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Studying the effect of wine type, temperature and carbon dioxide on the volumetric mass transfer coefficient (K_La) during nitrogen-induced oxygen removal in wine

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Introduction

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Where does O_2 come in contact with wine?

Images: Biorender

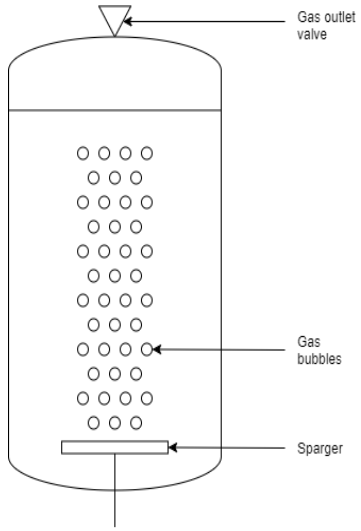
Introduction

- Oxidation: ↓ ↓ Varietal thiols, GSH and SO_2
- ↓ Certain acetate esters, others, higher alcohols, MZP –
- ↑ Acetaldehyde, methional, certain furfurals

7 mg/L → 12 mg/L → 17 mg/L → 22-30 mg/L

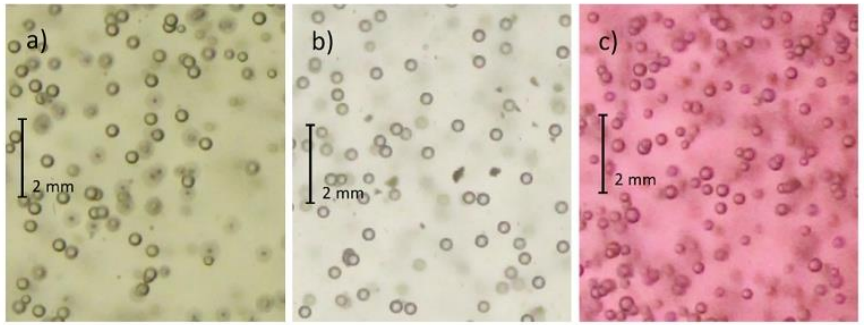
Coetzee, 2014

Oxygen removed: sparging

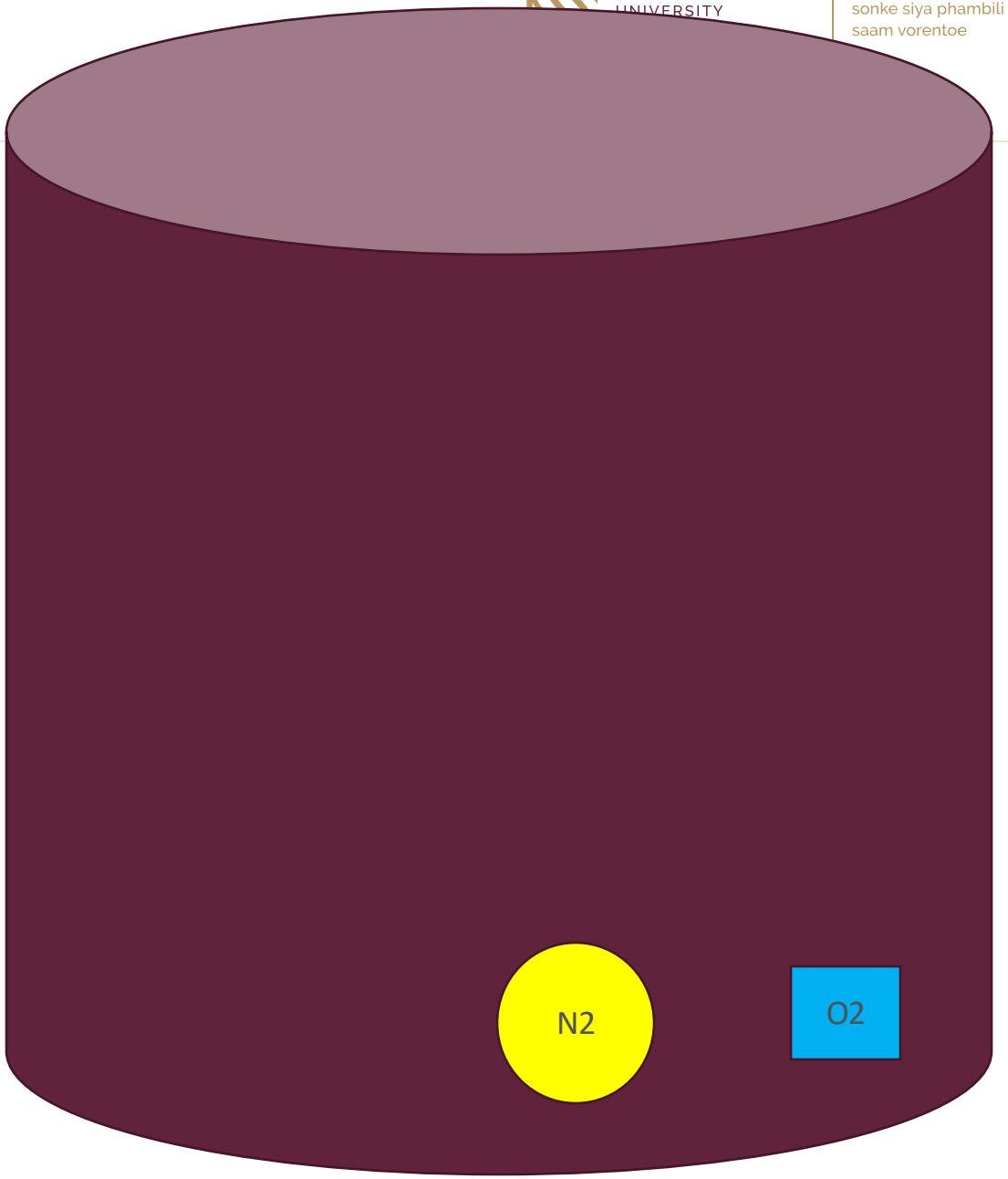


Reduce both O_2 and CO_2 concentrations

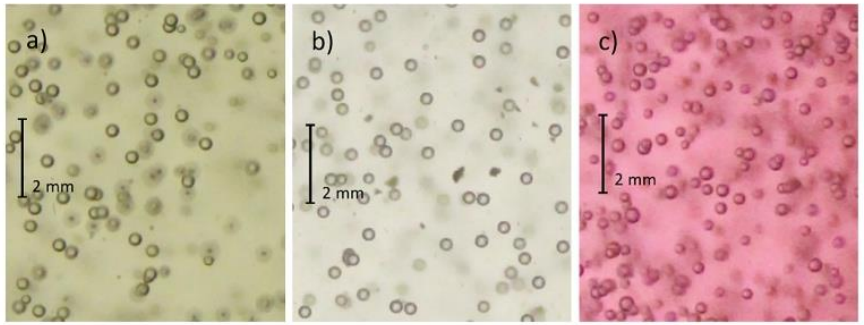
Mass transfer kL



Sutton, 2022



Mass transfer kL



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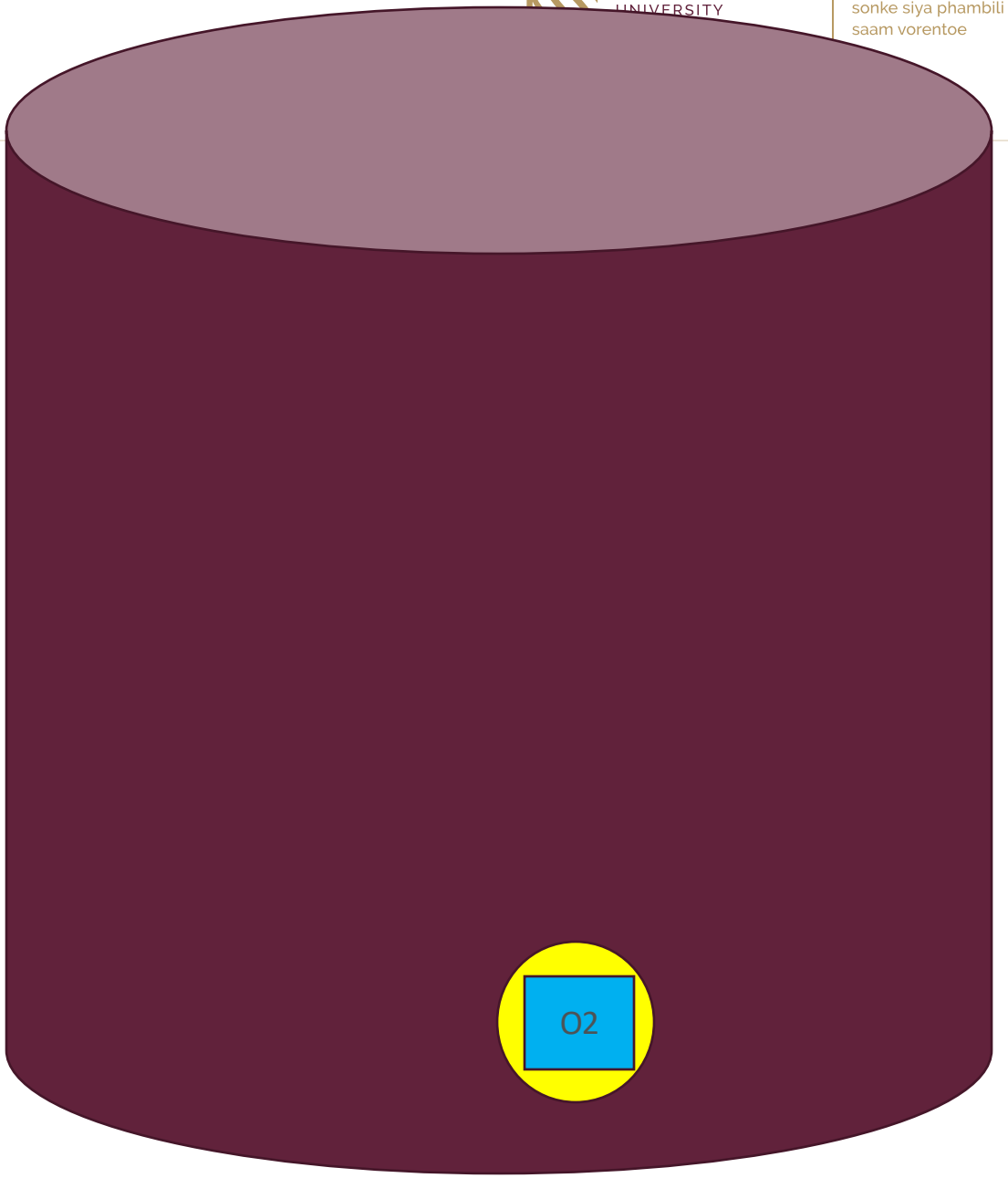
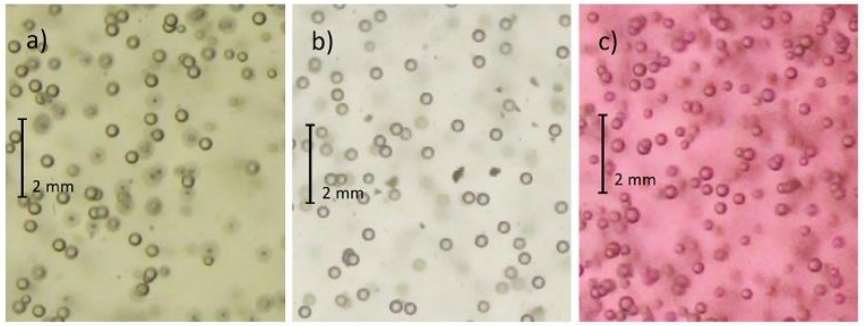


Mass transfer kL



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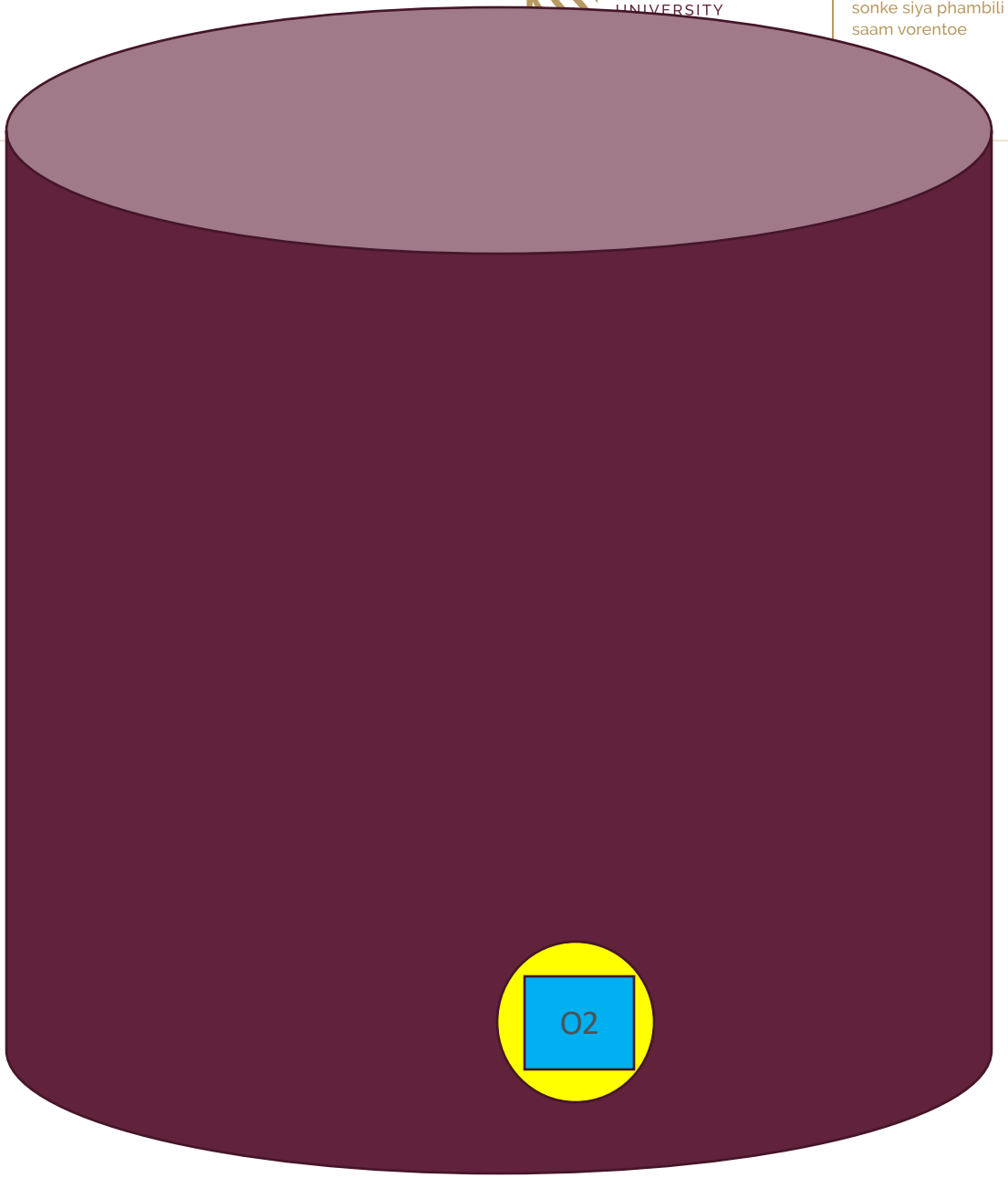
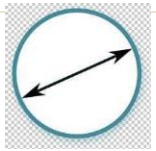


A few terms to keep in mind

- Sauter mean bubble diameter 
- Gas holdup 
- interfacial area (a)  surface area available for gas exchange/ unit volume of liquid
- oxygen mass transfer coefficient (k_L): Reflects the resistance to mass transfer within the liquid phase, particularly at the interface.
- volumetric mass transfer coefficient ($k_L a$): This is the product of the liquid-side mass transfer coefficient and the specific interfacial area.

Previous work

Australian Journal of Grape and Wine Research 28, 450–458, 2022

Sparging of white wine

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Desorption of oxygen from wine and model wine solutions in a bubble column

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ENOLOGY REVIEW ARTICLES

A review on understanding oxygen mass transfer in wine: influences, measurement methods, and implications

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Article number: 9320

Effects of CO_2, temperature and wine type not investigated in combination

Aims

Factors that can influence k_La

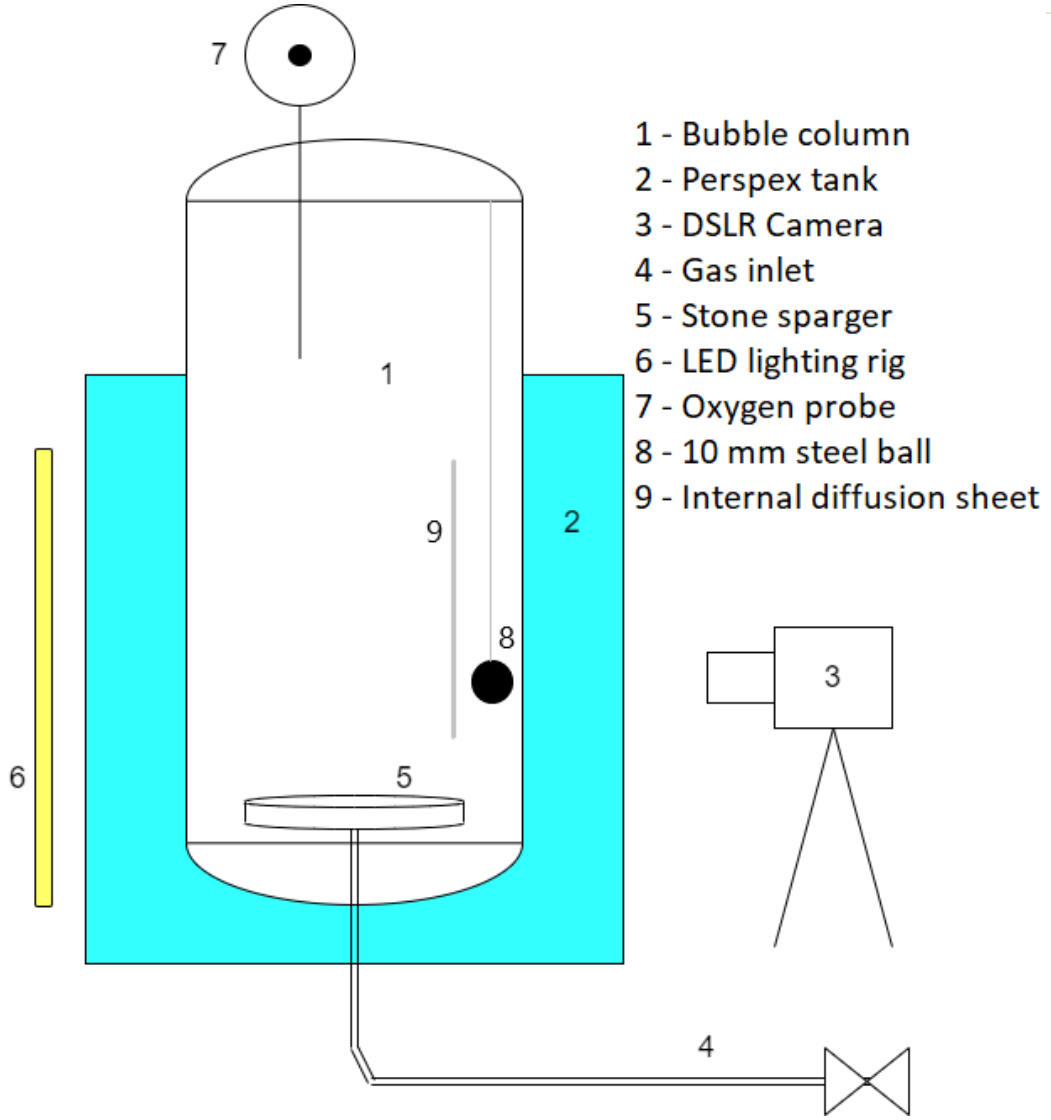
- Type of wine x CO_2 concentrations x Temperature
- k_La of O_2 and CO_2

Materials and Methods

White (Chenin blanc/Chardonnay, rose and red wine (Pinotage/ Cabernet Sauvignon) blends

Pinotage: White, rose and red wines

Different temperatures and CO_2 concentrations



Results: O_2 k_La of red and white wines (20 mg/L to <0.5 mg/L)

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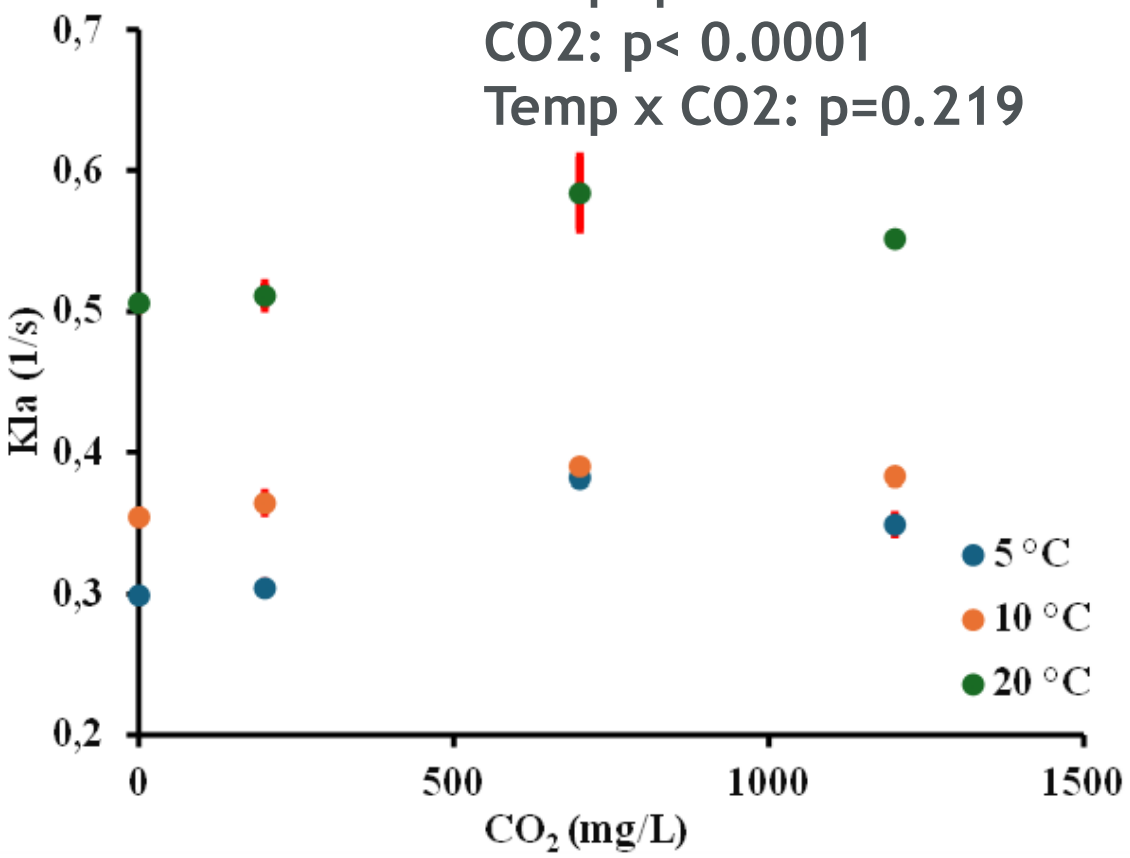
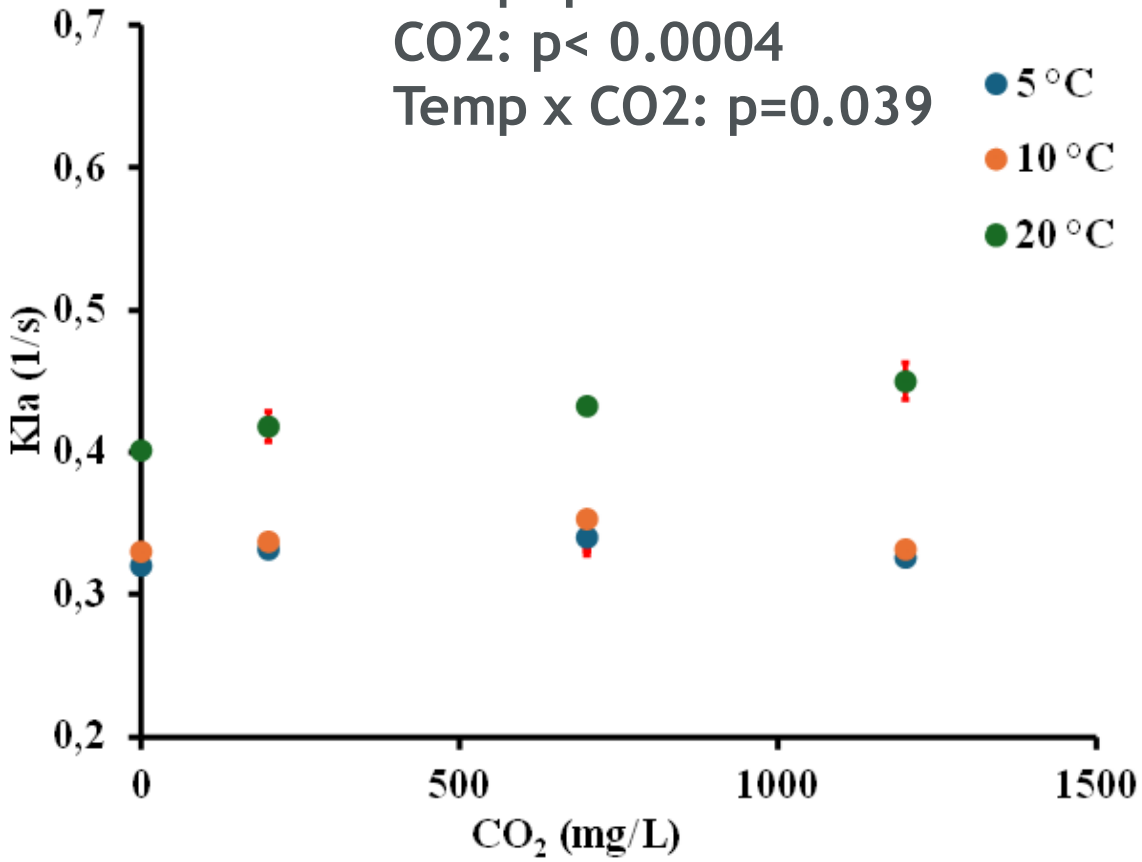
Temp: p< 0.0001
CO2: p< 0.0001
Temp x CO2: p=0.219



Red

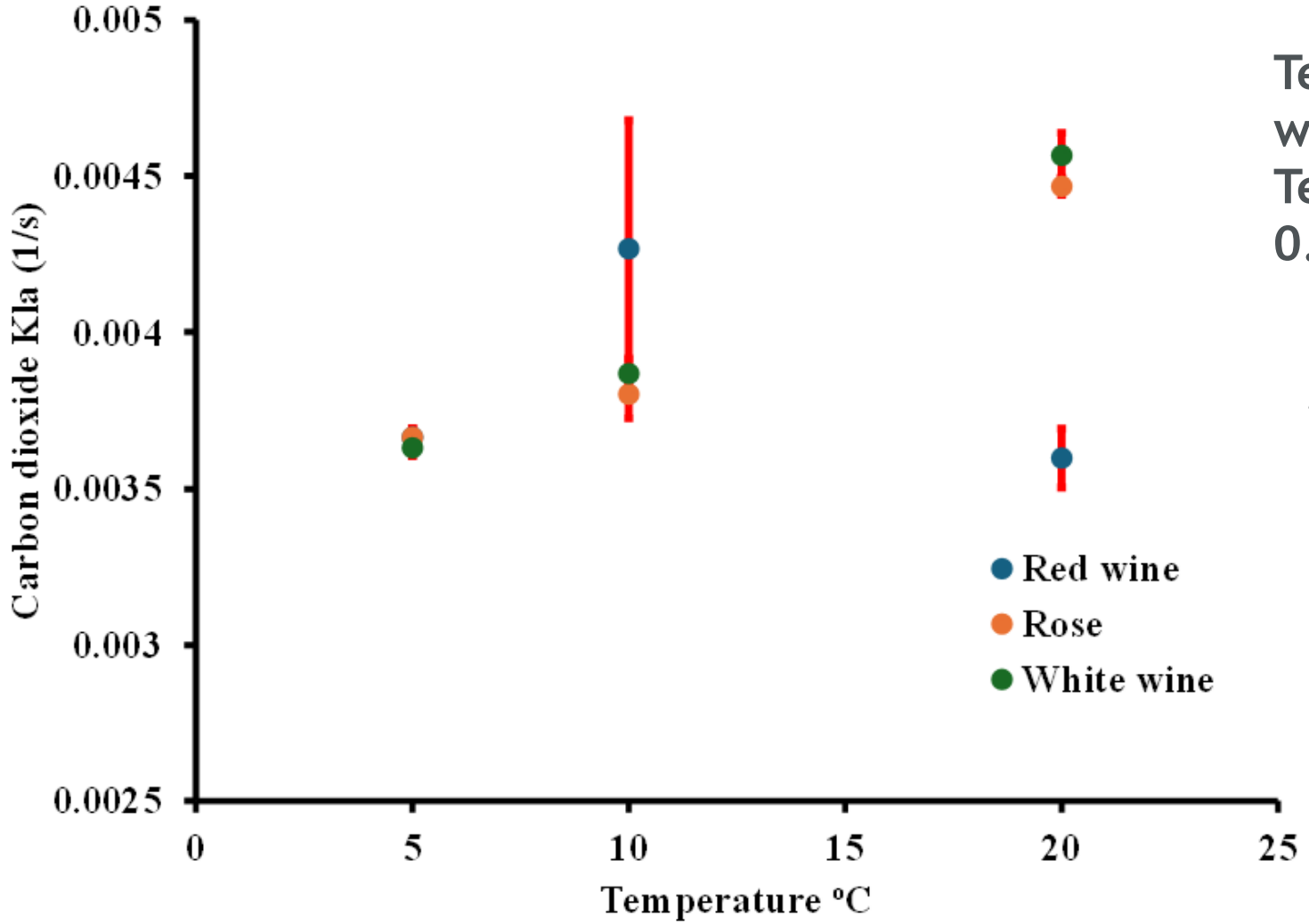
Temp: p< 0.0001
CO2: p< 0.0004
Temp x CO2: p=0.039



White

Rose: Temp: p < 0.0001
CO_2 : p = 0.0009
Temp x CO2: p = 0.101

CO_2 k_La at different temperatures (1300 mg/L to 0 mg/L)



Temp: (p = 0.005)
wine type: (p = 0.467)
Temp x wine type: (p = 0.007)

Might be due to phenolic interactions at higher temp in red

Role of temperature in $k_L a$?

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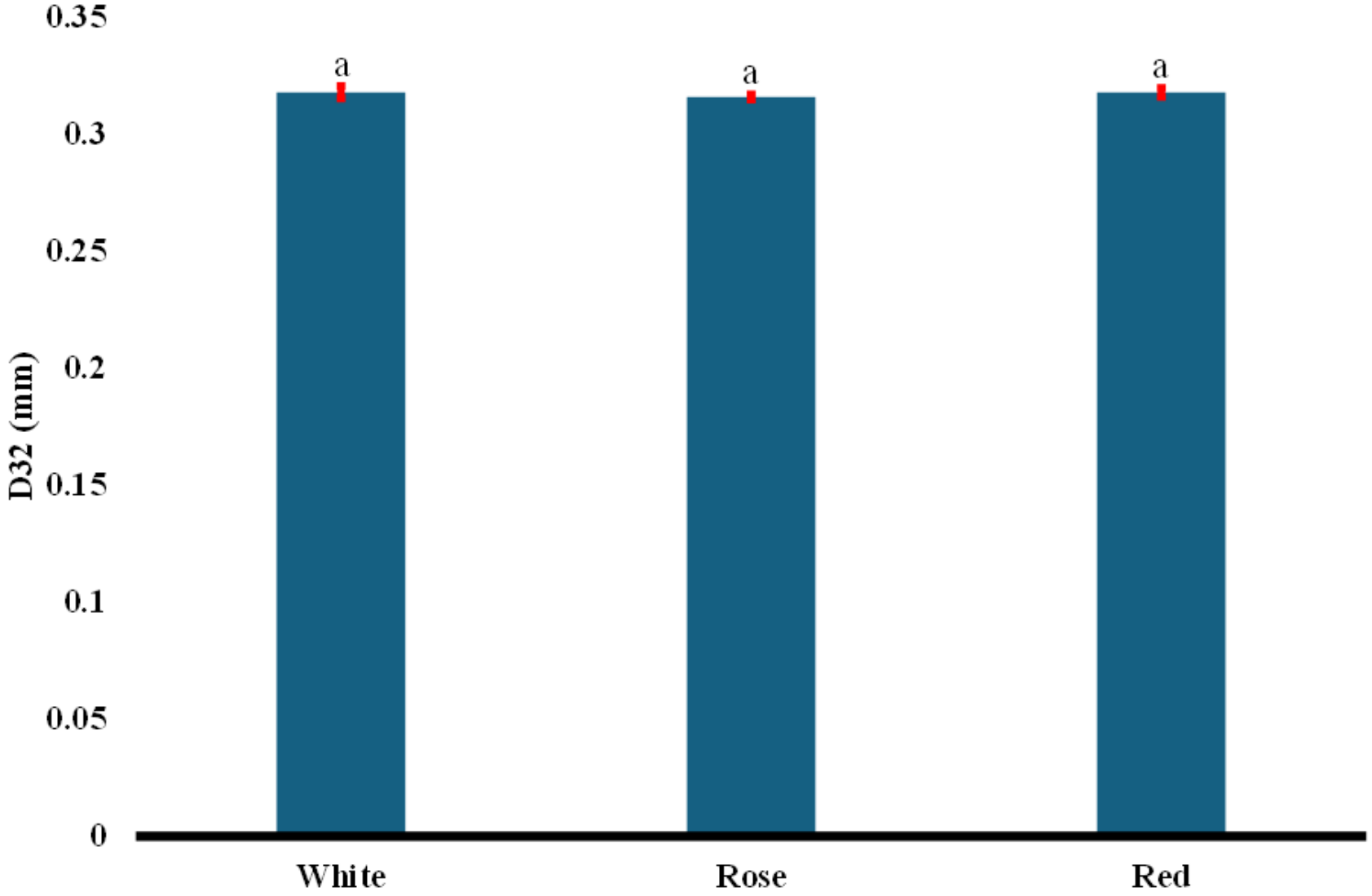
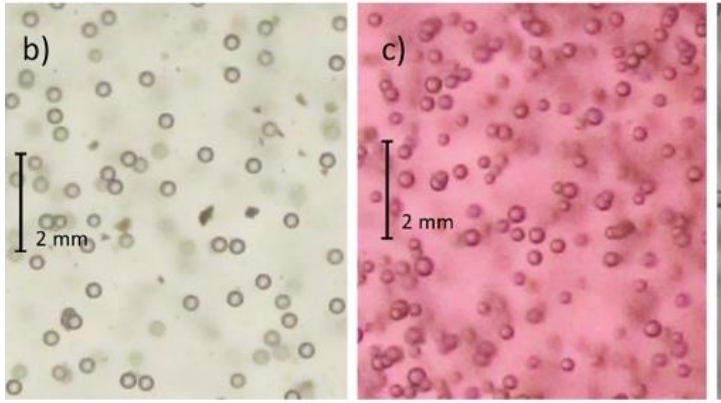
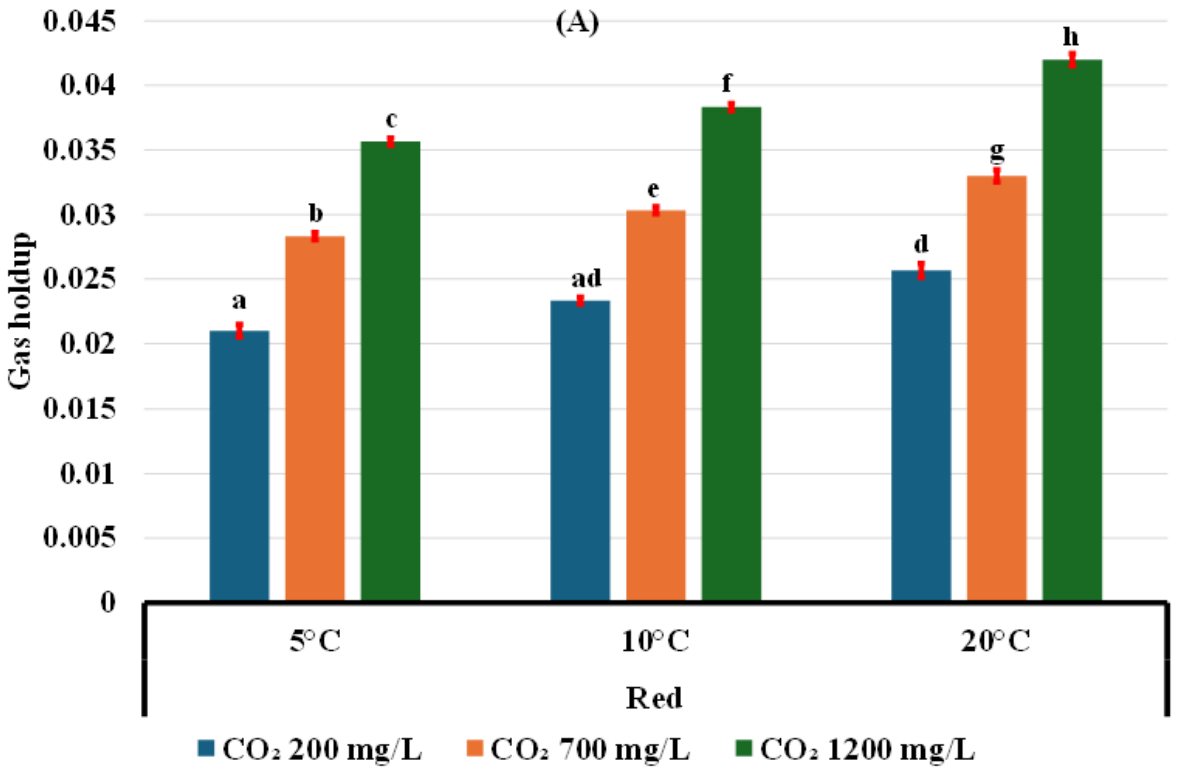
- Lower temperatures: liquid has a higher viscosity
- Molecules are “closer” to each other- resistance to flow and mass transfer
- Decreased Kl: decrease diffusion of O_2 from liquid into N_2 bubble
- Thicker laminar film around each bubble- reduce Kl
- Higher temperature: higher Kla
- Red wine benefits more at higher temperatures: reduced viscosity due high phenolics: at lower temperatures

Mean bubble size at 20 °C

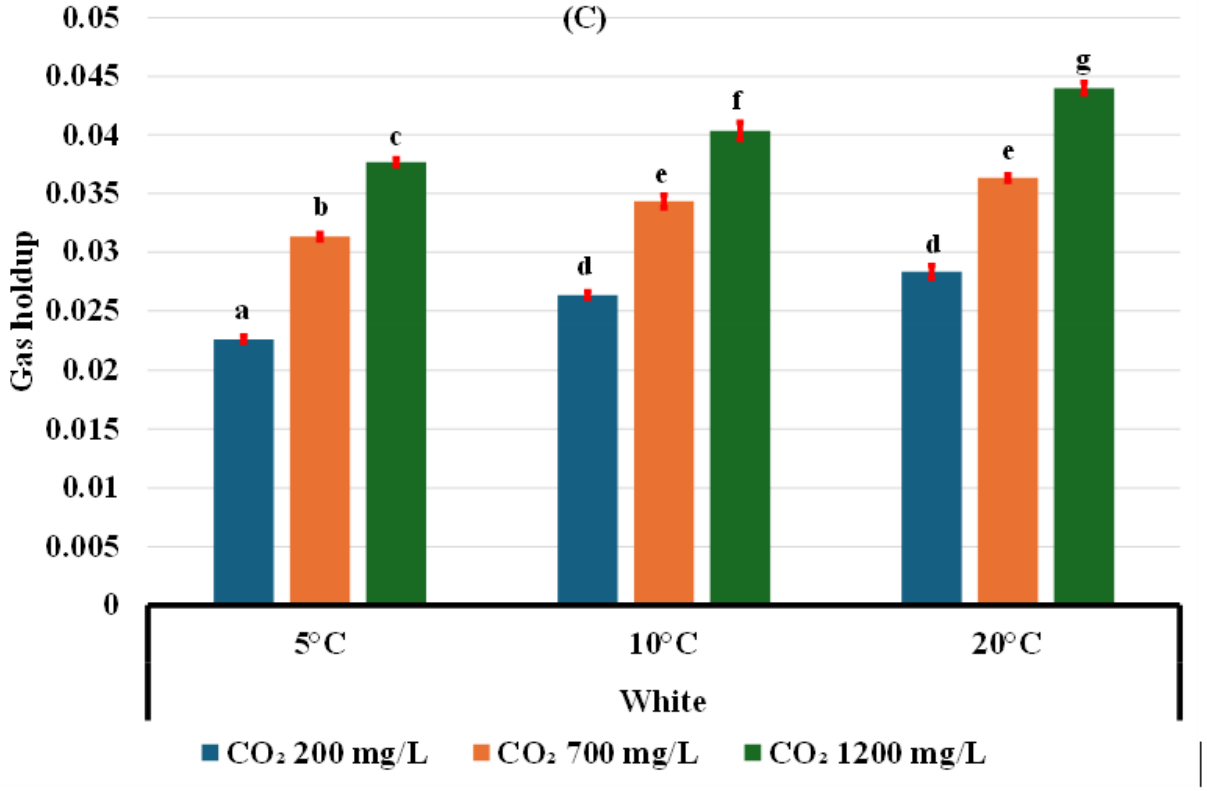




Gas holdup

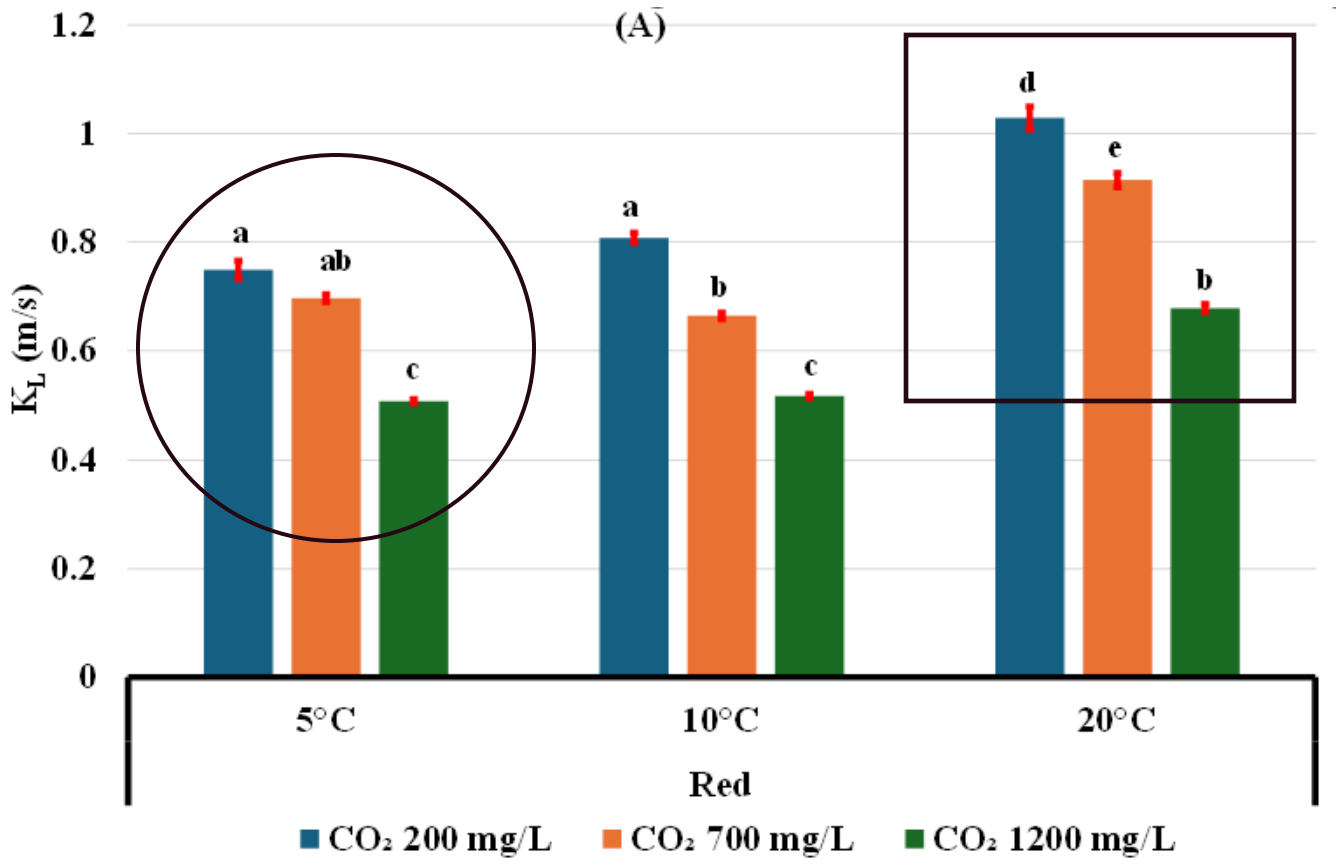


Red

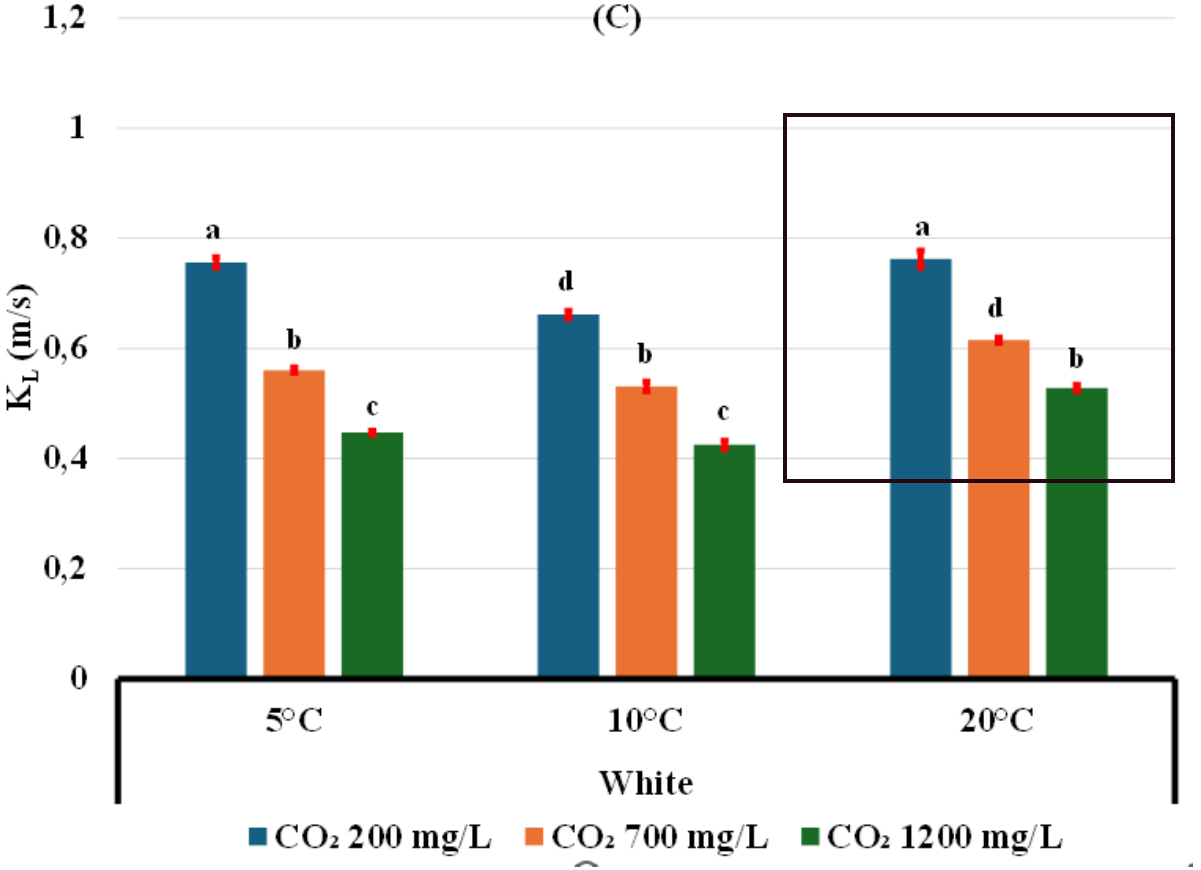


White

k_L for red and white wines

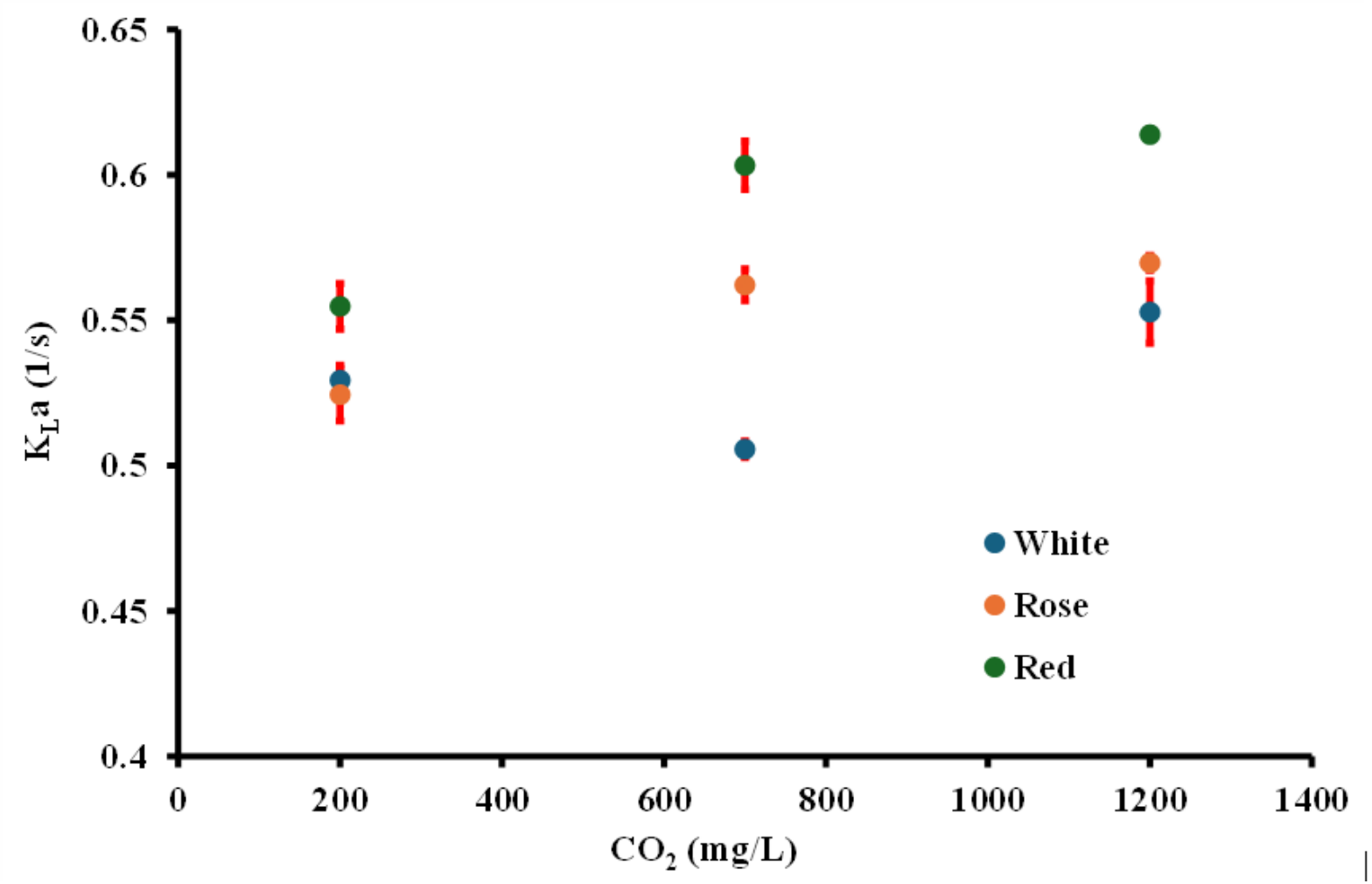


Red



White

k_La of red, rose and white Pinotage @ 20°C



Wine type, CO2 and wine type x CO2 $p<0.05$

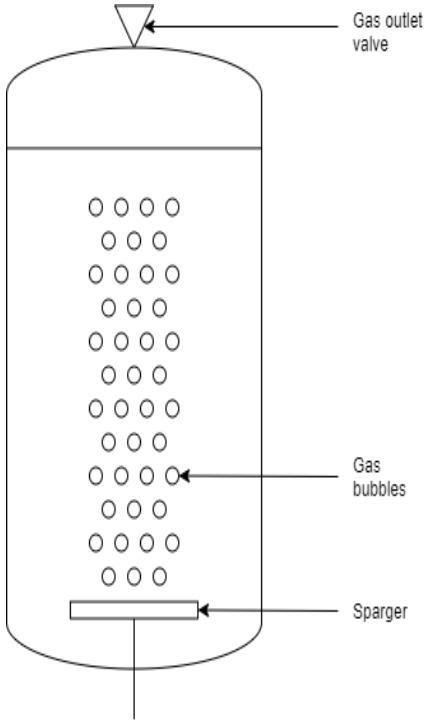
Conclusions

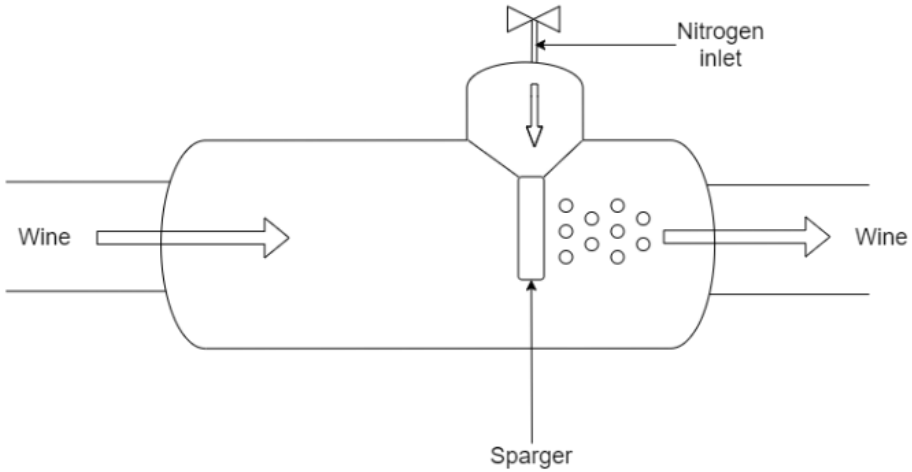
- Higher temperatures can lead to increased removal of O_2: more efficient sparging
- Red wine's $\mathbf{k_L a}$ of O_2 seems to be higher than that of white wine
- CO_2 concentrations can influence $\mathbf{k_L a}$ of O_2
- CO_2 $\mathbf{k_L a}$: higher temperature increases Kla in white and rose
- CO_2 $\mathbf{k_L a}$: increases with higher temperatures up to a certain point, can then decrease again; wine dependent.

So what?

Value of O_2 k_La studies

- Can be used to model and design an optimal sparging system for O_2 removal in wine
- Model/system perhaps different from red to white wine?





Acknowledgements

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