DISTRIBUTION OF MEDIATED OXYGEN TRANSFER RATE IN STIRRED BIOREACTORS USING OXYGEN VECTORS

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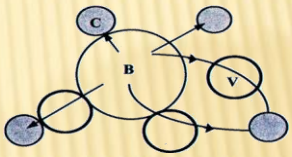
The oxygen supply into the broths constitutes one of the decisive factors of aerobic microorganisms' cultures, playing an important role in the scale-up and economy of large-scale fermentation systems. The aeration efficiency depends on the bioreactor capacity to generate high rate of oxygen diffusion from air to the broths, as well as of its transfer through the liquid phase to the microorganisms. The addition of oxygen-vectors induces the appearance of four phases in the bioreactor: the gas phase (air), the aqueous phase, the liquid organic phase, and the solid phase (biomass), as well as the formation of new interfacial areas between the gas and liquid phases.



OBJECTIVE

The aim of this study was to analyze the distribution of oxygen transfer rates in stirred bioreactor using n-dodecane as oxygen-vector for simulated, *P. shermanii*, and *S. cerevisiae* broths.

MATERIALS AND METHODS

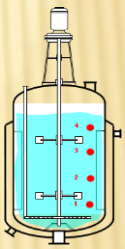
The experiments were carried out in 5 l (4 l working volume, ellipsoidal bottom) laboratory bioreactor (Biostat A, B. Braun Biotech International), with computer-controlled and recorded parameters.

In the experiments, simulated and real broths have been used:

- carboxymethylcellulose sodium salt solutions with apparent viscosity in the domain of 10 - 96 cP.
- bacteria (*P. shermanii*), C_X being of 30.5 - 120.5 g/l d.w., and apparent viscosity of 1.8 - 5.7 cP
- yeasts (*S. cerevisiae*), C_X being of 30 - 110 g/l d.w., and apparent viscosity of 2.2 - 7.8 cP.

n-Dodecane was used as oxygen-vector (oxygen solubility 54.9×10^{-3} g/l at 35°C and atmospheric air pressure). Its maximum volumetric fraction into the broth was 0.20.

For analyzing the distribution of oxygen transfer rate inside the broths, the oxygen electrode was introduced at four different positions, placed vertically from bioreactor bottom as follows: position 1: at 20 mm, position 2: at 70 mm, position 3: at 120 mm, position 4: at 170 mm.



RESULTS

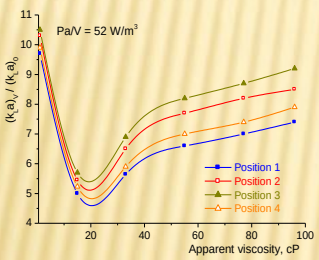
$$k_L a = \alpha \cdot \left(\frac{P_a}{V}\right)^{\beta} \cdot v_S^{\gamma} \cdot \eta_a^{\delta}$$

➢ **for simulated broths**

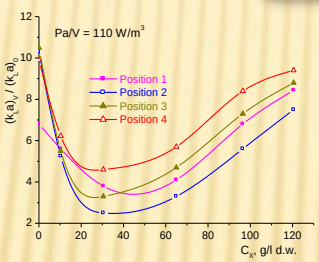
$$k_L a = \alpha \cdot \left(\frac{P_a}{V}\right)^{\beta} \cdot v_S^{\gamma} \cdot C_x^{\delta}$$

➢ **for bacterial and yeasts broths**

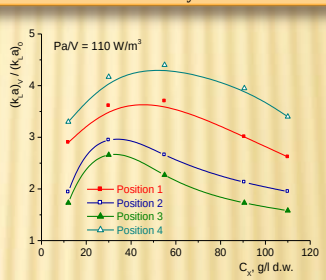
$k_L a$ = oxygen mass transfer coefficient, s^{-1}
η_a = apparent viscosity, Pa•s
P_a/V specific power input, W m^{-3}
v_S = superficial air velocity, m s^{-1}



Influence of apparent viscosity on amplification factor for different specific power inputs (v_S = 8,4x10^{-4} m·s^{-1}, Φ = 0.20)



Influence of bacterial cells concentration on amplification factor factor for different specific power inputs (v_S = 8,4x10^{-4} m·s^{-1}, Φ = 0.15)



Influence of yeasts cells concentration on amplification factor for different specific power inputs (v_S = 8,4x10^{-4} m·s^{-1}, Φ = 0.15)

Position 1

$$k_L a = 1.18 \cdot \left[\frac{\eta_a^{1.27}}{v_S^{2.12} \cdot \left(\frac{P_a}{V}\right)^{3.11}}\right]^{\phi}$$

Position2

$$k_L a = 1.12 \cdot \left[\frac{\eta_a^{3.63}}{v_S^{0.85} \cdot \left(\frac{P_a}{V}\right)^{2.35}}\right]^{\phi}$$

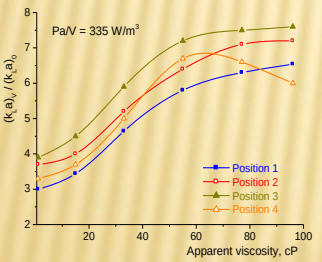
Position 3

$$k_L a = 1.72 \cdot \left[\frac{\eta_a^{1.91}}{v_S^{0.35} \cdot \left(\frac{P_a}{V}\right)^{3.10}}\right]^{\phi}$$

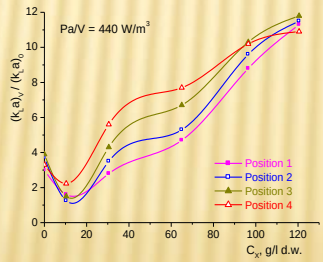
Position 4

$$k_L a = 2.17 \cdot \left[\frac{\eta_a^{2.67}}{v_S^{0.31} \cdot \left(\frac{P_a}{V}\right)^{3.77}}\right]^{\phi}$$

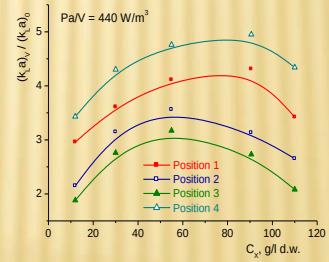
Simulated broth



Influence of apparent viscosity on amplification factor for different specific power inputs (v_S = 8,4x10^{-4} m·s^{-1}, Φ = 0.20)



Influence of bacterial cells concentration on amplification factor factor for different specific power inputs (v_S = 8,4x10^{-4} m·s^{-1}, Φ = 0.15)



Influence of yeasts cells concentration on amplification factor for different specific power inputs (v_S = 8,4x10^{-4} m·s^{-1}, Φ = 0.15)

Position 1

$$k_L a = 0.76 \cdot \left[\frac{C_X^{1.61}}{v_S^{0.46} \cdot \left(\frac{P_a}{V}\right)^{3.33}}\right]^{\phi}$$

Position 2

$$k_L a = 2.38 \cdot 10^{-2} \cdot \left[\frac{C_X^{2.27}}{v_S^{0.66} \cdot \left(\frac{P_a}{V}\right)^{8.19}}\right]^{\phi}$$

Position 3

$$k_L a = 3.81 \cdot 10^{-2} \cdot \left[\frac{C_X^{0.31} \cdot \left(\frac{P_a}{V}\right)^{0.15}}{v_S^{0.66}}\right]^{\phi}$$

Position 4

$$k_L a = 3.74 \cdot 10^{-2} \cdot \left[\frac{C_X^{0.15} \cdot \left(\frac{P_a}{V}\right)^{0.25}}{v_S^{8.7210^{-2}}}\right]^{\phi}$$

***P. shermanii* broth**

Position 1

$$k_L a = 8.91 \cdot 10^{-2} \cdot \left[\frac{C_X^{8.4610^{-2}}}{v_S^{0.39} \cdot \left(\frac{P_a}{V}\right)^{0.17}}\right]^{\phi}$$

Position 2

$$k_L a = 7.10 \cdot 10^{-2} \cdot \left[\frac{C_X^{1.95}}{v_S^{0.74} \cdot \left(\frac{P_a}{V}\right)^{3.81}}\right]^{\phi}$$

Position 3

$$k_L a = 6.12 \cdot 10^{-3} \cdot \left[\frac{C_X^{0.81} \cdot \left(\frac{P_a}{V}\right)^{0.11}}{v_S^{1.6010^{-2}}}\right]^{\phi}$$

Position 4

$$k_L a = 9.16 \cdot 10^{-3} \cdot \left[\frac{C_X^{0.33} \cdot \left(\frac{P_a}{V}\right)^{0.32}}{v_S^{6.2610^{-2}}}\right]^{\phi}$$

***S. cerevisiae* broth**

Conclusions

The addition of oxygen-vector, namely n-dodecane, leads to the enhancement for several times (from 2.2 until 9) of oxygen transfer rate compared to the conventional aerobic fermentations, without supplementary mixing or aeration intensification. However, the influence of oxygen-vector on $k_L a$ value and distribution inside the broths has to be analyzed in relation with the broth characteristics (apparent viscosity or biomass concentration), bioreactor operating parameters, and, most important, affinity of cells for hydrocarbon droplets.

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