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# Electricity generation from food wastes and characteristics of organic matters in microbial fuel cell

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## HIGHLIGHTS

- The MFC was used for food waste disposal and electricity generation.
- The maximum power density of 5.6 W/m$^3$ was achieved in the MFC.
- Characteristics of the food waste before and after MFC treatment were investigated.
- Biodegradation regularity of the food waste in MFC was discussed.
- The results may assist pre- and post-treatment choices for MFC fed with food waste.

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## ABSTRACT

The microbial fuel cell (MFC) was evaluated as an alternative way to recover electricity from canteen based food waste. Characteristics of the organics in food waste before and after the MFC treatment were analyzed to investigate how the organic matters were biodegraded and transformed during the MFC treatment. A maximum power density of 5.6 W/m$^3$ and an average output voltage of 0.51 V were obtained. During the MFC operation, the hydrophilic and acidic fractions were more readily degraded, compared to the neutral fractions. Additionally, aromatic compounds in the hydrophilic fraction were more preferentially removed than non-aromatic compounds. The MFC could easily remove the tryptophan protein-like substances in all fractions and aromatic proteins in hydrophilic and hydrophobic neutral fractions. Additionally, the hydrophobic amide-1 proteins and aliphatic components were readily hydrolyzed and biodegraded in the MFC. These findings may facilitate the pretreatment and posttreatment choices for MFC system fed with food waste.



## 1. Introduction

Food waste is organic waste comes from various sources including households, restaurants, cafeterias and so forth, accounting for a considerable portion of the municipal solid waste (Uçkun Kiran et al., 2014). It was reported by the Food and Agricultural Organization that one third of the food produced in the world for human consumption (1.3 billion tons per year) is wasted (FAO, 2012). In China, about 60 million tons of food wastes were produced yearly, and the daily food waste generation in Beijing has reached approximately 1.6 thousand tons (Meng et al., 2014). With large amount of organic matters, high moisture and high salinity (Meng et al., 2015), the food waste would cause serious environmental contamination and health threat without proper treatment (Shen et al., 2013). Nowadays most of the food wastes are disposed by the conventional methods such as landfill, compost and incineration, which could lead to ground water contamination, vermin attraction and toxic gas emission (Goud and Mohan, 2011). Additionally, the conventional methods are unsustainable and uneconomical, as the valuable source of nutrients and energy in the food waste cannot be fully or efficiently used. Thus, exploiting the highly biodegradable waste as an alternative source for energy recovery with simultaneous treatment could be an attractive approach.

Anaerobic digestion is increasingly accepted as an effective technology for organic waste treatment and bio-energy recovery,

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and it has been considered as an attractive and sustainable approach to viably overcome the current global energy crisis (Huang et al., 2015). The food waste is inexhaustible resource with high energy potential and good biodegradability, and significant energy recovery could be achieved during the anaerobic digestion (Grimberg et al., 2015). As a promising anaerobic waste treatment device, the microbial fuel cell (MFC) can use microorganisms as catalyst to recover electricity from diverse organic wastes including domestic wastewater (Ahn et al., 2014), industrial wastewater (Feng et al., 2015) and excess sludge (Jiang et al., 2009). The MFC could efficiently achieve safe, clean and direct electricity production and simultaneous organic matter removal. Therefore, employing food waste as a substrate in MFC for electricity generation could be a promising approach for food waste treatment and energy recovery. Recently, some researches on the MFC which directly employ the food waste as substrate have been reported (Jia et al., 2013; Moqsud et al., 2014), however, how were the organic matters of the food waste chemically converted during the MFC treatment has not been explored.

The organic matters are the major constituents of food wastes and mainly consist of various high molecular-weight polymers such as carbohydrate, cellulose, protein, and lipid. In the MFC fed with food waste, the organic matters are the energy sources of the electricigens for the electricity production and the characteristics of the organic matters significantly affect the electricity generation efficiency. Additionally, hydrolysis of the organic matters is commonly known as the rate limiting step for electricity generation (Ma et al., 2014). In order to accelerate hydrolysis of the substrate for more efficient electricity recovery, pretreatment processes were often required, such as sonication (More and Ghangrekar, 2010) and microwave-pretreatment (Yusoff et al., 2013). Additionally, to minimize the environmental pollution of the food waste, post-treatment process may be needed for the food waste after the MFC treatment. For appropriate selection of pretreatment and post-treatment method, it is necessary to research the characteristics and the biodegradation regularity of the organic matters in the food waste during the MFC treatment.

In this study, the food wastes collected from canteen were exploited as anodic fuel for direct energy generation in a single-chamber MFC. The electrochemical performance of the MFC was studied. Additionally, the food waste organics before and after the treatment were fractionated into five different fractions by XAD resins, and the properties of the organic fractions were investigated. This research aims at revealing the transformation characteristics of the organic matters in the food waste during the MFC treatment and determined which fraction of the organic matters in the food waste could be preferentially degraded. Such knowledge might assist in the understanding of the compositions and chemical properties of organic matter in food waste and the biodegradation regularity of the organics during MFC treatment, and, in turn, may facilitate the pretreatment and post-treatment choices for MFC system fed with food waste.

## 2. Methods

### 2.1. Food wastes

The food waste used as the substrate in the MFC was collected from the student canteen at Harbin Institute of Technology, Harbin, China. The food waste mainly comprises boiled rice, vegetables, fruit, cooked meat, bones, as well as plastics. In order to supply a suitable substrate for the MFC, the bones and plastics in the food waste were first removed, and then the left food waste was pulverised in an electrical pulverizer (JYL-C051, Joyoung, China) for two minutes. Avoiding the clogging problem, the pulverised food waste was filtered through a stainless steel mesh with an average pore diameter of 2 mm to remove the coarse material. The oil in the food waste was separated by gravity. The COD of the pretreated food waste was 71,000–90,000 mg/L. Before fed into the MFC, the food waste was diluted to a COD concentration of 2700 ± 20 mg/L. Finally, the pH of the diluted food waste was adjusted to 7 by NaOH solution (1 M).

### 2.2. MFC configuration and operation

A single-chamber air cathode MFC with a working volume of 120 ml was constructed using "Perspex" as previous description (Sevda et al., 2013). The spacing between the anode and cathode placed on opposite sides was 4 cm. The anode was made of carbon cloth without any pretreatment. The carbon cloth based cathode containing 10% platinum and three diffusion layers was prepared according to the method reported previously (Cheng et al., 2006). Before making the diffusion layers, a carbon base layer was prepared by applying a mixture of carbon powder and 30 wt% PTFE solution onto one side of the carbon cloth, air-drying at room temperature for 2 h, followed by heating at 370 °C for 30 min. Additional diffusion layers were made by brushing a PTFE solution (60 wt%) onto the coating side, followed again by drying at room temperature and heating at 370 °C for 10 min. Diffusion layers were applied for 3 times. 10% Pt/C catalyst (0.5 mg Pt/cm$^2$) was then applied to the other side (water-facing side) of the carbon cloth using Nafion as a binder.

The MFC was inoculated with anaerobic sludge from the laboratory-scale anaerobic reactor and the prepared food waste was directly used as the substrate. The external resistance connected across the anode and cathode was 1000 Ω. The MFC was repeatedly filled with the inoculant and substrate until the constant output voltage was obtained. After about one month's inoculation, the MFC achieved stable performance, and the MFC was changed to using food waste as substrate without anaerobic sludge. The MFC fed with food waste was operated in batch mode at room temperature and was refilled when the output voltage decreased to lower than 100 mV, which formed an operation cycle.

### 2.3. Fractionation procedure

The food waste was fractionated into five fractions namely hydrophilic (HPI), hydrophobic acid (HPO-A), hydrophobic neutral (HPO-N), transphilic acid (TPI-A) and transphilic neutral (TPI-N) fractions using XAD-8/XAD-4 resins according to the reported method (Chow et al., 2006). Briefly, 2 L of the food waste sample was acidified to pH 2 using HCl and passed through the XAD-8 and XAD-4 resin columns in series. HPI was the organic matter not retained on either resin and existed in the XAD-4 effluent. The XAD-8 and XAD-4 resin columns were backward eluted using 200 ml NaOH (0.1 mol/L) and 50 ml Milli-Q water, and the eluate were HPO-A and TPI-A fractions, respectively. After eluation by the NaOH and Milli-Q water, the HPO-N and TPI-N still adsorbed on the XAD-8 and XAD-4, respectively. And the HPO-N and TPI-N were respectively desorbed by 75% acetonitrile +25% Milli-Q water solution from the XAD-8 and XAD-4. Finally, the acetonitrile existed in the HPO-N and TPI-N samples was removed using rotary evaporation.

### 2.4. Analysis

The output voltage across the external resistance was monitored every 1 min using a paperless recorder (VX5100R/C2/U, Hangzhou, China). The polarization and power density curves were measured by varying the external resistance from 5000 to 50 Ω. Power (W) was calculated according to the formula $P = U \times I$.