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Microbial Fuel Cell with Garbage Treatment

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This study intends to develop a new application of MFC (Microbial Fuel Cells) to microbial garbage treatment; i.e. to perform decomposition of organic compounds in garbage and generation of electricity simultaneously. At first, the condition of electricity generation using a model substrate was established, and then the optimum condition for the two purposes stated above was clarified. For instance, active carbon is indispensable as a catalyst for the positive electrode. Since the amount of electricity generated by this system is very small, another suitable use of this system was pursued. One possible application was suggested: use as a diagnostic sensor for garbage treatment systems. Electricity generation occurs only when the system becomes anaerobic, which is bad for decomposition. No electricity was detected when decomposition of garbage was achieved in good, aerobic conditions.

1. Introduction

In our laboratory, microbial garbage treatment has been studied for a long time. One valuable result has been the development of static-type small scale garbage treatment systems [1]. On the other hand, the concept of MFC is relatively new and the main target application field is wastewater treatment [2, 3, 4]. This study intends to attempt the combination of the two concepts; i.e. A MFC was installed in a static-type garbage treatment system to establish the conditions for simultaneous continuous microbial decomposition of garbage and the generation of electricity. Also, the optimum conditions for both individually were pursued. In addition, this study tried to search for a new application of MFC other than as an electricity source, since the amount of electricity generated was generally very small compared with other sources of electricity [5, 6, 7, 8, 9,10]. One possible application was to use MFC as a diagnostic sensor in the garbage treatment system. The performance of garbage treatment becomes depressed if the input of substrates to the garbage decomposition process is too heavy. In such a situation, the inside of the reactor tends to become anaerobic and acidic, which leads to various practical issues such as a decrease in the rate of decomposition and the generation of bad smells. This is why a sensitive diagnostic sensor of the garbage treatment system would be useful, and MFC might be a possible candidate. Since microbial garbage treatment as well as MFC is a complicated system in which physical, chemical, and biological factors are mutually affected simultaneously, it is necessary to figure out the best operational conditions using a physical-chemical approach and an analysis of the microbial community in the reactor.

2. Material and Method

2.1 Operation of the microbial garbage treatment

A semi-batch type of microbial garbage treatment was used in this study, in which 10 liters (about 1.5 kg) of leaf mold were set as a microbial bed, and dog food (moisture content 70 percent) was fed every day as model garbage. The mixture was agitated by hand once a day at the feeding in order to maintain a well-mixed and aerobic condition in the reactor, and no other mixing operation was employed (i.e. "static type"). The operating parameters (pH, moisture contents, the amount of decomposition and temperature in the reactor) were measured every day.

2.2 Design of MFC and measuring method

Leaf molds and residues of microbial garbage treatment (100 to 200 g) were connected to the MFC (11×12×10 cm). Two carbon felts (11×11 cm) were used as both anode and cathode, and activated carbon as the cathode catalyst. The MFC design used is shown in Fig. 1. The electricity generation in this MFC was measured every 10 minutes using a data logger.

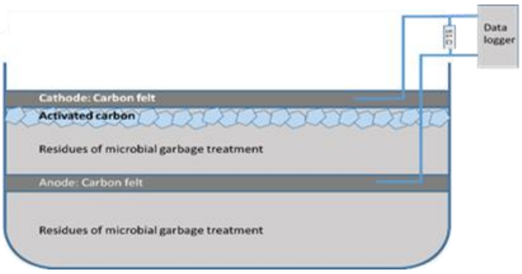

Fig. 1. Design of MFC

Table I. Setup condition

No.	Leaf mold	Accelerator of decomposition	Activated carbon	Garbage
1	+	+	+	+
2	+	+	−	+
3	+	−	+	+
4	+	−	−	+
5	+	+	+	−

3. Result & Discussion

3.1 Operating Conditions

The experiment was performed using the five different conditions shown in Table 1. The constituents of the MFC were leaf mold, activated carbon, the accelerator of decomposition and the substrate. Generation of electricity was observed in all devices for 8 days except for Device 5, in which only a very small amount of electricity was measured just after starting, meaning that the garbage (substrate) was indispensable for electricity generation. Device 1 showed the best result, a maximum current density of 81 mA/m^2, and Device 3 was second best, generating 11.8 mA/m^2 after 70 hours after measurement began (Fig. 2). The difference between the two was the presence of an accelerator for substrate decomposition. Additionally, the decomposition amounts of the substrate in devices 1 to 5 were 39.5 g, 22.5 g、29.0 g, 23.7 g and 13.7 g, respectively (Fig. 3).

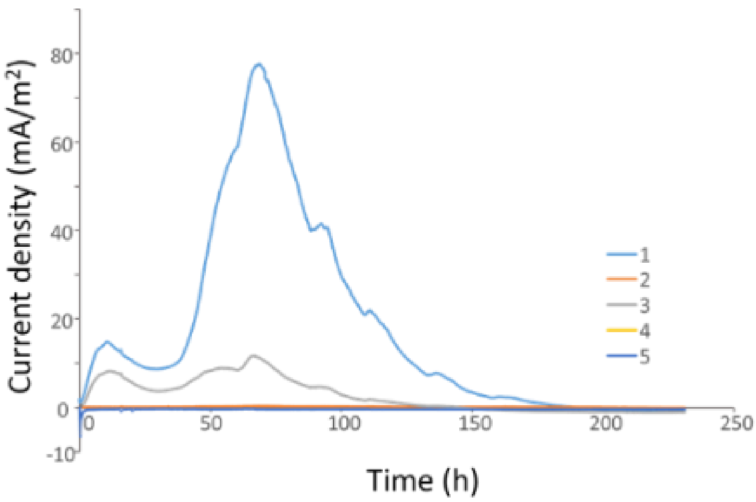

Fig. 2. Time course of electricity generation in MFC

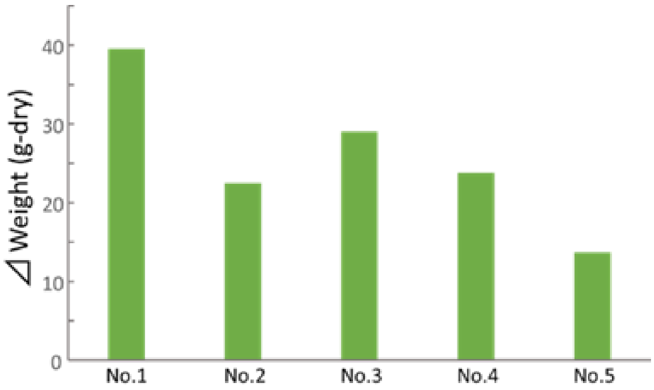

Fig. 3. The amount of substrate decomposition.

From the results of Figs. 2 and 3, it was suggested that garbage (substrate) was essential for electricity generation, however the amount of garbage decomposition was not always proportional to power generation, meaning that there might be both effective and noneffective decompositions of substrate for electricity generation.

Since electricity was detected in the case of Devices 2 and 4, active carbon did not appear to be an essential component, but the amount of electricity generated was very small in both cases, whereas in the case of Devices 1 and 3, in which active carbon was used, a significant improvement in performance was observed, suggesting that active carbon played an important role in electricity generation. A possible hypothesis is that activated carbon serves as a catalyst for the proton-oxygen reaction on the surface of the cathode. And also, the addition of an accelerator for substrate decomposition resulted in the best performance, indicating that all necessary factors functioned cooperatively to facilitate electricity generation.

3.2 MFC as a Diagnostic Sensor for Garbage Treatment System

In this study, a new application of MFC was investigated and attempted: use as a diagnostic sensor for garbage treatment. In order to clarify the relation between the conditions of the garbage treatment process and the performance of electricity generation, the decomposition process was researched first. In the case of organic loading at 40 g/L/day, the decomposition proceeded smoothly for 15 days. On the other hand, the decomposition rate decreased when organic loading increased to 150 g/L/day after day 9 as shown in Fig. 4.

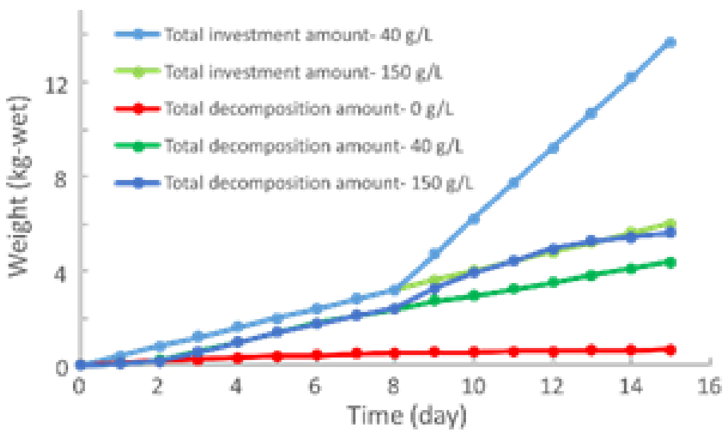

Fig. 4. Time course of the amount of decomposition

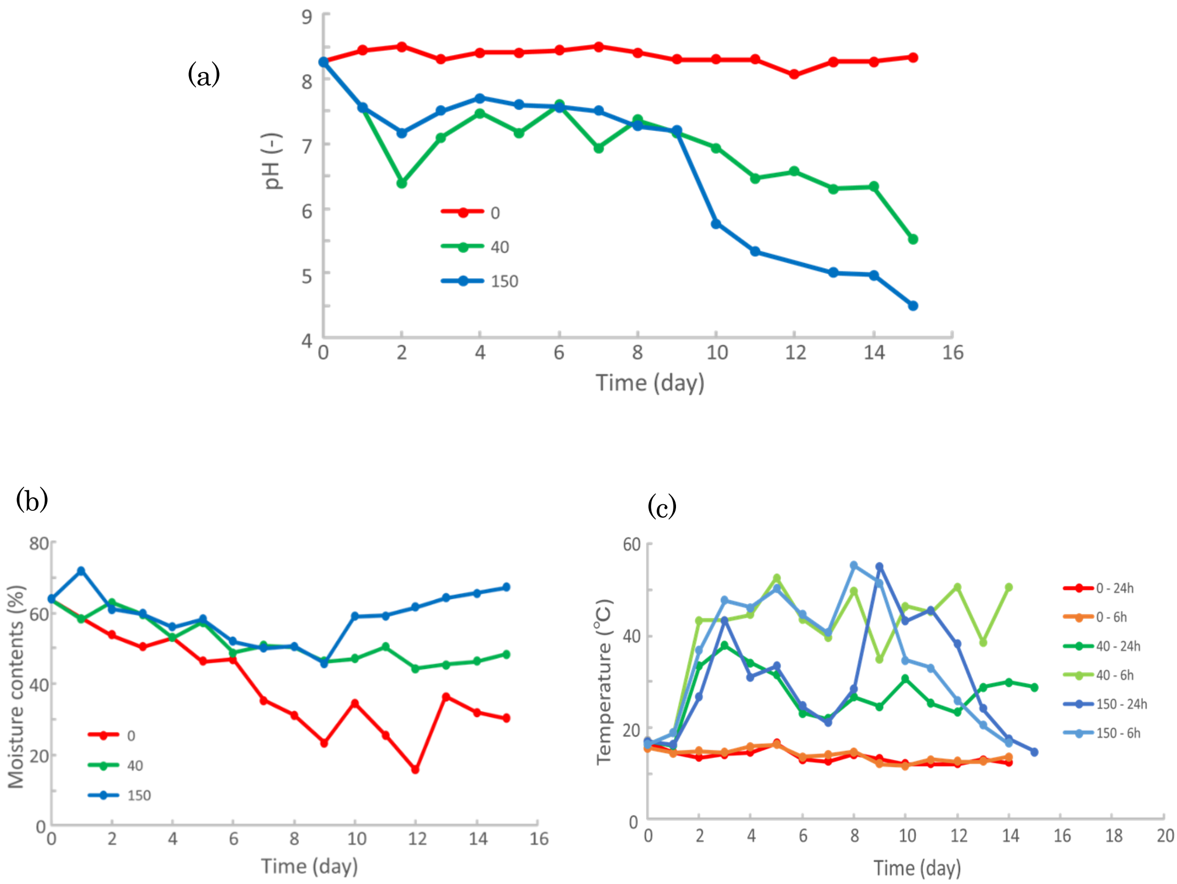

Fig. 5. Time course of garbage treatment system (a) pH, (b) Moisture contents, (c) temperature

It should be noted that the difference between the change in pH varied according to the organic loading as shown in Fig. 5 (a): when loading 150 g/L/day after day 9, the pH value decreased rapidly, lower than pH 4.5, which was too acidic for normal garbage decomposition. The moisture content was remained almost constant around 50 % after day 4 when loading 40 g/L/day, whereas the moisture content increased sharply after day 9 when loading increased to 150 g/L/day as shown in Fig. 5 (b). The moisture content with no garbage input, the negative control, clearly decreased due to drying.

Generally the temperature 6 hours after input was higher than 24 hours after because heat generation in the garbage decomposition process was activated around 6 hours after input, then stopped. When loading 40 g/L/day, this tendency was always observed, but when loading was increased to the point of overloading (150 g/L/day) after day 9, the opposite phenomenon was observed, meaning that the decomposition rate reduced, as shown in Fig. 5 (c). All these features indicated that the organic loading rate of 150 g/L/day constituted a state of overloading, which negatively affected the decomposition process. The MFC began generating electricity when loading increased to create this overloading state, after day 9. On the other hand, no electricity generation was detected during the period of loading 0 and 40 g/L/day, as shown in Fig. 6. In addition, the electricity generated in the overloading state continued to increase after day 10 when the amount of garbage decomposition decreased, suggested that MFC can be used as a diagnostic sensor for garbage treatment.

All the data shown in Figs. 4 and 5 indicated that an anaerobic condition was created and many

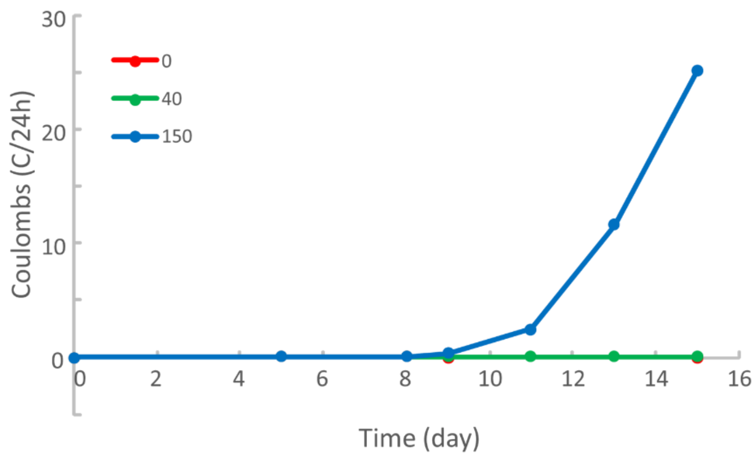

Fig. 6. Coulombs of Electricity generation

kinds of organic acids were produced in the reactor when the organic loading was increased to 150 g/L/day after day 9, and the rate of garbage decomposition decreased drastically. The change in temperature also supported this speculation. The fact that electricity generation occurred only when conditions were bad for the garbage decomposition implies the possibility of using a MFC as a sensor.

3.3 Unsolved problems

The result of this study might indicate the possibility of MFC as a sensor, but a lot of unsolved problems remain;

1)Mechanism of electricity generation [11]: It has been considered that specific microorganisms contribute to electricity generation. But this was not confirmed in the system used in this study. Further analysis of the microbial ecosystem, using molecular biological methods such as DGGE is necessary [12, 13].

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2) Concrete measures for a performance upgrade in MFC as a sensor: How can the sensitivity of a MFC sensor be improved ? What are the major parameters governing the performance of MFC, e.g. pH, ORP, Organic loading, size and/or position of activated carbon? The optimal conditions should be pursued on the basis of fundamental investigation into the mechanism of electricity generation.

4. Conclusion

・It was confirmed that decomposition of garbage was essential for generation of electricity.
・It was indicated that the amount of electricity generated was increased by using activated carbon and adding an accelerator for the decomposition of garbage.
・It was suggested that MFC could be used as a diagnostic sensor for the interior conditions of microbial garbage treatment systems using the quantity of electric power generation as an indicator.

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