MICROBIAL FUEL CELLS AS A RENEWABLE ENERGY SOURCE

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Microbial fuel cells (MFCs) are innovative bioelectrochemical systems that convert the chemical energy stored in organic compounds directly into electricity by means of microbial metabolism. This technology offers a sustainable and environmentally friendly approach to solving two major challenges simultaneously: renewable energy generation and wastewater purification. In an era of climate change and growing energy demand, MFCs represent one of the most promising directions in applied biotechnology and environmental engineering (Logan, 2008, p. 45).

Unlike conventional fossil fuel-based power generation that emits large amounts of CO_2, MFCs use naturally occurring microorganisms as biological catalysts. During metabolism, these microbes oxidize organic matter, transferring electrons to the anode. The electrons flow through an external circuit to the cathode, where reduction reactions generate electricity, while protons move through a membrane to complete the circuit.

The design of an MFC typically includes two main compartments – anode and cathode chambers – separated by the membrane. The anode provides an anaerobic environment where organic matter degradation takes place, while the cathode, in an aerobic environment, supports oxygen reduction to water. Exoelectrogenic microorganisms, primarily *Geobacter sulfurreducens* and *Shewanella oneidensis*, play a key role in transferring electrons to the anode surface (Pant et al., 2010, p. 1533). The efficiency of electricity generation depends on various factors, including the type of substrate, electrode material, pH, temperature, and the architecture of the fuel cell.

Recent studies indicate that microbial fuel cells can be successfully used for the treatment of municipal, agricultural, and industrial wastewater (Zhang et al., 2020, p. 109). In such applications, MFCs not only remove organic pollutants but also generate useful electrical energy as a byproduct. Moreover, the integration of MFCs with other bioelectrochemical systems – such as microbial electrolysis cells (MECs) or anaerobic digesters – can further enhance energy recovery and system sustainability.

An important area of research involves the optimization of electrode materials and reactor configurations. The use of nanostructured carbon-based materials, conductive polymers, and 3D-printed electrodes significantly increases surface area and biofilm stability, thus improving power density. In parallel, genetic engineering of microorganisms aims to enhance extracellular electron transfer and expand substrate utilization range (Santoro et al., 2017, p. 225).

Beyond wastewater treatment and renewable energy, MFCs also show potential as biosensors, in marine energy harvesting, and in self-powered environmental monitoring. Their ability to function under low-energy conditions and generate power from organic waste makes them suitable for decentralized and remote applications.

Thus, microbial fuel cells represent an innovative convergence of biotechnology, materials science, and environmental sustainability. With further advances in microbial physiology, biofilm engineering, and system design, MFCs may soon become a key element of the circular bioeconomy and a practical source of clean energy.

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