MicrOLED-photobioreactor: Design and characterization of a milliliter-scale Flat-Panel-Airlift-photobioreactor with optical process monitoring

Small-scale cultivation systems with real-time-monitoring of suspension parameters are important for high-throughput bioprocess development. This manuscript describes the design and characterization of a new photobioreactor (PBR) approach using 3D-printing and organic light emitting diodes (OLEDs) in the design step. The structurally complex miniaturized PBR periphery was manufactured from polyamide using the selective laser sintering technology. The MicrOLED-PBR - the first Flat-Panel-Airlift photobioreactor (FPA-PBR) with a working volume below 20 mL - was equipped and validated with non-invasive optical sensors for cell- (microalgal dry weight concentration and chlorophyll fluorescence) and suspension parameters (pH, dO₂ and dCO₂) allowing multiparametric high-resolution physiological studies of microalgae growth at low photon flux densities. The OLED modules used in the MicrOLED-PBR were characterized with respect to their spectral photosynthetically active radiation efficiency (35.31%), maximum photon flux density (83 μmol m⁻² s⁻¹) and resulting photon flux density profiles across the layer thickness of the FPA-cultivation chamber (10 mm) according to Lambert-Beers law (150 μmol m⁻² s⁻¹ for dual-plane external illumination). The hydrodynamic properties of the FPA-cultivation chamber, i.e. its volumetric oxygen transfer coefficient kₐ a (1.5-57 h⁻¹), superficial gas velocity (0.8-42 m h⁻¹), mixing time (1.5-34.5 s) and gas hold-up (0.016-0.2) were comparable to those for lab- and production-scale FPA-PBRs at volumetric aeration rates of 0.5-5.0 L h⁻¹. The application of the MicrOLED-PBR was demonstrated for optimizing the CO₂ conditions during batch-mode growth of Chlamydomonas reinhardtii 11-32b. By analyzing the suspension dynamics in real-time limitations of dissolved carbon dioxide were identified at a CO₂ amount of 0.1 vol% whereas 2.0 vol% CO₂ was identified as optimum conditions for growing C. reinhardtii 11-32b in the MicrOLED-PBR.

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Corresponding author: Krujatz, F.
Contributors: Krujatz, F., Fehse, K., Jahnel, M., Gommel, C., Schurig, C., Lindner, F., Bley, T., Weber, J., Steingroewer, J.
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