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Influence of Exogenous Bacteria in Cow-Dung-Fed Microbial Fuel Cell on Voltage, Current and Power Density

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Abstract

Present experimental study was aimed to examine the influence of exogenous microbial source in cow dung-fed MFC on electricity generation. Two reactors were designed and operated for about thirty days. Four important observations were made. (1) MFC-II loaded with cow-dung slurry mixed with domestic waste water exhibited early shoot up in voltage generation than MFC-I loaded with cow dung slurry alone. (2) There is no significant difference in maximum voltage generated in MFC-I and MFC-II. But the reactors have taken different times to reach the maximum voltage. (3) MFC-I generates the voltage till the end of thirty days while there is a decline in voltage of MFC-I which is earlier than the duration of MFC-II. (4) Neither electrodes or recharged during the testing period of thirty days. Therefore, it is demonstrated that in cow dung-fed MFCs, addition of exogenous bacterial source would speed up electricity generation. The proposed MFC is simple, reproducible, harmless and maintenance free. It is suggested that the scheme will be very much useful in harnessing moderate power in order to meet the power requirements of dairy farms, houses in the remote hilly areas.

Keywords: Microbial fuel cell (MFC), cow dung, domestic waste water-Bacterial community, Proton exchanges membrane (PEM), Voltage, Power density.

INTRODUCTION

Increasing global demand for energy has created strong quest for environmentally clean alternative energy resources. MFCs are devices which convert the chemical energy in the organic compounds to electrical energy mediated by microbial metabolism under anaerobic conditions [1]. Microbial Fuel Cell (MFC) is considered as an important new avenue for generating sustainable bioelectrical energy using organic waste capitalizing the metabolic activity of the bacteria [2-4]. With a view to increase the efficiency of MFCs, considerable work has been done on MFC configurations, their physical and chemical operating conditions, the choice of microorganisms, and optimization of the microbial metabolism to increase electron donation to the electrodes[5-11].The core inputs of MFC include inoculum source and mix of bacterial community [12,13]; substrate[14-15], anode material [16,17]catholyte [18]; ratio of electrolyte volume to electrode surface area [19]and type of proton exchange membrane [12]. Therefore**,** it is learned that the type of substrate used in MFC plays a s key factor in gauging suitability and stability of design and operation of MFC in terms of electricity generation. Search for potential substrate has been made in the recent past by many workers. In that pursuit, potentiality of Cow dung as substrate is being tested and reported in [20-24].

Report on electricity generation using cow dung in MFC is coming up regularly during the last decade in which MFC configurations and composition varied widely. Most of the systems are of batch type with recharging of anolyte[16], use of organics like acetate, glucose and phosphate buffer and inorganics like Ferricyanide[16,25,26,27], use of costly electrodes like platinum, bubbling of air into catholyte for oxygenation in the cathode chamber [28]. But in the present study, cow dung is used as substrate for the power generation using indigenously designed Microbial fuel cell. To be precise, presently an attempt has been made to find out whether addition of municipal waste water to cow dung slurry as source of exogenous bacterial community influences sustained electricity generation. Cow dung and untreated municipal waste water reported to possess mostly of specific group of bacterial communities [21, 16, 29-32] and untreated municipal waste [33-35]. In view of these studies, it is proposed to find out whether addition of untreated municipal water as a bacterial source has any influence on voltage generation in cow dung- fed MFC.

MATERIALS AND METHODS

A typical MFC consists of "H" shaped two chambered set up made out of cheap materials which included two polycarbonate bottles or made of glass, PEM and two electrodes. Presently two such reactors are designed and fabricated. Since each aspect of MFC components are important parameter, a detailed description on methods & materials are given in this part.

Fabrication of MFC

Two polycarbonate bottles (500mL) were used as anode and cathode chamber. The PVC pipe of diameter fitting to the diameter of the PEM (8cm diameter) was fixed between two chambers using araldite adhesive which makes the module leak proof Figure 1.

The proton exchange membrane (PEM-AMI 220) used was made of polyvinyl alcohol Sulphosuccinic acid obtained from Membrane International, USA. Before it was fixed in connecting pipe, the membrane was soaked in saline water overnight so as to make the pores open properly and later dried in shade.

Selection and preparation of anolyte and catholyte

Fresh cow dung weighing about 1kg was collected directly from nearby dairy farm and allowed to dry under shade for three days. At the end of third day surface of cow dung pile became rigid and dried. Dried layer was removed and about 500 grams of the cow dung below dried layer was taken out and made into slurry in 500ml of freshwater (cow dung: water -1:10) and used as anolyte in MFC-I. In MFC-II, same quantity of cow dung slurry in the same ratio was filled in anode chamber and about 10ml of untreated municipal waste water was added to anolyte as source of exogenous bacterial community to find out the advantage of adding exogenous bacterial community in terms of electricity generation.

Efficiency of MFC also depends on type of catholyte and its concentration. It is widely reported that potassium permanganate ($KMnO_4$) and $K_2Cr_2O_7$ were used commonly as catholyte. In the present study $KMnO_4$ is a strong oxidizing agent than $K_2Cr_2O_7$. It has +7 states, capable of getting reduced in a sustained manner influencing inflow of proton (Hydrogen) and the reduction product at the cathode also is clean, non-polluting H_2O. Therefore, the cathode chamber of MFC-I and MFC-II were filled with 500ml of 2% potassium permanganate solution ($KMnO_4$).

Selection and pre processing of electrodes

Basically, base materials of electrodes must generally be a good conductor, with high mechanical strength, good chemical and biochemical stability and preferably low cost. Therefore, carbonaceous materials and non–corrosive metals which meet the general requirements mentioned above, are widely used (Wei et al., 2011). Therefore, in the present experiment two graphite plates with surface area of $36cm^2$ were used as anode and cathode electrodes. In order to make the electrodes either wetting or activation, they were boiled in de-ionized water and soaked overnight in 1M HCL solution and rinsed in de-ionized water before it was linked to bioreactor [36]. Copper wires were fixed in the electrodes and sealed with epoxy resin as described in [37].

Data collection and Observation

Currently two MFC reactors (MFC-I & MFC-II) were run simultaneously. MFC-I was with cow dung slurry alone and MFC2 with cow dung slurry seeded with 10ml of untreated municipal waste water collected from street drain canals. Current was measured using 100Ω as external resistance every day about 30days .Anolyte samples were also collected aseptically to find out type of bacterial communities present in cow dung slurry and cow dung slurry seeded with municipal waste water. Screening of bacterial community both in cow dung and untreated municipal waste water was done as described [30].

Data collected on voltage generation were fed in Kaleidagraph version 3.6 for depicting characteristics of Time and Generated voltage, current, power. Current density and Power density were calculated using the formulation, Power Density=P/total surface area of electrode and Current Density= I/total surface of an electrode. The total surface area of each electrode was $36cm^2$.A graph has been drawn between current density and power density with respect to generated voltage using Kaleidagraph version 3.6.

DISCUSSION

Microbial Fuel Cells that convert biodegradable organic material directly into electricity using electrogenic micro organisms present in biowaste [38-41], is an interesting but challenging field of research. Present work was taken up to find out influence of exogenous microbial source on electricity generation. Two separate MFC–one with cow dung alone (MFC-I) and another with cow dung slurry with domestic waste water as exogenous source of microbial consortia (MFC-II) were run. Both systems were operative in terms of electricity generation continuously for 30 days.

In thirty days cycle, four important observations were made. (1) MFC-II exhibited early shoot up in voltage generation than MFC 1. (2) There is no significant difference in maximum voltage generated in MFC-1 and MFC-2. But the reactors have taken difference times to reach the maximum voltage. (3) MFC-1 generates the voltage till the end of thirty days. While there is a decline in voltage of MFC-I which is earlier than the duration of MFC-II. (4) Neither electrodes or recharged during the testing period of thirty days.

Considering observations 1 & 2, MFC -II (cow dung slurry with MWW) found to be shoot up in early for electricity generation when compared to MFC-I (Fig: 1), within 2 hours from the period of operation, MFC-II generated 0.487 V whereas MFC-I undergone two days to produce same level of voltage. MFC-II produced 1.0 V on the sixth day while MFC-I showed same level of voltage only by eleventh day. However, variation in maximum generated voltage between MFC-I &II is not significant (1.20V by MFC-I and 1.22V by MFC-II). Reason for such variations between MFC-I & II, might be due to the difference in type of bacteria present in the anolyte of MFC-II i.e. cow dung with untreated domestic waste water. It is previously reported that type of bacteria present in anode act as biocatalysts to pull electrons out from substrates [38]. Moreover anodic performance is inextricably dependent on (i) nature of substrate -the nature and the rate of the anaerobic metabolism, and (ii) the nature and the rate of the electron transfer from the microbial cells to the anode. Therefore, it is learned that the substrate cow dung with waste water might have supported variety of micro flora than by cow dung alone. The exogenous bacterial sources from waste water influenced measurable variation in electricity generation in terms of voltage. Reports on microbial consortia present in cow dung as well as waste water revealed significant variation in terms of quantity and quality (type of bacteria) depending upon age and source of sewage. Gram staining study in Cow dung slurry revealed presence of both gram-negative bacillus and gram-positive cocci and in domestic waste water supported Streptococci sp, E.coli and gram positive cocci (Figs.7 & 8). Previous studies on microbial consortia of cow dung [21, 16, 29-32] and untreated municipal waste [33, 34,42], are in conformity with presently reported microbial communities. It is already reported that each group of bacteria has its own metabolic potential which would result in variation in hydrogen ion production during oxidation of organic substrate; electrons generated by the oxidation of the organic matter at anode are transferred to an external terminal electron acceptor at the cathode [39; 43]. Few microbes would be of more efficient in releasing more protons during their metabolic activities. It was reported [44] that electricity production by the bacteria Brevibacillus .sp. PTH1 was high when it was co-cultured with another bacterium Pseudomonas sp. or on adding supernatant from a MFC run with the Pseudomonas sp. Therefore, it is clear that bacterial groups present in cow dung and waste water synergistically oxidised the organics in anode and speeded up voltage generation MFC2.

Considering observations 3 & 4, it is understood that in the beginning of operation, the organics in the substrate was plenty and hence there was higher level of metabolic activities by different type of bacterial groups available in domestic waste water in the anolyte of MFC2. Consequently release of more hydrogen ions taken place at a faster rate facilitating shoot up in voltage in MFC-II within six days; whereas MFC-I took thirteen days to reach maximum voltage due to lesser varieties of bacterial communities. However, there was no significant variation in maximum generated voltage (MFC-I -1.23V and MFC-II -1.203V). On the contrary, there was a steep decline in voltage in MFC-II from 20^{th} onwards recoding 0253V on twenty fifth day. But in MFC-I, there was a steady increase in voltage unlike in MFC-II and showed 0.845V at the end of cycle. The earlier decline in voltage generation in MFC-II might be due to exhaust of nutrients/organics in anolyte. Based on (Figure 5 & Figure 6), there was a deep trough in polarisation curve at the mass loss region indicating the polarisation was due to mass loss taken place in the middle of the cycle. Such mass loss might be due to short of nutrients in the anolyte resulted due to higher rate of consumption by different types of bacteria in MFC-II. Such limitation in nutrient availability mediated a steep drop in generated voltage in MFC-II earlier than in MFC-I. Similar explanation were also given that reduction in columbic efficiencies was due to utilisation of nutrients by non-electrogenic microorganisms and electrogenic microorganisms present in the anolyte. However, a detailed study on screening, isolation and identification of bacterial strains and assessment of their metabolic potential, are very much required. The higher efficiency of bacterial species can be capitalised to harness sustainable green energy from cow dung with domestic waste water using MFCs.

One of the most important observations made in the experiment is that the suitability of anolyte and catholyte viz. cow dung and potassium permanganate. During thirty days cycle, no electrolytes were recharged at any stage of the cycle. This implies the suitability and sustainability of the electrolytes used both quality and concentration. In terms of cost, cow dung is the principal bio-waste of Dairy farms. Therefore, from the present study it is demonstrated that in MFCs where Cow dung slurry is used as substrate, addition of exogenous bacterial source would speed up and enhance electricity generation.

RESULTS

The designed and operated MFC-I (bioreactors) fed with cow dung slurry at (1:5 ratio) generate a maximum voltage of 1.21V over an external resistance of 100 Ω and MFC-II with cow dung slurry added with exogenous bacterial source also generate 1.2 V during a period of thirty days. MFC-I generated a maximum voltage of 1.21V on fifteenth day and 1.22 V on seventh day in a thirty days cycle.

Secondly, the reactor MFC-I exhibits a sustained voltage of 1.0V and above for Thirteen days continuously from Seventh to Twenty first day in the cycle. MFC-II recorded above 1.0V for seven days from 13^{th} day to 20^{th} day. Thirdly, voltage generation in MFC-II with cow dung seeded with municipal waste water sludge starts to decline from$20^{th\ day}$ onwards and dropped down to 0.217V at the end of the 30 days cycle. But MFC-I generates a sustained voltage of0.814V at the end of the 30 days cycle. The trend of voltage generation by MFC-I and MFC-II in a 30 days cycle were depicted in Figure 2. The nature of current and power were represented in Figure 3 and Figure 4. The maximum current density shown by MFC-I was $1.59A/m^2$ and power density $1920.08mW/m^2$; MFC-II produced a maximum current density of $1.67A/m^2$ and power density of $2128.98wmW/m^2$ Figure 5 and Figure 6. The Screening process of cow dung has revealed the presence of bacterial community of both gram-negative bacilli and gram-positive cocci. Also the existence of Streptococci, E.coli and gram positive cocci have been found in municipal waste water Figure 7 and Figure 8.

Figure 1. Two-chambered Microbial fuel cell set up

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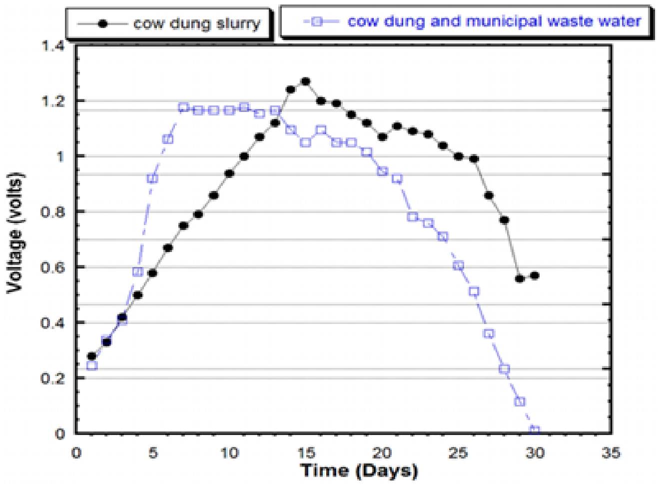

Figure 2. Variation in generated voltage during thirty days cycle

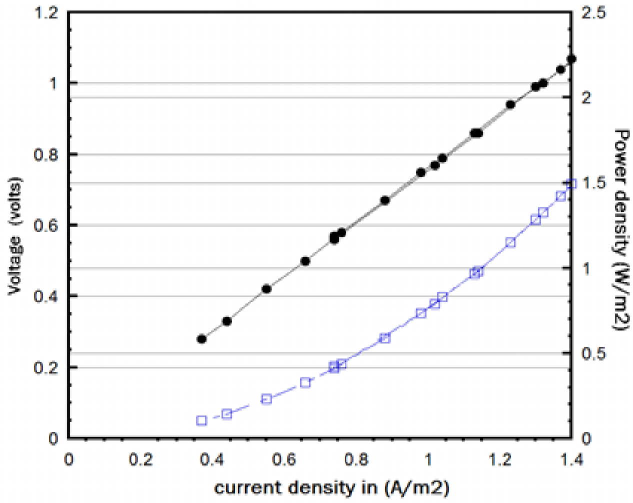

Figure 5. Power density, current density against generated voltage in MFC **using cow dung as substrate**

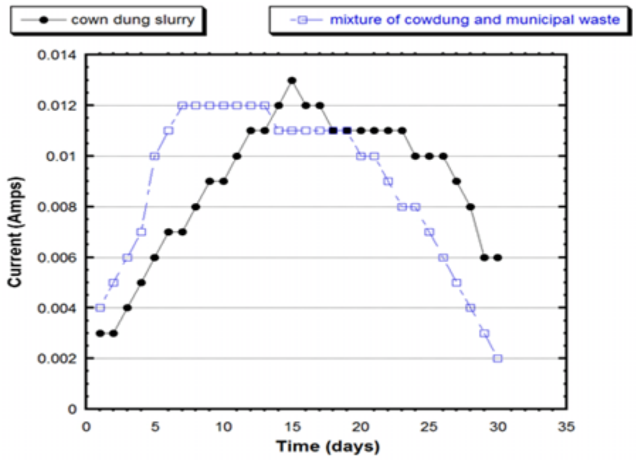

Figure 3. Variation in current in thirty days cycle

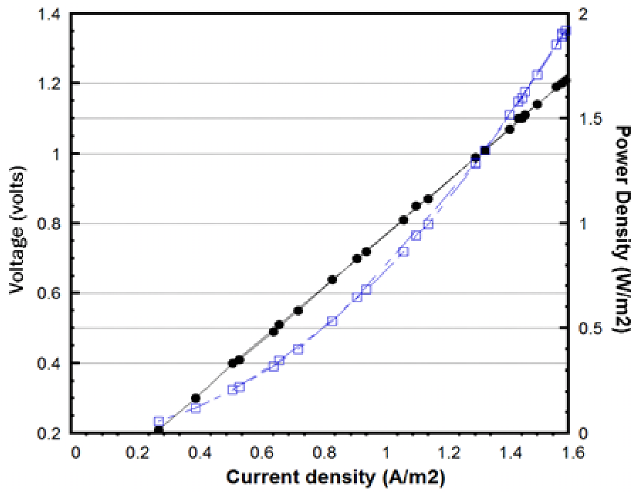

Figure 6. Power density, current density against generated voltage in MFC using cow dung seeded with municipal waste water) as substrate

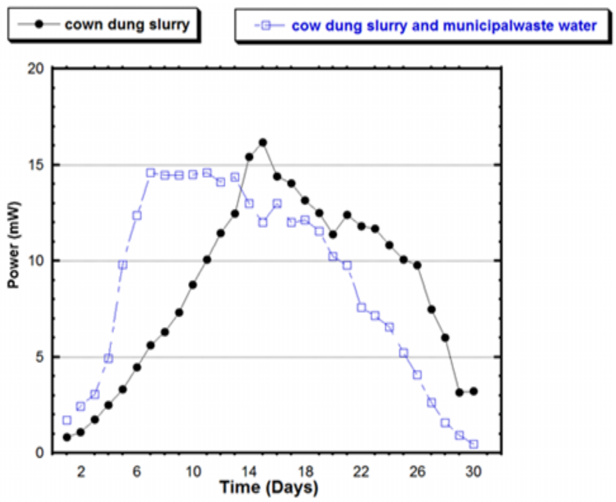

Figure 4. Variation in Power during thirty days cycle

Figure 7. Bacterial colonies in cow dung slurry used in anolyte

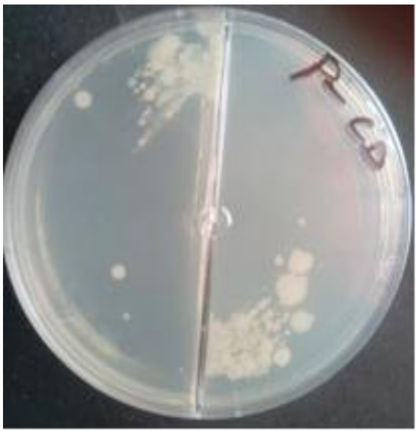

Figure 8. Bacterial colonies in domestic waste water mixed in cow dung

CONCLUSION

Based on the observations made in this investigation it can be concluded that the cow dung can be used as substrate in MFCs for the purpose of electric power generation. Moreover, it is available anywhere and may not release any harmful gases. More importantly, the electric power generation from renewable resources never releases carbon dioxide which is the expectation of power engineers in the arena of global warming and climatic changes. It is suggested that this scheme can be used to harness the moderate power in order to meet the power requirements in dairy farms, houses in the remote hilly areas.

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