A Novel Aeration Technique for Enhanced Mass Transfer and Optimization of Biocatalytic Reactions

TECHNISCHE BIOKATALYSE TUHH

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Introduction

Motivation

Scalable production of chemicals:

- Application of biocatalytic reactions in large scale are getting more common

Criteria for the commercial success:

- Retention of enzyme stability in the multiphase applications[1]
- Overcoming mass transfer limitations from gas to the liquid

In the previous studies:

- Fine bubble aeration enhanced the enzyme stability[2]
- Fine bubble aeration improved the mass transfer performance[3]

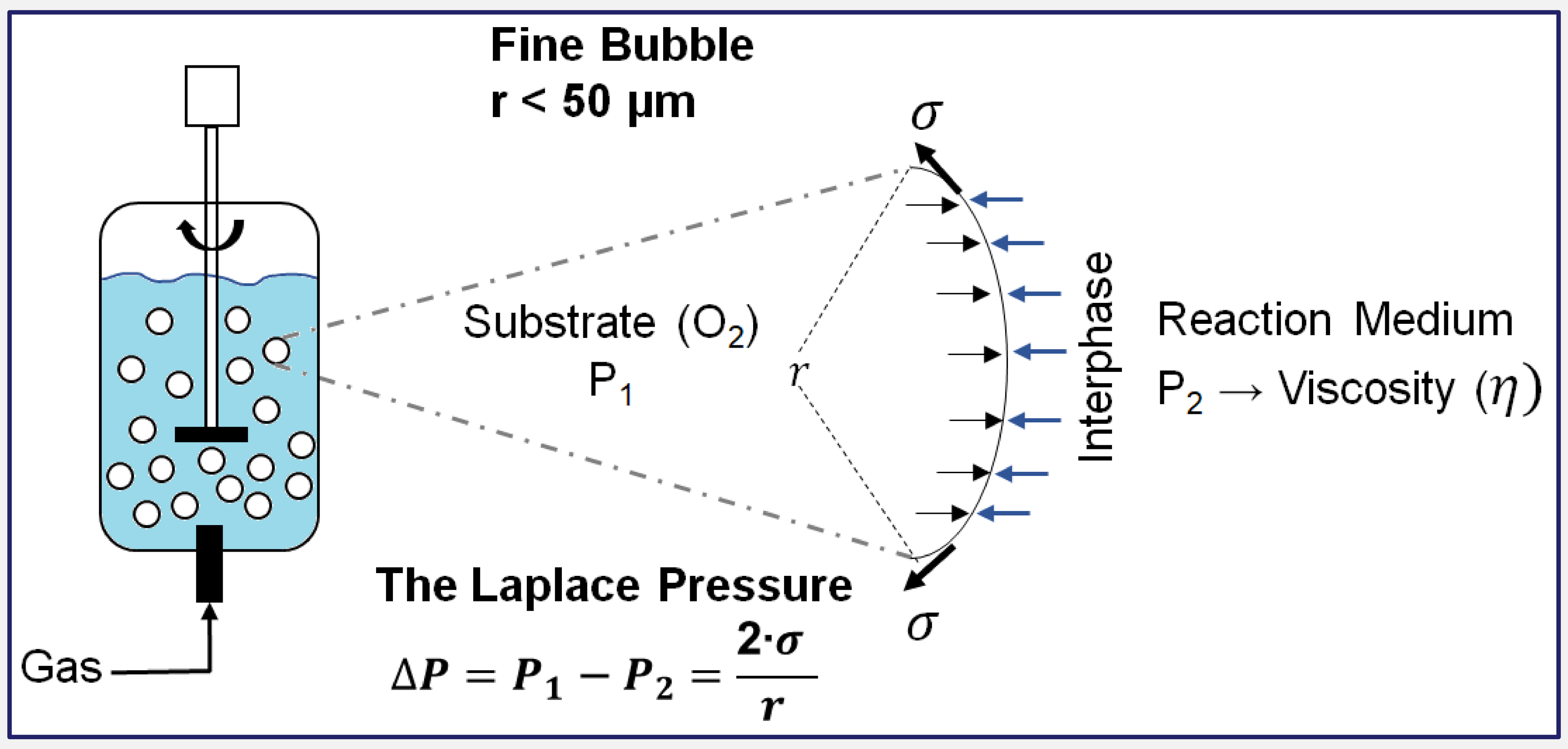


Fig. 1. Fine bubble aeration with an enhancement of the internal pressure due to reaching smaller bubble diameter. The Laplace pressure is defined as the difference in the pressure between inside and outside of the bubble.

Project Aim

Aim

Investigating innovative and sustainable approaches for:

- the applicability of fine bubble technology to various biocatalytic reactions
- the enhancement of the enzyme stability with the fine bubble technology

The reaction system: Conversion of HMF to FDCA

- **5-hydroxymethylfurfural (HMF):** Synthesized from fructose, which is derived from biomass resources
- **furan-2,5-dicarboxylate (FDCA):** Raw material of the biobased polymer PEF[4]

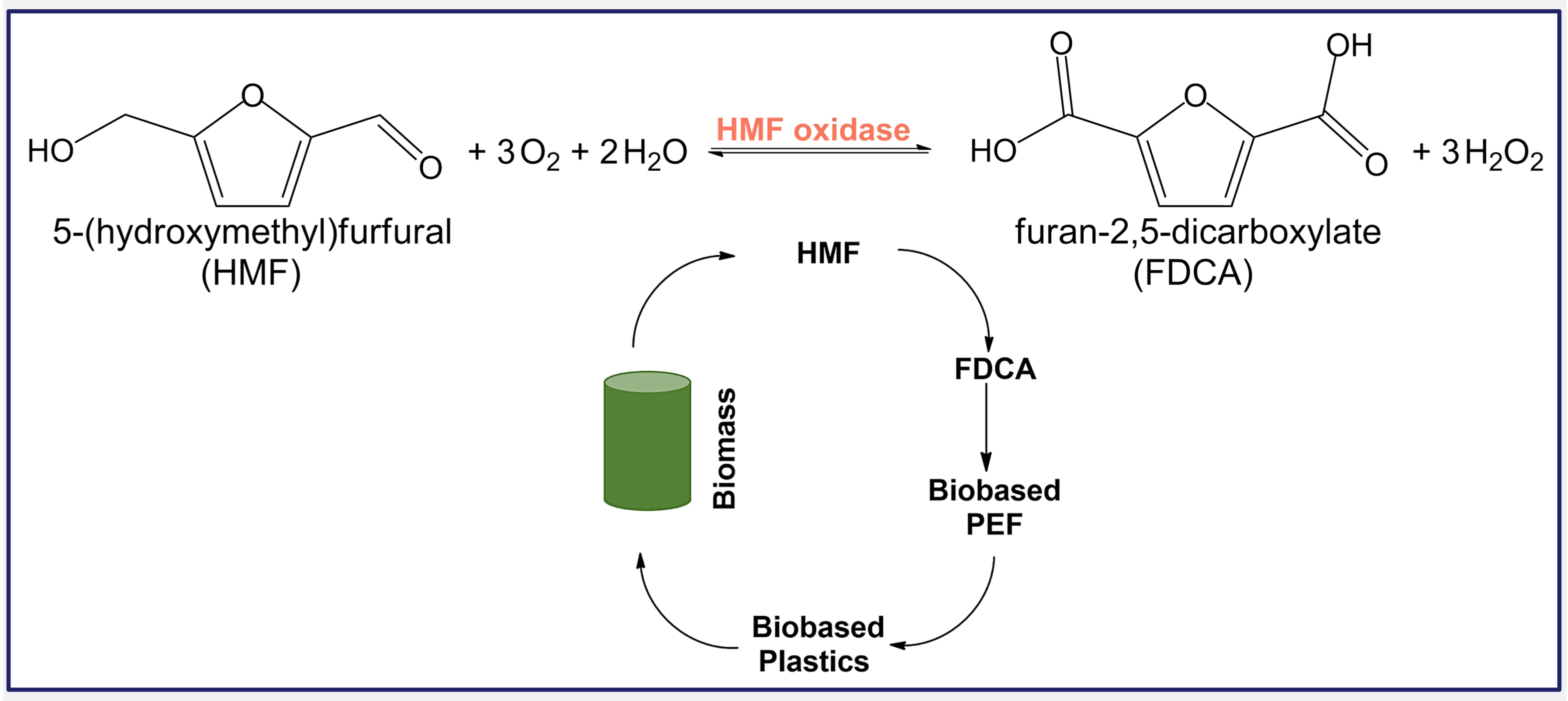


Fig. 2. Oxidation of HMF to FDCA catalyzed by HMF oxidase in water. Oxygen is used as gaseous substrate, which is dissolved using fine bubble generators.

Enhancement of Enzyme Stability

- Protein denaturation at the gas-liquid interface[6]
- Characterization of the enzyme stability in terms of half-life
- **Fine bubble aeration:** Improved the enzyme stability[2] and yields with less foam formation[7]

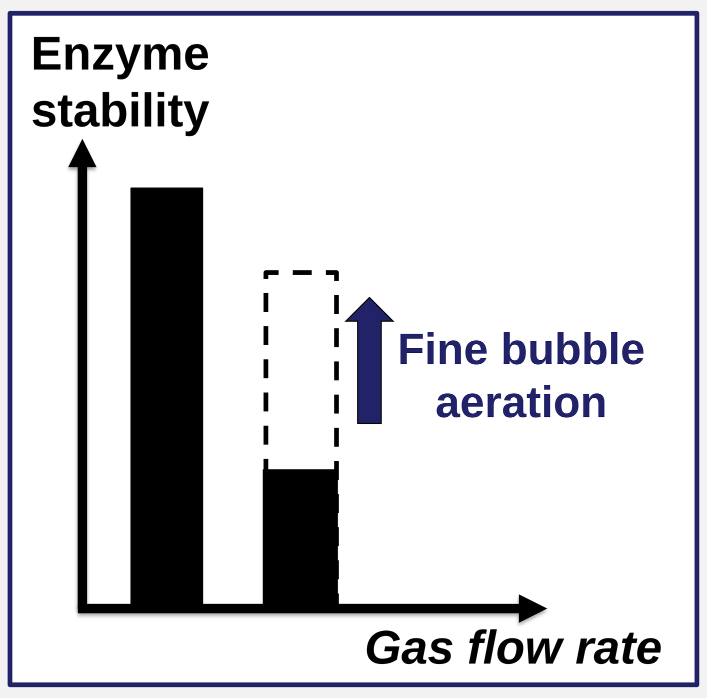


Fig. 3. Investigation of the relation between enzyme stability and gas flow rate

Reaction Rate

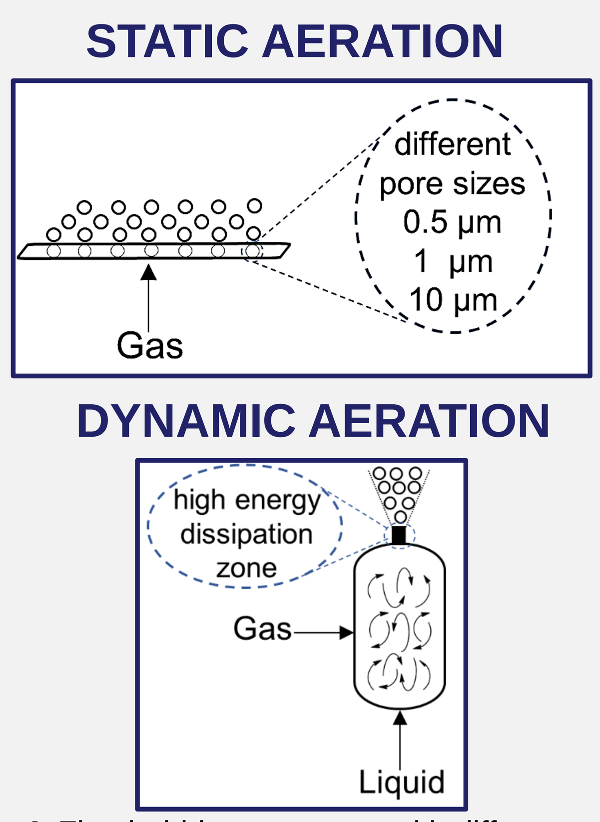
$$v(t) = v_0 \cdot e^{-k_{\text{deactivation}} \cdot (t - t_0)}$$

Enzyme Stability (half-life)

$$t_{1/2} = ln(2) \cdot k_{\text{deactivation}}^{-1}$$

Factors influencing the enzyme stability and the mass transfer performance:

- Reaction medium: Buffer, salt concentration and antifoaming agents
- Optimization of the bubble size distribution
- Fine bubble generators with various pore sizes and operating principles (static and dynamic aeration)



- Fine bubble generation through the pores of fine bubble generator
- No additional external energy[8]

- External energy as the power of a liquid jet is used
- Generating fine bubbles in a high energy dissipation zone[8]

Fig. 4. Fine bubble generators with different operating principles.

Outlook

- Developing innovative and sustainable approaches, which are continuously operated
- Evaluation of the performance metrics and enzyme stability
- Effective utilization of the gaseous substrates
- Cost analysis along with the oxygen economy
- The outcome can be used for alternative reaction systems in industry

Table 1. Performance Metrics

Reaction yield	$\frac{m_{\text{product}}}{m_{\text{substrate}}}$
Biocatalyst productivity (specific yield)	$\frac{m_{\text{product}}}{m_{enzyme}}$
Space time yield (reactor productivity)	$\frac{m_{\text{product}}}{V_{\text{reaction}} \cdot t}$

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