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Ionic liquid-tuned formate dehydrogenase-carbonic anhydrase enzyme cascades: temperature- and structure-dependent activity enhancement

Boglárka Gyuris-Bocska[1], Nándor Nemestóthy[1], László Koók[1]

[1] *Research Group on Bioengineering, Membrane Technology and Energetics, University of Pannonia, 10 Egyetem Street, H-8200 Veszprem, Hungary*
e-mail: bocska.boglarka@mk.uni-pannon.hu

Key words: Formate dehydrogenase; imidazolium-based ionic liquids; enzyme cascade; carbonic anhydrase; temperature-dependent enzyme activity

The activity of formate dehydrogenase (FDH) was investigated in imidazolium-based ionic liquid (IL) – phosphate buffer systems across a wide range of solvent compositions (IL/buffer ration= 0-60 V/V %) and temperatures (T= 37 – 50°C), both as a standalone enzyme and in an FDH – CA (carbonic anhydrase) enzyme cascade. The highest FDH activity was achieved in the presence of $BmimMeSO_3$ (20m/v%; 50°C), where the maximum specific activity reached 9.05 μmol min^{-1}, corresponding to a 31.21-fold increase compared to the aqueous reference system (0% IL, 50°C). In the FDH-CA cascade system, the incorporation of CA led to a further enchantment of catalytic performance, yielding an activity increase of 1.124-fold (12.4%) compared to FDH alone.
Statistical analysis revealed that the IL concentration, temperature and the structural properties of both the cation and anion significantly influence enzyme activity, with pronounced interaction effects between these parameters. Based on multivariate statistical evaluation, an optimal parameter window was identified that maximizes FDH activity and cascade efficiency. These results demonstrate that properly tuned IL-buffer systems enable enhanced high-temperature operation and efficient integration of FDH-CA enzyme cascades, providing a promising platform for advanced bio- and bioelectrochemical C1 conversion processes.
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