Optimization of soil microbial fuel cell: influence of feeding duration, electrode factors and diversity factor of uncontrolled mixed microbial communities.

Meshack Imologie Simeon[1,2] and Ruth Freitag[1]

[1] Chair of Process Biotechnology, School of Engineering Science, University of Bayreuth, Germany
[2] Department of agricultural and Bioresources Engineering, Federal University of Technology, Minna
Corresponding author email: meshack.simeon@uni-bayreuth.de; s.imologie@futminna.edu.ng

ABSTRACT

The electrochemical performance of the microbial fuel cell (MFC) depends not only on the operational and design parameters, but also on biological factors (Gadkari et al., 2019). Therefore, optimization studies that incorporate the interactive effects of the main influencing factors and the contributions of the biological factor would improve the understanding of the improvement strategies needed to advance the application of MFCs in the real world. While single factor experiments are simple and less expensive to conduct, reproducibility of results of such experiments cannot be established with a high degree of confidence, especially in a complex system such as MFC.

In this study, the feeding duration (4, 6 and 8 days), electrode material (carbon felt (CF) and modified stainless steel mesh (SM)), and electrode spacing (2, 4 and 8 cm) were integrated into a single design to optimize the performance of Soil MFC for stable and useful bioelectricity. The binder component of the SM was further optimized with four polymeric binders (epoxy, PVA, PVDF, and PTFE) and a new method - pasting and reinforcement (Simeon et al., 2022). PCR amplification and sequencing of 16 S rDNA fragments were performed on the genomic DNA extracted from the MFCs, and bioinformatics analysis was performed using the QIIME2 microbiome analysis package.

The results showed that the SM with a surface modified by conductive carbon black and epoxy binder exhibited superior performance in all experimental phases and achieved a maximum power three times higher than the CF at an electrode spacing of 4 cm and a feeding duration of 8 days. PVDF produced the highest current under real-time external loading, while epoxy produced the highest and more sustained power of 487.15 + 9.5 mW/m^2 under linear polarization. Bioinformatic analysis revealed a wide bacterial diversity, with the most abundant phyla belonging to *Proteobacteria* (30-35%), *Acidobacteriota* (10-13%), *Actinobacteriota* (4-14%), *Chloroflexi* (6-9 %), *Bacteroidota* (3-9%), *firmicutes* (3-6%). Complex diversity in composition and abundance was observed mainly between anode and cathode and between sampling time points, but no statistically significant difference was observed between the two electrode materials.

This study indicates that the electrode material has the greatest influence on the sustainability and extent of bioelectricity capacity of a soil microbial fuel cell. Therefore, an increased focus on improving the electrode material would be a step in the right direction to position SMFCs as viable energy systems that can compete with the other established bio-electrochemical systems

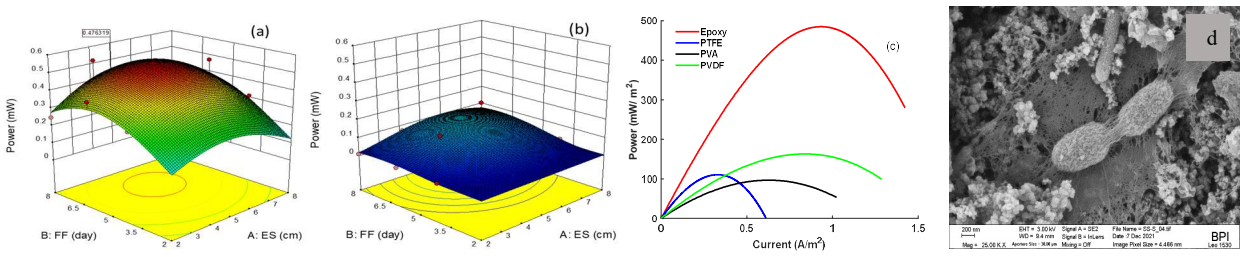

Fig 1 interactive effect of optimized parameters: (a) SM, (b) CF, (c) binders, (d) microbes-SM electrode

References:

Gadkari S, Shemfe M and Sadhukhan J (2019) Microbial fuel cells: A fast converging dynamic model for assessing system performance based on bioanode kinetics. International Journal of Hydrogen Energy 44(29): 15377–15386, 10.1016/j.ijhydene.2019.04.065.

Simeon IM, Herkendell K, Pant D and Freitag R (2022) Electrochemical evaluation of different polymer binders for the production of carbon-modified stainless-steel electrodes for sustainable power generation using a soil microbial fuel cell. Chemical Engineering Journal Advances 10: 100246, 10.1016/j.ceja.2022.100246.