Evaluation of Oxygen Supply Methods for Oxidative Biocatalysis

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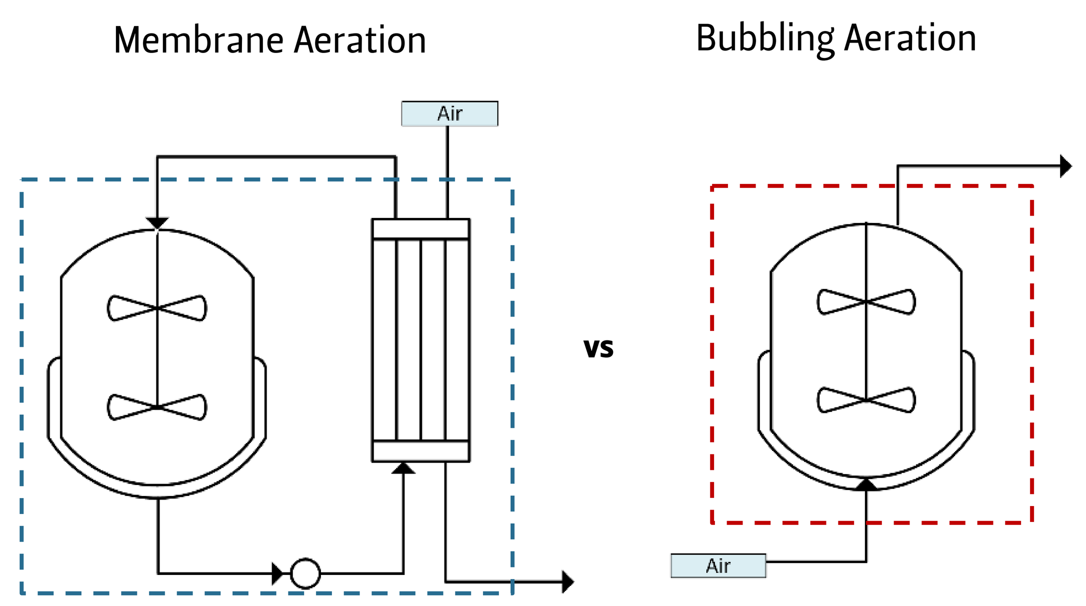
1. Motivation

When developing a feasible process for a biocatalytic oxidation reaction in order to fulfill the oxygen requirements of the biocatalyst, the mass transfer of oxygen from the gas to the liquid phase is a critical factor. In particular, when using isolated enzymes, the selection of the oxygen supply method becomes a crucial decision due to:

- Potential high rate of the reaction
- The enzymes can be inactivated at the gas-liquid interface

2. Objective

- Characterization of different membrane aeration systems based on the overall mass transfer coefficient (Ka)
- Comparison of membrane aeration systems with bubbling aeration in terms of liquid mass transfer coefficient (k_la) and oxygen transfer rate (OTR)

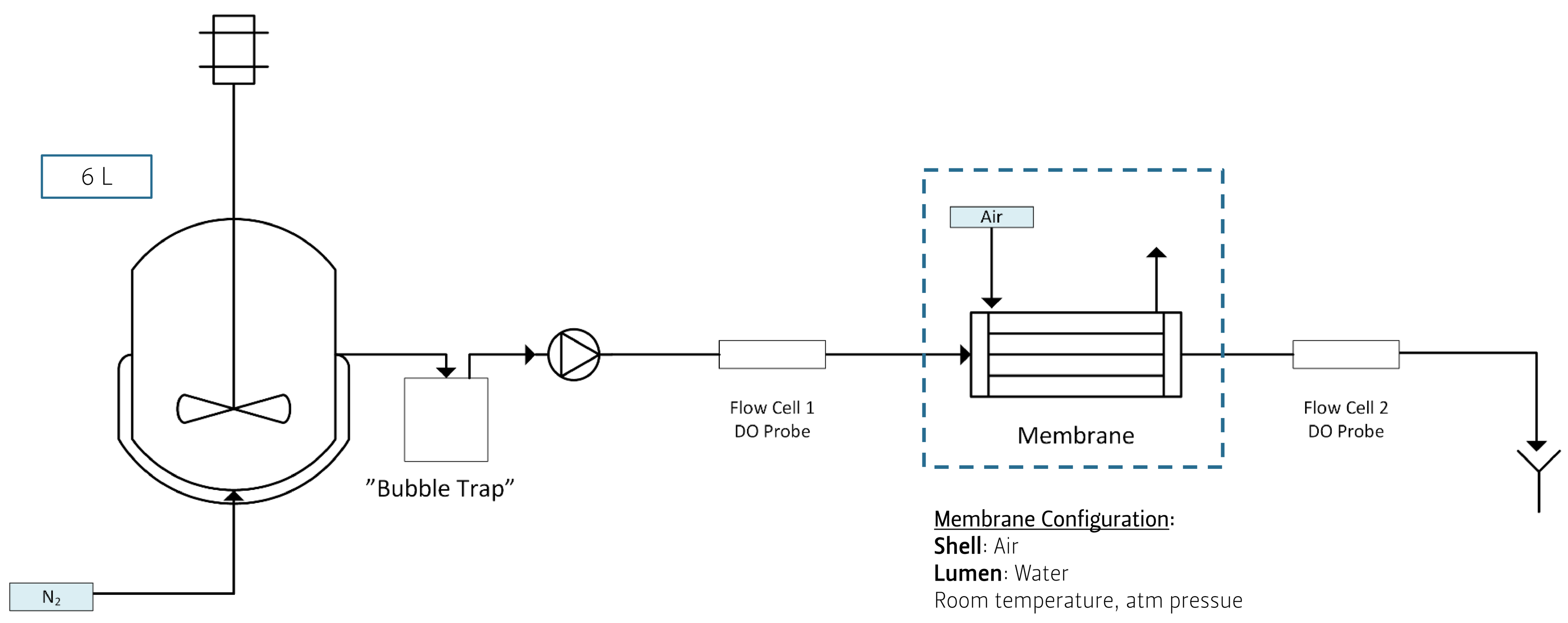


3. Characterization of Membrane Aeration Systems

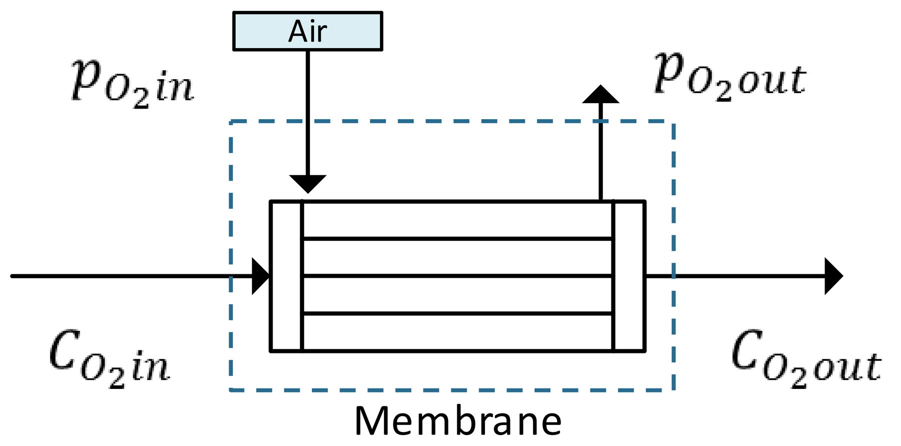
Three different hollow fiber membranes were studied:

- Porous membrane (Polyurethane)
- Non-porous membrane (PDMS)
- "Sandwich" membrane (composite, combination of porous and non-porous materials)

A method to determine the overall mass transfer coefficient (Ka) for the membranes was developed and the characterization was performed based on a steady-state approach.



Membrane Configuration:
Shell: Air
Lumen: Water
Room temperature, atm pressue



a = Specific membrane area (m^{-1})
A = Lumen active area (m^2)
Q = Liquid flow rate ($m^3\ h^{-1}$)
V_L = Liquid volume in the lumen (m^3)
ΔC_{lm} = logarithmic mean driving force (mM)
C_L = concentration of O_2 in the liquid (mM)

Flux O_2 Across Membrane:

$$OTR = Ka\Delta C_{lm} \quad a = \frac{A}{V_L}$$

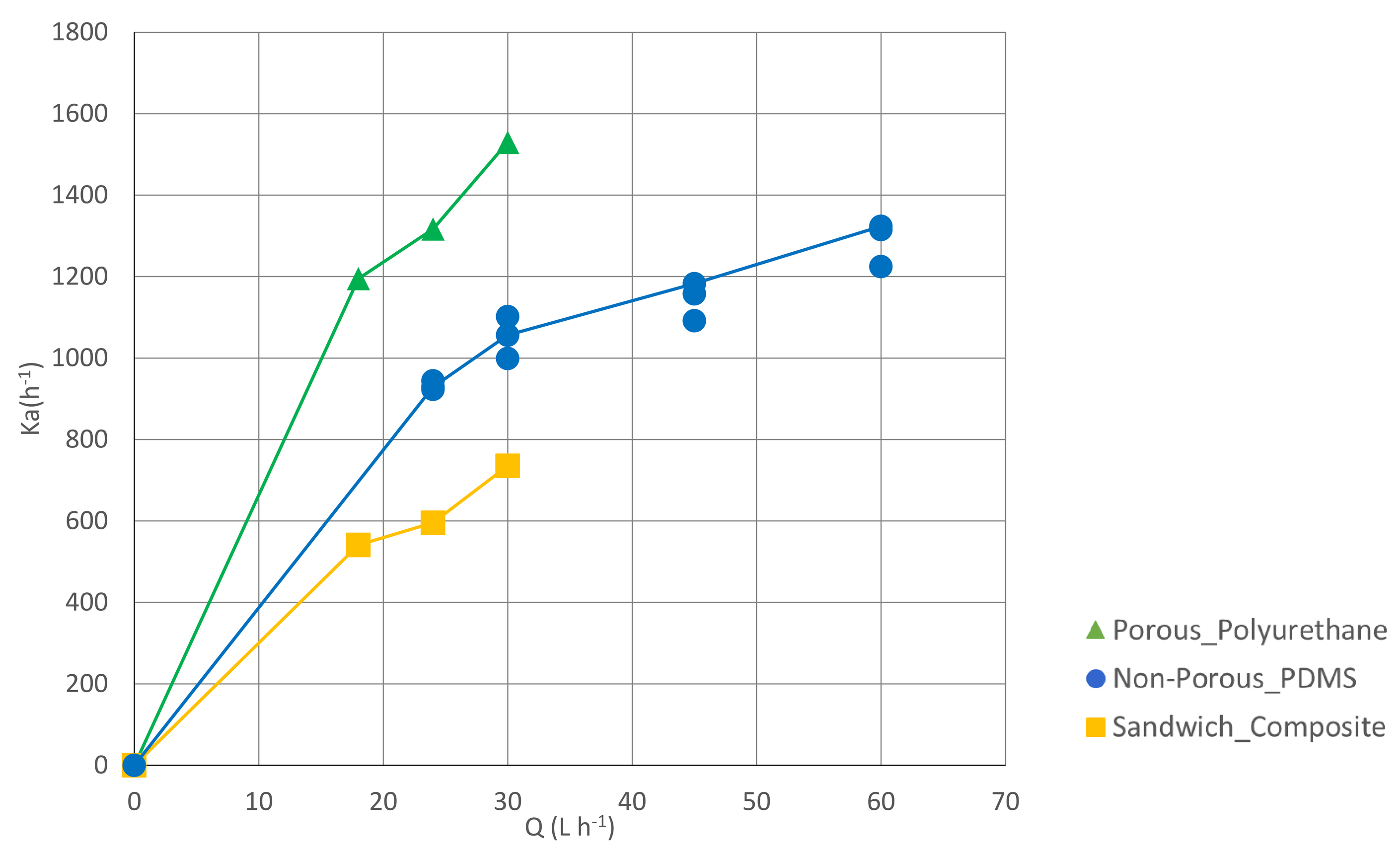
Mass Balance of O_2 on the Membrane:

$$OTR = \frac{Q}{V_L}(C_{O_2 out} - C_{O_2 in})$$

Steady- State Approach:

$$Ka = \frac{Q \cdot (C_{O_2 out} - C_{O_2 in})}{V_L \cdot \Delta C_{lm}}$$

4. Comparison of Different Membrane Aeration Systems

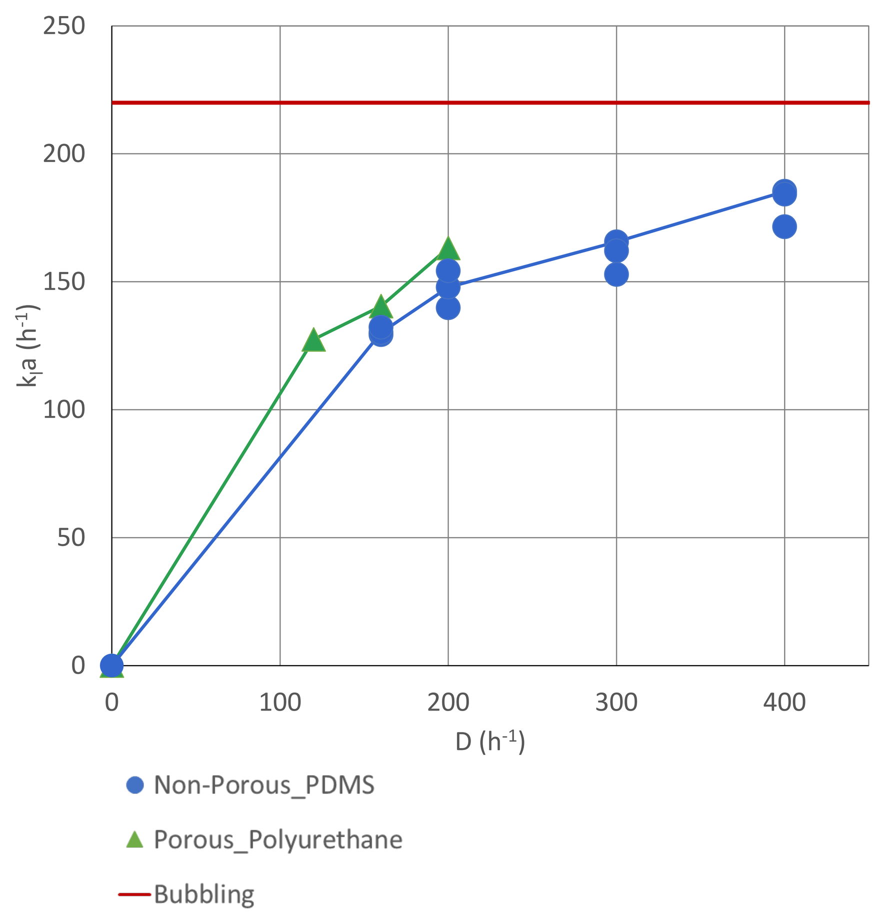


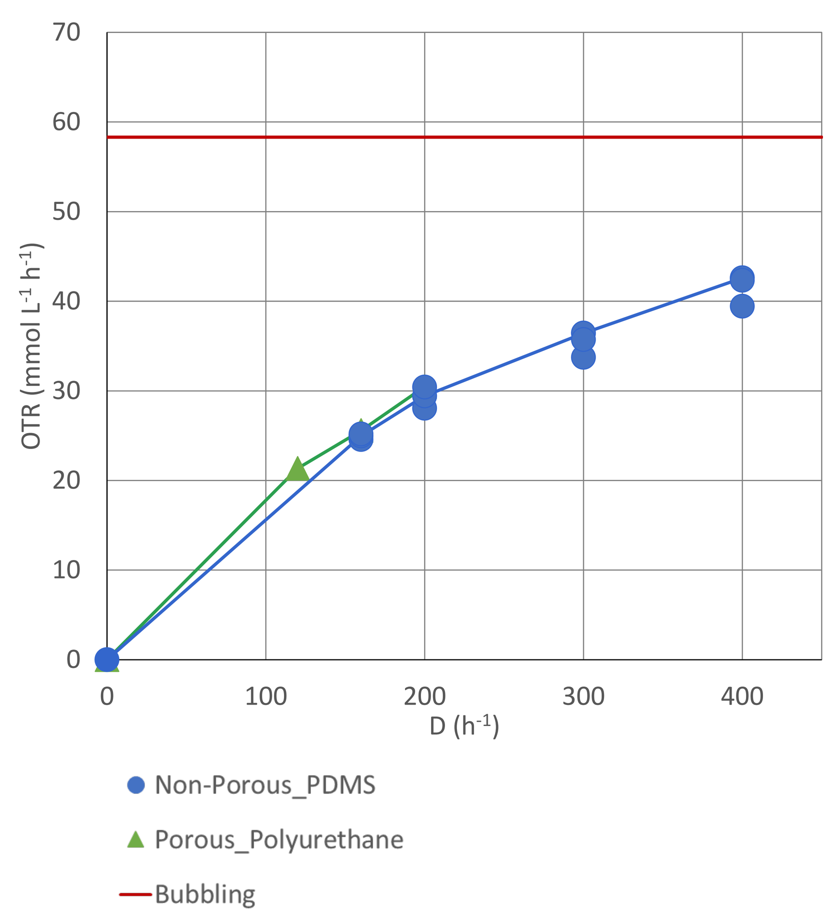
For each membrane the mass transfer coefficient increases with the increase of the liquid flow rate (linear velocity of the fluid), which shows that most of the mass transfer resistence is from the diffusion of the oxygen through the liquid boundary layer on the membrane. Therefore, the liquid film resistence has higher influence on the oxigen tranference.

Then, the overal mass transfer coefficient of the membranes (Ka) can be approximated to the liquid mass transfer coefficient (k_la).

5. Membrane Aeration vs Bubbling Aeration

The two methods were compared based on the k_la and OTR. The OTR can compare the real amount of oxygen that can be transfer to the liquid in both methods.





A standard liquid volume of 150 mL was used since oxygen transfer is problematic at small scale and not at large scale. So, the k_la for bubbling (1vvm, 10kW/m^3) was compared to the porous and non-porous membranes, normalizing the k_la values found for 150 mL reactor system. It can be seen that bubbling has a higher k_la and OTR than membrane aeration.

OTR overlap for both membrane types. This happens because the porous membrane has a higher linear velocity and a lower sectional area for the same dillution rate (D) that the non-porous membrane. Thus, the porous membrane has a lower driving force and consequently an higher kla, which leads to the same OTR in the two different membrane types.

6. Conclusions

- Oxygen supply by bubbling gives a higher OTR than by using a membrane system
- Membrane aeration has potential uses for solving enzyme inactivation at gas-liquid interface issues

Key References:

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