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COMPARISON OF POWERING THE MICROBIAL FUEL CELL WITH VARIOUS KINDS OF WASTEWATER

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Abstract

The possibility to combine wastewater treatment and electricity production can accomplish a microbial fuel cell. Microbial fuel cells use glucose from wastewater as a fuel. In recent years, both production of municipal and industry wastewater increases very much. Municipal wastewater is directed to the wastewater treatment plant. While industry wastewater can be use as a fertilizer. But, both municipal and industry wastewater can be used in the microbial fuel cells. The comparison of powering the microbial fuel cell with municipal and process wastewater from yeast production is presented in this paper. The measurements covered comparison of changes in the concentration of COD in the reactor without aeration, with aeration and with using a microbial fuel cell (powered with municipal and industry wastewater). The results of measurements of COD showed no differences between the microbial fuel cell powered with municipal wastewater and the microbial fuel cell powered with process yeast wastewater. But, the power output is higher with using process yeast wastewater to powering the microbial fuel cell.

Keywords: microbial fuel cell, wastewater treatment, environmental engineering, renewable energy sources, clean technology, process yeast wastewater

INTRODUCTION

It has been known for century (1911) that it is possible to generate electricity (in direct process) by using bacteria (or yeast) to break down organic substrates (Potter 1911). Two decades later, Cohen confirmed Potter's results and produced an overall voltage of 35 V at a current of 0.2 mA using a stacked bacterial fuel cell (Cohen 1931). These publications are generally considered the first reported cases of microbial fuel cells (MFCs), but they did not generate much interest because the current density and also power output of MFC were very small. It was not until the 1960s that the idea of microbial electricity generation was picked up again (Davis and Yarbrough 1962; Cohn 1963; Berk and Canfield 1964; Lewis 1966), also as a potential method to convert human wastes into electricity during long space flights (Canfield *et al.* 1963). In these studies, it was then realized that the complicated underlying bioelectrochemical processes in MFCs operations require systematic and long-term research efforts (Cohn 1963; Lewis 1966). Another the moment of growing interest of MFCs is the discovery that current density could be greatly enhanced by the addition of electron mediators (Delaney *et al.* 1984; Roller *et al.* 1984). Since the turn of the century (20th and 21st century) the research of MFCs on a wider scale was began (Liu *et al.* 2004; Logan *et al*. 2006; Logan 2008; Rabaey and Verstraete 2005; Wang *et al.* 2008).

MFC is bio-electrochemical system that uses bacteria (most commonly from activated sludge) as catalysts to oxidize organic and inorganic matter (Logan 2008). The most commonly used bacteria in MFCs are *Pseudomonas* spp., *Geobacter* spp. or *Shewanella* spp. (Bond and Lovley 2003; Chaudhuri and Lovley 2003; Kim *et al.* 2002; Park *et al.* 2001; Pham *et al.* 2003). In MFC the process of fuel (e.g. organic compounds) oxidation takes place on the anode, and the product of oxidation is CO_2 (and also electrons and protons). Exemplary reactions for glucose electrooxidation in MFC show equations (1)-(3) (Cheng *et al*. 2006; Logan 2008; Rabaey and Verstraete 2005)

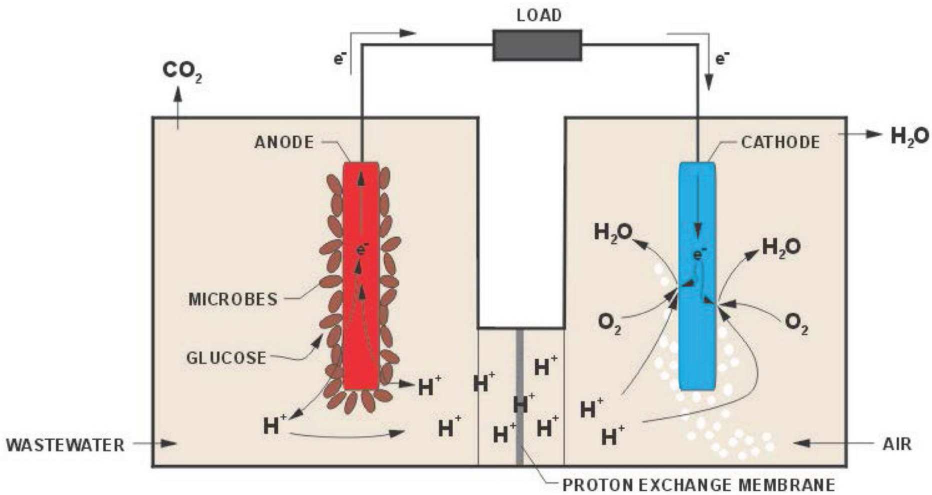
anode: $C_6H_{12}O_6 + 6H_2O \rightarrow 6CO_2 + 24e^- + 24H^+$ (1)

cathode: $6O_2 + 24H^+ + 24e^- \rightarrow 12H_2O$ (2)

summary reaction: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + electricity$ (3)

Figure 1 shows operation of MFC.

MFCs use glucose from wastewater as a fuel (Logan 2008). Municipal wastewater is directed to the wastewater treatment plant. While the industry wastewater, especially wastewater from food industry (mainly the industry which converts vegetable products) can be used as a fertilizer. An example of such wastewater is wastewater from yeast industry. Wastewater from the yeast industry has not only a high pollutants load but is produced in great amounts as well. Such wastewater is mainly supplied to the agricultural fields (AF) (Kutera 1986; Włodarczyk and Włodarczyk 2016; Włodarczyk and Włodarczyk 2017a; Włodarczyk and Włodarczyk 2019a). Those fields utilize the wastewater in the plant-soil environment (Brendecke *et al.* 1993, Kobya and Delipinar 2008, Thornton 2001, Zub *et al.* 2008). For wastewater treatment are used also another methods (Nowak *et al.* 2013, Płuciennik-Koropczuk *et al.* 2013). Most of them are suitable for transformation into raw materials for other technologies. This way we can reduce their negative impact on the environment and use them as a new source of raw materials. However, part of wastewater from yeast industry is sent to the treatment plant. This wastewater can be used to electricity production before final cleaning in treatment plant (Włodarczyk and Włodarczyk 2019b). Technical device that can accomplish this task is a microbial fuel cell (MFC) (Logan 2008). Thus, the comparison of powering the microbial fuel cell with municipal and process wastewater from yeast production is presented in this paper.



Source: Own elaboration

Figure 1. Operation of MFC

MATERIAL AND METHODS

The Table 1 shows the parameters of analysed wastewater. The wastewater from municipal wastewater treatment plant and process wastewater from yeast production was used in the measurements. The yeast process wastewater was from the vacuum filters.

Table 1. Parameters of analysed wastewater

Parameter	municipal wastewater	yeast process wastewater
pH	6,3	6,5
COD [$mg \cdot dm^{-3}$]	2211	2677

Source: Own elaboration

The measurements have included changes in the concentration of COD. The research was conducted in reactors with capacity equal 15 dm^3. Measurements of reduction of COD was conducted without aeration, with aeration and with using a MFC. The temperature of measurements was equal 293K. The measurements were carried out to obtain 90% effectiveness of COD reduction (Huggins *et al.* 2013; Włodarczyk and Włodarczyk 2018; Włodarczyk *et al.*, 2017). The figure 2 shows view of measurement position.

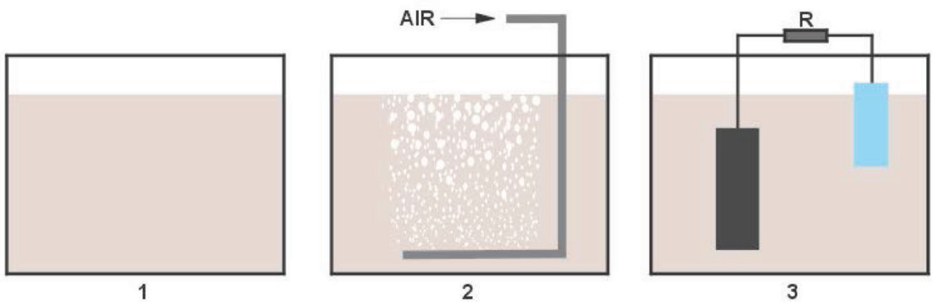


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Figure 2. Diagram of the measurements stand. Reactor: 1 –without aeration, 2 – with aeration, 3 – MFC

The measurements were carried out for three different reactors: one without aeration, one with aeration, and one conducted continuously in a working MFC. In the first reactor the wastewater had contact with air only through the wastewater–air interface. In the second reactor the wastewater was aerated (270$dm^3 \cdot h^{-1}$). The third reactor was used as the MFC. Figure 2 shows diagram of the MFC during operation.

The carbon cloth was used as electrodes material. The MFC was loaded with resistance equal 10Ω (Włodarczyk and Włodarczyk, 2017b; Włodarczyk and Włodarczyk, 2017c). The housing of cathode was printed on the 3D printer (layer thickness was equal 290μm) (Włodarczyk and Włodarczyk 2017b, Włodarczyk and Włodarczyk 2018). The Nafion 117 was used as PEM. The cathode was immersed in KOH catholyte. Microorganisms from activated sludge (from wastewater treatment plant) were used during measurements. Thus, was used a mixture of different microorganisms. Current density and power output was measured during the MFC operation.

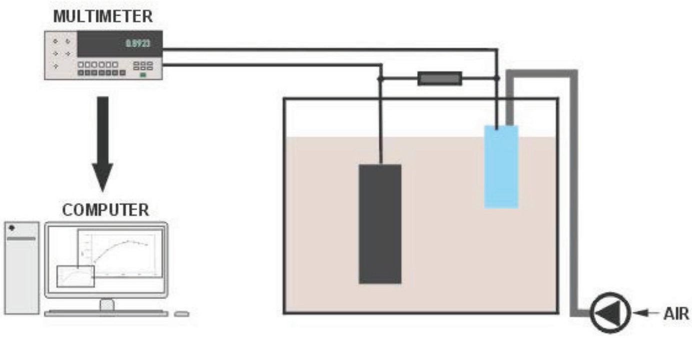

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Figure 3. Current density and power output measurement during the MFC operation

RESULTS

Figure 4 shows the measurements of change of COD concentration during the municipal wastewater treatment. Figure 5 shows the measurements of change of COD concentration during the process yeast wastewater treatment. Figure 6 shows the power output curves during the MFC operation.

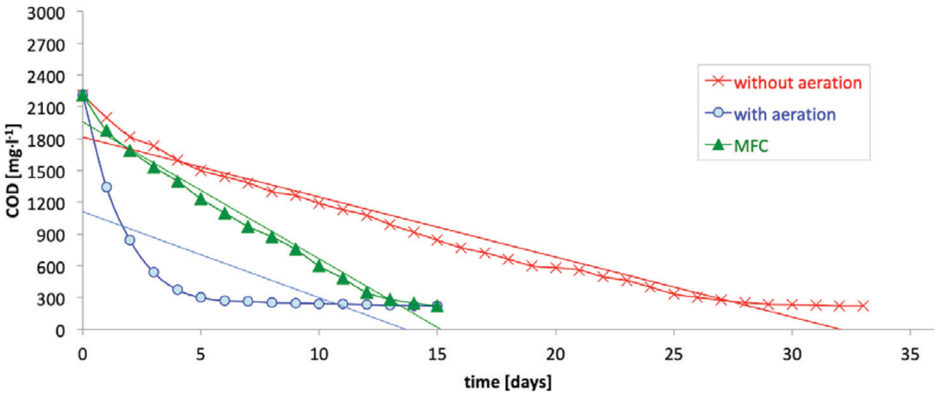

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Figure 4. Change of concentration of COD during municipal wastewater treatment without aeration, with aeration and with using a MFC. The colours indicate the trend lines of individual data

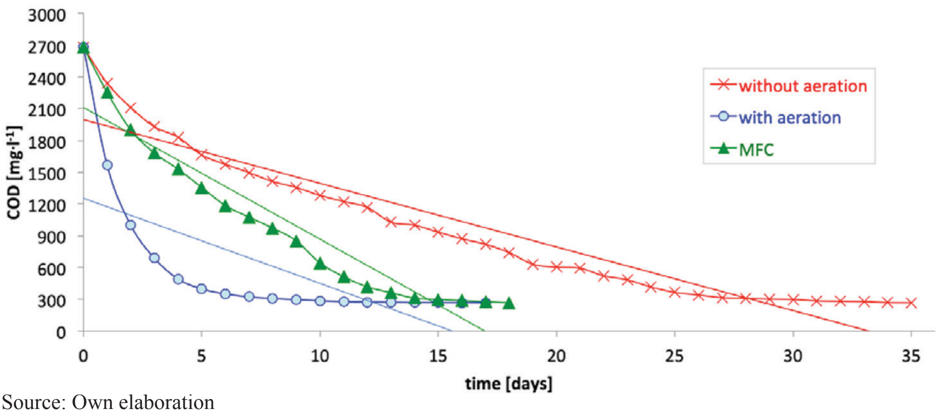

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Figure 5. Change of concentration of COD during process yeast wastewater treatment without aeration, with aeration and with using a MFC. The colours indicate the trend lines of individual data

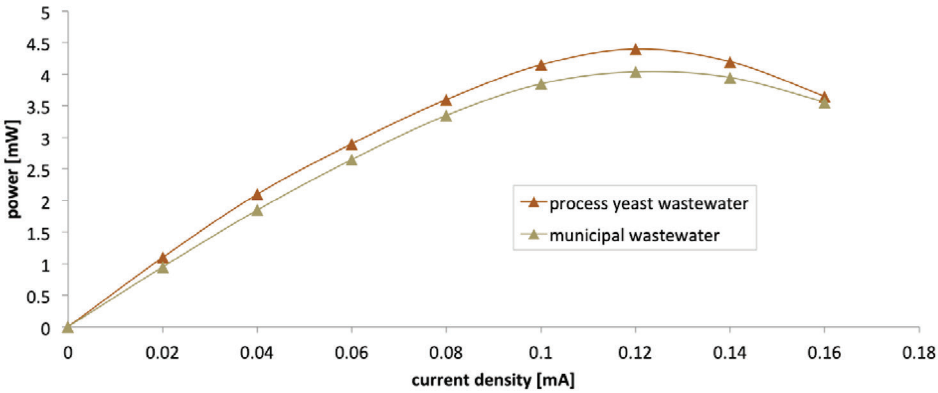

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Figure 6. Power output curves of MFC

CONCLUSIONS

In any cases (without aeration, with aeration and with MFC operation) the COD reduction reached 90% (fig. 4-5). Thus, measurements have shown the effectiveness of COD reduction for both analysed wastewater. The reduction time for COD with the use of MFC (both for municipal wastewater and for process yeast wastewater) is similar to the reduction time with aeration to obtain 90%

effectiveness. But, the characteristics of curves are different in any cases (fig. 4-5). The characteristic curve of aeration is more preferred than characteristic curve of MFC (both for municipal wastewater and for process yeast wastewater) because about 80% effectiveness of COD reduction after about 4-5 days. The power output of the MFC powered with process yeast wastewater is higher then the power output of the MFC powered with municipal wastewater (fig. 6). Thus, the process yeast wastewater is more preferred for the MFCs powering than the municipal wastewater. Moreover, the process yeast wastewater characterized by a much higher stability of chemical composition than the municipal wastewater. The results of measurements of COD showed no differences between the microbial fuel cell powered with municipal wastewater and the microbial fuel cell powered with process yeast wastewater. But, the higher power output with using process yeast wastewater to powering the microbial fuel cell was shown in this paper.

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