Bioelectricity Generation by Using Mixed Sample of Organic Waste and Soil in Microbial Fuel Cell

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Abstract

The microbial fuel cell (MFC) refers to a cell that generates electric power by using the electrons generated when microorganisms decompose the organic matter. This study used organic waste (cow dung, chicken droppings, leaf mold) and soil to prepare a microbial fuel cell, as a solid waste management option and measure the voltage. An one-chamber MFC was used for bioelectricity generation in laboratory experiments using cow dung, chicken droppings, leaf mold, and it filled flower soil and recorded the voltage by a data-logger every day across 100 ohm resistor at constant room temperature of 25^0C for around one week. The results in the experiments have shown relationship among the substrates and the performance of voltage output in the MFC. The maximum value of the voltage are 105.3 mV, 44.4 mV and 109.8 mV obtained by using a mixed sample of chicken droppings, cow dung, leaf mold and some amount of soil, respectively. For the single samples showed the maximum value of the voltage are 138.8 mV, 89.8 mV, 62.8 mV and 45.4 mV obtained by sample of chicken droppings, leaf mold, cow dung and the soil, respectively. Study showed The MFC by using mixed sample of organic waste and soil has emerged as an efficient and eco-friendly solution for organic waste management, provide green and safe electricity.

Keywords : eco-friendly solution, microorganism, microbial fuel cell, organic waste, sustainable bioenergy, waste management

1. Introduction

Energy problems and resolving

Electricity is the essential important thing for all aspects of human life, but the current supply is still not able to meet the increasing of electricity demand in almost all parts of the world. According Rakesh et al, 2014 in recent decades, world energy consumption has a progressive trend. At present, this energy requirement is satisfied mostly by fossil fuels. Depletion of conventional energy sources and also its negative effect on environment has led many researchers to look for alternative energy sources. The new sources of energy should be renewable and also environmental-friendly. Resource recovery from waste material is an important topic in both developed countries and developing countries. A major portion of the total solid waste in developing countries is organic waste, and it is not properly treated for resource recovery (Moqsud, 2003; Sujauddin and Hoque, 2008; Zurbrugg et al., 2005). The future of energy sustainability and supply is likely to rely on renewable energy sources. The production of electricity or biofuels using innovative technologies and renewable sources is a global priority in terms of energy strategies (Resch et al., 2008).

One of the renewable energy sources for the production of electricity is fuel cells (FC) (Mostafa et al, 2011). Microbial fuel cells (MFCs) are bio-electrochemical transducers that convert microbial reducing power (generated by the metabolism of organic substrates) into electrical energy (Allen and Bennetto, 1993; Bennetto, 1984; Habermann and Pommer, 1991; Logan and Regan, 2006; Hong et al., 2009). They use the available substrates from renewable sources and convert them into harmless by-products with simultaneous production of electricity. Many other forms of waste biomass exist, each containing large amounts of energy and can be a better source of power generation in MFCs. These remain generally unexploited and yet to be tested in MFCs for microbial degradation and ultimately bioelectricity generation. From the characteristic analysis of the solid waste of many developing countries it is found that the major portion (more than 80%) of the total solid waste comprises of organic waste, which does not usually get much attention for recycling or resource recovery (Moqsud et al., 2008). The annual organic waste generated from the food industries and kitchen waste in Japan is about 20 million tons per year (Koike et al., 2009). Most of this waste is directly incinerated with other combustible waste, and the residual ash is disposed of in landfills. However, incineration of this water-containing waste is energy-consuming. MFC in hybrid composting method by reusing kitchen waste as a raw material has also been proposed (Moqsud and Omine, 2010).

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There has already been some research of microbial fuel cells (MFCs) to generate electricity from organic wastes or wastewaters (Daniel et al.,2009; Khalid et al., 2011; Jiang et al., 2010; Logan, 2007; Luste and Loustarinen, 2011; Li et al. 2013; Zang et al., 2013; Spiegel and Preston, 2003) and from cheap biomass sources, such as raw corn stover (Wang et al., 2009), rice (Hassan et al., 2014) and wheat (Zhang et al., 2009) straw hydrolysate, and algae powders (Velasquez-Orta et al., 2009).

Reduce environmental impact of livestock waste

A characteristic of livestock waste is that it entails unique problems other than water pollution such as stink and noise. The livestock waste surrounding the world especially in Japan has expanded rapidly over the last few decades. Based on data from Ministry of Agriculture, Forestry and Fisheris Japan (MAFF, 2010), from 1973 to 1990, the number of cases of trouble decreased to one-third, or around 2,000 cases, and the number of cases has remained essentially stable since then. The composition of the problems that occurred in 2010 shows in Table 1 .

Table 1. Environmental Problems due to Livestock Farming in Japan (2010)

	Stink	Water pollution	Pest	Others	Total
Dairy cattle	390	199	24	151	685
Beef cattle	220	114	22	70	394
Hog	466	246	8	50	663
Poultry	254	44	87	33	399
Others	27	11	4	7	44
Total	1,357	614	145	311	2,185
Percentage	62.1%	28.1%	6.6%	14.2%	100.0%

Source: MAFF, Department of Production (2010).

Notes: 1) The number of problems indicates the number of local residents' complaints on environmental problems to local government in the given year.

2) The percentage is the rate of livestock farmers in trouble out of the total number of livestock farmers

3) 'Others' includes noise and inflow of animal waste.

While the total number of animals has increased, a vast amount of animal wastes is being produced, it has become a serious problem of organic waste, it should be utilized and recycled as a valuable resource. According to related statistics, the amount of livestock waste produced in Japan in 2010 reached 86.95 million tons, of which that from cattle occupied 58.9% and and 10% of it was abandoned in the environment without any treatment (MAFF, 2011). The wastes should be utilized, reuse and recycled as a valuable resource. These organic wastes contain large amounts of nutrients and various other minerals. Advancements in environmentally friendly technologies have expanded the variety of organic wastes and renewable biomass types that could act as potential substrates for the production of electrical energy or other high-value added products (Cristiani et al., 2013).

Objectives of study

The objective of this study is to explore some mixed samples of organic waste and soil as a low cost potential substrate for bioelectricity generation so that this organic waste can be recycled and provide some sort of solution to populations experiencing electricity shortage. It is an efficient and eco-friendly solution for organic waste management, provide green and safe electricity.

2. Materials and methods

2.1 Experimental materials and laboratory instruments.

To conduct the experiment, some materials were prepared, such as carbon felt, mulch, cow dung, chicken droppings, breaker, data logger, resistor, cable, some alligator clips and some equipment test used in loss on ignition test.

Cow dung was collected from the Department of Agriculture, Yamaguchi University at Yoshida campus, Japan. Some chicken dropping was collected from Japan Agricultural Office, Ube city Branch. However, if cow dung, chicken dropping and leaf mold is recycled properly then it could be a good source of compost, as well as soil conditioner after obtaining bioelectricity.

2.2 Design of MFC

Figure 1 below illustrates the experiment structure of MFC acrylic rectangular chamber. A rectangular (10x10x15 cm) acrylic container was used in the laboratory as a cell. Then 20 g and 40 g respectively of organic waste were mixed with 400 g of soil and 100 g of water and 3 g of effective microorganisms were blended properly by a blender. The blended sample was filled in the container. Carbon feld was used for both the anode and cathode. The anode was inserted into the sample and the cathode was placed on the top. The area of the electrode (carbon feld) was kept same with the cell areas (100 cm^2). Both the anode and cathode were connected with a data logger (Graphtec midi Logger GL 200) which was set to measure the voltage at 20 min intervals. The laboratory test was conducted in a constant room temperature of 26^0 C.

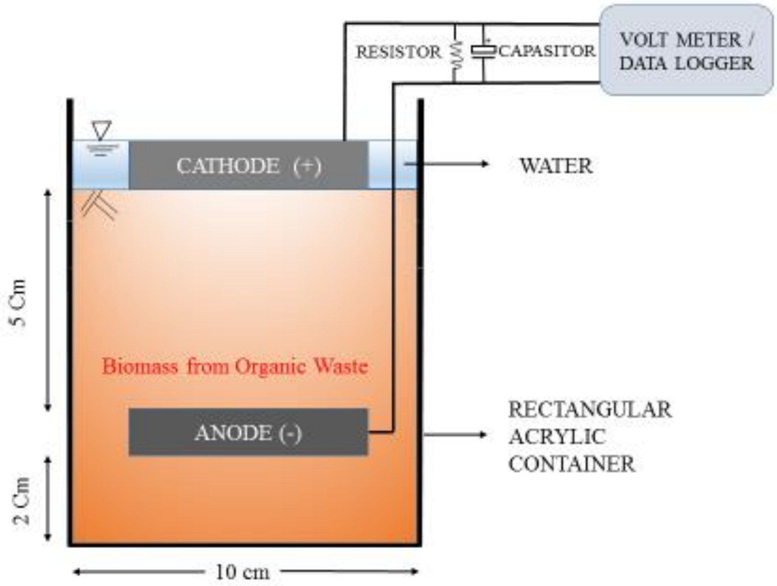

Figure 1. The experiment structure of the microbial fuel cell

Length of the anode and the cathode was set about 5 cm. In the microbial fuel cell, water plays a role of separator. The value of resistance were used of 100Ω. Experiments conducted with a single sample and in mixed samples.

2.3 Experiments in a single sample

In this experiment we compared the three samples in 20g and 40g of cow dung, chicken droppings and leaf mold are mixed with soil fill in each sample.

2.4 Loss on ignition test of the samples

The content of organic matter is I thought to be involved heavily on the amount of power generation for power generation of this microbial fuel cell. Since microorganisms reason that emits electrons when decomposing organic matter, and because he considered that organic substances can be obtained a high voltage the more.
It was subjected to ignition loss test to examine the organic content of the four samples used this time.

Table 2. Result of the loss on ignition test

SAMPLE NAME	Loss on Ignition (LOI)
Soil	20.33%
Cow dung	87.24%
Chicken dropping	82.55%
Leaf mold	80.33%

Table 2 is the test results of this four samples. Sample that contains the most organic matter of 87.24% is cow dung. Those values that contains the most low organic matter of 20.33% is the soil.

3. Results and Discussion

3.1 Experimental results of a single sample

Sample obtained the highest values as seen in Figure 2 illustrates the variation of voltage with duration of time by using some samples are 138.8 mV, 89.8 mV, 62.8 mV and 45.4 mV obtained by sample of chicken droppings, leaf mold, cow dung and the soil, respectively. In the case of chicken dropping show as the highest voltage. Sample obtained the second highest value was microbial fuel cell using the leaf mold. Then the lowest value was a microbial fuel cell of the mulch only. In the case of chicken droppings, the voltage (*V*) increased sharply during the initial time (3 days); after that, it decreased gradually after that. During the initial stage, the bacteria got ample food and their activities increased very rapidly (Moqsud et al., 2011). For that reason, the voltage increased sharply. The voltage decreased gradually with time as the supply of food was used up by the bacteria (Moqsud et al, 2014).

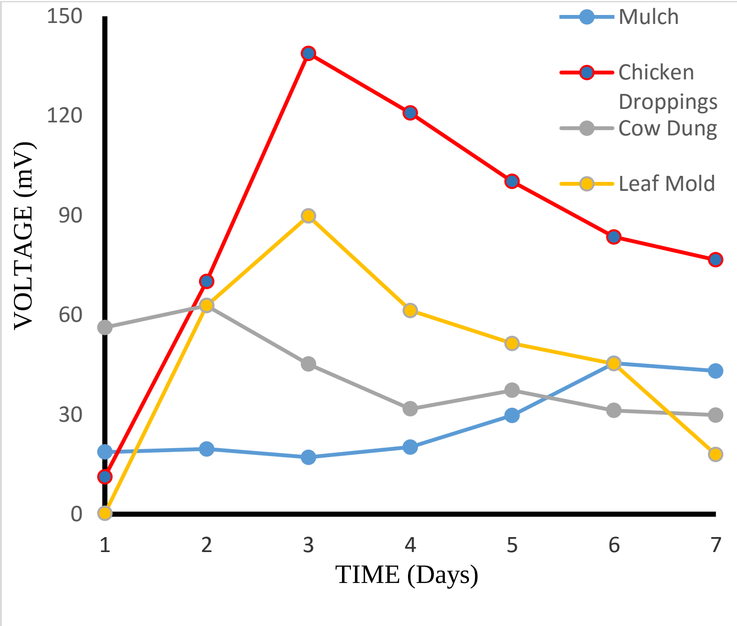

Figure 2. Variation of voltage with time obtained by single sample

3.2 Experimental results in the mixed sample.

Some result of using the mixed sample is illustrated in Figure 3. It shows a difference of initial value of the power generation as compared to the graph of a single sample. Maximum value of the voltage obtained by using a mixed sample of chicken droppings and the soil was 105.3mV. Maximum value of the voltage obtained by using a mixed sample of cow dung and soil was 44.4mV. Maximum value of the voltage obtained by using a mixed sample of leaf mold and soil are 109.8mV. It is the highest among the three mixed samples. The possible reason why leaf mold and soil showed a higher value of voltage than the other samples is that leaf mold as a form of compost, were rich in nutrients and organic matter which support the growth of microorganisms (Jati SH, 2001; Hamzah, 1983)

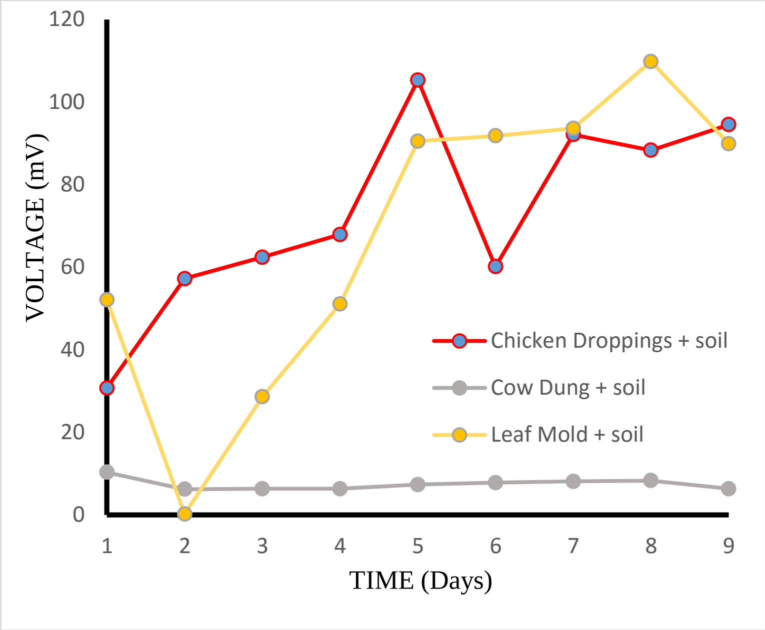

Figure 3 Variation of voltage with time obtained by mixed sample

3.3. Polarization curve for MFCs

The polarization curve of the MFC by using mixed sample of leaf mold and soil and also chicken droppings and soil in this experiment illustrated in Figure 4. A polarization curve is used to characterize current as a function of voltage. The polarization curve shows how well the MFC maintains voltage as a function of the current production. This polarization curve in Figure 4 was created at day of 5th and 8th after starting the experiment from each sample respectively. The polarization curve for all samples displayed similar trends. The trend of the polarization curve was very much similar with the polarization curve which was stated in other literature concerning MFCs (Logan and Regan, 2006; Moqsud et al., 2014; Moqsud et al., 2013). Figure 4 shows the maximum power density of around 0.07988 W/m^2 for sample of leaf mold and soil and around 0.07176 W/m^2 for sample of chicken droppings and soil. The power densities showed an incremental trend with decreasing external resistance and reaches to peak value. After that, the power densities began to fall with increasing current density, which indicated typical fuel cell behaviour. (M.A. Moqsud et al, 2015)

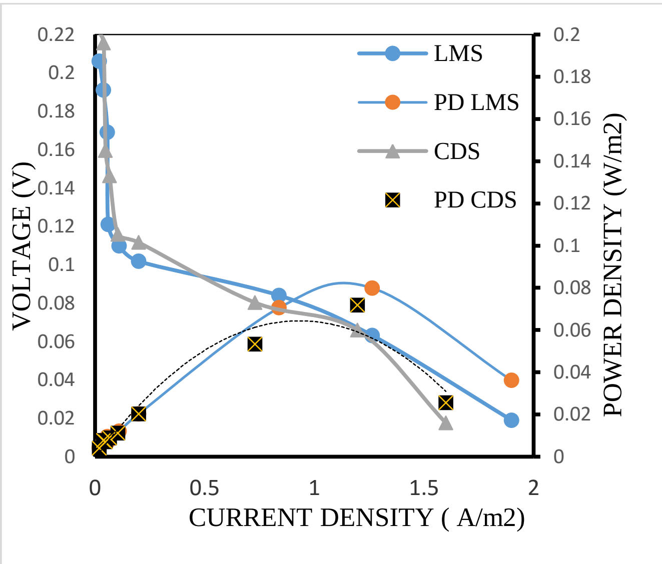

Figure 4. Polarization curve of the MFC at the 5^{th} and 8^{th} day after the experiment started

3.4. Relationship between voltage and current in the MFCs

Figure 5 shows the relationship between voltage and current in the MFCs for 5^{th} and 8^{th} day of elapsed time. It is found that the relationship was almost linear. The intercept and inclination of the line represents electromotive force and internal resistance for the MFCs, respectively. It represents that MFC with a good performance indicates high electromotive force and low internal resistance. The electromotive force of MFC was approximately 0.206 V and 0.201 V. The internal resistance of MFC was relatively low. On the other hand, the performance of MFC with chicken droppings and soil is lower than MFC with leafmold and soil. Maximum electric power is calculated from the linear relationship between voltage and current. The maximum power per anode area is 0.07988 W/m^2 for MFC of leaf mold and soil and 0.07176 W/m^2 for MFC of chicken droppings and soil.

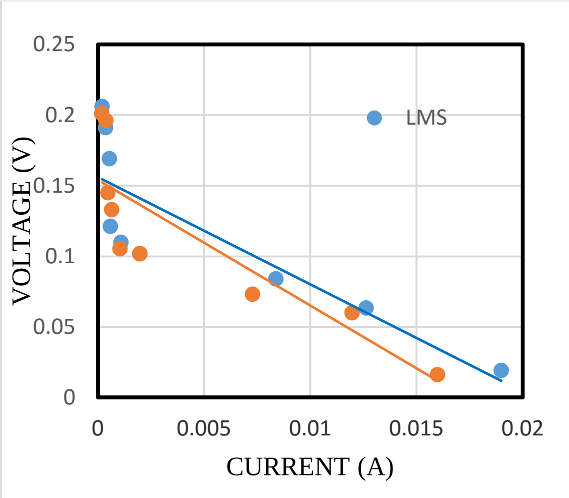

Fig. 4 Relationship between voltage and current in the MFCs

4. CONCLUSIONS

In this study, it was observed that some of the planet's tiniest inhabitants might help address two of society's biggest environmental challenges: how to deal with the vast quantities of organic waste produced and where to find clean, renewable energy. MFCs using soil and organic wastes in this experiment, have proved to be a good way to get green electricity generation and to recycle organic waste in order to maintain healthy and pollution free environments, particularly in developing countries where solid waste management is a great concern.

The results towards the microbial fuel cell of a single sample has been obtained a higher value than the power generation amount of the microbial fuel cell using the mixed sample. A small amount of electricity is also necessary for electricity-scarce populations (25% of the world's population are deprived of electricity). Small amounts of electricity can be used for lighting light-emitting diode lamps or just to charge a mobile phone in a particular household using their own waste. Though the amount of electricity is still small enough in this MFCs work, it is still very much needed for the future green energy era, as it is an abundant source of biomass in many developing countries, furthermore this relative importance since the organic wastes in this case is actually a wastes that must be disposed of at a non negligible cost. Increasing the portion of biomass in the energy matrix will help to diminish the negative environmental impact of atmospheric CO_2 accumulation and to meet the targets predicted in the Kyoto protocol. So, by using organic waste, we can address some important problems currently faced by the world, it is the health and pollution of geo-environment problems due to unmanaged organic waste, as this organic waste would be used as raw material to generate electricity (people will reuse it carefully and the urgent need to reuse organic wastes is very much an important concern for the sustainable geo-environment in surrounding the world. Finally, it is clear that bioelectricity can be produced by organic wastes, which could provide some sort of 'light of hope' to the 1.6 billion people who still live in the dark at night all over the world.

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