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BIOMASS CELLS : A KEY FOR SUSTAINABLE RURAL AREA APPLICATIONS

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ABSTRACT

Microbial Fuel Cells (MFC) use microorganism as natural catalyst to produce bioelectricity from organic substrate and proving to be an efficient means of sustainable energy generation. Based on this concept, biomass cell technology has been used for development of biomass cells by using metal anode zinc. The natural redox potential ability of zinc metal is the main contributor to enhance the performances of biomass cells. In Indian rural areas, cattle dung obtained from livestock are one of the main organic waste and abundant. Being rich in microbes, these cattle dung's are used as substrate for biomass cells. These cells are kept under observations for period of 45 days and electrical parameters have been obtained from polarization techniques. The maximum current and power density obtained are 1425 mA/m^2 and 861 mW/m^2 respectively. Although the efficiency of biomass cells in power generation are initially low, but the stacking of cells in series and parallel combinations can enhance the efficiencies. These stacking can produce enough electricity for off grid locations to small power applications in rural areas.

KEYWORDS : Biomass cells, Cattle dung, Substrate, Open circuit voltage (OCV), Bioelectricity

The exploitation of fossil fuels has formed serious threats for mankind, such as addition of carbon dioxide to atmosphere and global warming (Lovely, 2006). In addition, demand for energy is continuously rising and established assets of fossil fuels are limited by which humanity may perhaps be faced with severe scarcity of power in coming prospect. These significant issues have encouraged researchers to look for alternatives for fossil fuels (Strik et. al., 2008). One particular alternative of generating electricity is fuel cell. Fuel cells are source of renewable energy and environment friendly (Steele et. al., 2001). In fuel cells, the chemical energy in chemical bonds is directly converted to electricity through electrochemical process. Unlike fuel cells, biological fuel cells employ neutral electrode and active biocatalyst for production of bioelectricity. Biological fuel cells are named by the biocatalyst used in anodic chamber of cell (Gupta et. al., 2011). Microbial fuel cells employ microorganism for oxidation of organic substrate. Microbial fuel cells (MFCs) use microbes as catalyst to oxidize organic and inorganic matter in these bio-electrochemical devices and generate current. In anodic chamber, through anaerobic oxidation of organic matter electrons and protons produce with carbon dioxide and cell material as final product (Bruce et. al., 2006). The produced electrons are transferred to the cathodic chamber through an external circuit. MFC is gaining consideration due to their capability to use variety of biodegradable substrates under mild conditions. MFC performance mainly depends on several important factors such as system configuration, nature of organic matter, bacterial species, electrode material and surface area, type of catholyte, operating conditions, rate of oxidation in anodic chamber, electron shuttle from anodic chamber to surface of anode, way of supply and amount of consumption of cathode chamber, permeability of PEM etc. (Rahimnejad et. al., 2015, Rahimnejad et. al., 2012). The anode materials mostly used in MFC are of different formats of non metallic material carbon. The surface area of anode plays a contributive role in power generation of MFC (Schroder et. al., 2007). The metal materials have much more conductivity than carbon based materials but have limited application in MFC because of flat surface that hinders the sticking of the bacterial colony. Metallic anodes have natural oxidation-reduction potentials which help them to act as metallic anode for higher current densities (Aelterman, 2006; Hernandez et. al., 2015, Tharali et. al., 2016). Among the metals zinc has the inherent ability to enhance the rate of transfer of electrons to anode from the substrate without any mediator. In sediment MFC, anode zinc has achieved maximum power density as compare to aluminum, copper, iron and graphite (Haque et.al., 2015). This paper demonstrates the electrical performances of metallic anode zinc for small power applications in rural areas of country. This research is for rural applications, so abundantly available cattle dung was considered as substrate. The animal confinements are ideal candidate for bioelectricity generation because of high organic matter content which is easily degradable. As biological fuel cells are named by the biocatalyst used, so based on the theory of MFC, cells fabricated with biomass based cattle dung were named as biomass cells.

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MATERIALS AND METHODS

Collection of Cattle Dung Samples

The fresh cattle dung are named samples of different breeds were collected in neat containers from farm house of Punjab province, India. The substrate was prepared as slurry by adding distilled water in the ratio of 1:4. The untreated cattle dung was used to confirm the bioelectrical contribution because of natural microbial flora present in the dung.

Fabrication of Biomass Cells

Like MFC biomass cells were majorly constitutes anodic and cathodic chambers, electrodes and proton exchange membrane (PEM). Two configurations of biomass cells were setup as Double Chamber and Single Chamber, in double chamber two plastic containers of capacity 1000 ml act as anodic chamber and cathodic chamber. The chambers were connected by PEM of conventional salt bridge to facilitate the transfer of protons. The salt bridge was prepared by boiled 10% potassium chloride and 5% agar and settled in PVC pipe for 30 minutes. The zinc and carbon electrodes of areas 42.5 cm^2 were placed in anodic and cathodic chambers respectively. The connecting wires were connected to two electrodes to act as output ports and electrons flow through this external circuit. In the anodic chamber 700 ml of substrate was inoculated and microorganism metabolizes it in anaerobic conditions and produce protons and electrons. In cathodic chamber 700 ml of distilled water was filled and operate in aerobic conditions. The protons travel through salt bridge and electrons through external circuit to reach at cathode and react with oxygen to produce water. As a result of these biochemical reactions, a bioelectricity was produced in this cell. In single chamber only one plastic container of 1000 ml capacity was used which act as anodic chamber. The chamber was filled with 700 ml of substrate and zinc anode electrode of same area was placed in it. A hole of diameter of 1 cm was made on the lid of container to place salt bridge. An air carbon cathode was inserted (20-30% of area) into salt bride and rest is air exposed. The copper connecting wires were connected to two electrodes to act as output ports for voltage measurements.

Mediators in Biomass Cells

In MFC the materials with high redox potential are highly desirable as mediator to improve the electrical parameters of MFCs. The commonly used are potassium permanganate as oxidising agent and neutral red to enhance the rate of electron flow in anodic camber (Oh; 2004). In this research no additional mediator were used. The zinc metal has a very high redox potential and traditional mediators were replaced with this metal as natural redox agent. Here the zinc metal played a dual role of anode electrode and mediator. Most of the MFC researchers support the non-metallic electrodes for design, analysis and operation of MFC and promote mediators to enhance the MFC performances. After the complete observation of biomass cells for about 45 days, the physical parameters of zinc electrodes were analyzed and found no change at all.

Calculation of Electrical Parameters

Theoretically the maximum voltage that can be attained from this setup is of the order of 1.6 V. The oxygen reduction reaction at cathode does not give way the theoretical potential of +0.84 V, because of impact of activation losses on potential. Due to these losses, the measured MFC voltage was considerably lower. These voltages were recorded using a multimeter. The polarisation data was obtained by varying external resistances of range 1000 to 50 ohm for determination of electrical parameters of cells in the circuit and measuring the voltage across the external resistance. The peak voltage attained in cell is always the open circuit voltage OCV. The current and power densities were calculated as reported by various researchers. The current and power density was calculated by dividing the current and power by projected surface area of electrode (Choi et. al., 2013, Cheng et. al., 2006, Liu et. al., 2004,Cheng et. al., 2007).

RESULTS AND DISCUSSION

The bioelectricity generation was evaluated between double chamber biomass cell and single chamber biomass cell with same electrode couple and size. The cell voltages were measured regularly for biomass cells using a multimeter (MARS VC-97). These values were monitored over a period of 45 days and shown in figure 1. The maximum OCV achieved by DCBC was 1150 mV on day 27 and day 28, and the voltages were almost constant from day

19 to day 39. The maximum power and current densities obtained on day 32 were 550 mW/m^2 and 1139 mA/m^2 respectively. For SCBC the maximum OCV was 1232 mV achieved on day 30. Almost consistent voltages of above 1200 mV achieved from day 12 to day 43. The maximum power and current densities calculated from polarization curves were 861 mW/m^2 and 1425 mA/m^2 respectively. Table 1 and figure 2, 3 represents the current and power densities obtained on different days.

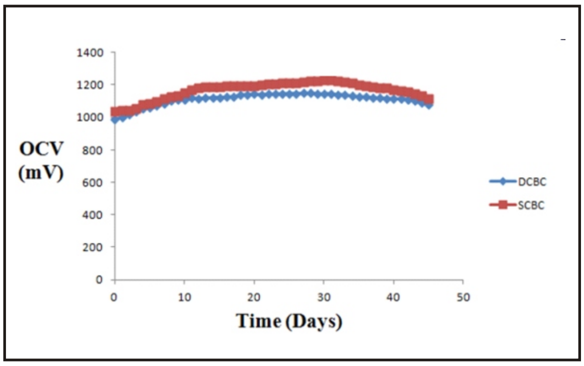

Figure1: OCV for DCBC and SCBC

Table 1: Current and Power Densities of DCBC and SCBC

Day	DCBC Current Density (mA/m^2)	DCBC Power Density (mW/m^2)	SCBC Current Density (mA/m^2)	SCBC Power Density (mW/m^2)
10	1101	514	1321	746
20	1132	543	1387	816
30	1137	548	1425	861
40	1106	519	1358	782

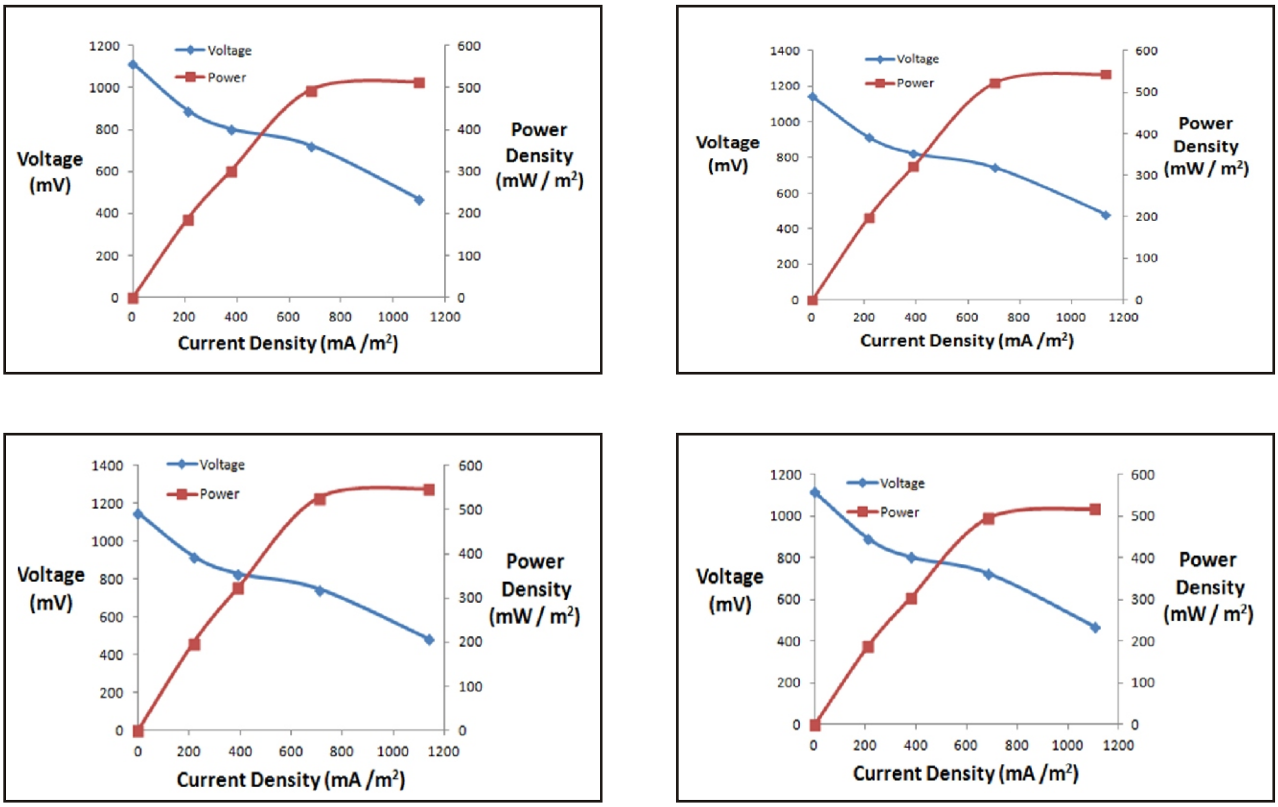

Figure 2: Current and Power Densities of DCBC on Day 10, 20, 30 and 40

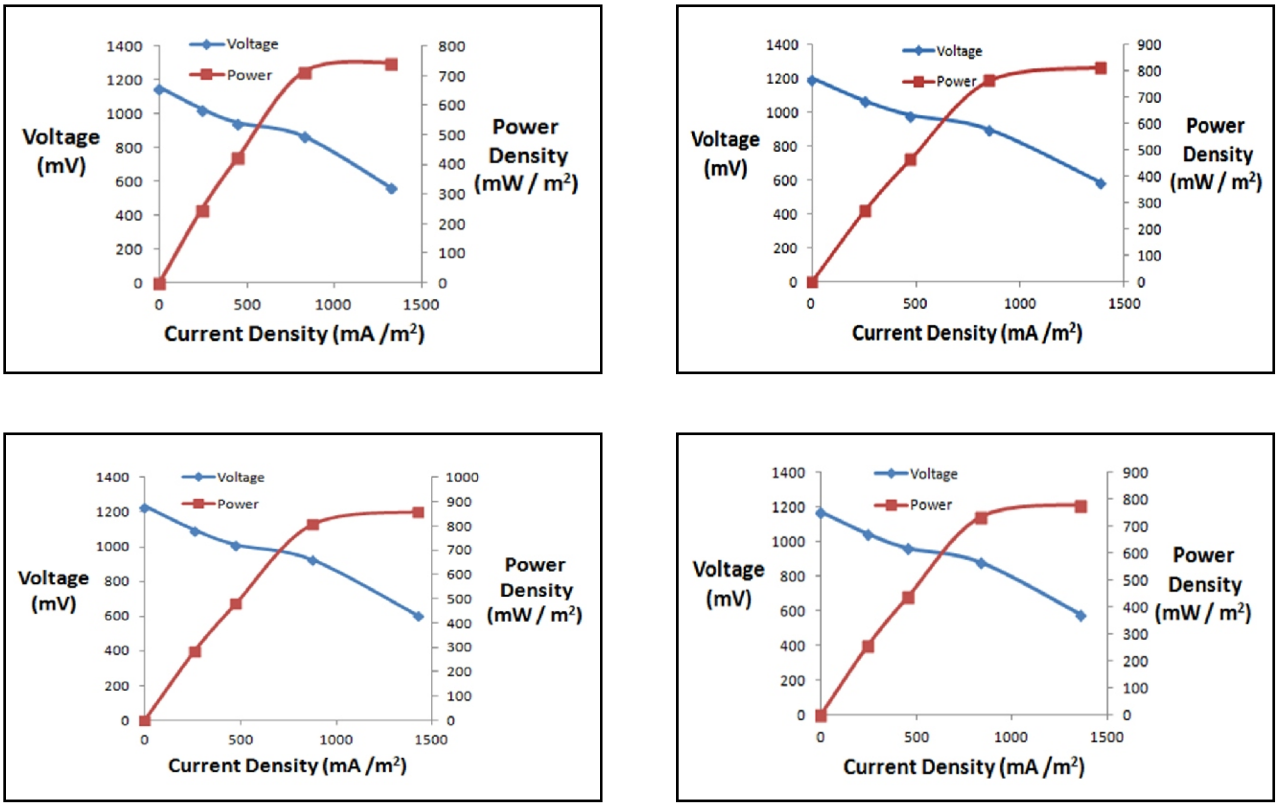

Figure 3: Current and Power Densities of SCBC on Day 10, 20, 30 and 40

The efficiencies of both the biomass cells for bioelectricity generation were obtained and results show that both cell configurations have capability to generate power and meet the small power applications. The single chamber biomass cell has presented the more promising result because of efficient cell configuration and low internal losses. Biomass cells of metal anode will become part of mainstream technology through series and parallel stacking of individual cells. The results obtained were helpful in designing an optimized zinc anode biomass cell with reduced cost and increased output. In coming time it will be central to successful commercial biomass cell employment for rural applications.

CONCLUSIONS

In the present work an attempt has been made to find the potential of bioelectricity generation of two configurations of biomass cells with zinc anode. Maximum current and power density achieved with lowest external resistance were 1425 mA/m^2 and 861 mW/m^2. The work demonstrates the feasibility of using zinc anode for mediator less biomass cells for rural applications. Though the efficiencies of cells were low, but appropriate stacking of these cells with series and parallel combinations may be helpful for off grid power application in rural India.

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