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Chapter

Biolectricity from Organic Solid Waste

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Abstract

Resource recovery and recycling of organic waste is a great challenge in the world. The unmanaged organic waste causes a great damage to the environment and the public health both in the developing countries and industrial parts of the world. In this research, an innovative method was adopted to generate bioelectricity from the organic waste by using the Microbial Fuel Cell (MFC). Various types of organic wastes such as livestock waste, food waste, fruit waste were used as the substrates of the microbial fuel cell. All the experiments were carried out in the same sized one chamber microbial fuel cell and the similar electrode materials. It was observed that all the organic wastes can be used to generate bioelectricity through microbial fuel cell. The generated electricity can be used in several environmental monitoring sensors and can be used as an alternate power source in the developing countries. The by-products of the bioelectricity generation can be used as soil conditioner in the organic depleted soil and agricultural fields.

Keywords: organic waste, bioelectricity, voltage generation, soil conditioner

1. Introduction

1.1 Organic waste state

Organic waste is generated in our everyday life. The amount of organic waste is increasing all over the world. By comparing other types of waste materials such as plastic waste, paper waste or metal waste, organic waste is the least cared waste in the world. The recycling rate of organic waste is not prominent both in developing countries and the developed countries. In Japan, the organic waste is burnt in the incineration plants [1]. However, to burn the organic waste is not good as the calorific value of the organic waste was not so high. The higher content of moisture of the organic waste can reduce the calorific value. The unmanaged organic waste has created several environmental pollutions and health hazards, especially in the developing countries. The traditional method of organic waste management such as composting is often not suitable and caused problems in the urban areas [2]. The landfill of organic waste is again causing a huge burden to the waste collection systems and the transportation and final disposal system in the hot and humid countries. So, to find some innovative method to recycle and resource recovery from organic waste is very crucial in recent time.

1.2 Microbial fuel cell to generate electricity

Microbial fuel cell is a biochemical device in where the bacteria can decompose the organic contents and generate the electricity [2–6]. In the previous research, it was observed that this MFC method can be used to clean the wastewater, bioremediated the sulfide contaminated sediment, and consequently bioelectricity generation [7–9]. The benefit of this method is that it can generate bioelectricity while cleaning the environment. Moqsud et al. showed that MFC can also generate electricity from the organic waste in a compost type MFC [1]. Since then, other researchers are trying to use this novel technology to generate bioelectricity and recycling the organic waste as a resource recovery options from the organic waste. The modified version of MFC with the employment of plants are called the plant microbial fuel cell (PMFC). It was observed that in PMFC, by using the compost from the organic waste, the bioelectricity can be generated more [3].

1.3 World energy status

Due to the population increase in the world, the demand of clean energy is increasing day by day. It needs to find the new source of electricity as most of the fossil fuels are decreasing. The global warming challenge make this problem more critical. To find a new source of green energy is the major challenge in the world in this current state of the world. In this background, microbial fuel cell can be a potential candidate for the future green energy in the world. The accidents of nuclear power plant are devastating in many cases. So, it is also needed to generate bioelectricity from the safe source for the sustainable future generations.

The main objective of this research is that to evaluate the efficiency of the MFC by using the different types of organic wastes. Another objective is to check the feasibility of organic content as a soil conditioner from the by-products of bioelectricity generation.

2. Materials and methods

2.1 What is bioelectricity?

Bioelectricity is the electricity which can be generated from the biological sources and with the help of living materials [2]. Many times, the microorganism such as bacteria are the main working factors to generate electricity while biodegradable the organic waste both in the aerobic and anaerobic bacteria. The electroactive bacteria are most responsible for the electricity generation.

2.2 Organic waste composting

Organic waste poses exceptional challenges during waste collection, particularly in hot and humid climates, where timely collection and disposal are critical. In some cities as much as 79% of municipal waste is organic [4]. Thus, organic waste management needs priority attention. The composting process which is the most common method for organic waste management, involves microorganisms feeding on organic material and consuming oxygen. The composting process generates heat, drives off moisture, and reduces bulky organic waste into a beneficial soil-like material containing nutrients, humus, and microorganisms in just a few months. Material in an unmanaged pile of organic debris will eventually break down but the process will take a long time and may result in odor or other nuisance problems due to poor aeration. Composting efforts may be easier to start if organic waste from food industry entities is used rather than household organic waste, because the quality of the organic inputs can be more closely controlled.

2.3 Biogas generation from organic waste

Many researchers are trying to produce the biogas from different organic waste. The bacteria can decompose the organic waste and consequently generate the bio gas which are mainly methane and the carbon di oxide. The management of organic waste is a critical problem and biogas generation can be a solution of it, however, there are some socio-economic problems associated with the biogas production from the organic waste. The design of biogas plant in the urban area is a very difficult task due to the land requirements. Again, the use of biogas in the kitchen for cooking has not become popular among the users in the developing countries due to the misconception of the bad odour and aesthetic point of view [7, 8].

2.4 Laboratory experiments for microbial fuel cell

One chamber MFC has been used for different types of organic wastes to generate bioelectricity. **Figure 1** illustrates the schematic diagram of the MFC which has been used in the laboratory experiment. Anode was embedded into the biomass while cathode was placed on the surface. The anode was set approximately 5 cm below the surface of the biomass, while the cathode was placed immediately above the biomass surface, but under the water.

The biomass used in the MFC were livestock waste such as cow dung, chicken droppings, rice waste, food waste and fruit waste. The basic properties of moisture content and organic content are listed in **Table 1**. It was noticed that the organic content of the different organic waste is not so much varied among them. It was also observed that the pH value of the initial condition of the different organic waste are within the range of 6.1–7.2 which was relatively suitable for the microorganisms working in the microbial fuel cell.

The design of the MFC was kept constant while changing the substrates inside the MFC as shown in **Figure 1**. The cylindrical shaped MFC chamber is 15 x 10 cm. The cross-section of the cell was 10 x10 cm. The electrode materials which were used in the MFC was carbon fiber, carbon felt for all the cases. The electrode amount was kept constant for all type of organic substances. The effective area of electrodes (anode and cathode) was kept the same as the cell areas (100 cm^2).

The organic wastes such as cow dung was collected from the Department of Agriculture, Yamaguchi University at Yoshida campus, Japan while the chicken droppings, rice bran leaf were collected from Japan Agricultural Office, Ube city branch. The food waste and fruit waste were collected from the student's cafeteria of Yamaguchi University, Japan. In microbial fuel cell (MFC), bacteria used as biocatalyst to convert biodegradable organic substrates harmless by-products with the simultaneous production of electrical energy. The blended sample was poured into the container and placed the electrode and make the MFC. The external circuit was created by using the insulated copper wire connecting with an external resistor.

The voltage which generated across the resistor and capacitor was monitored every day at 1 pm by a multimeter. Polarization curve and power density–current curves were investigated by using different resistors and internal resistances and power densities were calculated as described elsewhere [8, 9]. Electrode output was measured in volts (V) against time. The current I in amperes (A) and power (P) was calculated using Ohm's law.

Statistical analysis was carried out and significant was taken when the p value was less than 0.05.

Experiments were conducted under a constant room temperature of 25^0C [4].

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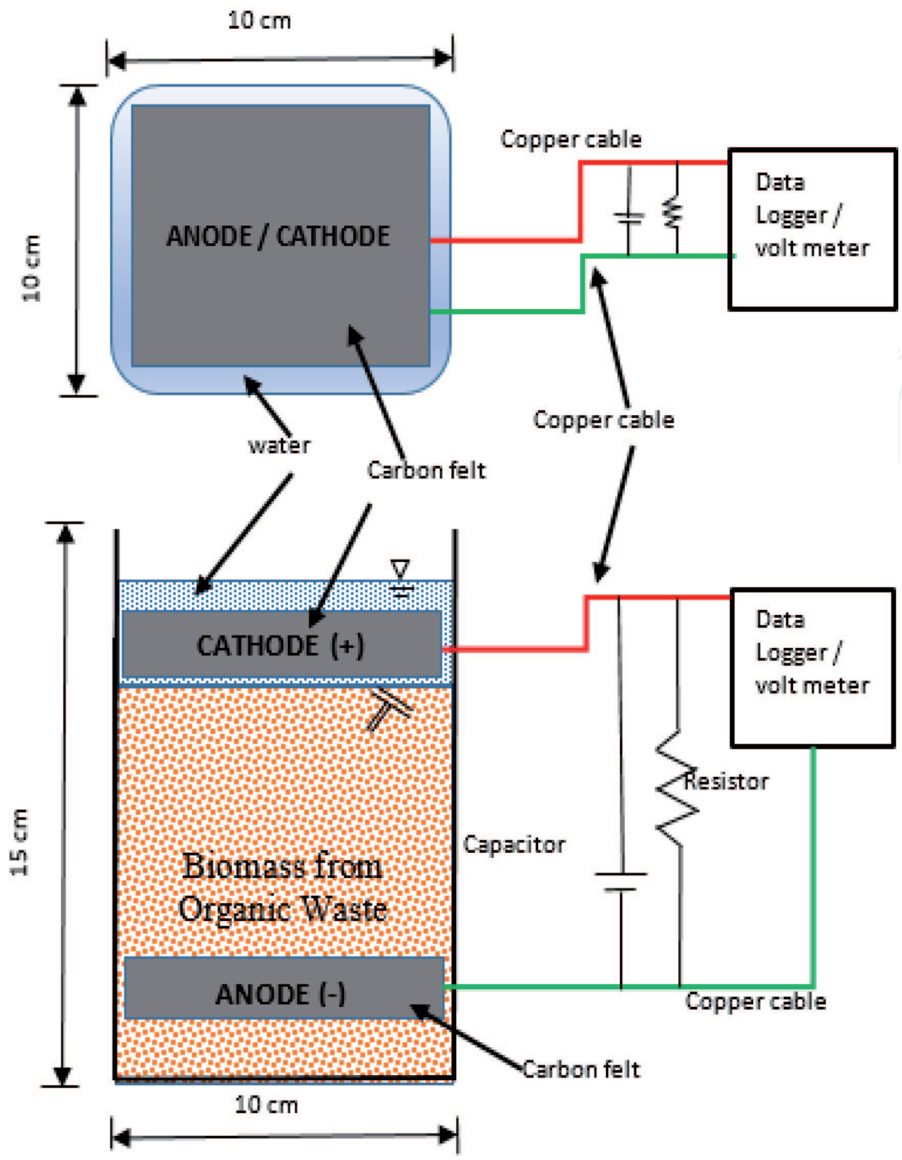

Figure 1.
Schematic diagram of the MFC used in the laboratory.

Sample used in the experiment	Moisture Content (%)	Loss on ignition (%)	pH
Fruit waste	70	80.33	6.9
Cow dung	79	87.24	6.1
Chicken dropping	65	82.55	6.3
Food waste	77	85	6.9
Rice bran	23	80	7.1
Leaf waste	20	87	7.2

Table 1.
Some basic properties of organic waste.

3. Results and discussion

Figure 2 illustrates the variation of voltage generation with time when using the feedstock waste as an organic waste in the MFC. It was found that when the cow dung and chicken dropping were used then the voltage generation was increasing sharply during the initial time. After one week the peak voltage reach at 450 mV and

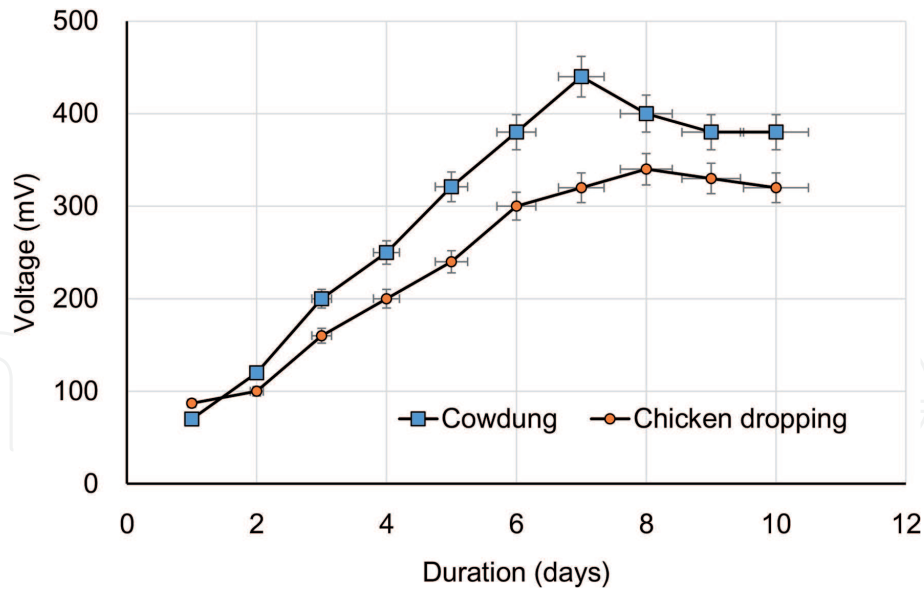

Figure 2.
Variation of voltage generation with duration by using live stock waste.

340 mV for the cow dung and the chicken droppings, respectively. It was also found that the cow dung generated more voltage than the chicken dropping. The organic content of cow dung was higher than the chicken dropping. This could be a reason why the voltage is higher while using the cow dung. Nevertheless, both feedstock waste can be used for the bioelectricity generation in the microbial fuel cell. The management of the feedstock waste was a great challenge for many years all over the world. The biogas generation is one option for recycling this waste however to setup a biogas plant is another big challenge in the urban area and the area where is densely populated. The use of cow dung and the chicken dropping in MFC as a substrate can be a great help for the future resource recovery in the future. The future research will be needed to control the smell from the MFC to make it more practicable for the household applications. The cost is significantly small in this system while comparing the biogas system. The feedstock waste can cause many environmental problems in the developing countries. The mismanagement of this waste is causing various environmental pollution such as water pollution and the soil pollution. In the future, if this feedstock can be used as the organic substance of the MFC system and generate bioelectricity, then it will be a source a resource. Many developing countries need to generate electricity for their development even in small amount.

Figure 3 shows the variation of the voltage with duration while using food waste and the fruit waste in the single chamber microbial fuel cell. It was found that when fruit waste was used then the MFC system can generate more electricity by comparing with the food waste. The fruit waste which were collected from the student's cafeteria contained a lot of fruit sections which were rich in sugar and carbohydrates. This sugar and the carbohydrates are the main source of energy for the electroactive bacteria. On the other hand, the food waste which are mainly comprised of the vegetable leftover and the other food remaining were not rich in sugar content and the carbohydrate content. This reason has influenced the result of the voltage generation while using the food waste and the fruit waste. The peak voltage reach at 380 mV and 300 mV when used as biomass in MFC in the fruit waste and food waste, respectively. While the voltage generation is lower when the food waste was used, it was also generated significant amount of voltage. This result reveals that the food waste which are currently disposed and burnt in the incineration plants in Japan can be recycled to generate bioelectricity in the MFC system.

Figure 4 illustrates that voltage generation with duration while using rice bran and the leaf waste. It was found that the bioelectricity can be generated from the rice bran

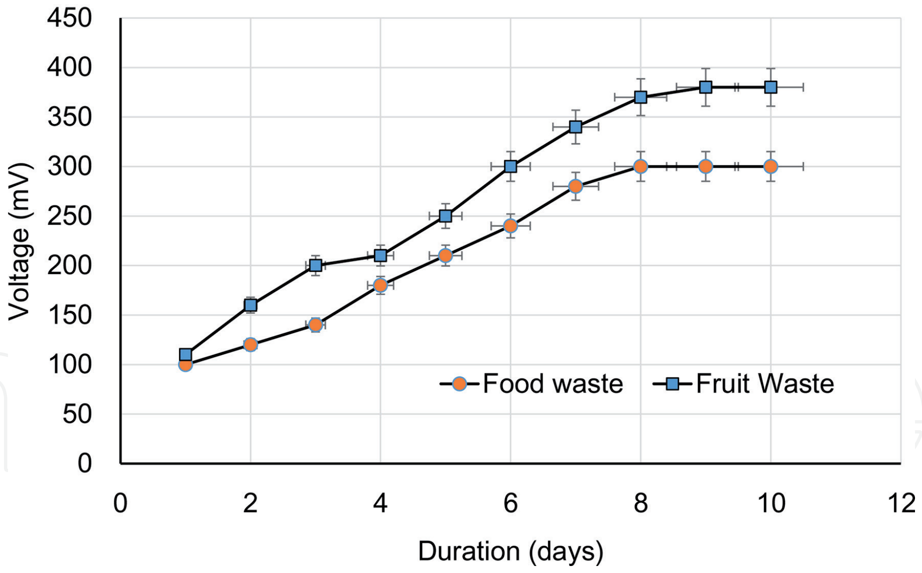

Figure 3.
Variation of voltage generation with duration by using food waste and fruit waste.

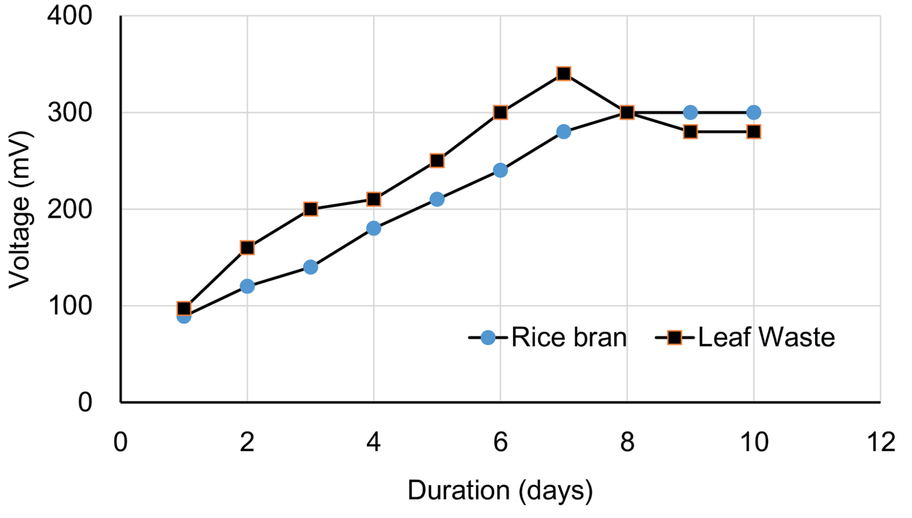

Figure 4.
Variation of voltage generation with duration by using rice bran and leaf waste.

and the leaf waste. The rice bran is produced in most of the time it was not reused or recycled in Japan. So, the use of this is very important for the bioelectricity generation in the MFC system. The garden waste often includes the dead leaves. Many times, this garden waste was not recycled and burnt with the other burnable waste. In this research this leaf can be used as the potential biomass in the MFC system. The carbon nitrogen ratio is very important for the microbial growth and the other activities for the best performance of MFC. However, this study showed that the voltage generation can be well even the garden waste was used in the MFC system. The peak voltage reached at 320 mV and 300 mV when using the rice bran and leaf waste, respectively. The interesting thig is that for the case of rice bran, the voltage generation was becoming constant after 8 days. The probable reason for that, the amount of food is depleted for the bacteria and the further biodegradation was not possible. The voltage generation by using the leaf mold decreased gradually after it reached the peak. The probable reason of this type of trend could be the substrates and the microbial degradation inside the biomass. As all the other factors are constant such as temperature, moisture content and sunlight, so it can be said that the organic content of the substances from the organic waste has the main influence to the voltage generation in this study. Nevertheless, the reason of this trend is, the organic waste from rice production and the garden waste can be used as a biomass in the MFC system for bioelectricity generation. In this research, the additional bacteria or food for the bacteria were not used to make the system uniform and compare it carefully. As a result, the electricity generation is the affected by the organic waste compositions mainly.

There are several types of organic waste all over the world. The management of this organic waste is always a great challenge for the people. So, the researchers are conducting their research to find out the innovative solutions to get rid of this problem. It is true that the MFC system needs to be more studied before it is practically used. The weather factors and the activities of the bacteria will be the major challenge in the future for the sustainable application in the real world. It is necessary to check the various factors which will be affecting in the field application of this system without any delay.

Resource recovery from organic waste is a long time due for the human society. The depletion of fossil fuels, global warming and climate change has increased the demand to find a new way to get rid of energy problems. The waste to energy is a popular term among the researchers all over the world. In these circumstances, the bioelectricity generation form the various organic waste is the very important part of advancement in this field.

One of the objectives of this experiment is to use the by-products from generating bioelectricity with MFCs of kitchen garbage and bamboo waste as soil conditioner or organic fertilizer in the agricultural fields. Hence, it is important to examine the values of different nutrients as presented in **Figure 5** [10]. Decomposition of organic matter is brought about by micro-organisms that use the carbon as a source of energy and nitrogen for building cell structure. From the results of both MFCs, nitrogen (N), phosphorus (P) and potassium (K) in the soil after bioelectricity generation were found to be in the range of 1.5–1.7%, 0.6–0.8% and 1.3–1.7% respectively, which is similar to the value of compost yielded by others [11]. It was observed that the values of nutrients, namely nitrogen, phosphorus, and potassium, were very similar to the soil reported in other countries [11]. As a result, the decomposed sample can be used as potential fertilizer or soil conditioner, offering a resolution to the problem of organic matter depletion in soil across the globe. Solid waste creation is a global dilemma due to development and industrialization. About 1.3 billion metric tons of municipal solid waste (MSW) is generated annually in the world and this quantity is expected to increase about 2.2 billion tons by 2025 [12–17]. The important thing is that the organic waste is all zero cost materials. It must be reused to get some resource for the future sustainable society.

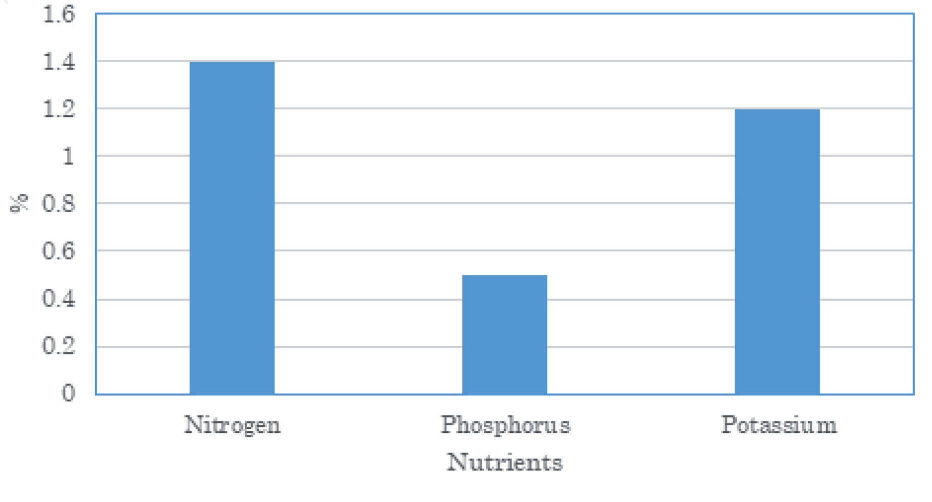

Figure 5.
Nutrient content of the by-products of bioelectricity generation.

4. Conclusion

Organic waste management is very critical in most of the developing countries in hot and humid conditions. It can pollute the environment including the surface water pollution and air pollution. These studies illustrate that the planet's tiniest inhabitants can address two of biggest environmental challenges our society faces today: generating clean renewable energy and handling vast quantities of organic waste. Through these studies, it is proven that MFCs are practical technology for the aforementioned problems. The generated bioelectricity can power devices such as LED lamps, phones, and geo-environmental sensors. Various kinds of organic waste such as livestock waste, kitchen garbage, agricultural waste can be used as a source of biomass for bioelectricity generation through MFC. The nutrient contents of the by-products of the MFC are rich and in a suitable range of a compost. Furthermore, the by-products from the decomposition of organic waste accelerated with the use of MFC can be used as soil conditioner, increasing the soil's organic content, and as a fertilizer to aid plant growth. In fact, there will be no by-product of generating bioelectricity by using the organic waste. The applicability of this study's results extends to both developing and developed countries where solid waste management and or sourcing of energy is a great concern. However, the future challenges for this research including the sustainable supply of organic waste will be a major problem in the industrialized parts of the world. Nevertheless, it can solve the problem of the waste management problems in the developing countries. In the future, the biomass such as algae can be used in the MFCs to generate the bioelectricity. MFCs can contribute to the maintenance of a healthy and pollutants-free environment for the future generation.

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Conflict of interest

The authors declare no conflict of interest.

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