A Deeper Look at Oxygen Desorption in Wine

By: Steven Sutton, Robert Pott, Wessel Du Toit

South African Grape and Wine Research Institute
Department of Viticulture and Oenology
Stellenbosch University

UNIVERSITEIT iYUNIVESITHI STELLENBOSCH UNIVERSITY

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BACKGROUND:

The removal of excess dissolved oxygen from wine prior to bottling is commonly done in winemaking. A widely used method involves sparging nitrogen through the wine in a vessel, in a process known as desorption. The desorption rate can be modeled on this simplified equation:

$$OTR = \frac{dC_{O2}}{dt} = k_L a\left(C_{O2,Liquid} - C_{O2,Gas}\right)$$

An indicator of the rate of desorption is the oxygen desorption volumetric mass transfer coefficient ($k_L a$), which can be determined experimentally. Factors that affect $k_L a$ are the physico-chemical properties of the solution and gas in the vessel, the operating conditions, and the vessel and sparger design.

Winemakers have pointed out that under similar conditions, the desorption of oxygen from different wines sometimes occurs at different rates. This suggests that differing concentration of certain components in wine increase or decrease the oxygen desorption rate. There has been little work evaluating how different concentrations of certain components in wine directly effect the desorption rate. A few studies have been done focusing on oxygen *absorption* during the fermentation process of winemaking, and some of this information is applicable to desorption as they are analogous phenomenon.

SELECTED PREVIOUS WORK:

Oxygen desorption:

- Oxygen desorption in a model wine solution increases when the dissolved CO2 in wine is greater (Devatine et al., 2007)
- Increasing temperature increases both absorption and desorption rates. A common correlation is $k_L a(T) = k_L a\,(20°C) * 1.024^{(20-T)}$
- The rate at which oxygen desorption and absorption improves with increasing gas velocity depends on vessel dimensions and flow characteristics (Besagni et al., 2018)

Oxygen absorption in wine:

- The oxygen absorption rates for white wine, pink wine, red wine and a model wine solution were not significantly different. The oxygen absorption rate was not affected by SO2 or polyphenols (Chiciuc et al., 2010)
- Fully saturating wine must with carbon dioxide dropped the oxygen absorption rate by an order of magnitude (Devatine et al. 2007)
- The oxygen absorption rate dropped significantly when biomass was introduced into a synthetic wine solution (Moenne, 2013)

AIMS:

- To examine how temperature and gas velocity, as well as ethanol, glycerol and sugar levels, effect the oxygen desorption $k_L a$ in a model wine solution.
- To determine the oxygen desorption $k_L a$ in wine relative to a model wine solution and to evaluate whether the above components can account for any difference in the oxygen desorption rates in different wines

It was found that in model wine solutions, changing the ethanol and glycerol concentration, *in the ranges found in wine*, had no effect on the oxygen desorption rate and $k_L a$. A strong correlation was shown between superficial gas velocity, temperature and the oxygen desorption $k_L a$. The strength of the correlations are shown in Figure 1.

It was found that one white wine had a similar oxygen desorption rate and $k_L a$ to a model wine solution, while another wine had a significantly lower rate. This does indicate that certain properties and components in some wines can significantly affect the desorption rate.

Figure 1: Pareto chart showing the standardised effects of changing the below variables on the oxygen desorption kla

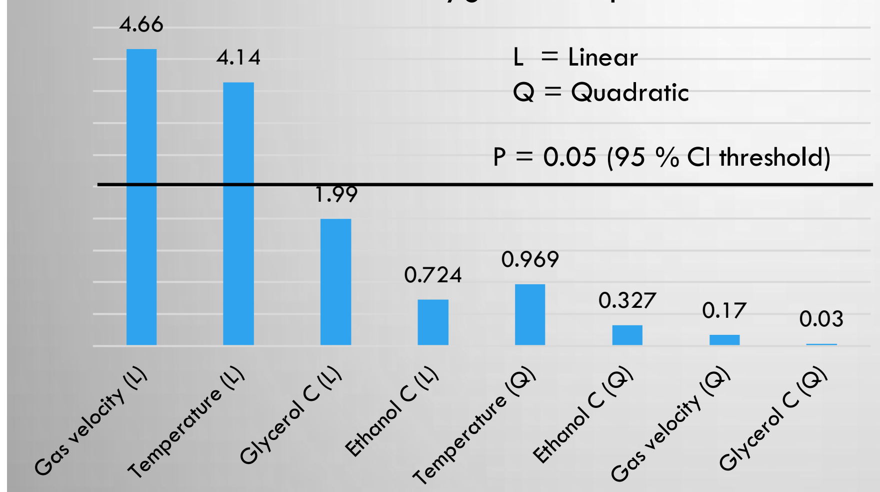
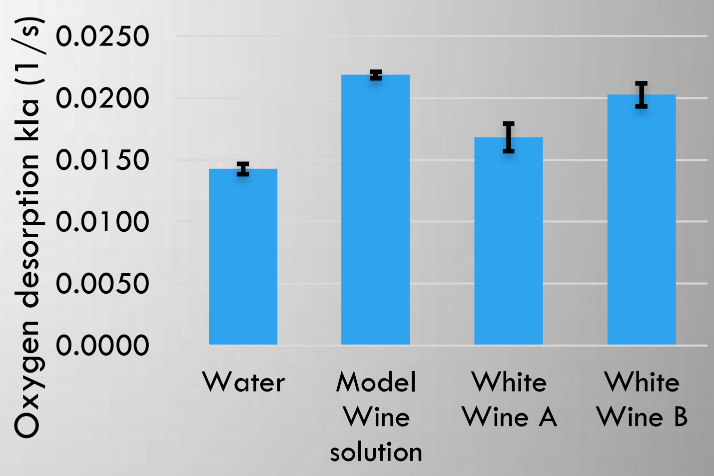


Figure 2: Oxygen desorption kla for water, model wine solution and white wines



It was found that an ethanol concentration of as little as 0.05% increased the oxygen desorption $k_L a$ significantly relative to pure water. Beyond this, the $k_L a$ did not change significantly. The results are shown below in Figure 3.

It was found that adding sugar to pure water increased the oxygen desorption $k_L a$. Raising the sugar level up to 40 g/L in a 10 % v/v ethanol solution did not affect the oxygen desorption $k_L a$. The results are shown in Figure 4.

Figure 3: Oxygen desorption kla for different ethanol solutions

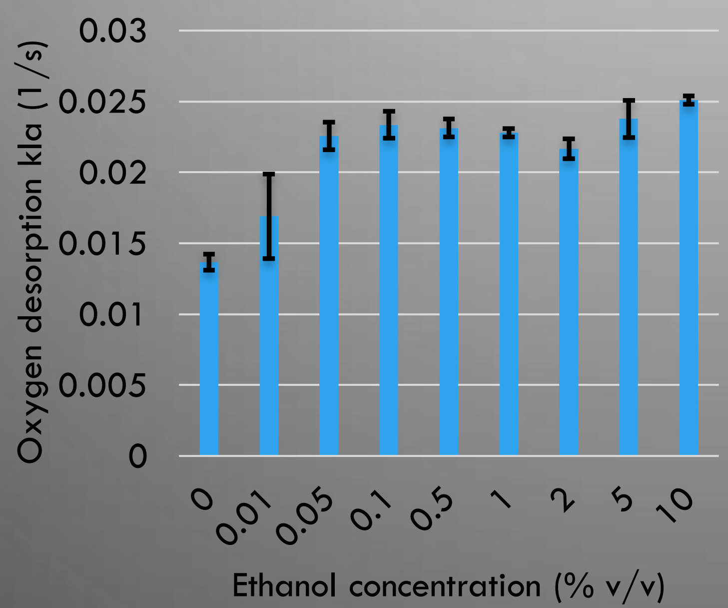
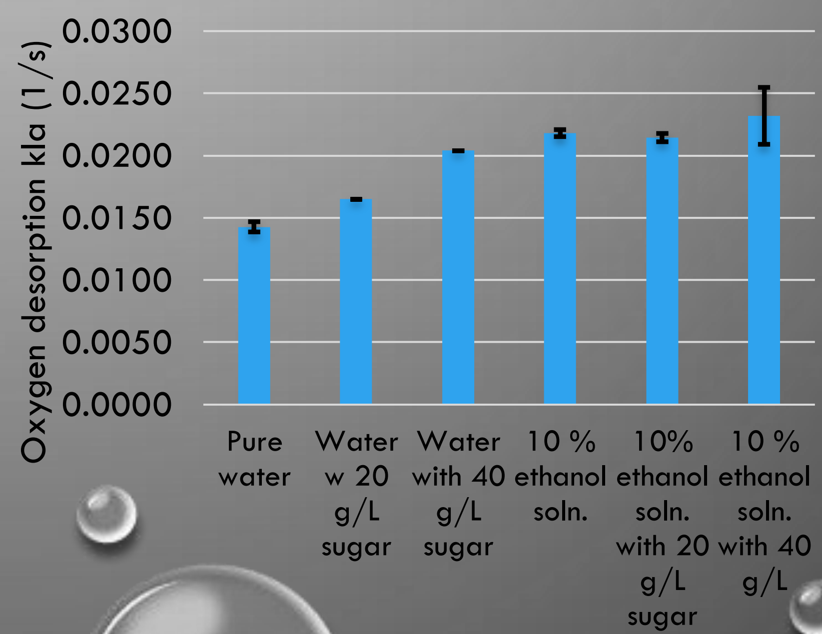


Figure 4: Oxygen desorption kla for different sugar concentrations in pure water and 10% ethanol solutions



References:

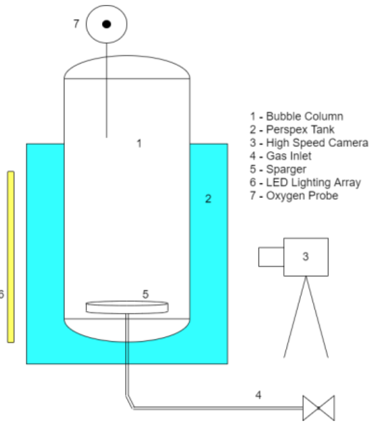
Besagni, G., Inzoli, F., & Ziegenhein, T. (2018). Two-Phase Bubble Columns: A Comprehensive Review. *ChemEngineering*, *2*(2), 13. https://doi.org/10.3390/chemengineering2020013

Chiciuc, I., Farines, V., Mietton-Peuchot, M., & Devatine, A. (2010). Effect of wine properties and operating mode upon mass transfer in micro-oxygenation. *International Journal of Food Engineering*, *6*(6). https://doi.org/10.2202/1556-3758.1770

Devatine, A., Chiciuc, I., Poupot, C., & Mietton-Peuchot, M. (2007). Micro-oxygenation of wine in presence of dissolved carbon dioxide. *Chemical Engineering Science*, *62*(17), 4579–4588. https://doi.org/10.1016/j.ces.2007.05.031

Moenne, I. M. (2013). *Oxygen Management During Alcoholic Fermentation.* Pontificia Universidad Catolica De Chile.

METHOD:



- The solution was placed into a 15 L bubble column
- The solution was saturated with oxygen using air through a stone sparger
- Once the system was stable, nitrogen was sparged through the bubble column, controlled using a flowmeter
- A polarographic oxygen probe measured the response
- The data was captured and $k_L a$ determined using the following equation:

$$\ln\left(\frac{C_{O2}}{C_{O2,i}}\right) = k_L a\,.\,t$$

RESULTS:

Changing ethanol (9-15% v/v) and glycerol (5-25g/L) concentrations in an aqueous solution had no significant effect on the oxygen desorption $k_L a$. This was unexpected as the physico-chemical properties of the solution change in the ranges tested. Consequently, a study was done on a wider range of ethanol concentrations. The results are shown in Figure 3.

It was found that raising the ethanol concentration to 0.05% increased the $k_L a$ significantly relative to water. Beyond this the $k_L a$ did not increase significantly.

Experiments were done to look at whether sugar in the presence of ethanol would affect the oxygen desorption $k_L a$. The results are shown in Figure 3. In the ranges tested, the addition of sugar to pure water increased the desorption $k_L a$, while the addition of sugar to a 10% ethanol solution did not affect the desorption $k_L a$. It is likely that the presence of ethanol in an aqueous solution disrupted the effect that sugar had on the desorption rate.

The desorption rate of a model wine solution (10 % ethanol, 15 g/L glycerol) was compared to two wines. The desorption rate was slower in wine A, while it was similar in wine B. It may be that there is a component in wine A at a concentration great enough to slow the oxygen desorption rate.

CONCLUSIONS:

- A model wine solution of ethanol and glycerol may overestimate the oxygen desorption $k_L a$ in wine.
- It is unlikely that it is the different levels of ethanol, glycerol, and sugar (below 40g/L) in wines that affect the rate of oxygen desorption. This indicates that other components within wine have a significant effect on the desorption $k_L a$.
- Oxygen desorption is significantly improved with the introduction of as little as 0.05 % ethanol. This would result in big differences in oxygen desorption in grape must vs wine.

FOLLOW UP:

- Further wines will be tested to determine how oxygen desorption varies in them relative to the model wine solution.
- The effect that components such as salts, acids and pH have on oxygen desorption in water and ethanol solutions will be examined.