

View metadata, citation and
CORE

provided by ..

MICROBIAL FUELS

Technologies and Applications



edited by
Farhad Karimi Horvati
Toralf Hilgendorf

7

Dark Fermentative Hydrogen Production: From Concepts to a Sustainable Production

*Patrícia Madeira da Silva Moura, Joana Resende Ortigueira,
Idania Valdez-Vazquez, Ganesh Dattatray Saratale,
Rijuta Ganesh Saratale, and Carla Alexandra Monteiro da Silva*

Contents

7.1	Hydrogen as Energy Source	220
7.1.1	Biohydrogen	220
7.1.2	Hydrogen Gas Production by Dark Fermentation	221
7.2	Biochemistry of Hydrogen Production in Dark Fermentation	221
7.2.1	Hydrogen Yield in Acetate and Butyrate Fermentation	224
7.2.2	Overview of Mesophilic, Thermophilic, and Psychrophilic Hydrogen-Producing Bacteria	226
7.2.3	<i>Clostridium butyricum</i> as Model Microorganism for Hydrogen Production	228
7.2.3.1	Characterization and Optimization of the Technology Process Conditions	228
7.2.3.2	Two-Stage Dark and Photofermentative Sequential Hydrogen Production	230
7.2.3.3	Cocultures with <i>C. butyricum</i>	231
7.2.3.4	Metabolic Engineering of <i>C. butyricum</i>	231
7.2.3.5	Low-Cost Substrates	232
7.2.4	Case Study I: Microalgal Biomass as Fermentation Substrate for Hydrogen Production by Pure Cultures	232
7.3	Hydrogen Production by Microbial Consortia	234
7.3.1	Selection of Hydrogen Producers in Consortia	235
7.3.2	Bacterial Composition as a Function of the Inoculum Origin	237
7.3.3	Ecological Functions of Bacterial Populations	239
7.3.4	Case Study II: Total Production Cost of Lignocellulosic-Based Hydrogen by Consolidated Bioprocessing	241
7.4	Renewable Resources for Dark Fermentative Hydrogen Production	242
7.4.1	Pretreatment of Lignocellulose-Based Biomass and Wastes	244
7.4.1.1	Physicochemical Methods	244
7.4.1.2	Biological (Microbial and Enzymatic) Methods	245
7.4.2	Bioconversion of Lignocellulosic Biomass to Hydrogen	246
7.4.2.1	Separate Hydrolysis and Fermentation	246
7.4.2.2	Simultaneous Saccharification and Fermentation	247
7.4.2.3	Consolidated Bioprocessing of Lignocellulosic Biomass to Hydrogen	247
		219

7.4.3	Different Wastes and Wastewater for Biohydrogen Production	248
7.4.4	Parameters Affecting Dark Fermentative Hydrogen Production Using Biomass and Wastes	249
7.4.4.1	pH	250
7.4.4.2	Temperature	250
7.4.4.3	Inorganic Nutrients	250
7.4.4.4	Trace Metal Elements	251
7.4.5	Case Study III: Biohydrogen Production from Lignocellulosic Biomass	251
7.5	Life Cycle Analysis	253
7.5.1	Methodological Issues	254
7.5.2	Integrated Hydrogen Biorefinery and Scale-Up Examples	256
7.5.3	Economics of Biohydrogen Production and Perspectives	256
7.6	Future Prospects for Biohydrogen	258
	Acknowledgments	258
	References	259

7.1 Hydrogen as Energy Source

The use of renewable sources and environmentally friendly processes is considered a priority for the construction of a sustainable energy future. The harmful impact of fossil fuels and the fact that we are reaching a disrupting point regarding environmental damage require the rapid implementation of new energy systems and a substantial increase in the use of alternative, unconventional energy sources. Hydrogen (H_2) is considered one of the most promising sources as a clean energy vector, because of its high energy density (120 MJ/kg) and carbon-free combustion (Argun and Kargi, 2011). Hydrogen is the simplest and most abundant element on earth; however, it barely exists in nature in its molecular state. Instead, it is almost always found as part of other compounds from which it should be separated, either by thermochemical processes or through biological conversion.

Currently, the dominant technology for direct H_2 production consists in the steam reforming of hydrocarbons, as well as additional thermochemical methods, such as electrolysis and thermolysis (Saratale et al., 2013). The major obstacles of the current H_2 -producing methods are the high production costs and energy demand involved in the production process. Therefore, there is an imperative need to come up with strategies that can make the process more sustainable and economically feasible.

7.1.1 Biohydrogen

The production of H_2 from renewable resources, such as water, organic wastes or biomass, either biologically or photobiologically, is termed “biohydrogen” ($bioH_2$). Compared with the thermochemical route, biological H_2 production is more favorable, owing to its environmentally friendly and energy-saving production process. The biological conversion occurs at near-ambient temperature and pressure, at far less extreme conditions, which lower the energy requirements substantially. Additionally, it is well suited for decentralized energy production in small-scale installations located