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STUDIES IN ENERGY GENERATION FROM COW DUNG IN MICROBIAL FUEL CELL

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Abstract: Microbial fuel cell (MFC) research is a rapidly evolving field that lacks established terminology and methods for the analysis of system performance. This makes it difficult for researchers to compare devices on an equivalent basis. In this paper cow dung is used for energy generation Describing MFC systems therefore involves an understanding of these different scientific and engineering principles .different materials and methods used to construct MFCs, techniques used to analyze system performance, and recommendations on what information to include in MFC studies and the most useful ways to present results.

Keywords: MFC, Cow dung, Electricity generation.

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INTRODUCTION

It has been known for almost one hundred years that bacteria could generate electricity [1]. But only in the past few years has this capability become more than a laboratory novelty. The microbial fuel cell (MFC) is a new form of renewable energy technology that can generate electricity from what would otherwise be considered waste. Electrons produced by cow dung are transferred to the anode and flow to the cathode linked by a conductive material containing a resistor. The anodes of an MFCs behave as bacteria's typical electron acceptor and thus, the movement of the electrons to the cathode of the MFC through a resistor, generate electricity. The construction and analysis of MFCs require knowledge of different scientific and engineering fields, ranging from microbiology and electrochemistry to materials and environmental engineering. In this paper, we are providing review of the different materials, methods used to construct MFCs and techniques used to analyze the performance. Microbial fuel cells (MFCs) are devices that use bacteria as the catalysts to oxidize organic and inorganic matter and generate current [9]. Electrons produced by the bacteria from these substrates are transferred to the anode (negative terminal) and flow to the cathode (positive terminal) linked by a conductive material containing a resistor or operated under a load. Electrons can be transferred to the anode by electron mediators or shuttles by direct membrane associated electron transfer or by so-called nanowires produced by the bacteria or perhaps by other as yet undiscovered means. MFCs operated using mixed cultures currently achieve substantially greater power densities than those with pure cultures [7]. In one recent test, however, an MFC showed high power generation using a pure culture but the same device was not tested using acclimated mixed cultures and the cells were grown externally to the device [8]. Community analysis of the microorganisms that exist in MFCs has so far revealed a great diversity in composition [8,11]. We believe that many new types of bacteria will be discovered which are capable of anodophilic electron transfer (electron transfer to an anode) or even interspecies electron transfer (electrons transferred between bacteria in any form). We can produce clean energy by using MFC for wastewater treatment. The benefits of using MFC for wastewater treatment include: clean, safe, quiet performance, low emissions, high efficiency and direct electricity recovery. MFCs are being constructed using a variety of materials and in an ever increasing diversity of configurations. These systems are operated under a range of conditions that include differences in temperature, pH, electron acceptor, electrode surface areas, reactor size and operation time. Potentials are reported with different reference states and sometimes only under a single load (resistor). The ranges of conditions and in some cases a lack of important data like the internal types of MFCs, provide information on construction materials. Microbial fuel cells produce electricity from organic matters. Unlike conventional fuel cells, MFCs have certain advantages like high energy-conversion efficiency and mild reaction conditions. In addition, a fuel cell's emissions are well below regulations [2]. MFCs also use energy much more efficiently than standard combustion engines which are limited by the Carnot Cycle. In theory an MFC is capable of energy efficiency far beyond 50%. In fact, using the new microbial fuel cells, conversion of the energy to hydrogen is 8 times as high as conventional hydrogen production technologies [3]. In an MFC, bacteria are separated from a terminal electron acceptor at the cathode so that the only means for respiration is to transfer electrons to the anode. An MFC is thus a bioelectrochemical system that derives electricity by mimicking bacterial interactions found in nature. Microorganisms catabolize compounds such as glucose [4], acetate or wastewater [5]. It is a device that converts chemical energy to electrical energy by the catalytic reaction of microorganisms [6].

A typical microbial fuel cell consists of anode and cathode compartments. In the anode compartment, fuel is oxidized by microorganisms, generating electrons and protons. Electrons are transferred to the cathode compartment through an external electric circuit, and the protons are transferred to the cathode compartment through a seperator. Electrons and protons are consumed in the cathode compartment, combining with oxygen to form water. The microorganisms have the ability to produce electrochemically active substances that may be either metabolic intermediaries or final products of anaerobic respiration [3]. When microorganisms consume a substrate such as sugar in aerobic conditions they produce carbon dioxide and water. However when oxygen is not present, they produce carbon dioxide, protons and electrons [9].

$C_{12}H_{22}O_{11} + 13H_2O$ ----------> $12CO_2 + 48H^+ + 48e^-$

$O_2 + 4^{e-} + 4H^+$ ----------> $2H_2O$

This is the principle behind generating a flow of electrons from micro-organisms. In order to turn this into a usable supply of electricity, this process has to be accommodated in a fuel cell. To generate a useful current, it is then necessary to create a complete circuit. The mediator and the micro-organism are mixed together in a solution to which is added a suitable substrate, glucose for example. This mixture is placed in a sealed chamber to stop the entry of oxygen, forcing the micro-organism to use anaerobic respiration thereby. An electrode is placed in the solution, which would then act as the anode. In the second chamber of the MFC, there is placed another solution and an electrode. This electrode, the cathode, is positively charged and is the equivalent of the oxygen sink at the end of the electron transport chain. It is however external to the biological cell. The solution is an oxidizing agent that picks up the electrons at the cathode. Incidentally, this is not particularly practical as it would require large volumes of circulating gas. A more convenient option is to use a solution of a solid oxidizing agent. Connecting the two electrodes there is a wire or any other electrically conductive path.

Completing the circuit and connecting the two chambers there has to be a salt bridge or an ion exchange membrane. This feature allows the protons produced to pass from the anode chamber to the cathode chamber. The reduced mediator carries electrons from the cell to the electrode. Here the mediator is oxidized when it deposits the electrons. The electrons then flow across the wire to the second electrode, which acts as an electron sink. From here they pass to an oxidising material completing the process.

LITERATURE REVIEW

Water based organic matters that can be used in an MFC can be simple carbohydrates, acetate and butyrate, and complex organic compounds, domestic wastewater, and manure sludge. It is noteworthy that anaerobic digestion is basically goes on inside the MFC. Anaerobic digestion is typically applied in sewage sludge treatment due to its advantages over aerobic systems, such as lower energy consumption, smaller amounts of solids generated, lower nutrient requirement and potential energy recovery from the produced biogas. Sewage sludge is stabilized during anaerobic digestion by converting most organic matter into biogas. Microorganisms have the ability to produce electrochemically active substances that may be either the metabolic intermediaries, or the final products of anaerobic respiration. For the purpose of energy generation, these fuel substances can be produced in one place and transported to a microbial fuel cell to be used as fuel. The biocatalytic microbial reactor produces the microbial fuel. The biological part of the device is however not directly integrated with the electrochemical part. It allows the electrochemical part to operate under conditions that are not compatible with the biological part of the device.

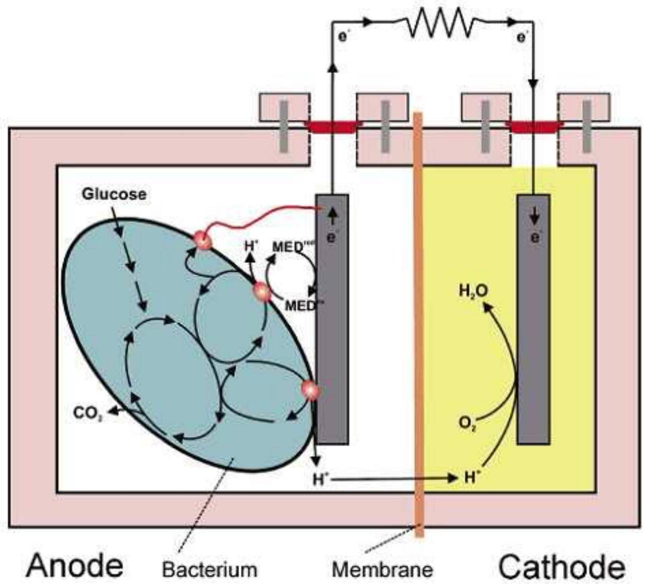
In another approach, the microbiological fermentation process proceeds directly in the anodic compartment of the fuel cell, supplying the anode with the fermentation products. In this case, the operational conditions in the anodic compartment are governed by the biological system, and therefore they are significantly different from those in conventional fuel cells. This would be a real microbial fuel cell which is not a simple combination of a bioreactor with a conventional fuel cell. This configuration is also often based on the biological production of hydrogen gas, but the electrochemical oxidation of H_2 is performed in presence of the biological components under mild conditions.

Yet a third approach involves the application of artificial electron transfer relays that can send electrons between the microbial biocatalytic system and the electrode back and forth. The mediator molecules take electrons from the biological electron transport chain of the microorganisms and transport them to the anode of the microbial fuel cell. In this case, the biocatalytic process performed in the microorganisms becomes different from the natural one, because the electron flow goes to the anode and not to a natural acceptor of electrons. Since the natural electron acceptor is expectedly more efficient, it can compete with the desired scheme, and hence it is usually removed from the system. In most of the cases, the microbiological system operates under anaerobic conditions, allowing electron transfer to the artificial electron relays and, finally to the anode.

There are many microorganisms producing metabolically reduced sulfur containing compounds such as sulfides and sulfites. Sulfate reducing bacteria form a specialized group of anaerobic microbes that use sulfate as a terminal electron acceptor for their respiration. These microorganisms yield while using a substrate, lactate for example, as a source of electrons. This microbiological oxidation of lactate with the formation of sulfide has also been used to drive an anodic process in microbial fuel cells.

Microbially catalyzed electron liberation at the anode and subsequent electron consumption at the cathode, when both processes are sustainable, are the defining characteristics of an MFC. Using a sacrificial anode consisting of a slab of Mg alloy does not qualify the system as an MFC because no bacteria are needed for catalyzing the oxidation of the fuel[6]. Systems that use enzymes or catalysts not directly produced in situ by the bacteria in a sustainable manner are considered here as enzymatic biofuel cells and are well reviewed elsewhere [3]. MFCs operated using mixed cultures currently achieve substantially greater power densities than those with pure cultures [5]. In one recent test, however, an MFC showed high power generation using a pure culture but the same device was not tested using acclimated mixed cultures and the cells were grown externally to the device [8]. Community analysis of the microorganisms that exist in MFCs has so far revealed a great diversity in composition [10]. We believe that many new types of bacteria will be discovered which are capable of anodophilic electron transfer (electron transfer to an anode) or even interspecies electron transfer (electrons transferred between bacteria in any form). We can produce clean energy by using MFC for waste water treatment. The benefits of using MFC for wastewater treatment include: clean, safe, quiet performance, low emissions, high efficiency and direct electricity recovery.

MFCs are being constructed using a variety of materials and in an ever increasing diversity of configurations. These systems are operated under a range of conditions that include differences in temperature, pH, electron acceptor, electrode surface areas, reactor size and operation time. Potentials are reported with different reference states and sometimes only under a single load (resistor). The ranges of conditions and in some cases a lack of important data like the internal types of MFCs, provide information on construction materials.



Material of construction for MFC

Anode: Anodic materials must be conductive, biocompatible and chemically stable in the reactor solution. Metal anodes consisting of non-corrosive stainless steel mesh can be utilized but coppern is not useful due to the toxicity of even trace copper ions to bacteria. The most versatile electrode material is carbon, available as compact graphite plates, rods or granules, as fibrous material (felt, cloth, paper, fibers, foam) and as glassy carbon.

The simplest materials for anode electrodes are graphite plate as they are relatively inexpensive, easy to handle and have unambiguous surface area. Much larger surface areas are achieved with graphite felt electrodes which can have high surface areas. All the indicated surface area will not necessarily be available to bacteria. Carbon fiber, paper, foam and cloth (Toray) have been extensively used as electrodes. Reticulated vitrified carbon (RVC) has been used in several studies. It is quite porous (97%) with different effective pore sizes specified by a manufacturer. The main disadvantage of the material is that it is quite brittle. It has been shown that current increases with overall internal surface area in the order carbon felt > carbon foam > graphite [7].

Cathode: Graphite is very popular as an experimental electron acceptor in microbial fuel cells, resulting in a cathode working potential close to its open circuit potential. The greatest disadvantage, however, is the insufficient reoxidation by oxygen, which requires the catholyte to be regularly replaced [7]. In addition, the long term performance of the system can be affected by diffusion mediators the CEM and into the anode chamber. Oxygen is the most suitable electron acceptor for an MFC due to its high oxidation potential, availability, low cost (it is free), sustainability and the lack of a chemical waste product (water is formed as the only end product). The choice of the cathode material greatly affects performance and is varied based on application.

Membrane: The majority of MFC designs require the separation of the anode and the cathode compartments by a CEM. Exceptions are naturally separated systems such as sediment MFCs or specially designed single-compartment MFCs. The most commonly used CEM is Nafion. Alternatives to Nafion, such as Ultrex CMI-7000 also are well suited for MFC applications and are considerably more cost-effective than Nafion. When a CEM is used in an MFC, it is important to recognize that it may be permeable to chemicals such as oxygen, ferricyanide, other ions, or organic matter used as the substrate. The market for ion exchange membranes is constantly growing, and more systematic studies are necessary to evaluate the effect of the membrane on performance and long-term stability [9].

FUNDAMENTALS OF VOLTAGE GENERATION IN MFC_S

Thermodynamics and the Electromotive Force: Electricity is generated in an MFC only if the overall reaction is thermodynamically favorable. The reaction can be evaluated in terms of Gibbs free energy expressed in units of Joules (J), which is a measure of the maximal work that can be derived from the reaction calculated as.

$$\Delta Gr = \Delta G^{o} r + RT\ln(\Pi) \text{ -----------1}$$

where ΔGr (J) is the Gibbs free energy for the specific conditions, ΔG^{o} r (J) is the Gibbs free energy under standard conditions usually defined as 298.15 K, 1 bar pressure and 1 M concentration for all species, *R* (8.31447 J mol-1 K-1) is the universal gas constant, *T* (K) is the absolute temperature and Π (dimensionless) is the reaction quotient calculated as the activities of the products divided by those of the reactants. The standard reaction Gibbs free energy is calculated from tabulated energies of formation for organic compounds in water available from many sources [7].

For MFC calculations, it is more convenient to evaluate the reaction in terms of the overall cell electromotive force (emf), E_{emf} (V), defined as the potential difference between the cathode and anode. This is related to the work W (J), produced by the cell.

$$W = E_{emf}\, Q = -\Delta Gr \text{ ------------2}$$

where $Q = nF$ is the charge transferred in the reaction, expressed in Coulomb , which is determined by the number of electrons exchanged in the reaction, n is the number of electronsper reaction mol and F is Faraday's constant (9.64853 ×104 C/mol). Combining these two equations, we have

$$E_{emf} = -\Delta Gr/nF \text{ --------------3}$$

If all reactions are evaluated at standard conditions,

Π = 1, then

$$E^{o}emf = -\Delta G{o}r/nF \text{ -------------4}$$

where E*o* emf (V) is the standard cell electromotive force. We can therefore use the above equations to express the overall reaction in terms of the potentials

$$Eemf = E{o}\ emf – (RT/nF)\ln(\Pi) \text{ --------------5}$$

The advantage of equation (5) is that it is positive for a favorable reaction, and directly produces a value of the emf for the reaction. This calculated emf provides an upper limit for the cell voltage.

Power Density: Power is often normalized to some characteristic of the reactor in order to make it possible to compare power output of different systems. The choice of the parameter that is used for normalization depends on application, as many systems are not optimized for power production. The power output is usually normalized to the projected anode surface area because the anode is where the biological reaction occurs.

CONCLUSION

As petroleum source is depleted, energy crisis encouraged researchers in the world to consider for alternative sources of energy. Moreover, using of fossil fuels may cause environmental pollution. Clean fuels, significantly fuel cells and biofuels, as new sources of energy without any pollution are suitable replacements of traditional fossil fuels. MFCs are individual kinds of FCs which use Cow dung. MFCs are one of the newest technologies to produce energy from different sources of substrates. Because of the promise of sustainable energy generation from different substrates such as organic wastes, research has been intensified in this field in the last few years. MFCs have different applications based on generated power. The generated power in MFC is still too low and researchers are working to improve it for commercial application.

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