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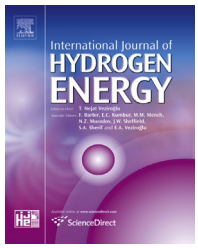

Book review

Biohydrogen production: fundamentals and technology advances, Debabrata Das, Namita Khanna, Chitralekha Nag Dasgupta, CRC Press (2014). Hardcover, 408 pp., b&w., $199.95, ISBN 978-1466-517-998.

The supply of hydrocarbon resources in the current economic scenario is limited, whereas the demand for hydrocarbon fuels is continuously increasing. Burning of hydrocarbon fuels emits carbon dioxide and other pollutants. It is in this context that the proponents of hydrogen economy argue that hydrogen can be an environmentally- cleaner source of energy, particularly in transportation, without release of pollutants at the point of end use. The combination of the fuel cell and electric motor is 2–3 times more efficient than an internal-combustion engine. However, the high capital cost of fuel cells is one of the major obstacles of its development at present besides the purity requirement of hydrogen used in fuel cells.

Hydrogen production is a large and growing industry with approximately 57 million metric tons of hydrogen, equal to about 170 million tons of oil equivalent, being produced in 2004. There are at present two major uses of hydrogen. The first is in the Haber process to produce ammonia, which is then used as fertilizer and the second is in converting heavy petroleum sources into lighter fractions, suitable for use as fuels, in hydrocracking process.

The book "Biohydrogen Production: Fundamentals and Technology Advances" starts with a brief overview of nonconventional energy resources such as solar energy and of conventional hydrogen production technologies along with their limitations. This sets the background for the subsequent detailed description of the biological processes for hydrogen production. Chapter 2 provides a glimpse of a variety of microorganisms, both eukaryotic and procaryotic, involved in biohydrogen production processes. Biohydrogen can be produced by photofermentation through phototrophic bacteria or by dark fermentation through heterofermentative bacteria. The biochemistry of these processes with their advantages and limitations have been elaborated in Chapter 3. Several hybrid processes have also been described with a view to increase the yield of hydrogen. Since the yield of hydrogen on the basis of production of end-products by heterofermentative microorganisms is described in Chapter 3, it would have been better to present Table 2.1 in Chapter 3. Further, the reader may find it a little difficult to comprehend the effectiveness of the microorganisms in terms of hydrogen production from Table 2.1, as the yield data have been given in different units (this might be due to the different units of hydrogen yield reported in the literature). Chapter 4 presents useful information in terms of various feedstocks that can be used for hydrogen production as their usage will have significant impact on production cost. In some cases, hydrogen production can meet the twin objective of producing biohydrogen as well as bioremediation of the waste material. In Fig 4.1, lignin has somehow been wrongly shown as a polysaccharide!

Chapter 5 gives a detailed account of the three main approaches, viz. biochemical, genetic and crystallographic, to study the hydrogenase enzymes involved in biohydrogen production process. Structural and functional aspects of the main types of hydrogenases such as [Fe-only] hydrogenase, [NiFe] hydrogenase, and [FeFe]- hydrogenase have been described, especially in relation to their function in the presence of oxygen. The chapter has also listed the reasons for oxygen insensitivity of hydrogenases and their possible solutions. This aspect is particularly important in view of the fact that oxygen- tolerant hydrogenases need to be developed for their industrial applications. Section 5.4.2 should perhaps read as "Possible Solutions to Overcome Oxygen *Sensitivity* of Hydrogenase" instead of "Possible Solutions to Overcome Oxygen *Insensitivity* of Hydrogenase". In the discussion on the role of hydrogenases in various processes, I would have liked to see the inclusion of their role in industrial bioprocesses also; as we know that hydrogenases play a crucial role in maintaining the redox balance of many industrial fermentations, such as the well-known acetone- butanol fermentation.

Metabolic engineering approaches represent the current trend of research for maximizing the production of biohydrogen. Several molecular approaches have been highlighted in Chapter 6 for this purpose. These include improvement of biomass production through (a) induction of CO_2- concentration mechanisms and cell recycle, (b) enhancing the availability of electrons through increased uptake rates of substrates, (c) improving photoconversion efficiency, (d) improving hydrogen- producing enzymes (hydrogenase and nitrogenase), (e) over-expression of indigenous as well as foreign hydrogenases, (f) deletion of hydrogen uptake genes, and (g) modification of ATP synthase, etc. Redirection of available electrons from competing pathways towards biohydrogen producing pathways will remain the main thrust of such efforts, some of which have been highlighted in the chapter.

After a promising hydrogen producing microorganism has been either isolated from nature or developed through molecular approaches, the next important step is to optimize the nutritional and environmental conditions that will best express the genetic potential of the microbe in a suitable bioreactor with the ultimate aim of commercialization of the

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technology. With this aim, Chapter 7 discusses the effect of various physico- chemical parameters on hydrogen production by dark fermentative bacteria, photofermentative bacteria and photosynthetic bacteria. In addition to various common parameters such as pH, temperature, inoculum, alkalinity, micro-nutrients, and partial pressure of hydrogen, hydraulic retention time also becomes an important parameter if continuous reactors are used, and light, if photofermentative/photosynthetic bacteria are used for biohydrogen production. These aspects have been adequately addressed in this chapter, along with a brief mention of statistical tools (available in standard text-books) that can be employed for optimization of these parameters.

Finally for commercialization of the developed technology, engineering inputs are required in terms of design and analysis of the bioreactors and associated equipment. Chapters 8–10 deal with such a subject in which engineering aspects of photobioreactors and their scale-up have been dealt with. Although several configurations of the photobioreactors and the effect of various physical and physicochemical parameters on their performance have been discussed along with their design criteria, the central message of the importance of light capturing efficiency and its distribution for attainment of these photobioreactors' productivity has been very well highlighted in Chapter 8. Various mathematical models which can be used to describe the biohydrogen production process have been described in Chapter 9 and the importance of the process parameters on systems' behaviour has been explained. These are the generalized models which one will find useful for updation depending on the systems' behaviour. Similarly, various scale-up criteria, that are normally used in development of a bioprocess, have been discussed in Chapter 10 which form the basis of successful scale-up of a process based on one of these criteria. The chapter also describes a few case studies where cost analysis of the biohydrogen production process has been done; these may serve as a valuable guide for further more intensive analysis of the process based on several operating parameters.

Overall, the book contains a wealth of information which will be very useful for those pursuing research in this exciting area of research and wish to realize the potential of biohydrogen as clean source of fuel for our needs. The book is strongly recommended as a good text book for offering a specialized course on "Biohydrogen Production Technology" or as a reference book for more general courses dealing with bioenergy production technologies. It is hoped that the newcomers involved in biological hydrogen production research work will also find the book very useful. The book is a comprehensive review on the biological hydrogen production processes consisting of technological and economical issues which are usually given little attention in other books. A strong feature of the book is that almost every aspect of biohydrogen production has been included in the book. One aspect of utilization of biohydrogen, which could have found some space in the book, is the purity of hydrogen and the processes involved in its purification especially if a chemical process has been used in its production. This, however, is not the major problem in biological hydrogen production processes. Several grammatical errors have also somehow creeped in the book, which could have been avoided. But these are minor shortcomings considering the overall quality of the scientific work that has been painstakingly presented by the authors, and I would like to compliment them for this enormous effort and hard work.

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