Pigments from Microalgae Handbook

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Editors

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Springer

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ISBN 978-3-030-50970-5 ISBN 978-3-030-50971-2 (eBook)
https://doi.org/10.1007/978-3-030-50971-2

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

This book is dedicated to the memory
of Eduardo Rodrigues Lopes.

Foreword

The colours of terrestrial plants are very familiar. The predominant green of photosynthetic tissues, especially leaves, is due to chlorophylls and masks the yellow carotenoids that are also present, though these are revealed in autumn leaves, along with red anthocyanins, as the green chlorophyll is degraded prior to leaf fall. The bright colours of flowers and fruit provide striking contrast and attract insects and other vectors for pollination and seed dispersal. In the oceans of the world, terrestrial plants are replaced by algae, which may be macroalgae (seaweeds) or microalgae (phytoplankton). These do not have flowers or fruit, so major classes of plant pigments—anthocyanins and other flavonoids, betalains and quinones—are not produced in the aquatic environment. Algae, however, do use pigments for their natural photosynthesis.

Photosynthesis in algae of all classes is similar in principle to that in land plants, taking place in chloroplasts and requiring pigments to harvest and use the available light energy. The intensity of the available light, however, decreases as water depth increases, and not all wavelengths of light penetrate water, especially seawater, to the same extent. Red light, which would be absorbed by chlorophylls, is mostly absorbed in the first few metres of water depth, and it is largely blue and green light that penetrates to greater depths. So the role of accessory light-harvesting pigments, carotenoids and phycobiliproteins, is much more important, to make the most efficient use of the available light for photosynthesis. Also, algae that may become exposed to bright sunlight during part of the day must be able to withstand a high level of light energy. Adaptation to low or high light intensity is, therefore, an important feature of algal life patterns.

Algae, including microalgae, use three kinds of pigments in photosynthesis, generally located in pigment–protein complexes. Chlorophyll is essential for photosynthesis. Chlorophyll *a* occurs universally in algae of all classes. Chlorophyll *b* is largely or entirely restricted to green algae (Chlorophyta), whereas chlorophylls *c* and *d* occur in many classes. Many green algae have carotenoid compositions rather similar to those of green leaves, but other classes of algae contain many different carotenoids. These have occupied the attention of carotenoid chemists for many years, and carotenoid compositions have been used in chemosystematic classification of algae. It is estimated that tens of millions of tonnes of fucoxanthin and peridinin are produced naturally in the world's oceans every year.

Phycobiliproteins are more specialised and restricted to the Cyanophyceae (blue-green algae, now classified as Cyanobacteria) and Rhodophyceae (red algae) in which they are localised in specialised aggregated structures, phycobilisomes and Cryptophyceae. There are two main types of phycobiliproteins, the blue phycocyanin and the red phycoerythrin, but both are usually present, though in differing proportions. Some 'blue-green algae' have a high proportion of phycoerythrin and are red and some 'red algae' have a high proportion of phycocyanin and are blue-green. The phycobilin prosthetic groups of these pigments are linear tetrapyrroles that are covalently linked to protein *via* cysteine residues.

Commercial activity is mainly focused on microalgae, which can be grown in monoculture. This is likely to expand as more commercial applications of these pigments are devised. Currently, two microalgae are used extensively for the commercial production of carotenoids. The green algae *Dunaliella* (*D. salina* or *D. bardawil*) under stress conditions can accumulate a high concentration of β-carotene, for use as a food colourant and health product. *Dunaliella* has the advantage that it tolerates high salt concentrations and can be grown cheaply, effectively as a monoculture, in large open ponds. Another green algae, *Haematococcus pluvialis*, is used to produce astaxanthin (as esters together with other carotenoids) for use in aquaculture feeds and for cosmetic and health purposes. This, though, is a freshwater species and is more expensive to produce because it must be grown in photobioreactors under sterile conditions to avoid contamination. Phycocyanin is under intensive investigation for possible use as a blue food colourant—safe and stable blue colourants are otherwise elusive—and phycoerythrin is under consideration as a red food colourant. The intense fluorescence of these phycobilins opens possibilities for their application in clinical diagnostics, e.g. in immunoassays.

This book is timely. There are many opportunities to develop new applications for pigments of microalgae and new ways of improving the production of the algae and their pigments. These aspects are covered extensively in this book, and exciting prospects are reported. The state of the natural environment, characterised by global warming due to increasing atmospheric concentration of carbon dioxide, is, however, a major concern for the future of our planet. Natural microalgae are a major contributor to fixing CO_2 from the atmosphere and generating O_2, but commercial production of microalgae may require the input of energy, and the addition of nutrients, which may lead to eutrophication. The impact of all environmental factors and the overall environmental balance may be different for different species, products and culturing conditions, and must, therefore, always be considered.

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Contents