www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Received: 12 May 2016
Accepted: 14 July 2016
Published: 09 August 2016

Investigating the association between photosynthetic efficiency and generation of biophotoelectricity in autotrophic microbial fuel cells

Gustavo P. M. K. Ciniciato[1,2], Fong-Lee Ng[1,3], Siew-Moi Phang[1,3], Muhammad Musoddiq Jaafar[4], Adrian C. Fisher[2], Kamran Yunus[2] & Vengadesh Periasamy[4]

Microbial fuel cells operating with autotrophic microorganisms are known as biophotovoltaic devices. It represents a great opportunity for environmentally-friendly power generation using the energy of the sunlight. The efficiency of electricity generation in this novel system is however low. This is partially reflected by the poor understanding of the bioelectrochemical mechanisms behind the electron transfer from these microorganisms to the electrode surface. In this work, we propose a combination of electrochemical and fluorescence techniques, giving emphasis to the pulse amplitude modulation fluorescence. The combination of these two techniques allow us to obtain information that can assist in understanding the electrical response obtained from the generation of electricity through the intrinsic properties related to the photosynthetic efficiency that can be obtained from the fluorescence emitted. These were achieved quantitatively by means of observed changes in four photosynthetic parameters with the bioanode generating electricity. These are the maximum quantum yield (Fv/Fm), alpha (α), light saturation coefficient (Ek) and maximum rate of electron transfer (rETRm). The relationship between the increases in the current density collected by the bioanode to the decrease of the rETRm values in the photosynthetic pathway for the two microorganisms was also discussed.

Microbial fuel cells (MFCs) are a novel and promising technology currently under development with the purpose of generating electricity through bioelectrochemical processes, by taking advantage of natural microbial redox activities[1]. The engineering of such devices are found in the literature with a large variety of designs that are developed to fit with the microorganisms' needs, as well as contribute on improvements in their performance. These improvements are mainly focussed on increasing the power output through the decrease of losses such as Ohmic polarization resulting from high internal resistances, activation polarization resulting from the poor electrical contact between the microoganisms with the electrode surface, and concentration polarization resulting from the low availability of substrates[2]. The latter may result either from the poor transport of mediators or nutrients in solution, or oxygen from the atmosphere, in the case of devices using air-breathing cathodes[3]. A noteworthy type of MFC, conventionally designated as a biophotovoltaic (BPV) device, involves the use of photoautotrophic microorganisms, where the source of the electrons is suggested to be light-driven, having the generation of electricity not depending on the use of organic substrates[4]. Typical BPVs proposed in the literature consider the use of different sources of microbial biocatalysts such as algae[5], cyanobacteria[6], or even soil microorganisms associated with moss, and even plants[7]. Other bioelectrochemical devices comprising organelles, or other sub-cellular

[1]Institute of Ocean and Earth Sciences (IOES), University of Malaya, 50603 Kuala Lumpur, Malaysia. [2]Department of Chemical Engineering and Biotechnology, University of Cambridge, New Museums Site, Pembroke Street, CB2 3RA Cambridge, United Kingdom. [3]Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia. [4]Low Dimensional Materials Research Centre (LDMRC), Department of Physics, University of Malaya, 50603 Kuala Lumpur, Malaysia. Correspondence and requests for materials should be addressed to S.-M.P. (email: phang@um.edu.my) or K.Y. (email: ky225@cam.ac.uk) or V.P. (email: vengadeshp@um.edu.my)