Bioelectricity Production from Fermentable Household Waste in a Dual-Chamber Microbial Fuel Cell

Chatzikonstantinou D.1, Tremouli A.1,* , Papadopoulou K.1, Kanellos G.1, Lampropoulos I.1, Lyberatos G.1,2

1 School of Chemical Engineering, National Technical University of Athens, Heroon Polytechniou 9, 15780, Zografou Athens, Greece
2 Institute of Chemical Engineering Sciences (ICE-HT), Stadiou Str., Platani, 26504, Patras, Greece

*Corresponding author: atremouli@chemeng.ntua.gr , tel: +302107723115

Abstract

In this study, the use of a dual chamber microbial fuel cell (MFC) for the production of bioelectricity from a food residue biomass (FORBI) product was investigated. FORBI was produced by drying and shredding the pre-sorted fermentable fraction of household food
waste collected door-to-door in the Municipality of Halandri, Athens, Greece. Different organic loads of FORBI were examined (0.7, 0.9, 1.4, 2.8, 6 and 14 g COD L\(^{-1}\) respectively). It was observed that an increase of the initial concentration of the final extract resulted in a corresponding increase in the operating time.

The MFC potential increased from 33.3 mV to 46 mV as the concentration was increased from 0.7 to 14 g COD L\(^{-1}\). The best performance in terms of maximum power density (29.6 mW m\(^{-2}\)) corresponding to a current density of 88 mA m\(^{-2}\) was observed for 6 g COD L\(^{-1}\). Setting the external resistance at its optimal value (R\(_{\text{ext}}\) = 2 kΩ) as determined by polarization experiments, P\(_{\text{yield}}\) drastically increased to 13.7 and 17.3 Joule (g FORBI)\(^{-1}\) in two consecutive cycles. The results demonstrate that readily biodegradable substrates such as FORBI can be effectively used for enhanced bioelectricity harvesting in an MFC.

**Keywords**

Microbial fuel cell, Power density; Bioelectricity; Fermentable Household Waste; Food Residue Biomass product
1. Introduction

Due to the large quantities of Municipal Solid Waste (MSW) generated globally, different waste management practices must be implemented to reduce environmental and health impacts and to preserve natural resources. Common practices used to manage MSW include materials or energy recovery by recycling, composting, land filling, incineration, anaerobic digestion etc. (Pendyala et al. 2016). 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). Negative health and environmental impacts caused by landfilling MSW include leachate production and greenhouse gas (methane) emissions (USEPA 2002; 2011). An alternative approach to manage MSW is to develop and improve alternative technologies, in order to produce value-added products from the fermentable fraction of municipal solid waste.

Bioelectricity production from fermentable household biomass using microbial fuel cells (MFCs) is an interesting waste-to-energy producing technology which has received attention as an alternative. Bioelectricity production involves generation of electricity by conversion of organic substrates by electrogenic bacteria under anaerobic conditions. An MFC is a
device for the production of bioelectricity, having the potential to simultaneously treat waste while generating electricity (Bennetto 1984, Habermann & Pommer 1991). MFC technology represents thus a new form of renewable energy since electricity is produced from what would otherwise be considered waste, such as food industry based waste (i.e. canteen based food waste or market vegetable waste), municipal solid waste (i.e. household food waste) etc.

A wide variety of food wastes have been investigated to date, as substrates for MFCs. Moqsud & Omine 2010 used a rectangular acrylic container as the cell and filled it with well mixed kitchen garbage (comprising of fruit waste and vegetable leftovers), leaf mold, effective micro-organisms and distilled water. The maximum power was 682 mW m$^{-2}$.

Schievano et al. (2017) studied the electrical signals produced by MFCs during anaerobic biodegradation of four different types of wastes: citrus pulp, fishery waste, cheese whey and kitchen waste. Coulombic Efficiency (CE) and soluble COD (sCOD) removal were monitored for 100 days. The maximum CE for kitchen waste was 9.91%, with a sCOD removal of 64.25%.

The present work proposes source separation and separate collection of the Fermentable Household Waste (FHW) in the Municipality of Halandri, Athens, Greece, followed by
drying and shredding at the Municipality level, aiming to evaluate the generated product, called FORBI (Food Residue Biomass), as a potential feedstock for the production of electricity using MFC technology, among various valorization alternatives. FORBI is a high-quality homogenized and dry biomass product with a weight approximately 25% of the original food waste, which may be stored for prolonged periods of time without deterioration.

2. Materials and Methods

2.1 MFC set-up

All experiments were performed in an H-type dual chamber MFC consisting of two 310 ml glass cylindrical bottles connected via a glass tube (Tremouli et al. 2013). The solutions in the two bottles, where the two electrodes of the MFC were immersed, were kept in electrolytic contact via a proton-exchange membrane (PEM, Nafion 117). The temperature in all experiments was maintained at 35°C by performing the experiments in a temperature-controlled box.

Carbon fiber paper (Toray, 10 wt% wet proofing) was used as the anode electrode and carbon cloth coated with a Pt catalyst (E-Tek, 0.5 mg cm⁻¹) as the cathode electrode. The electrodes, each with dimensions 4 cm x 2.7 cm, having an apparent surface area A= 2 x 10.8 = 21.6
cm², were connected via silver wires with a 100 Ω external resistor, forming a closed electrical circuit. The cell voltage $U_{\text{cell}}$ was monitored and recorded at 50 s intervals, using a data acquisition system (Advantech ADAM-4019+), connected to a personal computer, while the current $I$ passing through the cell was measured using a precision multimeter (Mastech MY 61).

### 2.2 Culture inoculation and reactor operation

The MFC was inoculated with anaerobic sludge obtained from the Athens (Greece) Wastewater Treatment Plant. The main characteristics of the sludge were: pH = 7.26 ± 0.21, conductivity = 2.78 ± 0.78 mS cm⁻¹, dissolved chemical oxygen demand (dCOD) = 0.20 ± 0.03 g dCOD L⁻¹, total chemical oxygen demand (TCOD) = 33.01 ± 4.30 g TCOD L⁻¹, total suspended solids (TSS) = 44.30 ± 0.93 g L⁻¹ and volatile suspended solids (VSS) = 18.55 ± 0.64 g L⁻¹. The nutrient medium (250 ml) in the anode chamber contained (per L): 5.29 g NaH₂PO₄ ·2H₂O, 3.45 g Na₂HPO₄ ·2H₂O, 0.16 g KCl, 5 g NaHCO₃ and 10 mL of a trace elements solution (Skiadas & Lyberatos 1998). NaH₂PO₄ ·2H₂O and Na₂HPO₄ ·2H₂O were added to the medium forming a Phosphate Buffer Solution (PBS, pH 7), while KCl was added to increase the solution conductivity. All cycles were conducted in batch mode. The anolyte
and the catholyte were replaced after the MFC voltage dropped to approximately zero, designating the end of a cycle. Glucose was used as carbon and energy source (0.7 g COD L\(^{-1}\)) and 10% (v/v) of the anaerobic sludge was added to the anodic chamber. The cathode chamber was continuously aerated and contained PBS (pH 7), while KCL (0.16 g L\(^{-1}\)) was added. The aeration of the cathode was carried out via an air-pump.

After the acclimation period, glucose was replaced by the liquid extract from a FORBI suspension, at different initial concentrations (ranging from 0.7 to 14 g COD L\(^{-1}\)), without further addition of sludge. Moreover, following the MFC operation at the concentration of 14 g COD L\(^{-1}\) two batch cycles were conducted at initial concentrations of 6 g COD L\(^{-1}\) and 0.9 g COD L\(^{-1}\), respectively. In order to understand the system’s metabolic activities, during these cycles, anolyte pH and VFAs were measured at selected time intervals. All cycles were conducted in batch mode. The anolyte and the catholyte were replaced after the MFC voltage dropped to approximately zero, designating the end of a cycle (COD consumption). The cathodic chamber was continuously aerated via an air-pump, while the anodic chamber was sealed with a rubber stopper and the anolyte was sparged with a gaseous mixture of N\(_2\)/CO\(_2\) in order to ensure anaerobic conditions. The external load of the MFC was regulated using a resistance decade box (RS, No. 211 – 159). The current, MFC voltage and temperature were
continuously monitored, while COD, pH, VFAs and conductivity were measured at selected time intervals after the addition of substrate.

### 2.3 FORBI pretreatment and characteristics

Fermentable household food waste (FORBI) was produced by drying and shredding the pre-sorted fermentable fraction of household food waste collected door-to-door in the Municipality of Halandri, Athens, Greece. A 2 mm sieve was used to achieve the desired particle size of the dry mixture of FORBI. FORBI was suspended in tap water and was vigorously stirred for 30 minutes. Then the slurry was filtered under pressure using a cloth filter. The liquid extract retained 95% of the soluble organic content of the waste. Prior to use, the extract was filtered using sequential Whatman filters of pore sizes 1.2 μm to 0.7 μm. The final extract was diluted to different extents giving solutions ranging from 0.7 to 14 g COD L⁻¹ and these were used as energy source for electricity production in the MFC.

**Table 1.** The main characteristics of the FORBI extract.

| Characteristics          | Value |
|--------------------------|-------|
| pH                       | 6.43  |
| Conductivity (mS cm⁻¹)   | 2.31  |
| Total COD (g L⁻¹)        | 9.98  |
|                        |          |
|------------------------|----------|
| Dissolved COD (g L⁻¹)  | 6.92     |
| Total Carbohydrates (g L⁻¹) | 8.02     |
| Soluble Carbohydrates (g L⁻¹) | 6.12     |
| Total Suspended Solids – TSS (g L⁻¹) | 2.36     |
| Volatile Suspended Solids – VSS (g L⁻¹) | 2.29     |
| Total Solids – TS (g L⁻¹) | 9.83     |
| Volatile Solids – VS (g L⁻¹) | 8.04     |
| Total Kjeldahl nitrogen (TKN) (g L⁻¹) | 0.22     |
| Total phosphorus (g L⁻¹) | 0.06     |

2.4 Calculations and analysis

The performance of the MFC system was evaluated in terms of COD removal efficiency, CE and power density. The calculation of power density was based on the aforementioned apparent surface area of each electrode (21.6 cm²) (unless stated otherwise). The COD removal efficiency and the CE were calculated as described in Logan et al. (Logan et al. 2006). The measurements of dissolved and total COD, TSS and VSS, total Kjeldahl nitrogen (TKN) and total phosphorus were carried out according to Standard Methods (APHA, 1998). For the quantification of volatile fatty acids (VFAs), 1 mL of sample, acidified with 30 µL of 20 % H₂SO₄ was injected into a gas chromatograph (SHIMADZU GC 2010 plus), equipped with an automatic sampler (type SHIMADZU AOC -20s) and a capillary column.
(Agilent Technologies HP-FFAP, 30 m x 0.53 mm ID x 1μm film). The oven temperature was raised from 105 to 160 °C, at a rate of 15 °C min⁻¹ and subsequently, to 225 °C at a rate of 20 °C min⁻¹ and was held for 3 min. Helium was used as the carrier gas at 30 mL min⁻¹ and the detector temperature was set at 230 °C. The dissolved and total carbohydrates were measured according to Josefsson (1983). The pH and conductivity were measured using a digital pH-meter (WTW INOLAB PH720) and a conductivity meter (WTW INOLAB), respectively.

2.5 Polarization measurements

Polarization experiments were conducted for each batch cycle, at the period of the highest voltage output for an external resistance 100 Ω. Particularly, the U_cell vs. current density and power density (P) vs. current density curves were obtained by varying the external resistance (external load) in the range of 0.1-1000 kΩ and recording the corresponding steady-state (quasi – steady – state) MFC voltage and current values.

The internal resistance $R_{in}$ of the MFC was calculated by the power density peak method (Logan, 2008), according to which, at maximum power output, the internal resistance is equal
to the external resistance, i.e., $R_{in}$ is equal to the external resistance (load) $R_{ext}$ that must be connected to the MFC to obtain the maximum power output.

3. Results and discussion

3.1. MFC start -up

Fig. 1a shows the changes in the monitored cell voltage $U_{cell}$ (100 $\Omega$ external load) and in COD during the start-up stage (eight batch cycles). Glucose was used as the electron donor for all cycles. From Fig. 1a it can be clearly observed that the peak voltage $U_{peak}$ gradually increased from 22 mV (cycle 1) to 29 mV (cycles 5 and 6), while the CE was 1.4 and 3.8 % for the first and the sixth cycle, respectively. Cycles 7 and 8 occurred without further addition of sludge. The $U_{peak}$ which was achieved was equal to 30 mV for both cycles while the CE was 3.1 and 3.4% for cycles 7th and 8th, respectively. Moreover, the polarization experiments (Fig. 1b) indicated that during the acclimation period, the maximum power density increased from 17.7 mW m$^{-2}$ (3rd cycle) to 20.2 mW m$^{-2}$ (8th cycle). The COD removal efficiency was over 75% for all acclimation cycles. The almost stable performance of the last four cycles (5th, 6th, 7th and 8th cycle) confirmed that the formation of an electrogenic biofilm was completed.
Fig. 1. a) MFC voltage $U_{cell}$ and COD consumption versus time during the acclimation period (cycles 1 - 8), b) MFC voltage $U_{cell}$ and power density versus current density corresponding to polarization experiments performed during acclimation period (cycles 3 - 8).

3.2 Effect of FORBI extract concentration on the MFC performance
The FORBI extract was used as substrate in the anode chamber, in concentrations ranging from 0.7 – 14 g COD L⁻¹. The MFC voltage (R_{ext} = 100 Ω) and the COD consumption versus time for the different initial final extract concentrations are shown in Fig. 2. The final extract concentration was sequentially increased, by addition in the anolyte of the proper amount of final extract after the end of each operation cycle. As shown in Fig. 2, the MFC potential before the abrupt decrease was higher for higher initial concentrations of the final extract, increasing by approximately 13 mV as the concentration was increased from 0.7 to 14 g COD L⁻¹. Moreover, the duration of the operation cycle increased with increasing initial concentration of the substrate (76 h, 85 h, 98 h, 179 h, 261 h and 357 h for 0.7, 0.9, 1.4, 2.8, 6 and 14 g COD L⁻¹ initial FORBI concentration, respectively). The substrate removal efficiency at the end of each operation cycle was relatively high, ranging from 71% - 91%. As far as the CE (R_{ext} = 100 Ω) is concerned, it was very low, averaging at a value of 2% for all initial concentrations of final extract. The low CE implies that most of the COD was removed by methanogens or other non-electrogenic microbes established in the anode rather than by electron transfer bacteria (He et al. 2005).
3.3. Effect of FORBI concentration on the polarization performance
Fig. 3 shows the dependence of the MFC voltage $U_{\text{cell}}$ and the produced power density, $P$, on the current density passing through the MFC, at different final extract concentrations. The data were obtained after the MFC voltage had leveled off to a practically constant value, following the addition of the substrate in the anolyte. As shown in Fig. 3, the increase of the final filtrate initial concentration from 0.7 (1st cycle) to 6 (12th cycle) g COD L$^{-1}$, results in an increase of the maximum power density from 20.4 to 29.6 mW m$^{-2}$ (ca. 9.2% increase). However, a further increase of the initial concentration to 14 g COD L$^{-1}$, results in a decrease of the maximum power density from 29.6 to 24.6 mW m$^{-2}$ indicating that an increase of initial substrate concentration above a critical value leads to a limitation of the MFC performance.

The internal resistance of the MFC, operating with final extract as substrate at concentrations 0.7 to 14 g COD L$^{-1}$, as determined by the power density peak method for the data presented in Fig. 3, was approximately 2 kΩ. Moreover, the almost constant slope of the polarization curves (Fig. 3) indicates the very significant contribution of ohmic losses (ohmic overpotential) in the dual chamber MFC of the present study.
Fig. 3. MFC voltage $U_{cell}$ and power density versus current density when using the final filtrate as substrate at different initial concentrations $C_{in}$.

3.4 Effect of the cathodes’ surface area
Following the MFC operation at the concentration of 14 g COD L$^{-1}$ two batch cycles were conducted at initial FORBI extract concentrations of 6 g COD L$^{-1}$ and 0.9 g COD L$^{-1}$, respectively. In order to examine whether the MFC performance was limited by the cathode surface area, the cathodic electrode was replaced by a new similar one, with almost double the surface area (39.6 cm$^2$). As shown in Figs 2, 4b and 5b, $U_{\text{peak}}$ and the operation time of these cycles were not affected by changing the electrode size. Moreover, the maximum power density did not significantly change (23.4 mW m$^{-2}$ - 0.9 g COD L$^{-1}$; 25 mW m$^{-2}$ - 6 g COD L$^{-1}$) in comparison with the cycles operated with half size cathodic surface area (26 mW m$^{-2}$ - 0.9 g COD L$^{-1}$; 29.6 mW m$^{-2}$ - 6 g COD L$^{-1}$). These results indicate that the surface area of the cathode electrode is not a limiting factor for the MFC performance of the present experiments.

\textit{pH and Volatile fatty acids}

In order to understand the system’s metabolic activities, during these two cycles, anolyte pH, VFAs and COD were measured at selected time intervals after the addition of substrate. Figs 4 and 5 show VFAs concentration, pH, $U_{\text{cell}}$ and COD consumption versus time using FORBI at initial concentrations of 6 g COD L$^{-1}$ and 0.9 g COD L$^{-1}$, respectively. As shown in Figs
VFAs concentration was practically zero in the beginning of batch cycles ($t = 0$ h). However, VFAs production (mainly acetic and butyric acid) showed a sharp increase after approximately 20 h of operation in both cycles. The sharp increase of VFAs indicates that in the anode chamber hydrolysis and fermentation of FORBI macromolecules occurred. Following this increase, VFAs concentration was gradually reduced until their full depletion at the end of each batch cycle. This result can be attributed to the consumption of VFAs in the metabolic activities in the anode chamber. The pH variation was observed to correspond well with the VFA profile.

It is worth mentioning that the sharp increase of VFAs concentration was accompanied with the increase of $U_{\text{cell}}$ (at approximately $t=20$ h) for both cycles (Figs 4b and 5b). In particular, $U_{\text{cell}}$ changed from 25 mV to 36 mV for the cycle with 6 g COD L$^{-1}$ and from 34 mV to 36 mV for the cycle with 0.9 g COD L$^{-1}$. This result indicates that FORBI hydrolysis in the anode chamber, boosted MFC performance due to the increase of the simple substrate concentration (mainly acetic and butyric acid) available for bacterial consumption. The fact that VFA accumulation is observed during the cycle implies that the rate of acidogenesis is higher than the rate of VFA consumption by the electrogenic population.
Fig. 4. a)

[Graph showing g VFAs L\(^{-1}\) vs. time (h) for different acids at 6 g COD L\(^{-1}\).]

Fig. 4. b)

[Graph showing U\(_{cell}\) (mV) and COD (g L\(^{-1}\)) vs. time (h) for 6 g COD L\(^{-1}\).]
**Fig. 4.** a) VFAs concentration and anolyte pH versus time, b) MFC voltage $U_{cell}$ and COD consumption versus time at 6 g COD L$^{-1}$ of FORBI initial concentration. External resistance $R_{ext} = 100 \, \Omega$.

**Fig. 5.** a)
Fig. 5. a) VFAs concentration and anolyte pH versus time, b) MFC voltage $U_{cell}$ and COD consumption versus time at 0.9 g COD L$^{-1}$ of FORBI initial concentration. External resistance $R_{ext} = 100$ Ω.
3.5. Power yield per g of FORBI

The MFC performance was further assessed in terms of power yield per g of FORBI (Joule /g FORBI). In order to estimate this factor the produced power (P) was calculated using the equation \( P = I U_{\text{cell}} \) (1) where, \( I \) denotes the current and \( U_{\text{cell}} \) the cell voltage monitored at 50 s intervals. The power yield per initial g of FORBI for each cycle, was then calculated using the following equation: \( P_{\text{yield}} = \int_{0}^{t} P \, dt \times (\text{g of FORBI})^{-1} \) (2).

The results indicated that although \( P_{\text{yield}} \) increased with increasing the initial FORBI concentration (\( R_{\text{ext}} = 100 \, \Omega \)), these values did not drastically change. In particular, \( P_{\text{yield}} \) was 0.9, 0.8, 1.1, 1.25, 1.1, and 1.7 joule (g FORBI)\(^{-1}\) for 0.7 and 0.9, 1.4, 2.8, 6 and 14 g COD L\(^{-1}\) initial FORBI concentration, respectively.

In order to assess the effect of external resistance on the power yield per g of FORBI, \( R_{\text{ext}} \) was switched to its optimal value for maximum power production, as this was determined by the polarization experiments. In order to achieve this goal and examine the reproducibility of the results, two more cycles were conducted at the initial concentration of 0.9 g COD L\(^{-1}\), while setting the \( R_{\text{ext}} \) to its optimal value (\( R_{\text{ext}} = 2 \, k\Omega \)), \( P_{\text{yield}} \) drastically increased to 13.7 and 17.3 Joule (g FORBI)\(^{-1}\) (Fig. 6). These results indicate the importance of how a relatively
small intervention in the system, such as the external resistance, can affect the system performance. Consequently, the proper selection of an MFC configuration as well as the selection of the optimal operation conditions could drastically increase FORBI exploitation using MFC technology.

![Graph](image_url)

**Fig. 6.** MFC voltage $U_{cell}$ and COD consumption versus time using initial concentration 0.9 g COD L$^{-1}$ of FORBI extract at external resistance $R_{ext} = 2 \, \Omega$. 

4. Conclusions

It was shown that power generation is possible using FORBI extract as substrate in a two-chamber MFC. The highest power density obtained was 29.6 mW m$^{-2}$. The COD removal was in the range of 71% - 91%. The experiments showed that the period of time needed to degrade the final extract increases with the increase of final extract concentration and that by doubling the cathodic electrode surface area, no change in the MFC performance was observed. The increase of VFAs indicated that in the anode chamber hydrolysis of FORBI macromolecules occurred boosting the MFC performance. In order to optimize the process an improved configuration should be designed, mainly aiming to minimization of the ohmic losses.

Acknowledgements

This work is produced under research project Horizon 2020, Grant Agreement No 688995. «Moving towards Life Cycle Thinking by integrating Advanced Waste Management Systems-[WASTE4THINK].
References

APHA, AWWA, WPCF, American Public Health Association, American Water Works Association, Water Environment Federation (1998). Standard Methods for the examination of water and wastewater, Washington, DC.

Bennetto, H.P. (1984). Microbial Fuel Cells, pp. 363-453, London: Life Chemistry Reports Harwood Academic.

Food and Agriculture Organization (FAO) (2012). Towards the Future We Want: End Hunger and Make the Transition to Sustainable Agricultural and Food Systems, United Nations Rome.

Goud RK, Babu PS & Mohan SV (2011) Canteen based composite food waste as potential anodic fuel for bioelectricity generation in single chambered microbial fuel cell (MFC): bio-electrochemical evaluation under increasing substrate loading condition. *International Journal of Hydrogen Energy* 36 (10): 6210–6218.

Habermann W & Pommer EH (1991) Biological fuel cells with sulphide storage capacity. *Applied Microbiology and Biotechnology* 35(1): 128–133.
He Z, Minteer S & Angenent L (2005) Electricity generation from artificial wastewater using an upflow microbial fuel cell. Environmental Science Technology 39: 5262–5267.

Hui L, Yu T, Wei Z, Jun Z, Xiaoyue P., Lipin L & Xinying S. (2016) Electricity generation from food wastes and characteristics of organic matters in microbial fuel cell. Bioresource Technology 205: 104–110.

Jia J, Tang Y, Liu B, Wu D, Ren N & Xing D (2013) Electricity generation from food wastes and microbial community structure in microbial fuel cells. Bioresource Technology 144: 94–99.

Josefsson B. (1983). Rapid spectrophotometric determination of total carbohydrates – from Methods of Seawater Analysis, Grasshoff K., Ehrhardt M., Kremling K., pp. 340-342, Verlag Chemie GmbH.

Logan, B.E. (2008). Microbial Fuel Cells, Hoboken, New Jersey.

Logan BE, Hamelers B, Rozendal R, Schroder U, Keller J, Freguia S, Aelterman P, Verstraete W & Rabaey K (2006) Microbial fuel cells: methodology and technology. Environmental Science Technology 40: 5181–5192.

Moqsud, M.A & Omine K (2010) Bio-Electricity Generation Using Organic Waste in Bangladesh. Proceedings of the International conference on Environmental aspects of Bangladesh, 4th September, pp.122-124, Kitakyushu, Japan.
Pendyala B, Chaganti SR, Lalman JA & Daniel D (2016) Optimizing the performance of microbial fuel cells fed a combination of different synthetic organic fractions in municipal solid waste. *Waste Management* 49: 73–82.

Schievano A, Colombo A, Cossettini A, Goglio A, D’ Ardes V, Trasatti S & Cristiani P (2017) Single-chamber microbial fuel cells as on-line shock-sensors for volatile fatty acids in anaerobic digesters. *Waste Management* 71: 785-791.

Tremouli A, Antonopoulou G, Bebelis S & Lyberatos G (2013) Operation and characterization of a microbial fuel cell fed with pretreated cheese whey at different organic loads. *Bioresource Technology* 131: 380-389.

United States Environmental Protection Agency (USEPA) (2002). Solid waste management: A local challenge with global impacts. Report # EPA530-F-02- 026d (5306W).

United States Environmental Protection Agency (USEPA) (2011). Municipal solid waste generation, recycling and disposal in the United States.

Skiadas VI & Lyberatos G (1998) The Periodic anaerobic baffled reactor. *Water Science Technology* 38: 401- 408.

**Figure Captions**
**Fig. 1.** a) MFC voltage $U_{cell}$ and COD consumption versus time during the acclimation period (cycles 1-8), b) MFC voltage $U_{cell}$ and power density versus current density corresponding to polarization experiments performed during acclimation period (cycles 3-8).

**Fig. 2.** MFC voltage $U_{cell}$ and COD consumption versus time using the final filtrate as substrate at different initial concentrations. External resistance $R_{ext} = 100 \, \Omega$.

**Fig. 3.** MFC voltage $U_{cell}$ and power density versus current density when using the final filtrate as substrate at different initial concentrations $C_{in}$.

**Fig. 4.** a) VFAs concentration and anolyte pH versus time, b) MFC voltage $U_{cell}$ and COD consumption versus time at 6 g COD L$^{-1}$ of FORBI initial concentration. External resistance $R_{ext} = 100 \, \Omega$.

**Fig. 5.** a) VFAs concentration and anolyte pH versus time, b) MFC voltage $U_{cell}$ and COD consumption versus time at 0.9 g COD L$^{-1}$ of FORBI initial concentration. External resistance $R_{ext} = 100 \, \Omega$

**Fig. 6.** MFC voltage $U_{cell}$ and COD consumption versus time using initial concentration 0.9 g COD L$^{-1}$ of FORBI extract at external resistance $R_{ext} = 2 \, k\Omega$. 
Table captions

Table 1. The main characteristics of the FORBI extract.