Chapter 14
Extremophiles in Sustainable Bioenergy Production as Microbial Fuel Cells

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ABSTRACT

Microbial fuel cell (MFC) technology is considered one of the renewable sources of energy for the production of bioelectricity from waste. Due to the depletion of fossil fuels and environmental considerations, MFC haa garnered increasing importance as it is a sustainable and environmentally-friendly method of generation of bioenergy. In MFC, electroactive bacteria (EAB) and biofilms are harnessed to convert organic substances to electrical energy. Extremophiles survive in extreme environments, and they have demonstrated potential applications in microbial electrical systems (MES) and MFC technology. The key limitations of MFC are the low power output and engineering constraints of the fuel cell. Hence, it is imperative to understand the genetics, key metabolic pathways, and molecular mechanisms of the EAB for enhancing the power generation in MFC. This chapter gives a brief overview of the scope and applications of extremophiles in wastewater treatment, bioelectricity, and biohydrogen production using MFC, eventually enhancing the functional efficiency of MFC.

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INTRODUCTION

Massive industrialization in the recent past has increased the energy needs and usage many fold. Excessive utilization of fossil fuels has not only led to depletion of natural reserves but also has posed major problems in terms of global warming, atmospheric changes and potential threat to natural ecosystems. Hence, alternative mechanisms are being sought for generation of sustainable renewable energy using environment friendly approaches namely wind energy, solar energy, tidal energy etc. Biohydrogen and bioelectricity production using Microbial fuel cells (MFCs) is also the one step in this direction. Journey of MFCs began in 1911 with glucose as a substrate and Platinum as electrode using *S. cerevisiae,* till the present time with several advancements in terms of usage of efficient microbial communities, electrodes, substrates and modes of operations leading to environment friendly mode of energy production (Anshu, 2021; Latika Bhatia et al., 2020). Still, even today the commercialization of MFC is a big challenge due to high cost of production and comparative low yield of electricity. Extremophiles being able to thrive in extreme physical and geothermal conditions can be used in MFCs. Thombre et al (2016a; 2016b) reported eco-friendly methods of usage of halophilic archaea and role of Bacteriorhodopsin in bioelectricity generation. Further, different approaches like de novo protein engineering and genetic engineering can be explored and could possibly make this energy option cost effective in near future. Present chapter explores the recent progress in metabolic and genetic engineering for manipulation of electroactive bacteria (EAB) and scope of extremophiles for enhanced production of bioenergy (Latika Bhatia et al., 2020; Jamile Mohammadi Moradian et al., 2021).

BACKGROUND

MFCs are bioelectrochemical devices which consist of anode and cathode chambers which are physically separated by a proton exchange membrane (PEM). Microbial cells work as biocatalysts where they oxidize the organic substrates to generate electrons and protons in anode chamber (Rahimnejad et al.,2015; Yibrah Tekle & Addisu Demeke, 2015). Microorganism transfers the electrons to anode through which electrons then travel to the cathode with the help of an external circuit to produce electricity. General reactions at anode and cathode are as follows: (Chang et al., 2006; Yibrah Tekle & Addisu Demeke, 2015)

Anode oxidation reaction:

$$(CH_2O)n + nH_2O \rightarrow nCO_2 + 4ne - +4nH^+ \quad (1)$$

Cathode reduction reaction:

$$4e - +4H^+ + O_2 \rightarrow 2H_2O \quad (2)$$

There are different variants of MFCs available based on its construction. Double-chamber MFC is the simplest of all types and consists of two separate chambers of anode and cathode; and chambers are compartmentalized with the help of membrane permeable for proton exchange. Single- chamber MFCs are made up of single chamber containing anode and cathode electrodes separated by proton exchange