Chemosphere 151 (2016) 163–170

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Influence of sludge age on the performance of MFC treating winery wastewater

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HIGHLIGHTS

- Power generation increases by decreasing the SRT.
- SRT control helps in the selection of electrogenic microorganisms.
- SRT did not influence on organic matter removal in biological treatment.
- Decreasing the SRT, Coulombic efficiency can be increased from 3.4% to almost 42.2%.
- Maximum power density of 890 mW m^{-2} can be achieved with MFC with SRT 1.2 d.

ARTICLE INFO

Article history:
Received 31 July 2015
Received in revised form
9 November 2015
Accepted 7 January 2016
Available online 15 March 2016

Handling Editor: Y Liu

Keywords:
Wastewater treatment
Energy recovery
Winery wastewater
Microbial fuel cell
Sludge retention time

ABSTRACT

The objective of this paper was to determine the influence of sludge age on microbial fuel cell (MFC) performance for generating electricity and removing organic matter from winery wastewater. Six Solid Retention Times (SRT) were used: 1.2, 1.4, 1.8, 2.3, 3.5 and 7.0 d. Results demonstrate that the electricity generation increases by decreasing the SRT, selecting electrogenic microorganisms, once the specific organic loading rate (SOLR) increased and the competition for substrate was reduced. Decreasing the SRT, coulombic efficiency can be increased from 3.4% to almost 42.2% and maximum power density from 58 to 890 mW m^{-2}. However the SRT did not influence on organic matter removal in biological treatment, because only a small part of COD was removed oscillating around 600 mg L^{-1} $d^{-1}$and it was very similar at all SRT studied.

1. Introduction

Microbial fuel cells (MFC) have become an emerging and promising technology that converts the chemical energy stored in organic and inorganic molecules directly into electricity, using microorganisms as biocatalysts (Rodrigo et al., 2007). Microorganisms oxidize organic matter on the anode producing electrons, which move through an external electrical circuit towards the cathode reducing an electron acceptor. Transport of ions through the bulk liquid or through an ion selective membrane keep the charge balance in the cell (Logan et al., 2006; Rabaey and Verstraete, 2005; You et al., 2006). MFC permits dual benefits like the wastewater treatment and power generation, seeming to be a promising approach to mitigate the environmental impact caused by wastewater. Nevertheless, the low power generation is one of the main bottlenecks for MFC technology, which greatly limits its development and industrial application (Rabaey and Verstraete, 2005).

Several parameters, such as operating conditions, reactor configuration, electrode material, membrane type, electrode

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http://dx.doi.org/10.1016/j.chemosphere.2016.01.030

surface area and external resistance, are known to affect MFC performance and are typically studied in works found in the literature (Akman et al., 2013; Gonzalez del Campo et al., 2013; Larrosa et al., 2009; Li et al., 2013; Patil and Gogate, 2012; Rahimnejad et al., 2011; Wei et al., 2012; You et al., 2006). However, to best of our knowledge, there are no studies on the effects of Solid Retention Time (SRT) on MFC performance.

The SRT or sludge age is an outstanding parameter for the design and operation of biological wastewater treatment processes (Rodrigo et al., 1996) and, consequently, it is expected to have a critical influence on the MFC performance, as well. SRT represents the average time spent by microorganisms in the biological reactor; and it is directly related to the population of microorganisms and the distribution of species, being a very effective method for the selection of populations. The lower the SRT, the faster should be the growth rate of microorganisms remaining in the biological reactor to avoid their wash out.

Although the choice of an SRT can lead to many consequences related to the biological wastewater process performance, its influence on the performance of the MFC were not yet well studied. Opposite, what it has been studied in the literature related to SRT is the influence on performance of the MFC of the Hydraulic Retention Time (HRT), although the literature is also scarce at this point (Kim et al., 2015b) and it is focused on the results obtained by changing HRT in a very limited range by feeding the MFC with different fuels such as domestic wastewater (Min and Logan, 2004) (Puig et al., 2011), milk processing wastewater (Kim et al., 2015a), synthetic wastewater (Wang et al., 2014) and urban wastewater enriched with glycerol (Guimaraes and Linares, 2014).

In previous papers of this group, the application of MFC technology to treat wineries wastewater was exhaustively studied and hence a deep understanding of the performance of this system was obtained. Taking into account this background, this paper focus on the effect of different SRT in the performance of a dual chamber MFC fed with winery wastewater, paying special attention to the study of COD removal of winery wastewater and the energy recovery.

2. Material and methods

2.1. MFC configurations and operation

Two MFC were used in this work (Fig. 1). They were made of acrylic tubes (inner diameter 40 mm; length 180 mm). Sterion® membrane (preconditioned using a 3% (v:v) hydrogen peroxide solution, 0.5 mol L^{-1} sulfuric acid and ultrapure water) was used to separate the MFC into two chambers with 70 mL (anode) and 100 mL (cathode), respectively. Carbon felts (KFA10, SGL Carbon Group®) were used as electrodes in both chambers. A stainless steel wire and an external resistance of 120 Ω connected the anode and the cathode. The electrodes in both chambers were not replaced when the SRT was changed.

The MFC was operated in parallel in semi-continuous mode with cycle time of 1 day or 24 h and at room temperature (25 ± 3 °C). The anode compartment was inoculated only at the beginning of experiment. To regulate the SRT, every day, a volume of anolyte was taken from the anode chamber and replaced by fresh winery wastewater. It is important to point out that using this technique (the purge of mixed liquor microorganisms) only the microorganisms contained in the bulk of the MFC are directly affected and this procedure does not affect to microorganism fixed on surfaces (biofilm). It is also important to point out that at the same time, the Hydraulic Residence Time was simultaneously modified in the system. The amounts removed in the tests were 10, 20, 30, 40, 50 and 60 mL, which resulted in SRT of 7.0, 3.5, 2.3, 1.8, 1.4 and 1.2 d, respectively.

An important observation that should be taken into account in the discussion of results is that the SRT influence on performance was studied by changing this parameter in two different cells sequentially. MFC1 was operated at 7.0 d during 45 d and then the SRT was changed to 2.3 for 35 d and finally to 1.4 d for 10 days. Complementary, MFC2 was operated at 3.5 d during the firsts 41 d and then the SRT was changed to 1.8 for 35 d and finally to 1.2 d for 10 days. Overlapping of results obtained in both MFCs will be a clear indication of the reproducibility of the performance of this type of MFC and will support the conclusions drained from this work.

The cathode compartment of the MFC was connected to a water reservoir with 250 mL. A peristaltic pump was used to recirculate the solution of HCl (pH 3.5) from the reservoir through the cathodic chamber of the MFC at 1.66 mL s^{-1}. An aquarium aerator and porous stones diffusers were used in the reservoirs tank for supplying the oxygen to the cathode chamber.

2.2. Inoculum and wastewater

The anode compartment was inoculated with 90% (V:V) of

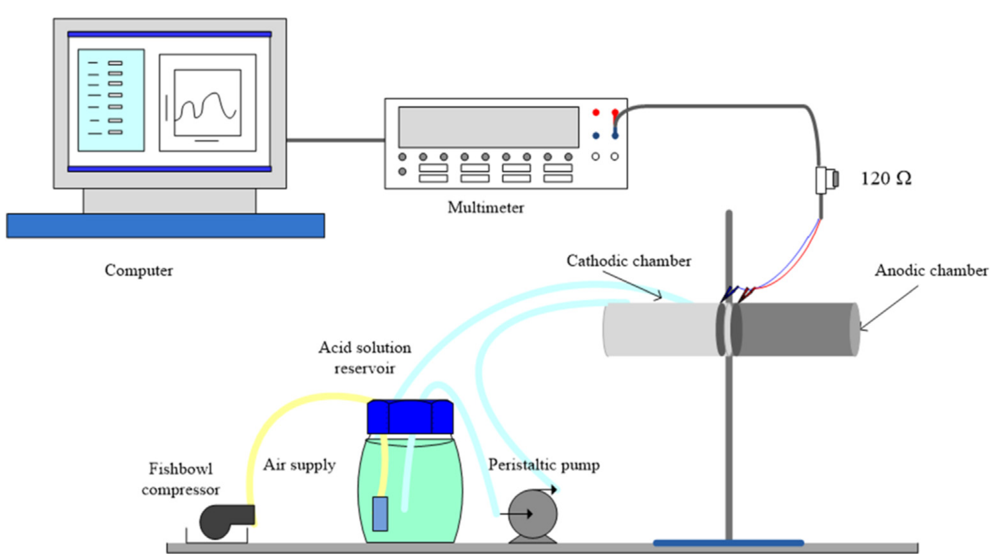

Fig. 1. Experimental setup.