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The potency of electrical energy production from urine by microbial fuel cell using boron-doped diamond electrode

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The potency of electrical energy production from urine by microbial fuel cell using boron-doped diamond electrode

I Rahmawati, T A Ivandini and E Saepudin

Department of Chemistry, Faculty of Mathematics and Natural Sciences Universitas Indonesia, Kampus UI Depok, Depok 16424, Indonesia

Corresponding author's e-mail: ivandini.tri@sci.ui.ac.id

Abstract. Microbial fuel cell was developed since it is one of the prospective alternative energy and eco-friendly, using urine as the fuel and *Candida fukuyamaensis* as a biocatalyst. Boron-doped diamond was used as the electrode. At pH 7, maximum power and current densities of 109.6 mW/m^2 and 970 mA/m^2 can be obtained, respectively. The results indicated the potency of the system to produce an alternative energy. Furthermore, glucose and creatinine in urine are proposed to be responsible as the carbon sources for the metabolism of *C. fukuyamaensis*.

Keywords: MFC, urine, Candida fukuyamaensis, boron-doped diamond, glucose, creatinin

1. Introduction

In the last decades, many researches focused on finding an environmentally friendly alternative energy to replace fossil energy and batteries. Microbial fuel cell (MFC) is one of the prospective alternative energy, which is also eco-friendly. MFC converts organic material into electrical energy by using microorganisms as biocatalysts [1].

Urine is an abundant waste. Normal person can produce urine approximately 1-2 L/day, which usually useless and wasted. Urine contains many dissolved organic compounds [2] that can contaminate the environment, especially water, causing an unpleasant odor and eutrophication. On the other hand, the organic substances contained in urine are potential to be applied as fuels in MFC.

In this study, urine is used as fuel in MFC. As a biocatalyst in the system, a local yeast *Candida fukuyamaensis* UICC Y-247 is employed. This yeast was selected based on its properties, such as easinest to obtain, aerobic property, as well as relatively stable and easily grow property [3]. Boron-doped diamond (BDD) was selected as the electrode due to its superior properties among other conventional solid electrodes, including wide potential window, low background current, and high stability of the surface [4, 5]. Whereas there are many reports of BDD applications for sensors and biosensors [6, 7], a very limited work were reported to discuss its potency to produce energy. This work shows the MFC system with BDD electrodes can successfully produce electrical energy with urine as the fuel.

2. Materials and methods

The urine samples used in this study were from three women, aged 20-25 years old. KH_2PO_4, K_2HPO_4, Nafion 117, NaOH, $K_3Fe(CN)_6$, H_2SO_4, glucose, urea, creatinine, H_2O_2 3%, and other compounds were

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from Sigma or Sigma-Aldrich. *Candida fukuyamaensis* UICC Y-247 were obtained from Universitas Indonesia Culture Collection (UICC).

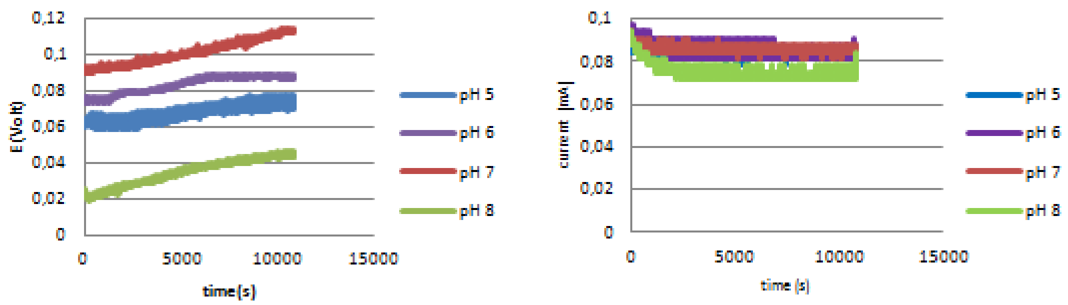
The urine was characterized for its pH as well as the content of glucose, protein and creatinine. *C. fukuyamaensis* was regenerated by transfer it into YMA medium aseptically followed by 24-h incubation. Then, the yeast from YMA were transferred into YMB aseptically and incubated for 24 h. This suspension in YMB was used as the biocatalyst in MFC experiments.

A two compartments reactor was used in this study with a total volume of 100 mL. These compartments were separated by Nafion-117 membrane. The anode compartment contained suspension of *C. fukuyamaensis* and urine, while cathode compartment contained a solution of 0.1 M phosphate buffer and 0.1 M potassium ferri cyanide solution. BDD was used as the anode with a surface area of 1 cm^2, while a spiral-shaped platinum was used as the cathode and an Ag/AgCl system was used as the reference electrode. The anaerobic anode compartment was set up by closing the compartment firmly with nitrogen gas flown to the system to prevent oxygen entrance. On the opposite, the aerobic cathode compartment was set up with an open-air compartment.

3. Results and discussion

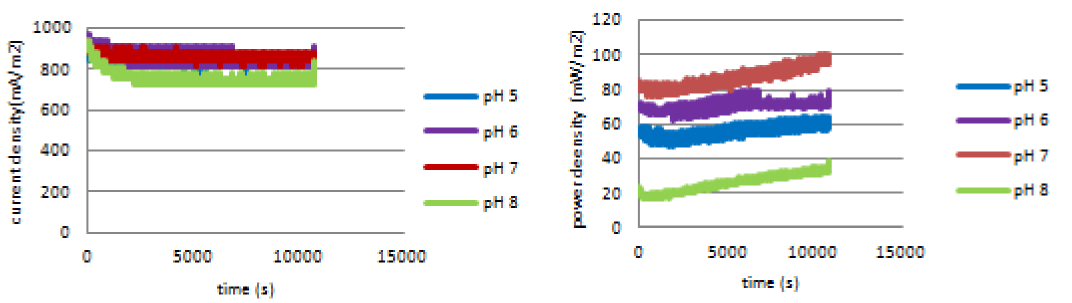
Prior to the application, urine for the fuel of the MFC fuel was characterized. The urine pH was around 6, whereas the content of glucose, other proteins, and creatinine were 0.5%, 10 mg/dL, and 0.6 mg/dL, respectively, which was in the normal range of the human urine.

Various pHs from pH 5-8 were examined to observe the effect of pH on the electrical energy produced. The pH changes in anode compartment may affect the microbial activity in substrate metabolism, which indirectly affects the produced electrical energy. The data of current and voltage produced is presented in figure 1.



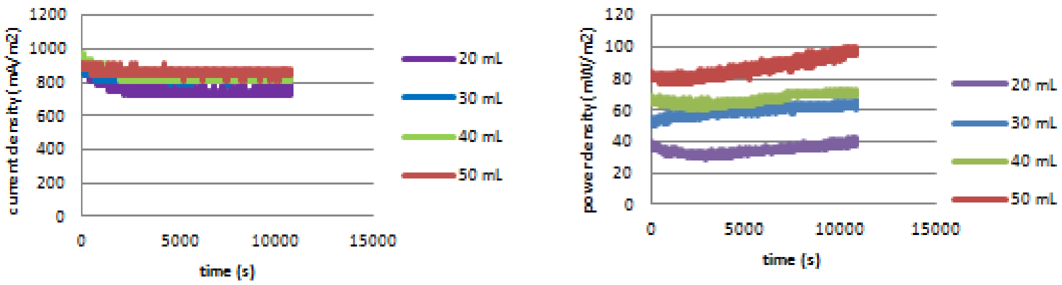
(a) (b)

Figure 1. Graph of current (a) and potential (b) measurements at various pH.



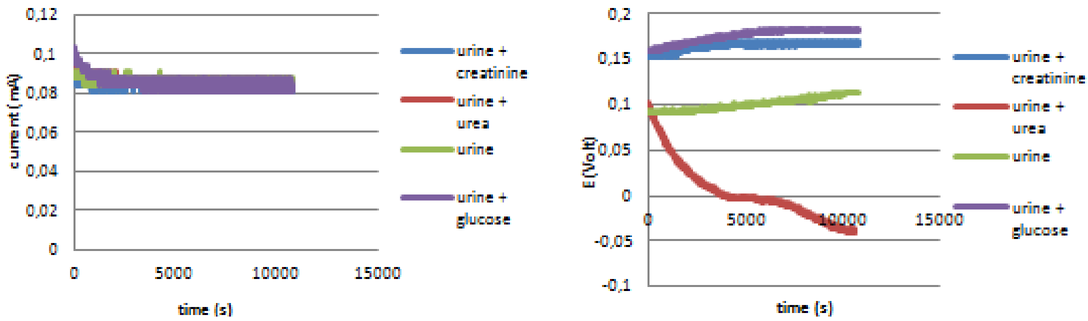
(a) (b)

Figure 2. Graphs of current (a) and power (b) densities at various pHs. The data was transformed from figure 1.



(a) (b)

Figure 3. Graph of current (a) and power (b) densities at various volume of *C. fukuyamaensis* suspension.



(a) (b)

Figure 4. Graph of current (a) and potential (b) mesaurements at various subtrates.

Conversion to the current density and power density is shown in figure 2. The figures show that the change in pH affects the electrical energy produced. At pH 7, the optimum current density and power was generated, whereas at pH 8, the generated energy significantly decreased. In this study, the measurement of energy was performed without the addition of external mediator. Therefore, it can be assumed that the generated electrons are transferred directly from microbial cells to the electrode surface or commonly called the direct electron transfer [8].

Furthermore, various volumes of *C. fukuyamaensis* suspension (20-50 mL) were examined to study the correlation between the number of microbes and the production of electrical energy. As expected the more *C. fukuyamaensis* the higher energy will be generated. The data of the current and power densities generated by the developed MFC in various amount of microbes is displayed in figure 3.

The influences of glucose, creatinine, and urea in the MFC system were also studied to confirm the main carbon sources used for the metabolisms of *C. fukuyamaensis*. Figure 4 shows the data of current and potential measurements in the system with the presence of glucose, creatinine, and urea. The data shows that the addition of glucose and creatinine in urine increase the current and power density. Meanwhile, the addition of urea into urine decreases the potential significantly as *C. fukuyamaensis* cannot metabolize urea to produce protons and electrons. In addition, the urea induced the system to be highly alkaline for *C. fukuyamaensis*. Therefore, the potential different between the cathode and the anode becomes very high, hence the potential generated become dropped dramatically.

The energy produced by the MFC was stable for 3 h. Until the second day the system was applied, the generated current and power density was stable. However, after the third day the current and power density drastically decreased to zero. The reasons may probably due to the limited substrate in urine as well as the lifetime of *C. fukuyamaensis*. Therefore, it is necessary to consider the method to input the fuel continously.

4. Conclusions

Boron-doped diamond electrodes were successfully employed in urine-based MFC with *C. fukuyamaensis* as the biocatalyst with the optimum pH of 7. Glucose and creatinine containing in urine play the role in the production of the MFC systems.

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