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Improvement of electric power of microbial fuel cells

THESES OF DISSERTATION

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1. Introduction

The treatment of both industrial and communal wastewaters is essential in the concept of the sustainable quality life. In the last few decades, due to the development in biotechnological field, the efficiency of emerging technologies for wastewater treatment increased significantly. The wastewater has to be biological treated before emission to environment. However, these strict directives put the cost of the applied technology to higher level, and thus somehow these are limiting factors. Microbial fuel cells (MFC) technology is a rapidly evolving and a very promising alternative energy source. This technology offers a possibility to treat municipal wastewaters and neutralize organic wastes. Like to conventional technologies applied in wastewaters treatment, the microbes in microbial fuel cells degrade the organic substrates while producing carbon-dioxide, biomass and with the beneficial side effect of electric current generation. The generated electricity can be used for operation of direct-current devices or supply to electricity networks using converts. The use of MFC technology is not limited to wastewater treatment only; other fields of the industry can gain attention of this technology as an energy source, such as meteorology, seismology, operation of analytical devices, *etc*.

Use of microbes for production of electricity is not a new idea. The first MFC with redox mediator was created in the 1910's, and in the 60's the mediator-less MFC was introduced. Unfortunately, up to the end of last century the development of MFC did not gained much more attention due to the drop of prices of the fossil fuel as well some barriers in material science and biotechnology. The evolution of the information and biotechnology, new inventions (proton-selective membranes, graphite fiber electrodes, nanotechnological materials, *etc*.) in material sciences, the price of fossil energy sources, problems of climate change as well as looking for global solutions *etc.* put this attractive technology back to frontier. The largest pilot-scale MFCs were developed and applied in Australia and in the USA (trial operation) for treatment of the brewery and winery wastewaters in Queensland, Australia and Oakland, California, respectively.

Despite of intensive research and development, microbial fuel cell technology still faces numerous problems with overcome needed such as scaling up, efficiency, low voltage power output, utilization of the whole anode chamber, the increase of proton transfer from anode to cathode chamber, the improvement of interaction between microbial cells and anode surfaces, enhance of voltage generation, problem of cathode chamber aeration, *etc*. The metabolic features of microbes are very divers, and in fact, these factors play key rules in the power of

MFC. The selection and development of suitable cultures are also key factors for success construction of the working MFC system. Furthermore, scientific and technological information about the electrogenic properties of microbe species, different engineering works (metabolite engineering, electrode engineering, etc.), new constructions of bioreactor are also indispensable in the development of MFCs. My PhD research work focused on improvement of the electric performance of MFC systems.

2. Main objectives

The goal of my PhD research is improvement of the electric power of microbial fuel cells.
Main objectives are the followings:

- Development of a rapid screening method for estimating capability of production of exo-electrons and their transportation either to electron acceptors or to electrodes of different microbe strains.
- Adaptation of method for evaluation of electrogenic profile of microbes.
- Evaluation of electrogenic profile of *Geobacter toluenoxydans* DSMZ 19350 strain: determination of kinetics parameters of growth and product formation, modelling the relationship between growth and iron(III)-reduction properties of the microbe.
- Evaluation of electrogenic profile of *Shewanella xiamenensis* DSMZ 22215 strain: determination of kinetics parameters of growth and product formation, modelling the relationship between growth and iron(III)-reduction, adhesion to different surfaces as well as the production and secretion in the extracellular redox-mediators.
- Creation of an electrically conductive gel-anode construction and operation in different modes (batch, semi-continuous, continuous) in microbial fuel cell systems.
- Creation of a non-noble metal based air-cathode catalyst construction and application in a single chamber microbial fuel cell system.

3. Materials and methods

Microorganisms used in my research were coming from different sources. *Geobacter* and *Shewanella* were purchased from the culture collection of Deutsche Sammlung von Microorganismen und Zellkulturen (DSMZ). *Saccharomyces cerevisiae* WS-120 strain was obtained from the yeast collection of the University of Weihenstephan (Hefebank Weihenstephan, TUM, Freising, Germany), and the *Lactobacillus plantarum* 2142 strain and

the *Escherichia coli* ATCC 8739 strain were kindly supplied by the University of Perugia (Perugia, Italy).

The microbial growth was followed by two methods: measuring the optical density (OD) at wavelength of 600 nm and pour plating technique. The maximal specific growth rate values were calculated from the exponential phase of the growth curves.

For evaluation of microbial substrate utilization minimal nutrient medium (contained only the examined carbohydrate) was used without organic carbon- and nitrogen sources. After inoculation with the bacterium culture the growth and/or iron(III)-reduction properties were monitored by measuring OD_{600nm} and the absorbance change at 460 nm.

The microbial iron-reduction was measured by the Fe^{3+}-ion concentration. The nutrient broth was supplemented with iron(III)-citrate in concentration of 5 g/L. The quantity change of iron(III)-ions was measured by ammonium-thiocyanate (NH_4SCN) method (MSZ 318-14:1987).

Production of the microbial extracellular mediators was determined at different environmental conditions: the microbe culture was incubated for 48 hours on 30 °C at aerobic and anaerobic condition as well as in a microbial fuel cell reactor. After incubation the cells were separated from the medium by centrifugation for 10 minutes on 15 °C with acceleration force of 5500 g. The supernatant was filtered with a 0.2 μm PTFE filter and the extracellular electron shuttle molecules (proteins and flavones) were determined in the filtrate.

The adhesion of microbes to different kind of surfaces was detected by placing a small species of certain material in a well of a 6-well microplate, and 4.5 mL medium were added. The wells were inoculated with 500 μL of overnight bacterial suspension contained at least 10^7 CFU/mL. The plates then were inoculated for 48 hours on 30 °C without shaking. After the inoculation the mediums were removed and washed several times (3-4 times) with 0.5 M Sorensen phosphate buffer (pH=7). The adherent cells were fixed with 1 mL 96 V/V% ethanol, and washed again with phosphate buffer. The fixed cells were stained for 2 minutes with 1 mL 0.41 m/V% crystal violet solution. After that the wells were washed again with phosphate buffer. The stained cells were re-suspended by 1 mL 96V/V% ethanol and the absorbance of the suspension was measured on 595 nm. The experiments were run in 5 parallels.

The gel-anodes were created from electro-conductive hydro-gels. For preparing the gels, 0.1 g Na-alginate were dissolved in 10 mL distillated water and aniline (in concentrations of 0-0.02 g/mL) was added with rigorous mixing. The aniline-alginate gel-network was established by ultrasonific homogenization for 2 hours. In order to create the

nano-composite structure titanium-dioxide and ammonium-persulphate were used and ultrasonic treatment was applied for 2 hours on -10 °C. In the last step graphite powder (in concentrations of 0-0.05 g/mL), electrogen bacterial culture (*Shewanella algae*, 10^7 CFU/mL) and droplets of 10 mM calcium-chloride solution were added to the mixture.

The nickel coating was made on copper mesh by electroplating. The copper mesh was defatted by 0.6 M Na_3PO_4 and 1 M $(NH_4)_2CO_3$ solutions at 90 °C, and then washed with distilled water. After that, the electrode was placed in galvanic bath (0.5 M $NiCl_2$ solution) and galvanization was done at low voltage (2 V) and electric current (10 mA/cm^2).

A „sandwich"-type dual-chamber MFC was used. The chambers were separated by Nafion 117 proton-exchange membrane. The total volume of the cell was 24 cm^3. According to the measurements different electrode material were used (woven graphite sheet, steel or aluminum sheet, *etc*.). The MFCs were inoculated with microbe cultures containing about 10^6-10^7 CFU/mL or conductive gel entrapped microbes were used. In the cathode chamber was filled with 0.1 M potassium-hexaferrocyanate as oxidant and 0.5 M Sorensen phosphate buffer (pH=7). After inoculation the MFC was connected to a digital multimeter (voltage measurement) that was also connected to PC. During the measurement the MFC was connected to a variable resistance in range of 100-1000 Ω (potentiometer) and from the voltage values with the help of Ohm's law the electric current was calculated. For the development of an air-cathode design single-chamber MFC was used in batch operation mode without redox-mediator.

The riboflavin concentration of the supernatant was measured by photometric method. Calibration curve was prepared using standard riboflavin solutions.

The protein concentration of samples was determined by modified Bradford method.

Electric conductivity of proteins was measured in a two-electrode resistance cell. 1 mL protein solution was injected and electric current was led in. The resistance/conductivity was calculated based on Ohm's law.

4. Summary of the results

4.1 Evaluation of microbes as MFC bio-catalysts

The iron(III)-reduction capability of different microorganisms with and without methylene-blue mediator was investigated. This redox phenomenom is performed through the donation of electrons to extracellular iron(III) ions through the coenzyme regeneration electron transport chain at anaerobic conditions on the outer cell membrane. It is well-known that the production of extracellular electrons is strongly correlated to the microbial propagation (primary metabolite), and the Fe^{3+}-reduction is significantly influenced by the microbial cell concentration. All of the investigated microbes except *Lactobacillus plantarum* showed relevant Fe^{3+}-reduction in the presence and in the absence of redox mediators as well. This phenomenon proposes the production of electrons and their secretion into extracellular space. In case of *Lactobacillus plantarum* species Fe^{3+}-ion reduction was detected only in the presence of methylene-blue, which means that this strain could not able to transport directly electrons to extracellular acceptors.

The novel and fast screening method was developed for the estimation of the capacity of extracellular electron production of different bacterial species. The method is based on the iron(III)-reduction capability of the selected microbes. Strong linear correlation between the microbial Fe^{3+}-reduction (**Model 1**), the cell count of the inoculation and the generated electricity was found.

$$\boldsymbol{Model\ 1:\ z = 41{,}771 \cdot x + 0{,}726 \cdot y + 1{,}513}$$

where: z: electric current density (mA/m^2), x: absorbance change on 460 nm, y: logarithm of the initial cell count (CFU/mL).

In the case of the inoculation with a higher cell count (10^6 CFU/mL), this part of model can be omitted, thus it should become simpler. The modified model is the following (***Model 2***).

$$\boldsymbol{Model\ 2:\ z = 46{,}04\ x + 4{,}17}$$

where: z: electric current density (mA/m^2), x: absorbance change on 460 nm.

The model was validated with different *Geobacter* (*G. sulfurreducens, G. toluenoxydans, G. metallireducens*) and *Shewanella* (*S. algae, S. japonica, S. woody*) species. Additionally, this model was also tested in the MFC systems and the adequate if it was confirmed by the results

observed. Summarizing, this method is suitable to predict the microbial electricity generation in MFC systems.

4.2 Determination of electrogen profile of microbes

Properties of growth and electric current generation of two barely-known bacterial species were studied. In the case of growth of *Geobacter toluenoxydans* the inhibited substrate concentration was determined to be 2 g/L sodium-acetate. The growth kinetics of this microbe can be described by the Luong model with the following kinetic constants: μ_{max} = 0.033 1/h; K_S = 0.205 g/L; n = 1.1; S_{max} = 3.10 g/L. The *Geobacter toluenoxydans* does not grow when the medium contains Na-acetate concentration higher than 3.1 g/L.

In case of the Fe^{3+}-reduction (product formation) similar inhibition of substrate concentration was also determined to be 2 g/L. The Haldene model seems to be as good as to describe the iron-reduction kinetics. The kinetic constants are the followings: μ^P_{max} = 0.12 mg Fe^{3+}/h, K_S = 0.18 g/L, K_{SI} = 1.10 g/L. When Na-acetate concentration was higher than 1.104 g/L, inhibition of the iron-reduction ability of *G. toluenoxydans* was observed.

The correlation between microbial growth and iron(III)-reduction was modeled and evaluated by the Luedeking-Piret method. According to the results both the growth rate and the number of the cell count have significant effect on the iron(III)-reduction, thus on the electricity generation.

In case of the *Shewanella xiamenensis* DSMZ 22215 strain a comprehensive electrogenic profile analysis was performed. The utilization of substrate of this strain at anaerobic condition in presence of iron(III)-ions was investigated. Meanwhile this strain grew well on both glucose and maltose substrate, whereas the maximal specific growth rate of glucose substrate was significant higher than of maltose. On the contrary, more intense of iron(III)-reduction was observed in the case of maltose media than of glucose. Furthermore, the propagation of *S. xiamenensis* can be described by the Monod model with the following constants:

glucose substrate: μ_{max} = 0.12 1/h, K_S = 0.89 g/L
maltose substrate: μ_{max} = 0.096 1/h, K_S = 1.0 g/L

In the cases of maltose or maltodextrin substrates, significantly higher iron(III)-reduction was detected than with glucose, galactose or lactose. Kinetic parameters of iron(III)-reduction

kinetics of *S. xiamenensis* on glucose or maltose substrates were determined by Lineweaver-Burk method. In the case of maltose substrate, the maximal reduction rate and K_S were 73.6 mgFe^{2+}/h and 0.196 g/L, respectively; while in the case of glucose the values were 62.5 mgFe^{2+}/h and 0.717 g/L, respectively.

The evaluation of correlation between iron-reduction and growth properties suggested that only the growth rate had significant effect on the iron-reduction on glucose substrate, while on maltose substrate, both growth rate and the number count of residing microbes had significantly affect the product formation.

The adhesive properties of *S. xiamenesis* DSMZ 22215 strain were also tested on different surfaces such as polystyrene, aluminum, stainless steel and graphite. According to the results, the *S. xiamenesis* DSMZ 22215 strain was able to bind onto all investigated surfaces. The highest attached cell count was detected on the graphite plate having fibrous structure, while on the less rough metal surfaces, the adhesion was significantly lower. The addition of iron(III)-ions to the nutrient broth relevantly decreased the adhesive properties of the microbes.

The production of electrical conductive proteins and extracellular flavin compounds (redox shuttle) of the microbe was also studied under different incubation conditions (aerobic, anaerobic+Fe^{3+}, MFC). In case of anaerobic samples significantly higher quantity of extracellular proteins (2.47±0.05 μg/10^7 CFU) were found and the electric conductivity of the proteins (0.0267 mS/10^7 CFU) were appeared to be considerably higher than the conductivity of aerobic samples (0.0172 mS/10^7 CFU). In the case of anaerobic samples amount of flavin content (8.38±0.05 μg/10^7 CFU) was significantly higher in the extracellular matrix than in the case of aerobic incubation (0.17±0.01 μg/10^7 CFU). These results confirm the assumption that flavin type materials have significant effect on the creation of electron chain of the microbes. In the presence of dissolved oxygen the terminal oxidation takes place intracellularly, therefore the synthesis of shuttle molecules is not necessary. This assumption was confirmed by that addition of exogenic riboflavin to the medium has significantly increased the electricity production of the microbe.

4.3. Engineering of electrodes for enhancement of the performance of MFC

Engineering of anode and cathode structure was performed as well. Alginate-polyaniline copolymer and graphite powder were used to create an electrically conductive gel-type electrode. Addition of 0.01 g/mL of aniline could boost the electric conductivity to 6-folds higher (from 3.4 S/mm to 21.5 S/mm), while addition of 0.02 g/mL of PANI increased

the conductivity of the gel-electrode 10-folds higher (to 35.5 S/mm). Furthermore, supplement of 0.03 g/mL and 0.05 g/mL of graphite powder increased the electric conductivity to 27.8 S/mm and to 33.3 S/mm, respectively. The simultaneous application of PANI and graphite powder significantly increased the conductivity of the electrode. Addition of 0.01 g/mL PANI and 0.03 g/mL graphite powder given a 22-folds higher in conductivity, while addition of 0.05 g/mL graphite powder and 0.02 g/mL PANI concentrations the electric conductivity increased by 105-folds higher (from 3.4 S/mm to 366 S/mm). It was worth marked that higher concentration of these compounds caused stability problems and decreased flexibility of the gel-structure. The MFC systems comparted with the conductive gel-anodes containing electrogenic culture (*Shewanella algae* DSMZ 9167) were constructed and operated in different modes: batch, semi-continuous and continuous. In batch operation the output voltage increased 1,5-folds higher in the case of 0.01 g/mL and almost double in the case of 0.02 g/mL aniline concentrations meaning two and three times higher in power-density of the fuel cell (from 1.45 W/m^3 to 3.02 and to 4,39 W/m^3). When adding 0.05 g/ml graphite powder, the voltage of the cell increased to almost the double from 0.17 V to 0.34 V, and 4 times higher in power-density from 1.45 W/m^3 to 5.77 W/m^3 were detected. The simultaneous supplementation of polyaniline and graphite resulted increase in electric performance of the MFC as well. The addition of 0.02 g/mL PANI and 0.05 g/mL graphite increase by 3-folds higher in voltage from 0.17 V to 0.44 V, and more than 7-folds higher in power-density from 1.45 W/m^3 to 9.86 W/m^3, respectively. In the semi-continuous operation mode, the electricity production was intensive and reached constant (maximum 7.88 W/m^3) soon after the inoculation. Stop of substrate feed caused rapid decrease of the electricity production and it can be started again when the new nutrient media is supplied.

The gel-electrode MFC was also investigated in continuous operation mode as well. The increase of feed rate from 0.5 mL/h to 2 mL/h resulted 2.5-folds higher power-density of the fuel cell from 0.81 to 3.55 W/m^3. The maximum of the electricity performance reached 7.92 W/m^3 at the feed rate of 3 mL/h substrate. This value was stable during the operational period. Further increase of feed rate did not change considerably the electric performance of the MFC, however the maximum power-density could be reached in earlier time. The retention of microbes in the conductive gels was also sufficient, since very minimal microbe cells was washed out. This electrode type provides the possibility to create a continuously operated MFC system, which protects the microbes from the contamination.

The copper electrode coated with nickel was developed in order to replace noble metal. This new cathode construction worked properly in a single chamber MFC system generated 330

mV output voltage, and 90 mW/m^2 of the power-density. The electric current produced is still lower than the noble metal constructions; however the specific cost of this new cathode catalyst is friendlier.

These scientific results are fundamentals, but can serve a good basic for the development of the microbial fuel cell technology.

5. Novel scientific results

1. Novel and rapid screening method was developed for the selection of microorganisms for potential application in MFC. The method is based on the measurement of absorbance of bacterial and yeast cultures at 460 nm, providing a robust and high sample throughput approach. In the case of initial cell count is at least 10^6 CFU/mL, the current density produced by certain microorganism (if the initial cell count is higher than 10^6 CFU/ml) can be estimated by the model of current density = 46.77 **Δ**A/460nm/ + 4.17 (SZÖLLŐSI *et al.*, 2015b).
2. The relationship between growth kinetics and electricity production of *Geobacter toluenoxydans* DSMZ 19350 strain in case of sodium-acetate substrate was determined. The growth kinetics of the microbe could be described by LUONG model, whereas HALDENE model was better to describe the kinetics of product formation. Substrate inhibition was observed if the Na-acetate concentration is higher than 2 g/L in case of growth kinetics as well as in case of Fe^{3+}-reduction. LUEDEKING-PIRET method was fit for the correlation between growth and iron-reduction. The method showed that both growth rate and actual cell mass significantly affect the iron-reduction and therefore the electricity production (SZÖLLŐSI *et al.*, 2015a).
3. The relation between growth kinetics and electricity production of *Shewanella xiamenensis* DSMZ 22215 strain, and the substrate utilization, adhesion properties as well as the production of extracellular conductive protein and riboflavin were evaluated. Using iron(III)-citrate as electron acceptor and maltose and maltodextrin as carbon source significantly higher iron(III)-reduction was observed, than in case of glucose, galactose or lactose substrates. The ability of the microbe to adhere on different surfaces such as polystyrene, aluminum, stainless steel or graphite was investigated. The highest adhered cell mass was detected on fila surface of graphite. Addition of iron(III)-ions in the media reduced relevantly the adhesive ability of the microbe on polystyrene. Anaerobic

incubation of the microbe culture resulted higher quantity of extracellular protein and riboflavin than at aerobic conditions. In addition exogenic riboflavin supplementation increased the electricity production of the microbe.

4. New type of conductive hydrogel electrode was formed, where microbes were entrapped in polyaniline-alginate-titanium-dioxide-graphite gel. The MFC set using this new anode was constructed and operated in different modes (batch, semi-continuous, continuous) with increased efficiency (Szöllősi *et al.*: Formation of novel hydrogel bio-anode by immobilization of biocatalysts in alginate/polyaniline/titanium-dioxide/graphite composites and its electrical performance in microbial fuel cell, Journal of Power Sources, *under review*, ref. no.: POWER-D-15-03121).
5. The cathode without any noble metal catalyst was successfully created by electroplating of nickel on copper electrode, and it was used as an air-cathode in single-chamber MFC. Even the power-density of this MFC is still low, but the cost is much friendlier than use of noble metal catalyst.

6. Conclusion and suggestions

One of the determining factor in microbial fuel cell technology is the applied microbial cultures, which are responsible for converting electrical energy from chemical bonds in substrates. In the last decade in spite of the intensive development there is a deficiency of knowledge about electricity production of microbes/microbe community and screening for electricity production. The fast screening method is based on the microbial iron(III)-reduction, and do not require any MFC infrastructures. The method is suitable for evaluation of numerous microbe species/strains simultaneous, in this way there is a possibility to extend the range of potential MFC bio-catalysts and to predict the electricity generation of the cultures.

The knowledge which is generated from growth- and iron(III)-reduction, substrate utilization, adhering- and biofilm-forming properties, extracellular conductive proteins and redox mediator production measurements is essential for utilization of *G. toluenoxydans* and *S. xiamenensis* species for different types of MFC applications (wastewater treatment or energy production). These information is very important for further strain-improvement and for create an efficient electricity production MFC design. *S. xiamenensis* DSMZ 22215 species is able to utilize maltose or maltodextrin properly. This ability makes the microbe available to be useful in MFC systems for treatment of starch based wastewaters (e.g. brewery, starch industry or paper industry wastewater).

The electrical conductive gel-anode construction provides more profit of space in anode chamber, because of high specific surface. The gel-matrix also provides appropriate protection against contaminations; therefore it will give more changes to create non-sterile, high performance microbial fuel cell systems. The gel-anodes achieved sufficiently in different operations, and it is ready to scale up to pilot scale and forward to industrial applications. The cathode electroplated by nickel will open the opportunity to create single-chamber MFC systems without any noble metal catalysts. One of the main drawbacks of cathode is the cost of noble metal catalyst, thus the new cathode provides a low-cost MFC construction approach.

The results of my PhD research are basics, but these should contribute to the spread of the MFC technology as well as offer an alternative for value-added treatment of wastewater. Moreover, my results also open new opportunities to other application of MFC technology such as in diagnostics, in energetics or even in space research.

7. Publications

Articles in journals

Journals with impact factor

Szöllősi A., Hoschke Á., Rezessy-Szabó J., Nguyen Q.D. (2015a). Novel method for screening microbes for application in microbial fuel cell. *Bioresource Technology*, 179, 123-127, (IF2013: 5,039)

Szöllősi A., Narr L., Kovács A.G., Styevkó G. (2015b). Relationship between kinetics of growth and production of exo-electrons: case study with *Geobacter toluenoxydans*. *Acta Microbiologica et Immunologica Hungarica*, 62 (3) 101-110, (IF2013: 0,780)

Conference proceeding

Szöllősi A., Bárány N., Hoschke Á., Rezessy-Szabó J., Nguyen Q.D. (2013). Effects of different substrates on growth of *Shewanella xiamenensis, Food Science Conference*, Budapest, Proceedings, 265-268.

Book chapter

Nguyen Duc Quang, **Szöllősi Attila**, Rezessyné Szabó Judit, Bujna Erika, Kun Szilárd, Hoschke Ágoston (Inpress): Mikrobák a mikrobiális üzemanyagcellákban. In: Mikrobiális üzemanyagcellák, Ed: Bélafiné Dr. Bakó Katalin. Pannon Egyetem Kiadó, 3. Fejezet (in Hungarian only)

Abstracts presented at scientific conferences

Hungarian abstracts

Szöllősi A., Hoschke Á., Rezessy-Szabó J., Nguyen Q.D. (2013) Mikrobiális energiacella vizsgálata*, 350. Tudományos kollokvium*, Budapest

Szöllősi A., Nguyen Q.D. (2014) Mikrobiális üzemanyagcella fejlesztési lehetőségei *XX. nemzetközi környezetvédelmi és vidékfejlesztési diákkonferencia*, Szolnok

International abstracts

Szöllősi A., Baranyai L., Kun Sz., Hoschke Á., Rezessy-Szabó J., Nguyen Q.D. (2012) Effect of sodium acetate on production of exo-electons by *Geobacter sulfurreducens DSMZ 12127* strain *Conference of Chemical Engineering* '12, (181. o.), Veszprém

Szöllősi A., Hoschke Á., Rezessy-Szabó J., Nguyen Q.D. (2013) Fast method for detection of exoelectron-production of microorganisms *Conference of Chemical Engineering* '13, (58. o.), Veszprém

Szöllősi A., Narr L., Hoschke Á., Rezessy-Szabó J., Nguyen Q.D. (2014) Effects of sodium-acetate on growth, reduction of Fe^{3+} and production of exoelectrons of *Geobacter toluenoxydans Conference of Chemical Engineering* '14, (170. o.), Veszprém

Szöllősi A., Hoschke Á., Rezessy-Szabó J., Nguyen Q.D. (2013). Electricity generation by single-chamber microbial fuel cell using nickel on air-cathode. *Acta Microbiologica et Immunologica Hungarica* (92. o.)

Szöllősi A., Hoschke Á., Rezessy-Szabó J., Nguyen Q.D. (2013) Enhancement of performance of microbial fuel cells using a new gel-type anode and semi-continuous fermentation, *Acta Microbiologica et Immunologica Hungarica* (245.o.)

Szöllősi A., Nguyen Q.D. (2014) Growth and Fe(III)-reduction of *Shewanella xiamenensis* on some carbohydrates *A Magyar Mikrobiológiai Társaság 2014. évi Nagygyűlése*, Absztraktfüzet, Keszthely