Slovak Society of Chemical Engineering
Institute of Chemical and Environmental Engineering
Slovak University of Technology in Bratislava

PROCEEDINGS

52nd International Conference of the Slovak Society of Chemical Engineering SSCHE 2026

Hotel SOREA TRIGAN
Štrbské Pleso, Slovakia
May 26 - 29, 2026

Editors: Assoc. prof. Mário Mihaľ

ISBN: 978-80-8208-177-3, EAN: 9788082081773

Published by the Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava in Slovak Chemistry Library for the Institute of Chemical and Environmental Engineering; Radlinského 9, 812 37 Bratislava, 2026

Beliančínová, K., Frišták, V.: Waste biomass-to-electrode materials: biochar-based carbon for electrochemical flow systems, Editors: Mihaľ, M., In *52nd International Conference of the Slovak Society of Chemical Engineering SSCHE 2026*, Štrbské Pleso, Slovakia, 2026.

Waste biomass-to-electrode materials: biochar-based carbon for electrochemical flow systems

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Key words: biochar, electrodes, modification, green chemistry, ascorbic acid

The valorization of plant-based waste into functional carbon materials represents a promising route for integrating waste management with advanced material engineering. In this study, lignocellulosic residues—sunflower seed shells, beech wood sawdust, cereal straw, and Chinese silvergrass—were converted into biochar via slow pyrolysis at 750 °C under a controlled nitrogen atmosphere. The process conditions were selected to promote the development of porous carbon structures suitable for electrochemical applications. The produced biochars were characterized with respect to key physicochemical parameters, including specific surface area, micropore volume, surface chemistry (pH, point of zero charge), electrical conductivity, and ion exchange capacities. Based on these properties, electrodes were fabricated either from pure biochar or as composites with reticulated vitreous carbon (RVC) at mass ratios of 70:30 and 90:10 (RVC:biochar), enabling the tuning of structural integrity and electroactive surface properties. Electrode performance was evaluated in a continuous flow electrochemical system using chronopotentiometric detection of ascorbic acid as a model compound. Operational parameters, including current density and flow conditions, were optimized to ensure stable signal response and mass transport control. The composite electrodes exhibited linear response ranges of 18–500 mg L^{-1} (70:30) and 15–500 mg L^{-1} (90:10), with minimal sensitivity to electrolyte composition. Improved repeatability and signal stability were observed for the 90:10 configuration, indicating a favorable balance between conductivity and active surface area. Application to real samples (fruit beverages and vitamin supplements) confirmed the practical applicability of the developed system. The results demonstrate that thermochemically derived biochar from waste biomass can be engineered into functional electrode materials with competitive performance in flow electrochemical systems. This approach highlights the potential for scalable integration of biomass conversion processes with the production of value-added electrochemical components.