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Research Article
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Characterization of Generated Voltage, Current, Power and Power Density from Cow Dung Using Double Chambered Microbial Fuel Cell

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Abstract

The present work deals with the fabrication of a laboratory scale double chambered microbial fuel cell (MFC) to generate electricity from cow dung. The experiment was performed to generate electricity from locally available cow dung as substrate using the fabricated MFC. The device was operated at anaerobic condition at varying time duration of 6 days, PVC pipe was used to make a salt bridge using agarose. The experimental readings were recorded at an interval of 1 hour. The performance was evaluated by characterizing the generated voltage, current, power and power surface density. It was observed that despite of high impedance of the substrate, all the general parameters have shown maximum values at day 5 and then a decline in trend was observed on 6 days onwards. The corresponding maximum values of the generated parameters are 0.825 V, 0.0113 μA, 0.009223 μW and 0.000000947 mW/m^2. The obtained graphs of voltage, current, power and power density were also found to have similar pattern. Thus, this study has demonstrated such that the fabricated MFC can be used for electrical energy generation from cow dung and other biowaste.

Keywords: Cow dung; Microbes; Microbial fuel cell; Renewable sources

Introduction

Throughout the world there is intense interest in evaluating and implementing alternative energy sources. Through public and even political impetus, reports identifying the concerns of global warming and increasing atmospheric carbon levels have been increasingly prevalent. The levels of carbon dioxide in the atmosphere have risen appreciably since the use of fossil fuels [1-3]. Although many researchers feel that this increase is harmful and could only be due to anthropogenic carbon emissions from the burning of fossil fuels [2]. This increase in carbon dioxide has been implicated as a cause of global warming due to the greenhouse effect, which is further exacerbated by other products of fossil fuel combustion such as nitrous oxides and incompletely combusted hydrocarbons [4]. Global warming is of concern for many reasons, for example the increase in sea level due to the melting of the ice caps [5]. This particular problem that would cause flooding in many coastal areas and only be exacerbated by the reduction in the size of the ice caps which would reflect less solar energy into to space. This increase in solar energy would then increase global temperatures, melting more of the polar ice, which would then increase sea level even further [6]. One of the remediation tactics for the problem of global warming is to reduce the release of carbon emissions by using carbon-neutral and possibly carbon-negative fuel sources [7]. In an MFC, microorganisms oxidize a substrate and transfer those electrons to an anode electrode. The electrons then flow through an external circuit, creating a useable current, and then reduce an oxidant at the cathode. A critical component of this system is the ability to achieve extracellular electron transfer [8]. This capability was discovered about a century ago by Potter, who looked at potential decreases with the placement of a platinum electrode into an *Escherichia coli* culture. In the 1960s, this work was expanded by decoupling the half reactions present in this biochemical reaction to produce an electrical current. Performed with *E. coli*, these reactions showed very little power production until the addition of a mediator, which served to shuttle electrons between the cell and the anode of this simple system. More interest was garnered into the 1980s, and mediators became of great interest [9]. However, due to toxicity concerns (especially with treating waste streams that would be released into potable water sources) and cost (since the mediators were regularly broken down throughout the cycle), using exogenous mediators in an MFC is not thought to be a sustainable technology. Presently, much of the work in MFCs focuses on mediatorless systems, fuel cells which do not have to use an added mediator to transfer electrons to the anode [10]. This was first demonstrated in 1999 by Kim et al. Such bacteria are known as exoelectrogens and an example of such a microorganism would be *Geobacter sulfurreducens*. The mechanism by which the electrons are transferred is being explored presently, and could involve the production of mediators by the cells themselves, the use of outermembrane cytochromes, or the use of conductive filaments (known as nanowires) to transfer the electrons directly from the cell to the anode [11-13]. The coulombic efficiency, or the number of electrons captured by electrical current divided by the number of electrons that are extracted from the substrate, is one of the defining measurements in the performance of a fuel cell. An MFC is based on the fact that different redox potentials of chemical reactions can generate power, as in conventional batteries. Electron donor substrate at the anode is oxidized and these electrons travel to the cathode generating an electrical current [14]. At the cathode, an electron acceptor is then reduced. To calculate the overall potential, the reduction potentials must be adjusted for pH, reactant and product concentrations, and temperature. There are many electrochemical losses that may further reduce this maximum value, such as, but not limited to, the internal resistance of the MFC and the microorganism's ability to degrade the feedstock [15]. MFC architecture generally consists of three main components, the anode, the cathode, and a membrane that separates

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the anode and the cathode but allows the flow of protons from the anode to the cathode. The anode is a conductive material, often carbon based (carbon fiber brushes, carbon paper, graphite rods, etc.), and is submersed in an anaerobic environment [16]. The anode material has to be able to carry a current as well as allow microorganisms to colonize on it; this colonization is also very important for the production of electricity in the fuel cell. The cathode is often a limiting aspect of an MFC. The most common and feasible electron acceptor for large-scale application is oxygen. Other compounds such as ferric cyanide and permanganate can be used, with higher coulombic efficiencies (electron recovery), but pose problems such as toxicity to the microbes and regeneration issues after their use [11-13]. Using oxygen as the electron acceptor has several drawbacks, one being that the chemical reaction at the cathode is slow, so a catalyst (either chemical or biological) is needed for the reaction to proceed at useful rates. This can prove to be costly, as the most common material used in this manner is platinum, but alternative catalysts such as lead dioxide and has shown to work as well, with lead producing 2-4X the power densities and cobalt slightly lower power densities compared to platinum catalysts on the cathodes [17]. Also the infiltration of oxygen into the anaerobic anode chamber reduces the columbic efficiency of the system. Biocatalysts on the cathode offer another interesting challenge, requiring the correct microbial communities to maintain a significant potential difference between the electrodes, allowing the flux of electrons [18]. A membrane is not always used in an MFC because it can reduce system performance by limiting the rate of proton transfer to the cathode and the cost of the membrane can be prohibitive [19]. Such a membrane is necessary in a two-chambered MFC, but not in a single-chamber MFC with an air cathode [20]. One advantage of a membrane is that it can reduce oxygen diffusion into the anode chamber, thereby reducing electron loss due to aerobic respiration and increasing columbic efficiency. Most of the work with MFCs has been done using soluble substrates, but real wastewaters generally contain particulate materials with varying degrees of solubility and degradability [21-23]. Likewise, other waste streams have a substantial portion of biomass and therefore are recalcitrant to biological degradation. One treatment process for these wastes is anaerobic digestion [24]. For MFCs to be a viable technology, many feel that the anaerobic digestion "benchmark" (of energy or products produced per mass of substrate utilized) must be met. MFCs are thought to be a more viable technology where the environmental constraints (e.g., dilute waste stream, low temperature) preclude the use of the digestion technology to produce energy [25]. The aim of this research paper is to use MFC for voltage generation by utilizing of cow dung as a substrate. The efficiency of MFC was investigated by utilizing cow dung as a substrate in MFC for electricity generation (Figure 1).

Materials and Methods

A double chambered MFC with substrate cow dung in the anodic chamber run for 6 days to observe the characteristics of generated voltage and current. The construction of double chambered MFC device requires inexpensive materials (Table 1).

MFC construction

Two 2.5 L bottles were prepared as an anode chamber and a cathode chamber. Two small holes were made in the caps of the bottles as to insert wire through it. Wire using aluminum clips were attached to copper electrodes. The anode chamber was filled with the substrate (0.1 kg of cow dung mixed with 1 L of water) while the cathode chamber was filled with plain water of 1 L. Other two ends of wires were attached to digital multimeter.

Salt bridge construction

The PVC pipe used in salt bridge construction had dimensions of 5 cm length and 2 cm diameter. Volume 15.7 cm^3 was calculated using the formula $\pi r^2 h$. Salt bridge was prepared using 20 ml of 1M KCl solution and 3% agarose. The solution was first subjected to heat for blending, which in return gave a clear solution of agarose and KCl. the same was poured into the PVC pipe and was kept in the freezer at -4°C for solidification. The solidified salt bridge was attached to the chambers using araldite adhesive which makes them leak proof.

Observation

The generated voltage and current was recorded from the digital multimeter at an interval of 1 hour for 6 days. While the corresponding power and power density was calculated by using formula P = VI and P/a (a= total surface area = 90 cm^2) respectively (Table 2).

Results and Discussion

MFC was operated for 21 hrs, consecutively for 6 days and DC voltage and current was measured using digital multimeter. The data collected was graphed using OriginPro 8.0 software.

Generated voltage

Voltage generated by cow dung using double chamber MFC was recorded at an interval of 1 hr per day for the entire time period of 6 days (Figure 2). The maximum generated voltage in each of the six days is depicted in Table 3. It is observed that there was a definitive increase

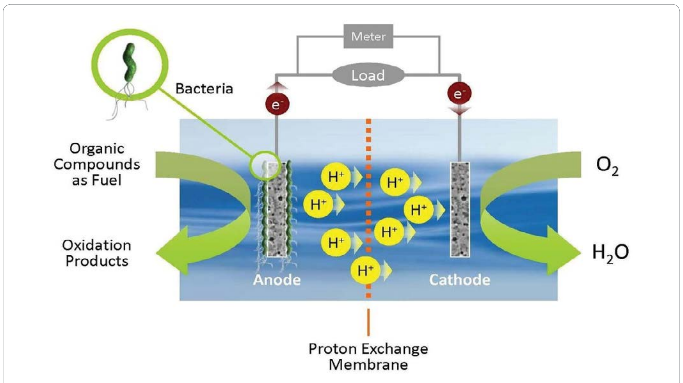

Figure 1: Double chambered MFC.

S No	Materials	Quantity
	PVC bottles (2.5 L)	2
	PVC pipe (5 cm)	1
	Copper rods (5 × 5)	2
	Cow dung	0.5 kg
	Copper wire	0.5 m
	Aluminum clips	2
	Digital multimeter	1

Table 1: MFC fabrication prerequisites.

Day	Voltage (V)
1	0.487
2	0.631
3	0.633
4	0.680
5	0.825
6	0.563

Table 2: Generated voltage from day 1-6.

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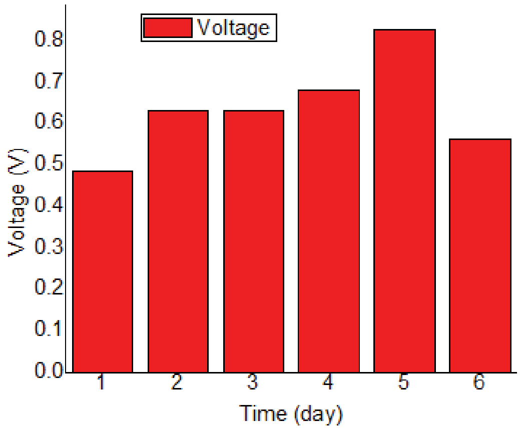

Figure 2: Generated voltage from day 1-6.

Day	Current (µA)
1	0.009
2	0.0086
3	0.0095
4	0.0097
5	0.0113
6	0.007

Table 3: Generated current from day 1-6.

in the generated voltage from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated voltage at day 5 was 0.825 V and the minimum generated voltage of 0.487 V was observed on day 1. The voltage measured was open circuit voltage since the external resistance is not used. Hence the voltage generated was due to internal impedance, which seemed to be very high in the range of mega ohms.

Generated current

Current generated by cow dung using double chamber MFC was recorded at an interval of 1 hr per day for the entire time period of 6 days (Figure 3). It is observed that there was a definitive increase in the generated current from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated current at day 5 was 0.0113 µA and the minimum generated current of 0.007 µA was observed on day 1. The current measured was open circuit voltage since the external resistance is not used. Hence the voltage generated was due to internal impedance, which seemed to be very high in the range of mega ohms.

Generated power

Power generated by cow dung using double chamber MFC was recorded at an interval of 1 hr per day for the entire time period of 6 days (Figure 4). The maximum generated current in each of the six days is depicted in Table 4. It is observed that there was a definitive increase in the generated voltage from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated current at day 5 was 0.009223 µW and the minimum generated voltage of 0.002523 µW was observed on day 1. The power measured was open circuit power since the external resistance is not used. Hence the power generated was due to internal impedance, which seemed to be very high in the range of mega ohms (Table 5).

Generated surface power density

Power density generated by cow dung using double chamber MFC was recorded at an interval of 1 hr per day for the entire time period of 6 days (Figure 5). It is observed that there was a definitive increase in the generated power density from day 1 to day 5 and then a decline in trend is observed on day 6. The maximum generated power density at day 5 was 0.000000947 W/m^2 and the minimum generated power density of 2.69211E-07W/m^2 was observed on day 1. Power density measured was open circuit voltage since the external resistance is not used. Hence the power density generated was due to internal impedance, which seemed to be very high in the range of mega ohms. The maximum generated voltage, current, power and surface power density is observed to have similar characteristics from day 1-6. The pattern of their increase and decrease are also follows the similar trend. On day 5, all the parameters measured are observed to have maximum value while on day 1 the minimum values are obtained except in the case of maximum current which might be due to high impedance of substrate resulted because of improper mixing of substrate and water.

Conclusion

Due to the rapid depletion and escalation of prices of conventional fossil fuel, the whole world is urgently looking for an alternative source of energy, which is renewable and can be produce in an economical manner. In this context, energy produced from a potential organic biowaste is an attractive option. Keeping this view, the present work has been undertaken to produce electrical energy from cow dung as biowaste in microbial fuel cell. In the first phase of project work, a microbial fuel cell was successfully constructed using two 1.5 L bottles,

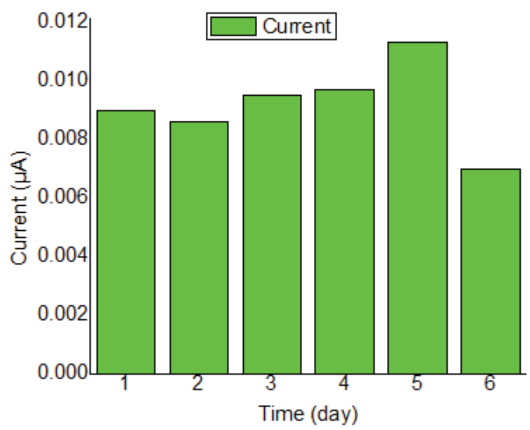

Figure 3: Generated current from day 1-6.

Day	Power (µW)
1	0.002523
2	0.003864
3	0.003376
4	0.003726
5	0.009223
6	0.005612

Table 4: Generated power from day 1-6.

Day	Surface power density (µA)
1	2.69211E-07
2	4.28134E-07
3	3.74143E-07
4	4.12786E-07
5	0.000000947
6	7.44333E-07

Table 5: Generated surface power density from day 1-6.

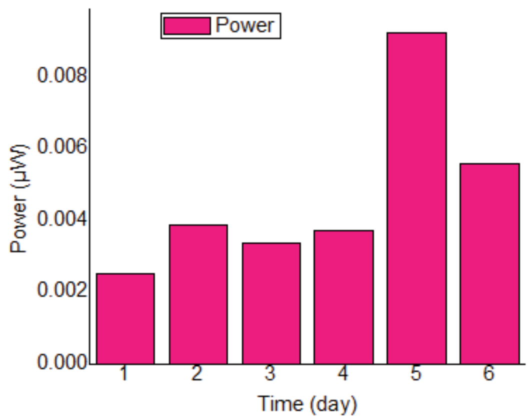

Figure 4: Generated power from day 1-6.

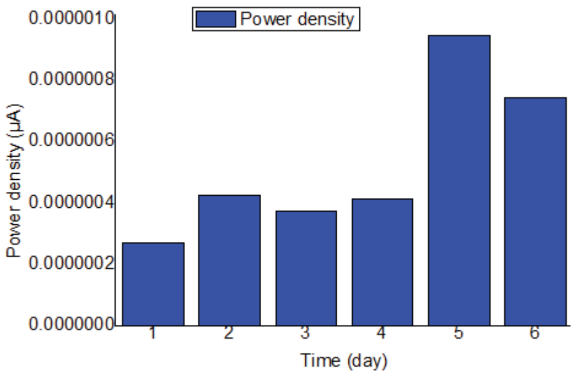

Figure 5: Generated power density from day 1-6.

which were operated as cathode and anode chambers. The salt bridge was made using KCl and agarose. Graphite plates were used as electrodes in MFC. In the second phase, experiment was conducted to generate energy from locally available cow dung, which was used as a substrate for MFC. The whole system was connected to desktop multimeter for obtaining précised readings of voltage and current. In the last phase, characterization of generated voltage, current, power and surface power density was done. The maximum values of these parameters obtained were 0.825 V, 0.0113 µA, 0.009223 µW and 0.000000947 mW/m^2. Overall, this study has shown that the constructed the fabricated microbial fuel cell can be used for the generation of electricity from cow dung and possibly other waste.

Suggested Further Study

The study and development of MFC is still in initial phase. The fabricated MFC has produced satisfying amount of voltage, though there is wide scope for development of MFCs in terms of design and power output as for now the power density is too low for their use in automobiles, electronic devices, medical appliances and other industrial applications. Modification in design components will provide improved results. High quality substrates can be used in MFC that can provide high power to run electrical appliances. The microorganisms which supply electrons can be modified genetically to provide more efficient electron transfer to electrodes. Optimizing the process parameters involved production of electricity can be increased. It is the matter of proper electrodes, salt bridge, volume of anode chamber and an appropriate resistance to produce high power. Since the use of catalyzed electrodes have added most of the cost of fabrication and maintenance, different innovations like bio cathodes can be applied as a substitute. High quality proton exchange membranes can effectively increase the ion exchange without hindrance in the electricity production. Nanoparticles may be incorporated in salt bridge, cathode chamber or anode chamber which might boost up the output values. A mathematical model may be developed for explaining the similarity and pattern recorded in this study, which might help to find the rate of reactions responsible for maximum and minimum values of the observed parameters.

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