UTILIZATION OF CARBONIZED COFFEE RESIDUES FOR BIOELECTRICITY GENERATION IN SEDIMENT MICROBIAL FUEL CELLS

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Overview

South Korea is experiencing a significant increase in global coffee production and a growing coffee market, primarily centered on coffee shops. This high consumption generates a significant amount of coffee residues (CR) in South Korea. CR valorization is a process of converting CR into valuable material such as biochar to minimize waste and improve environmental sustainability. Biochar is a cost-effective material with unique features such as large surface area, high electrical conductivity and excellent nutrient absorption. The sediment microbial fuel cell (SMFC) is a bioelectrochemical system that efficiently converts chemical energy in sediments and organic matter into bioelectricity through microbial oxidation. This study explores the use of CR for sediment amelioration in the anodic region of SMFC systems to verify that coffee residues can improve SMFC bioelectricity generation without any chemical modification. The integration of SMFC and CR valorization as a renewable energy source is a promising contribution to climate change mitigation and sustainability in the context of the circular economy.

Methods

The coffee residues (CR) are heated in a muffle furnace at 1000 ℃ for 1 h with prior exposure to nitrogen to improve catalytic activity and physiochemical properties of carbonized coffee residues (CCR). Different weights of CCR are employed in SMFC-0 (0g), SMFC-1 (1g), SMFC-3 (3g) and SMFC-7 (7g). Elemental analysis, Brunauer-Emmett-Teller (BET) analysis, field emission scanning electron microscopy (FESEM) and electron dispersive X-ray analysis (EDX) are performed to evaluate the elemental compositions, specific surface area, pore formations and minerals in CCR may contribute to the improvement of sediment quality. The generated current density, polarization analysis and cyclic voltammetry (CV) are performed to evaluate the overall SMFC performance for 150 days.

Results

The FESEM-EDX analysis of CCR demonstrates numerous pore formations and minerals in CCR that could contribute to the improvement of sediment quality. The specific BET surface area of CCR increases from 0.49 mg^2/g (CR) to 370.23 mg^2/g (CCR) with a total pore volume from 0.0017 cm^3/g (CR) to 0.1629 cm^3/g (CCR) due to the carbonization process at 1000 ℃. Souza et al. [1] highlighted the potential of CCR as a soil conditioner as the content of magnesium (Mg), potassium (K) and calcium (Ca) increased after carbonization by EDX analysis. The current density of SMFC-7 increases when the highest amount of CCR is inoculated during SMFC operation, which ranging from 0-170 mA/m^2, as compared to SMFC-0 (0-95 mA/m^2). The polarization analysis reveals that the SMFC-7 achieves the highest maximum power density of 33.5 mW/m^2 at the highest loading of CCR, which is due to the enhancement of redox activity in the sediment matrix that could be characterized by anodic cyclic voltammetry (CV). The high current response in anodic CV shows the enhancement of electrocatalytic activity ofthe anode in promoting the metabolism of exoelectrogens for high bioelectricity production by the addition of CCR.

Conclusions

The addition of CCR could efficiently improve SMFC performance in terms of bioelectricity production, minimization of internal resistances and improvement of redox activity. The results show that coffee residues are a cost-effective and environmentally friendly method to improve bioelectricity production and minimize environmental impacts. It is expected that the results will be useful for developing practical strategies to improve SMFC performance for high scalable performance in renewable energy production.

Reference

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