

CONTINUOUS GAS PROCESSING WITHOUT BUBBLES USING THIN LIQUID FILM BIOREACTORS CONTAINING BIOCOMPOSITE BIOCATALYSTS

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Continuous microbial gas processing without bubbles is possible with thin liquid film, plug flow bioreactors. We have demonstrated that power input can be minimized by using a falling liquid film operating under laminar wavy flow conditions ($Re < 200$) in contact with highly concentrated living, non-growing microbes stabilized in a porous biocomposite biocatalyst. This composite materials approach to continuous gas processing can dramatically increase mass transfer rates >100 fold compared to bubble aeration, decrease process volume, significantly decrease gas-liquid mass transfer energy input, decrease water use, and increase secreted product concentration. We have shown that this approach can also increase microbial specific activity for some organisms compared to microbes suspended in liquid media. Paper-based biocomposite biocatalysts provide a rough hydrophilic surface resulting in uniform ~ 300 μm thick falling liquid films. Paper roughness enhances gas-liquid-microbe mass transfer. This mass transfer enhancement has been simulated using a finite element (FEM) CFD model. The paper structure also functions as a separation device - the secreted products are released into the falling liquid film and continuously removed from the reactor. We are investigating biocomposite biocatalyst design and stabilization using a 0.05 m^2 prototype cylindrical paper falling film bioreactor (FFBR). This approach can be used for continuous gas processing with either non-photosynthetic or photosynthetic microorganisms. Current experimental model systems we are investigating include *Clostridium ljungdahlii* OTA1 for absorbing CO from syn-gas, *Methylobacterium alkaliphilum* 20Z for absorbing CH_4 in air, and *Chlamydomonas reinhardtii* for CO_2 emissions. Critical to biocomposite biocatalyst design are generation of nanoporous coating microstructure, microbe adhesion to paper during film formation (which may include engineering the surface of the microbes), surviving osmotic shock in coating formulations, as well as desiccation tolerance to drying and prolonged dry storage. Spatially correlated Raman microspectroscopy and hyperspectral imaging techniques have been developed as a non-destructive method to monitor the distribution of residual water surrounding and within the cells. The distribution of vitrified residual water may contribute to desiccation resistance. Other types of thin liquid film reactors, such as a spinning disk bioreactor (SDBR), that enhance mass transfer by reducing liquid film thickness to <100 μm with wave induced turbulent flow using centrifugal force ($1000 \times g$) can be used in the future to further intensify continuous gas processing rates using biocomposite biocatalysts.