics, and pharmaceutical sectors.

Specifically, a review of sources of available algal biomass, current applications of marine algae in different industries, and the recent trends in algal biotechnology is presented at the beginning of this volume (Chapter 1). This is followed by a description of secondary metabolites (structure and function) produced by macroalgae (Chapter 2); then different extraction techniques are outlined, ranging from the traditional Solid-Liquid Extraction (SLE; Chapters 4–7, 10, 11, 13–18, 21) to the use of enzymes (Chapter 8) or Microwave Assisted Extraction (MAE; Chapter 9). The following chapters detail several analytical methods: Spectrophotometry (Chapters 3, 5, 7, 20, 21), Thin Layer Chromatography (TLC; Chapters 11, 13, 14), Electrophoresis (Chapter 5), Liquid Chromatography with or without Mass Spectrometer(s) (LC with/without MS; Chapters 6, 10, 15–18), Gas Chromatography associated with different detectors or Mass Spectrometer (GC; Chapters 11, 14, 21), Mass Spectrometer (Chapters 19, 21), liquid or solid state Nuclear Magnetic Resonance Spectroscopy (RMN; Chapters 7, 12–14, 20–22), Infra-red Spectroscopy (IF; Chapters 21, 22), and Raman Spectroscopy (Chapter 23). Also methodologies to highlight different bioactivity of compounds or extracts are described: antioxidant (Chapters 7 and 24), antimicrobial (Chapter 25), antifungal (Chapter 26), and antifouling (Chapter 27). In each case, these techniques are applied to primary or secondary algal metabolites: proteins (Chapters 3, 4), polysaccharides (Chapters 3, 9, 19–22), lipids (Chapter 11), pigments (Chapters 3, 5, 15), mycosporine-like amino acids (MAAs; Chapter 6), phenolic compounds (Chapters 3, 7, 16), oxylipins (Chapter 10), terpenes (Chapters 13, 14), betaines (Chapter 17), and different biotoxins (Chapter 18).

Active in both ecophysiological and applied biotechnological algal research, we continue to be intrigued by the newly described diverse adaptations of algae to their extreme and fluctuating environments and the resultant "twists" in chemical structures that are discovered. Algal responses to their physical and chemical habitats and microhabitats, chemical ecology and its application in natural products research, are likely to continue to be a fascinating and rich field that will yield new chemicals of value to humans. However the exploitation and commercial application of algae will need to ascertain, perhaps with the aid of novel cultivation methods and further biotechnological developments, that natural resources, their biological and chemical diversity, and their surrounding marine ecosystems will be protected, in particular, under globally increased environmental pressures.

We are grateful to our colleagues who have provided support and encouragement throughout our careers, including our Ph.D. supervisors, colleagues at NUI Galway and other institutions in Ireland, France, and abroad, and especially our colleagues in the field of marine biotechnology for stimulating and challenging discussions. A special "thank you" goes to Dr Zoë Popper. We would like to thank our families for their continued support and patience, and the valuable advice and support from Springer during the preparation of this volume.

Galway, Ireland ***Dagmar B. Stengel***
Cherbourg, France ***Solène Connan***
Saint Nazaire, France

Contents

Contributors

Katarina Abrahamsson • *Department of Chemistry and Molecular Biology, University of Gothenburg, Gothenburg, Sweden*

Björn V. Adalbjörnsson • *Biotechnology and Biomolecules/Faculty of Food Science and Nutrition, Matis Ltd. Icelandic Food and Biotech R&D/University of Iceland, Reykjavík, Iceland*

R. Noemí Aguila-Ramírez • *Instituto Politecnico Nacional-Centro Interdisciplinario de Ciencias Marinas, La Paz, Mexico*

Charles D. Amsler • *Department of Biology, University of Alabama at Birmingham, Birmingham, AL, USA*

Stanislav D. Anastyuk • *G.B. Elyakov Pacific Institute of Bioorganic Chemistry, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russian Federation*

Paula B. Andrade • *REQUIMTE/Laboratório de Farmacognosia, Departamento de Química, Faculdade de Farmácia, Universidade do Porto, Porto, Portugal*

Paula Ximena Arata • *Cátedra de Química de Biomoléculas, Departamento de Biología Aplicada y Alimentos, Facultad de Agronomía, Universidad de Buenos Aires, Buenos Aires, Argentina*

Erwan Ar Gall • *LEMAR – UMR6539, IUEM, Plouzane, Brittany, France; University of Brest (University of Western Brittany – UEB), Brest, France*

Bill J. Baker • *Department of Chemistry, Center for Drug Discovery and Innovation, University of South Florida, Tampa, FL, USA*

Christoph Braun • *School of Biological Sciences, University of Queensland, St. Lucia, QLD, Australia*

Nigel P. Brunton • *Department of Agriculture and Food Science, UCD, Dublin, Ireland*

Stéphane Cérantola • *Plateforme technologique de Résonance Magnétique Nucléaire, Résonance Paramagnétique Électronique et Spectrométrie de Masse, Brest, France*

Marina Ciancia • *Cátedra de Química de Biomoléculas, Departamento de Biología Aplicada y Alimentos, Facultad de Agronomía, Universidad de Buenos Aires, Buenos Aires, Argentina; CIHIDECAR-CONICET, Departamento de Química Orgánica, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, Buenos Aires, Argentina*

Solène Connan • *Photobiotechnology, INTECHMER, Conservatoire National des Arts et Métiers, Cherbourg, France; CNRS, GEPEA, UMR6144, Boulevard de l'Université, Saint Nazaire, France*

Cheryl Craft • *Aquatic and Crop Resource Development, National Research Council of Canada, Halifax, NS, Canada*

Gérald Culioli • *Nice Institute of Chemistry – PCRE and PFTC, UMR 7272 CNRS, Université de Nice Sophia-Antipolis (UNS), Nice, France; MAPIEM, EA 4323, Université de Toulon (UTLN), La Garde, France*

Andrew P. Desbois • *Marine Biotechnology Research Group, Institute of Aquaculture, School of Natural Sciences, University of Stirling, Stirlingshire, United Kingdom*

Justine Dumay • *LUNAM Université, Université de Nantes, MMS, Nantes, France*

Søren Balling Engelsen • *Department of Food Science, Faculty of Science, University of Copenhagen, Frederiksberg C, Denmark*
Katrin Erler • *Institute of Nutrition, Faculty of Biology & Pharmacy, Friedrich-Schiller University, Jena, Germany*
Paula Virginia Fernández • *Cátedra de Química de Biomoléculas, Departamento de Biología Aplicada y Alimentos, Facultad de Agronomía, Universidad de Buenos Aires, Buenos Aires, Argentina; CIHIDECAR-CONICET, Departamento de Química Orgánica, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Ciudad Universitaria, Buenos Aires, Argentina*
Richard J. FitzGerald • *Department of Life Sciences, University of Limerick, Limerick, Ireland*
Joël Fleurence • *LUNAM Université, Université de Nantes, MMS, Nantes, France*
José L. Garrido • *Instituto de Investigaciones Marinas (CSIC), Vigo, Pontevedra, Spain*
Marc Gaysinski • *Nice Institute of Chemistry – PCRE and PFTC, UMR 7272 CNRS, Université de Nice Sophia-Antipolis (UNS), Nice, France*
Vladimir I. Gorbach • *G.B. Elyakov Pacific Institute of Bioorganic Chemistry, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russian Federation*
Freddy Guihéneuf • *Botany and Plant Science, School of Natural Sciences, Ryan Institute for Environment, Marine and Energy Research, National University of Ireland Galway, Galway, Ireland*
Pádraigín A. Harnedy • *Department of Life Sciences, University of Limerick, Limerick, Ireland*
Claire Hellio • *LEMAR UMR 6539 IUEM, Université de Bretagne Occidentale, Plouzané, France*
Claudia J. Hernández-Guerrero • *Instituto Politecnico Nacional-Centro Interdisciplinario de Ciencias Marinas, Av. IPN S/N, La Paz, Mexico*
Mélanie Hupel • *Salipouss, Fouesnant, Brittany, France*
Dominique Jacquemoud • *Institute for Inorganic and Analytical Chemistry, Bioorganic Analytics, Friedrich Schiller University Jena, Jena, Germany*
Camille Jégou • *Lubem Quimper – EA3882, Quimper, Brittany, France; University of Brest (University of Western Brittany – UEB), Brest, France*
Henrik Max Jensen • *DuPont Nutrition & Health, DuPont Nutrition Biosciences ApS, Braband, Denmark*
Rósa Jónsdóttir • *Biotechnology and Biomolecules, Matis Ltd., Icelandic Food and Biotech R&D, Reykjavík, Iceland*
Mats Josefson • *Pharmaceutical Development, AstraZeneca R&D, Mölndal, Sweden*
Owen Kenny • *Department of Food Biosciences, Teagasc Food Research Centre, Dublin, Ireland*
Nelly Kervarec • *Plateforme technologique de Résonance Magnétique Nucléaire, Résonance Paramagnétique Électronique et Spectrométrie de Masse, Brest, France*
Bernd Krock • *Ecological Chemistry, Alfred-Wegener Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany*
David Kvaskoff • *University of Queensland Centre for Clinical Research Herston, University of Queensland, St. Lucia, QLD, Australia*
Flemming Hofmann Larsen • *Department of Food Science, Faculty of Science, University of Copenhagen, Frederiksberg C, Denmark*
Florian Lelchat • *BMM Laboratory, Ifremer-Brest, ZI Began Diaoul, Plouzane, Brittany, France*

Graciliana Lopes • *REQUIMTE/Laboratório de Farmacognosia, Departamento de Química, Faculdade de Farmácia, Universidade do Porto, Porto, Portugal*
Bernd Luckas • *Institute of Botany and Plant Physiology, Faculty of Biology & Pharmacy, Friedrich-Schiller University, Jena, Germany*
Youjing Lv • *Shandong Provincial Key Laboratory of Glycoscience and Glycotechnology, Ocean University of China, Qingdao, People's Republic of China; Key Laboratory of Marine Drugs, Ministry of Education, School of Medicine and Pharmacy, Ocean University of China, Qingdao, People's Republic of China*
Shawna L. MacKinnon • *Aquatic and Crop Resource Development, National Research Council of Canada, Halifax, NS, Canada*
Jeremy E. Melanson • *Measurement Science and Standards, National Research Council of Canada, Ottawa, ON, Canada*
Michèle Morançais • *LUNAM Université, Université de Nantes, MMS, Nantes, France*
Solange I. Mussatto • *Department of Biotechnology, Delft University of Technology, Delft, The Netherlands*
Huu Phuo Trang Nguyen • *LUNAM Université, Université de Nantes, MMS, Nantes, France*
Annick Ortalo-Magné • *MAPIEM, EA 4323, Université de Toulon (UTLN), La Garde, France*
Georg Pohnert • *Institute for Inorganic and Analytical Chemistry, Bioorganic Analytics, Friedrich Schiller University Jena, Jena, Germany*
Nedeljka N. Rosic • *School of Biological Sciences, University of Queensland, St. Lucia, QLD, Australia*
Suzanne Roy • *ISMER, Université du Québec à Rimouski, Rimouski, QC, Canada*
Jacqueline L. von Salm • *Department of Chemistry, Center for Drug Discovery and Innovation, University of South Florida, Tampa, FL, USA*
Matthias Schmid • *Botany and Plant Science, School of Natural Sciences, Ryan Institute for Environment, Marine and Energy Research, National University of Ireland Galway, Galway, Ireland*
Kathryn M. Schoenrock • *Department of Biology, University of Alabama at Birmingham, Birmingham, AL, USA*
Natalia M. Shevchenko • *G.B. Elyakov Pacific Institute of Bioorganic Chemistry, Far Eastern Branch, Russian Academy of Sciences, Vladivostok, Russian Federation*
Gaëlle Simon • *Plateforme technologique de Résonance Magnétique Nucléaire, Résonance Paramagnétique Électronique et Spectrométrie de Masse, Brest, France*
Valerie J. Smith • *Scottish Oceans Institute, School of Biology, University of St Andrews, St Andrews, Fife, United Kingdom*
Thomas J. Smyth • *Department of Life Sciences, Institute of Technology Sligo, Sligo, Ireland*
Angélica Ribeiro Soares • *Núcleo em Ecologia e Desenvolvimento Sócioambiental de Macaé, Grupo de Produtos Naturais de Organismos Aquáticos (GPNOA), Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil*
Dagmar B. Stengel • *Botany and Plant Science, School of Natural Sciences, Ryan Institute for Environmental, Marine and Energy Research, National University of Ireland Galway, Galway, Ireland*
Valérie Stiger-Pouvreau • *LEMAR – UMR6539, IUEM, Plouzané, Brittany, France; University of Brest (University of Western Brittany – UEB), Brest, France*
Olivier P. Thomas • *Nice Institute of Chemistry – PCRE and PFTC, UMR 7272 CNRS, Université de Nice Sophia-Antipolis (UNS), Nice, France*

Rozenn Trepos • *School of Biological Sciences, University of Portsmouth, Portsmouth, UK*
Patrícia Valentão • *REQUIMTE/Laboratório de Farmacognosia, Departamento de Química, Faculdade de Farmácia, Universidade do Porto, Porto, Portugal*
Alexandra Walsh • *Department of Chemistry and Molecular Biology, University of Gothenburg, Gothenburg, Sweden*
Bo Yang • *Shandong Provincial Key Laboratory of Glycoscience and Glycotechnology, Ocean University of China, Qingdao, People's Republic of China; Key Laboratory of Marine Drugs, Ministry of Education, School of Medicine and Pharmacy, Ocean University of China, Qingdao, People's Republic of China*
Ryan M. Young • *Department of Chemistry, Center for Drug Discovery and Innovation, University of South Florida, Tampa, FL, USA*
Guangli Yu • *Shandong Provincial Key Laboratory of Glycoscience and Glycotechnology, Ocean University of China, Qingdao, People's Republic of China; Key Laboratory of Marine Drugs, Ministry of Education, School of Medicine and Pharmacy, Ocean University of China, Qingdao, People's Republic of China*
Junzeng Zhang • *Natural Products Chemistry, Aquatic and Crop Resource Development, National Research Council of Canada, Halifax, NS, Canada*
Xia Zhao • *Shandong Provincial Key Laboratory of Glycoscience and Glycotechnology, Ocean University of China, Qingdao, People's Republic of China; Key Laboratory of Marine Drugs, Ministry of Education, School of Medicine and Pharmacy, Ocean University of China, Qingdao, People's Republic of China*