Book review

Biohydrogen

DOI 10.1515/gps-2015-0107

Matthias Rögner (Ed.)
De Gruyter, 2015
Paperback, XIV, 284 pp.
Print ISBN: 978-3-11-033645-0

Hydrogen has been studied as a potential future fuel for the past few decades, but the efficient production and storage of H_2 present obstacles to its wide adoption. One way to produce hydrogen efficiently and sustainably is the photobiological production of hydrogen. This book by Professor Dr Matthias Rögner (Fakultät für Biologie & Biotechnologie, Ruhr-Universität Bochum, Bochum, Germany) entitled *Biohydrogen*, aims to capture the latest developments in this field by collating relevant work carried out by different research groups worldwide and presenting them in a structured manner. It presents an in-depth analysis of the structures of the catalysts, their mechanisms, the steps involved, and introduces novel engineering methods to develop and enhance these systems.

The first chapter of the book starts off by introducing a cyanobacterial design cell for the production of H_2 from water. It discusses ways to reduce the antenna size, hydrogenase design strategies and design of the photobioreactor.

Chapter 2 presents the results of a life cycle assessment carried out for a unit producing photobiological hydrogen via cyanobacteria, compared to conventional H_2 generation technology such as electrolysis (using electricity from various electricity sources like PV and wind, and H_2 from steam methane reforming).

Chapter 3 reviews the catalytic properties and maturation of hydrogenases, and presents a working hypothesis for the catalytic mechanism of H+ reduction and H+ oxidation at the H-cluster of [FeFe]-hydrogenases. The different interactions between the H-cluster and the protein environment, and the description of a promising new procedure to produce the H-cluster, called spontaneous *in vitro* maturation, are explained in detail.

Chapter 4 goes on to elaborate upon the sensitivity of [FeFe]-hydrogenases to O_2, and the distinction between the structural characteristics and mechanisms of O_2-tolerant and O_2-insensitive hydrogenases.

Chapter 5 examines the application of X-ray spectroscopy for the detailed study of the structural and electronic properties of metal centres in the three kinds of hydrogenases – [Fe]-, [FeFe]- and [NiFe]-hydrogenases, and a brief comparison of the results.

Chapter 6 discusses the [Fe]-hydrogenase enzyme; it covers the physiological functions, structure, catalytic properties and mechanism of the [Fe]-hydrogenase and the biosynthesis of the FeGP cofactor. Lastly, it discusses the possible applications of the [Fe]-hydrogenase and the FeGP cofactor.

Chapter 7 delves into the occurrence, evolution and function of [FeFe]-hydrogenases in eukaryotic algae. The two pathways to produce H_2, along with two pathways to utilize H_2 in the green alga *Chlamydomonas reinhardtii*, are reviewed and explained in detail. Further, fermentative H_2 production in algae, disruption of fermentative enzymes in *C. reinhardtii*, hydrogenases in algae and saltwater organisms are studied and discussed.

Chapter 8 studies the genetic engineering of cyanobacteria for H_2 production; it also describes the various bottlenecks in the process which reduce the yield, and suggests two main ways to address them: (i) engineering of nitrogenases and hydrogenases; and (ii) engineering of metabolic pathways. Each method has a number of potential approaches, which are explained in brief, along with the outlook for the future.

In Chapter 9, the semi-artificial photosynthetic Z-scheme for H_2 production from water is discussed. It explains the synthesis of photosystem 1 (PS1) and photosystem 2 (PS2)-based photoanodes and photocathodes to build a bio-photoelectrochemical cell.

Moving on to Chapter 10, we are presented with a review of the physiological and molecular basics of photosynthesis and hydrogen turnover in algae and bacteria. The active sites, structure, catalytic activity of [NiFe]- and [FeFe]-hydrogenases and *in vitro* systems are discussed in detail.

Chapter 11 touches upon ways to re-route the redox chains; this can be achieved by extending the electron transfer chain for PS1, as well as replacing synthetic compounds in the hydrogen-generating module. This chapter looks at both natural and synthetic ways to achieve this.

The last chapter of this book explores the latest developments in the application of the biohydrogen process as a stabilizing element of a power grid supplied solely by renewable energy. It is proposed here that the grid be supplied by a combination of renewable energy technologies, where the components compensate for each other's intermittency. The system in this case is a renewable energy system that uses photo-fermentation (RESUP), along with other technologies like wind turbines and solar PV. A detailed case study is presented and evaluated, along with simulation results.

Although the content is very detailed and well-elaborated, the sequence of the chapters in this book could be changed for a better flow of information, particularly for readers who are not fully familiar with the concept of biohydrogen production. For example, Chapter 10, which explains the basics of photosynthesis and hydrogen turnover in algae and bacteria, could be the first chapter, since a thorough understanding of photosynthesis and hydrogen production in algae is essential to be able to understand the rest of the chapters. Also, the life cycle assessment of the biohydrogen process could be placed towards the end, since it does not involve an explanation of the mechanism of the photo-biohydrogen process.

With that said, this book is rich in content and provides a good review of the state-of-the-art in the field of photobiological production of hydrogen. It is a highly specialized work and is a must-read for students who are already familiar with the basics of biohydrogen production and would like to enhance their knowledge, as well as researchers who would like to keep abreast of the latest developments in this field.

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