

Measuring Oxygen Transfer Coefficients in Multiphase Bioprocesses: The Challenges and the Solution

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Abstract : Accurate quantification of the overall volumetric oxygen transfer coefficient (KLa) is ubiquitously measured in bioprocesses by analysing the response of dissolved oxygen (DO) to a step change in the oxygen partial pressure in the sparge gas using a DO probe. Typically, the response lag (τ) of the probe has been ignored in the calculation of KLa when τ is less than the reciprocal KLa, failing which a constant τ has invariably been assumed. These conventions have now been reassessed in the context of multiphase bioprocesses, such as a hydrocarbon-based system. Here, significant variation of τ in response to changes in process conditions has been documented. Experiments were conducted in a 5 L baffled stirred tank bioreactor (New Brunswick) in a simulated hydrocarbon-based bioprocess comprising a C14-20 alkane-aqueous dispersion with suspended non-viable *Saccharomyces cerevisiae* solids. DO was measured with a polarographic DO probe fitted with a Teflon membrane (Mettler Toledo). The DO concentration response to a step change in the sparge gas oxygen partial pressure was recorded, from which KLa was calculated using a first order model (without incorporation of τ) and a second order model (incorporating τ). τ was determined as the time taken to reach 63.2% of the saturation DO after the probe was transferred from a nitrogen saturated vessel to an oxygen saturated bioreactor and is represented as the inverse of the probe constant (KP). The relative effects of the process parameters on KP were quantified using a central composite design with factor levels typical of hydrocarbon bioprocesses, namely 1-10 g/L yeast, 2-20 vol% alkane and 450-1000 rpm. A response surface was fitted to the empirical data, while ANOVA was used to determine the significance of the effects with a 95% confidence interval. KP varied with changes in the system parameters with the impact of solid loading statistically significant at the 95% confidence level. Increased solid loading reduced KP consistently, an effect which was magnified at high alkane concentrations, with a minimum KP of 0.024 s⁻¹ observed at the highest solids loading of 10 g/L. This KP was 2.8 fold lower than the maximum of 0.0661 s⁻¹ recorded at 1 g/L solids, demonstrating a substantial increase in τ from 15.1 s to 41.6 s as a result of differing process conditions. Importantly, exclusion of KP in the calculation of KLa was shown to under-predict KLa for all process conditions, with an error up to 50% at the highest KLa values. Accurate quantification of KLa, and therefore KP, has far-reaching impact on industrial bioprocesses to ensure these systems are not transport limited during scale-up and operation. This study has shown the incorporation of τ to be essential to ensure KLa measurement accuracy in multiphase bioprocesses. Moreover, since τ has been conclusively shown to vary significantly with process conditions, it has also been shown that it is essential for τ to be determined individually for each set of process conditions.

Keywords : effect of process conditions, measuring oxygen transfer coefficients, multiphase bioprocesses, oxygen probe response lag

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