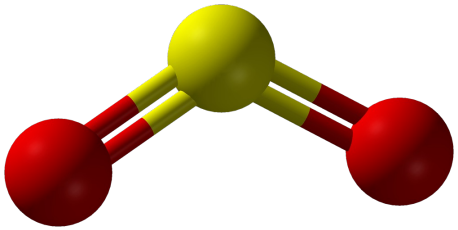
Session E03
Smart Strategies for SO_2 use from Crush to Bottle

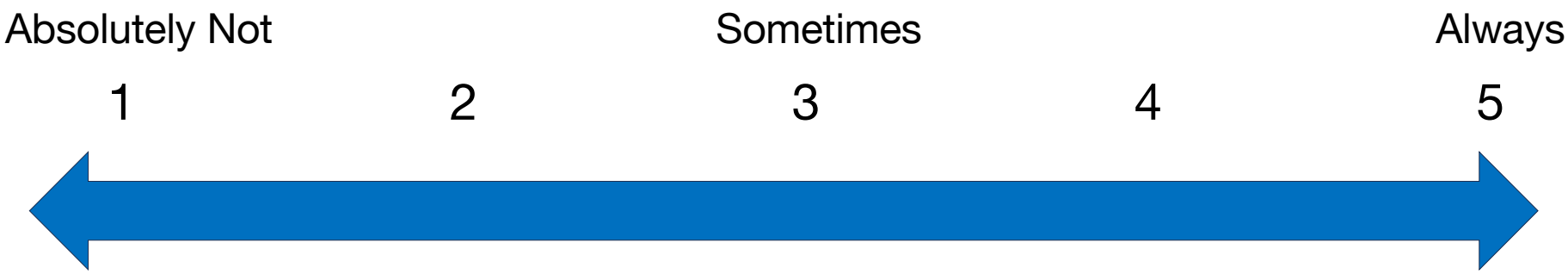
Kirsty Harmon
Joy Ting

Agenda

- Principles
  - Quick review of SO_2 chemistry
- Philosophy
- Practice
  - Pre-fermentation
  - Post-fermentation (post-malolactic)
  - Pre-bottling
- Questions/discussion



SO_2 Philosophy - Where do you stand?



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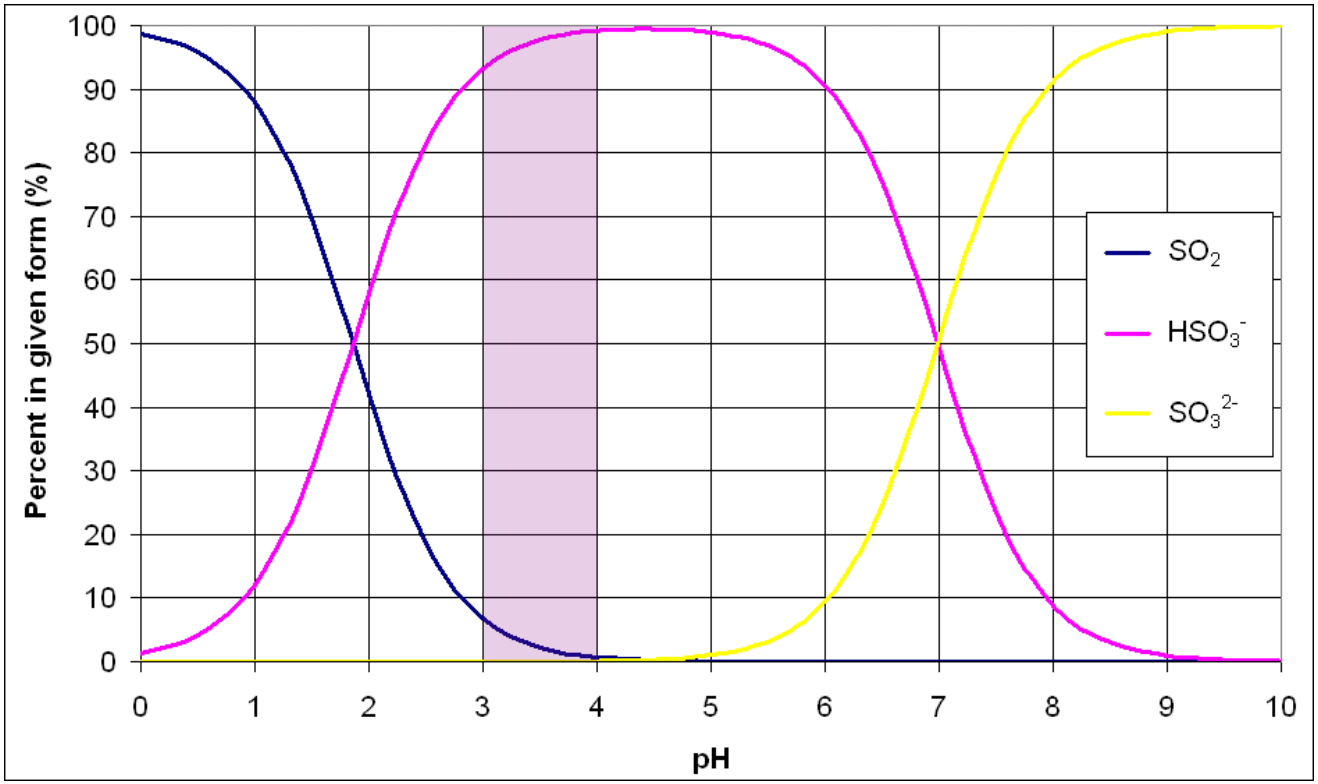
$$H_2O + SO_2 \leftrightarrow H^+ + HSO_3^- \leftrightarrow 2H^+ + SO_3^=$$

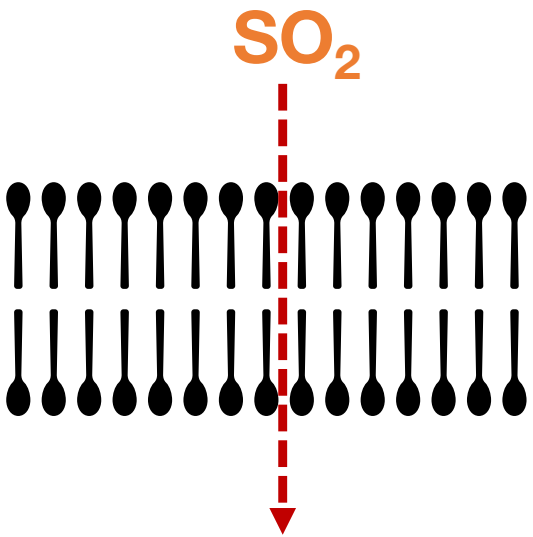
water + molecular sulfur dioxide hydrogen ion + bisulfite hydrogen ion + sulfite



$$H_2O + SO_2 \leftrightarrow H^+ + HSO_3^- \leftrightarrow 2H^+ + SO_3^=$$

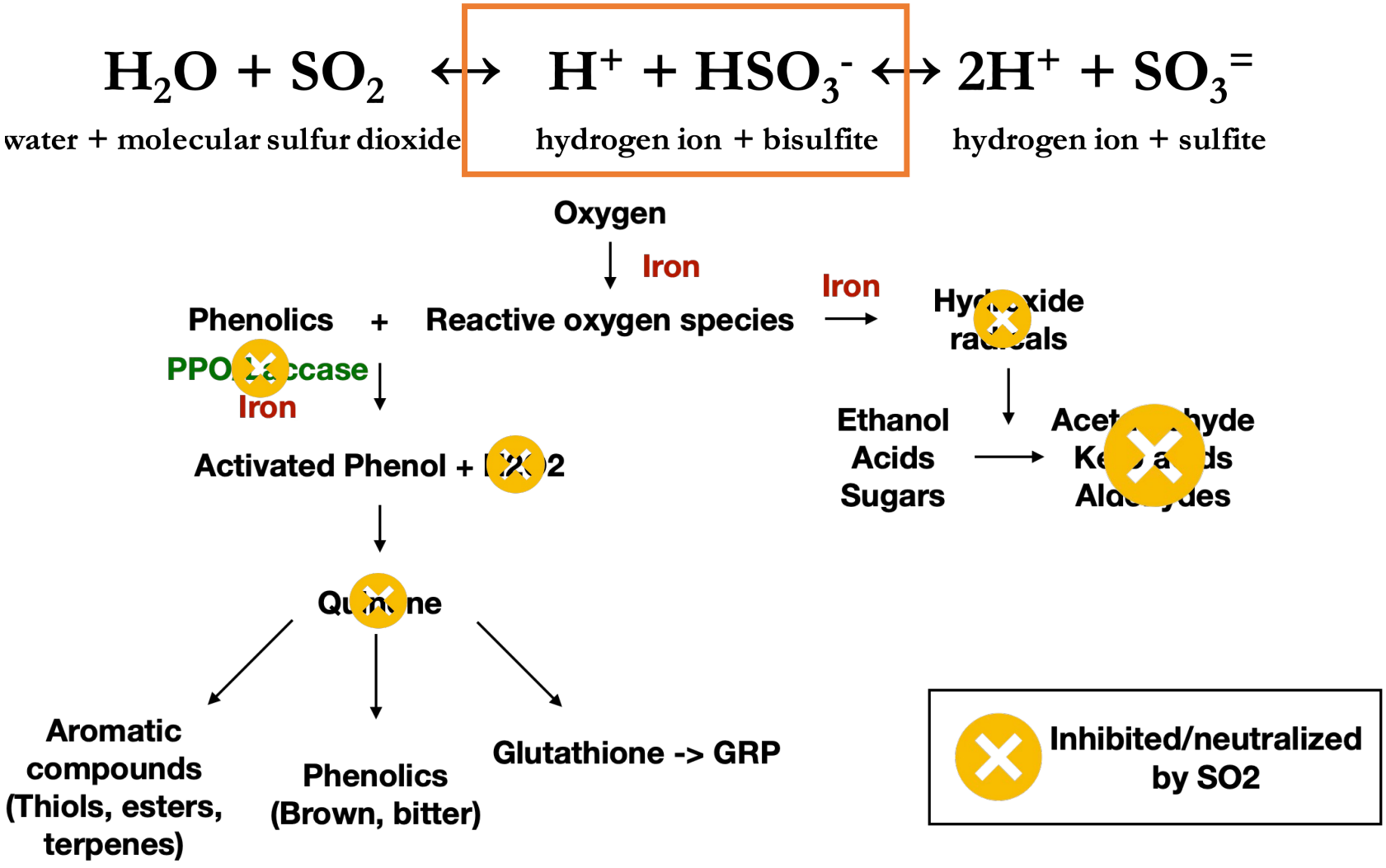
water + molecular sulfur dioxide | hydrogen ion + bisulfite | hydrogen ion + sulfite

Wine pH (3.0 - 4.0)



$SO_2 \leftrightarrow HSO_3^-$

Cellular pH (7.0)

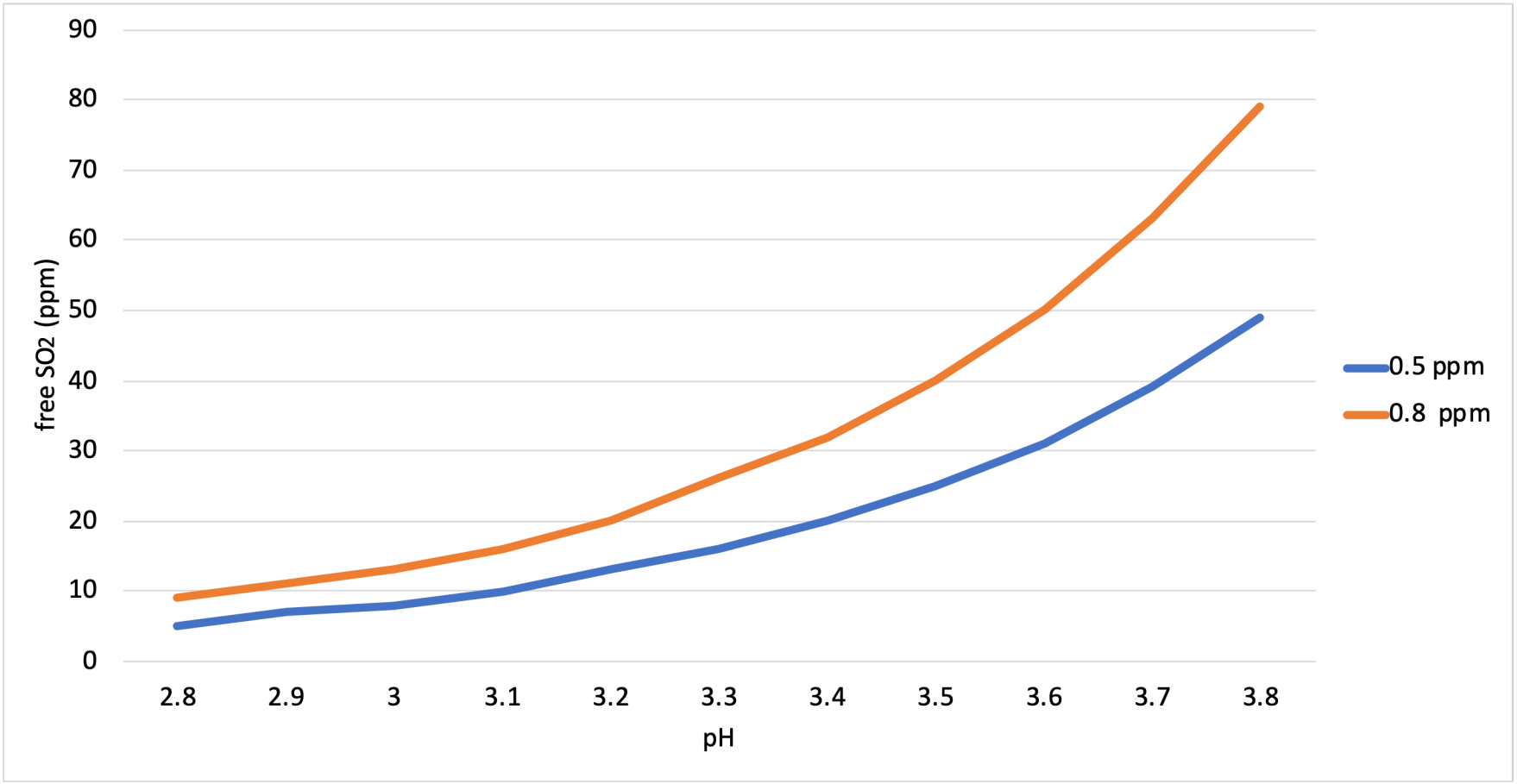

$H_2O + SO_2 \leftrightarrow H^+ + HSO_3^- \leftrightarrow 2H^+ + SO_3^=$
water + molecular sulfur dioxide
hydrogen ion + bisulfite
hydrogen ion + sulfite
Oxygen
Iron
Phenolics + Reactive oxygen species
Iron
Hydroxide radicals
PPO / Laccase
Iron
Activated Phenol + O2
Ethanol
Acids
Sugars
Acetaldehyde
Ketoacids
Aldehydes
Quinone
Aromatic compounds (Thiols, esters, terpenes)
Phenolics (Brown, bitter)
Glutathione -> GRP
Inhibited/neutralized by SO2

Total sulfur dioxide			
Free sulfur dioxide			Bound sulfur dioxide
Molecular SO_2	Bisulfite HSO_3^-	Sulfite $SO_3^=$	Sulfites attached to sugars, acetaldehyde, and phenolic compounds

From: Zoecklein 1995

Antimicrobial (fungicide, bacteriocide)	0.6 ppm molecular for reds 0.8 ppm molecular for whites
Againt yeast	Varies: up to 100 ppm free (Saccharomyces, Hanseniaspora, Candida) 0.8 - 1.5 ppm molecular
Against ML bacteria	10 ppm **tota**l slows, 50-80 total ppm prevents ML (0.6 ppm molecular); 50 g/hL inhibits ML, even if bound
Against Acetic Acid Bacteria	0.9 ppm molecular, >50 ppm free
Against Brett	0.3 ppm molecular to inhibit activity
	0.825 ppm molecular to eliminate viability (10,000 fold decrease in viable Brett)
Antioxidant	Target 20-40 ppm free during aging
Against enzymes at crush	20-80 ppm depending on fruit (50 ppm to healthy juice reduces PPO by 90%); 35 ppm will inhibit tyrosinases at crush
Red Wine oxidation	Risks below 10 ppm free
White Wine oxidation	Risks below 20 ppm free
Wine made from rotten grapes	Risks below 30 ppm free due to laccase

Molecular SO_2



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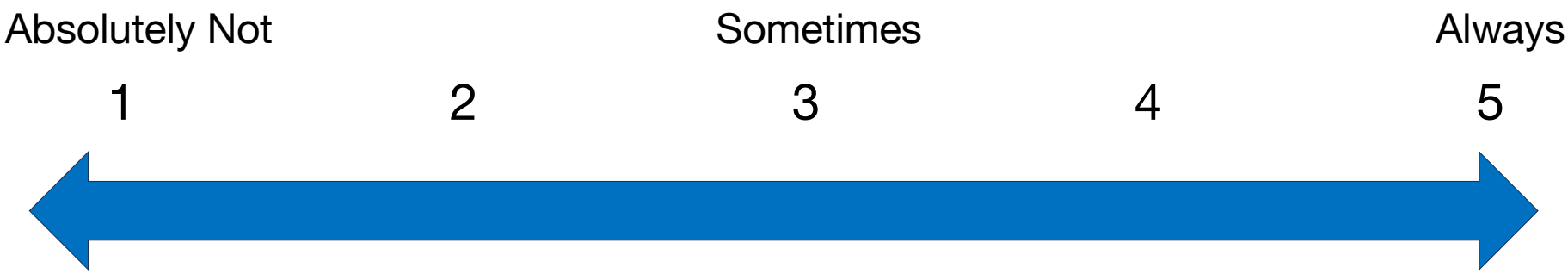
SO_2 Philosophy - Where do you stand?



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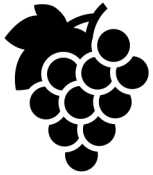
5. I have no objection or reservation about using SO_2. I use it liberally at several stages of winemaking for its potent antimicrobial and antioxidant properties.

	Phase	Purpose	Effective Dose	At Blenheim
	At the press			
	End of Fermentation			
	At bottling			

Acetaldehyde

Production

By-product of fermentation (intermediate between glucose and ethanol)(10-30 mg/L)

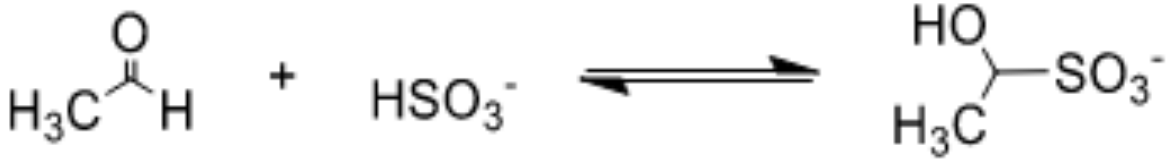
SO_2 at crush stimulates yeast to produce more acetaldehyde

Metal – catalyzed oxidation of ethanol during wine storage (slow)(20-75 mg/L)

Consumed by lactic acid bacteria in late stages of malolactic fermentation

Binds to bisulfite more strongly than other carbonyls (pyruvic acid, α-ketoglutaric acid, galacturonic acid, glucose), but still reversible

Sensory: Bruised apple, nutty, oxidized sensory impact (75 – 100 mg/L)



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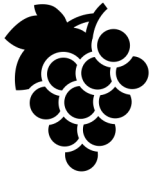
	At the press	Antioxidant Antimicrobial	20 - 80 ppm antioxidant 50 - 100 ppm antimicrobial Yeast more resistant than bacteria	30 vs. 70
	End of Fermentation			
	At bottling			

Single press load

30 ppm SO_2 addition

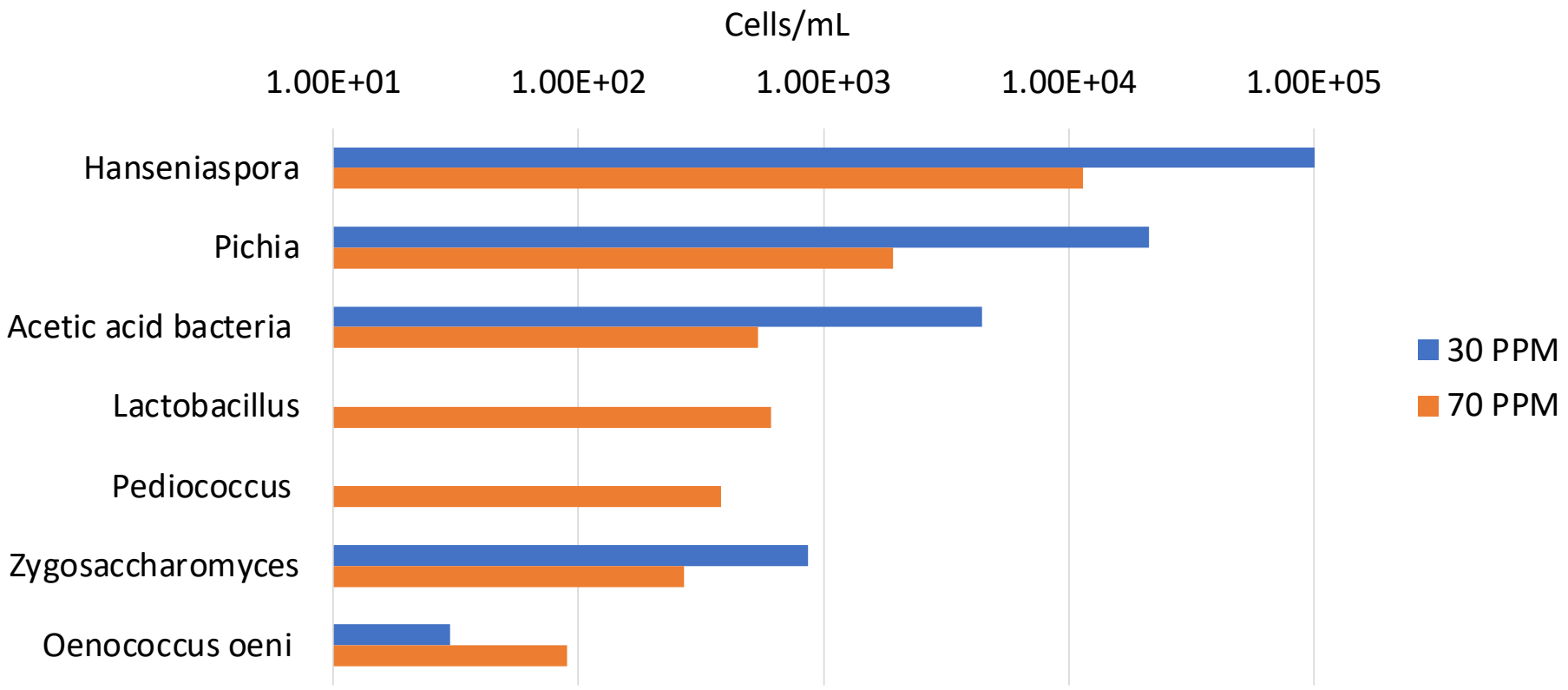
Mixed to suspend solids

1/2 transferred to second tank

Transferred to barrels for fermentation

40 ppm SO_2 addition

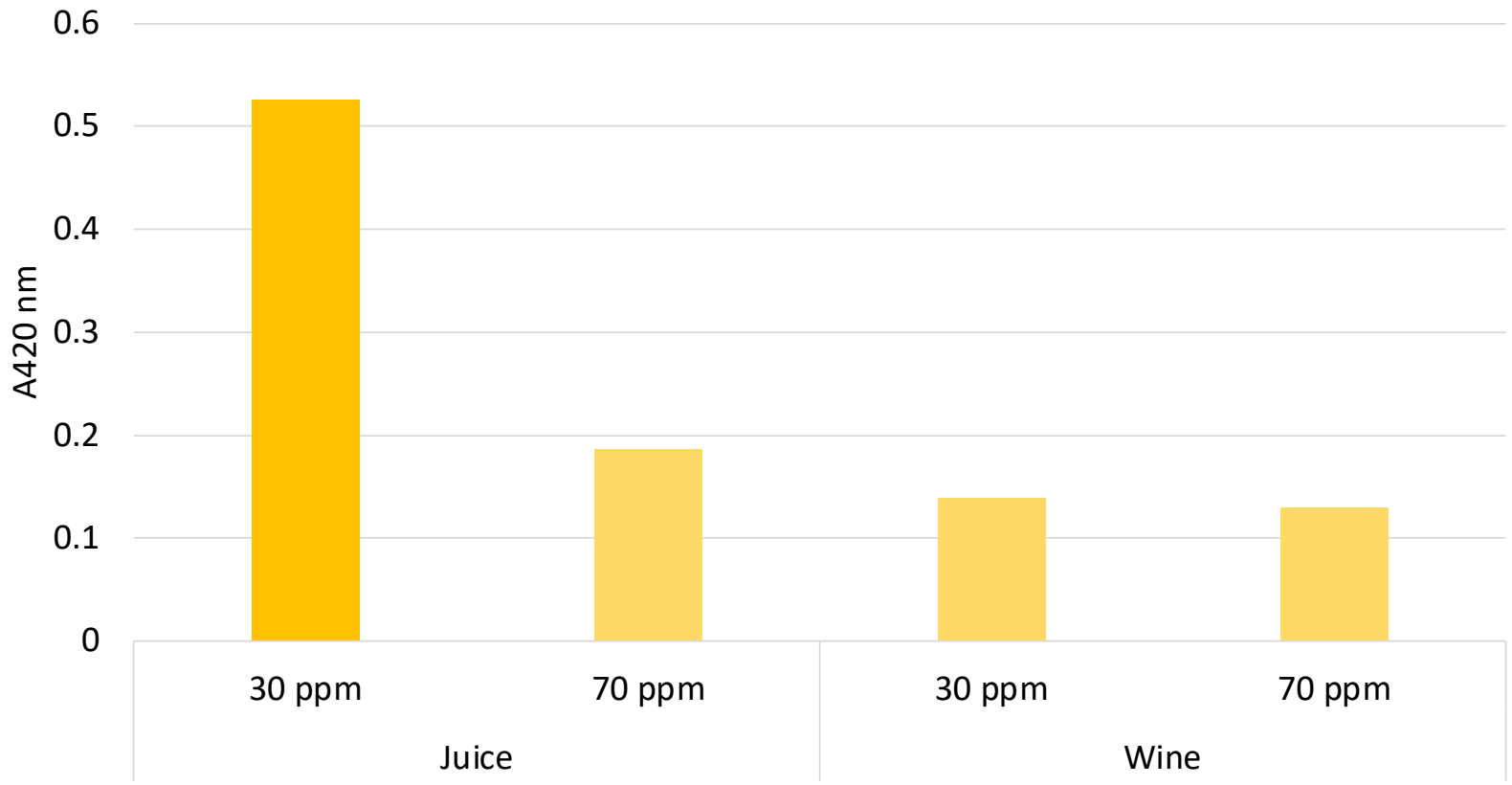
2023 Blenheim Chardonnay



Post-fermentation acetaldehdye

SO_2 Treatment	Barrel #	Acetic Acid (g/L)	Acetaldehyde (mg/L)	
			Total	Free
30 ppm	1201	0.35	43	0
	1504	0.35	42	0
	1505	0.3	46	0
70 ppm	1202	0.39	56	0
	1503	0.37	53	0
	1506	0.33	55	0

2024 Blenheim Viognier



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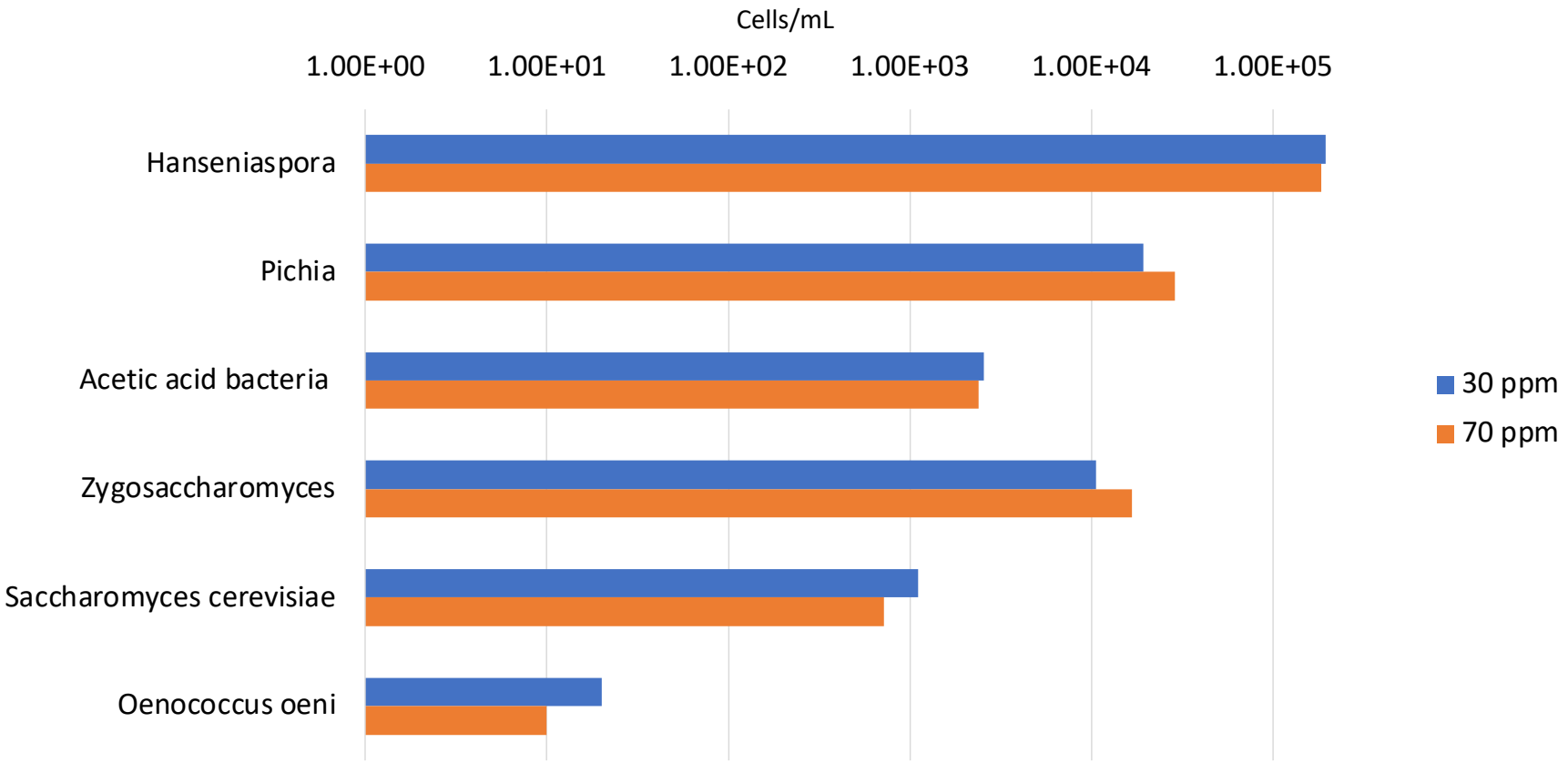
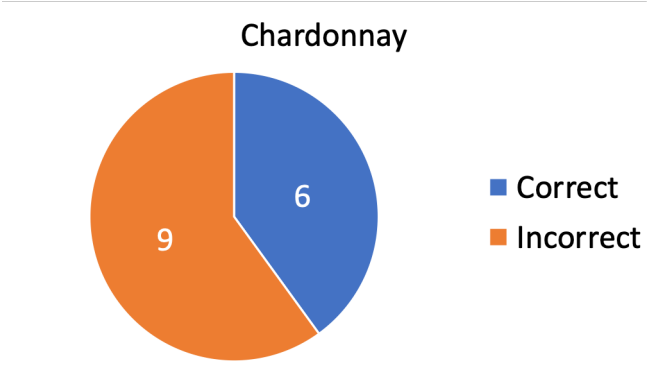
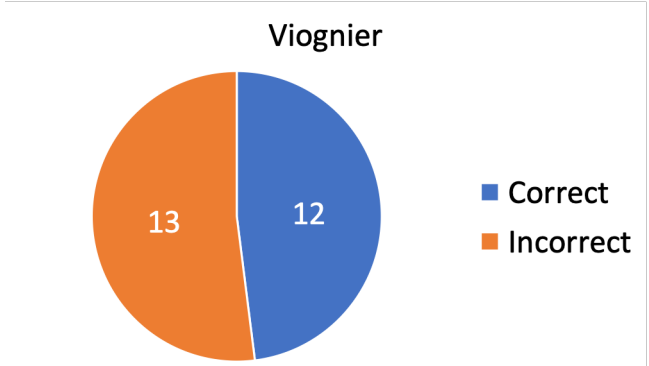


Why the difference?

	Chardonnay		Viognier	
pH	3.36		3.80	
SO_2 Addition	30ppm	70 ppm	30 ppm	70 ppm
Molecular SO_2	0.82	1.92	0.3	0.71

Sensory





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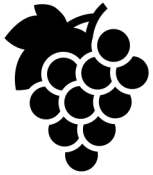	At the press	Antioxidant Antimicrobial	20-80 ppm antioxidant 50-100 ppm antimicrobial Yeast more resistant than bacteria	30 vs. 70
	End of Fermentation			
	At bottling			

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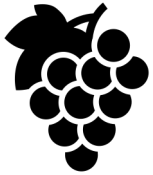	At the press	Antioxidant Antimicrobial	20-80 ppm antioxidant 50-100 ppm antimicrobial Yeast more resistant than bacteria	30 vs. 70
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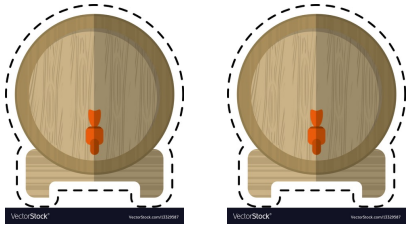
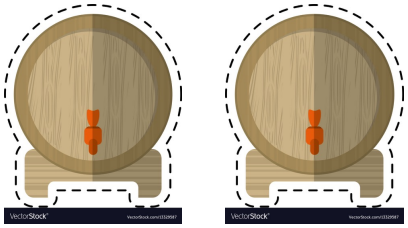
	At bottling			

SO_2 addition post ML

Low vs. High, Prompt vs. Delay



30 vs. 70 ppm
4 days after ML
Neutral barrels



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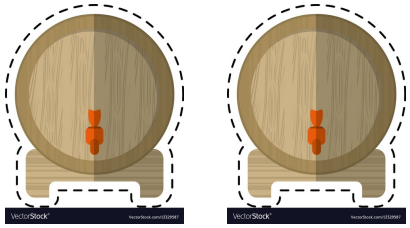
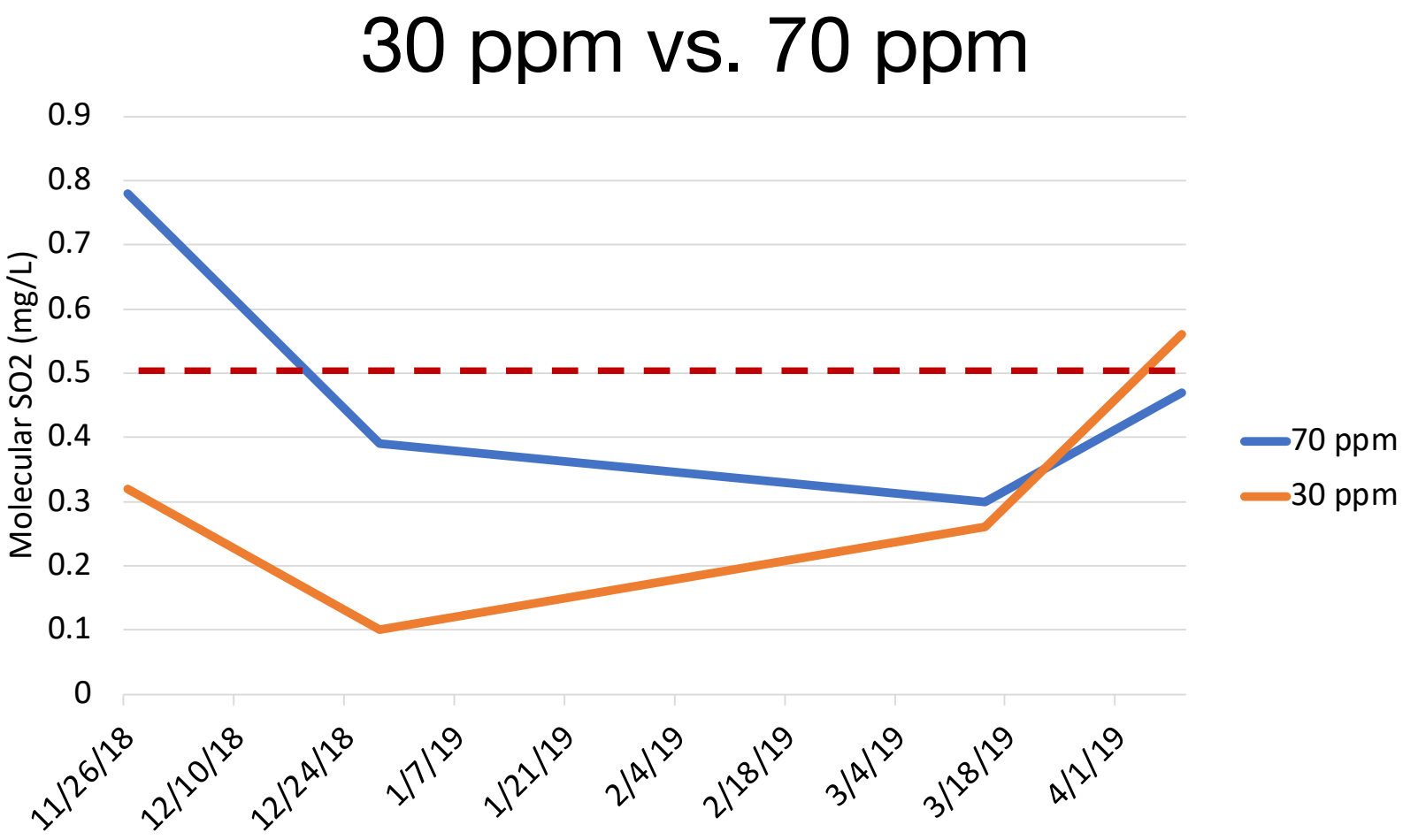


30 vs. 70 ppm
19 days after ML
Neutral barrels


30 ppm vs. 70 ppm
Molecular SO2 (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
11/26/18
12/10/18
12/24/18
1/7/19
1/21/19
2/4/19
2/18/19
3/4/19
3/18/19
4/1/19
70 ppm
30 ppm

Impact of delayed addition (70 ppm)

	SO_2 (ppm)			Additions during aging	
	Total	Free	Molecular	Number	Amount
No delay	103	18	0.47	2	30
Delay	77	27	0.67	1	7

SO2 addition post ML

Year 1

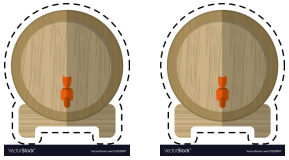
30 vs. 70 ppm
4 days after ML
Neutral barrels

30 vs. 70 ppm
4 days after ML
New barrels

30 vs. 70 ppm
19 days after ML
Neutral barrels

Year 2

Claim Vineyard



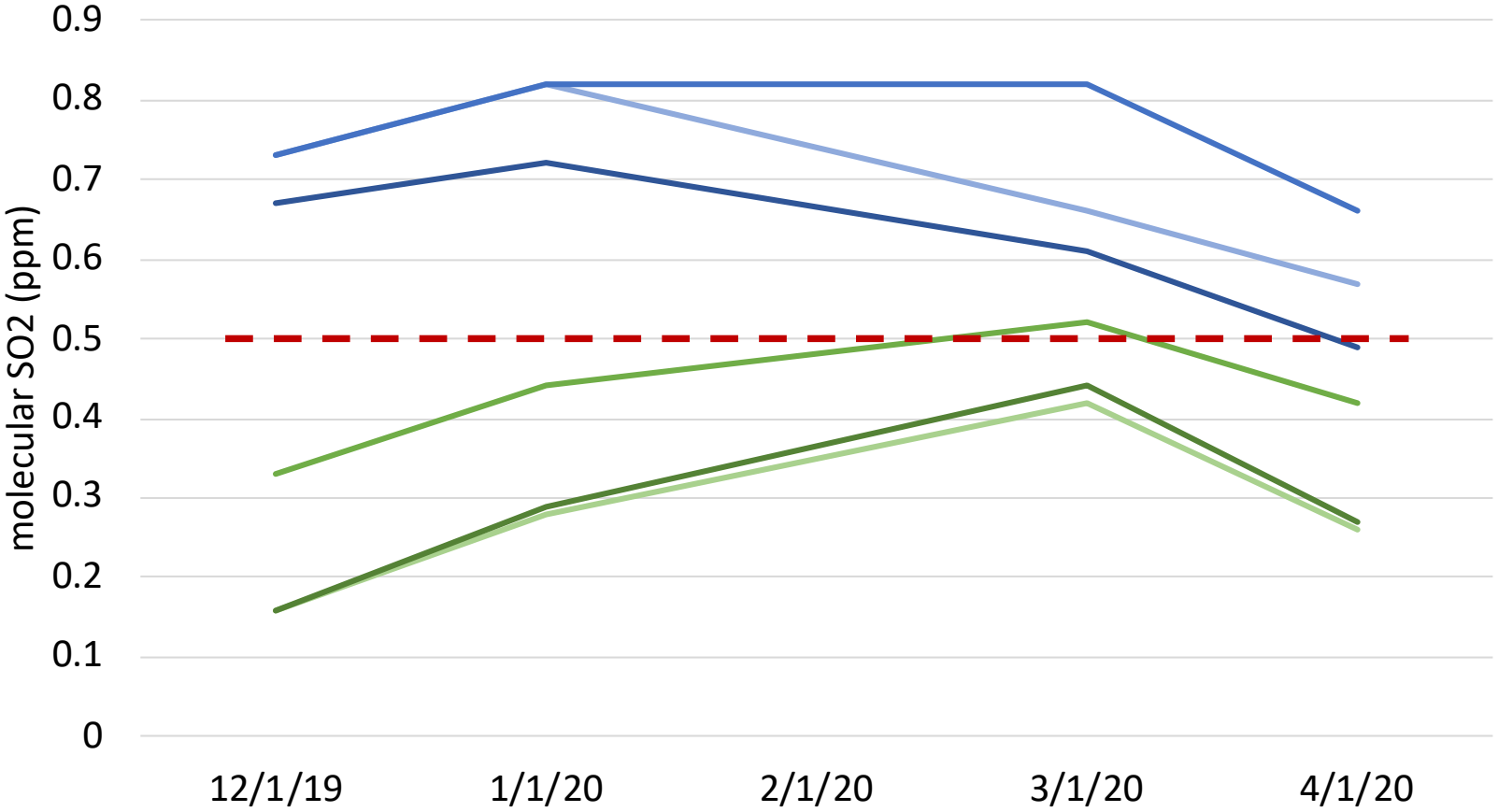
75 vs. 100 ppm
Delayed 14 days
Neutral barrels

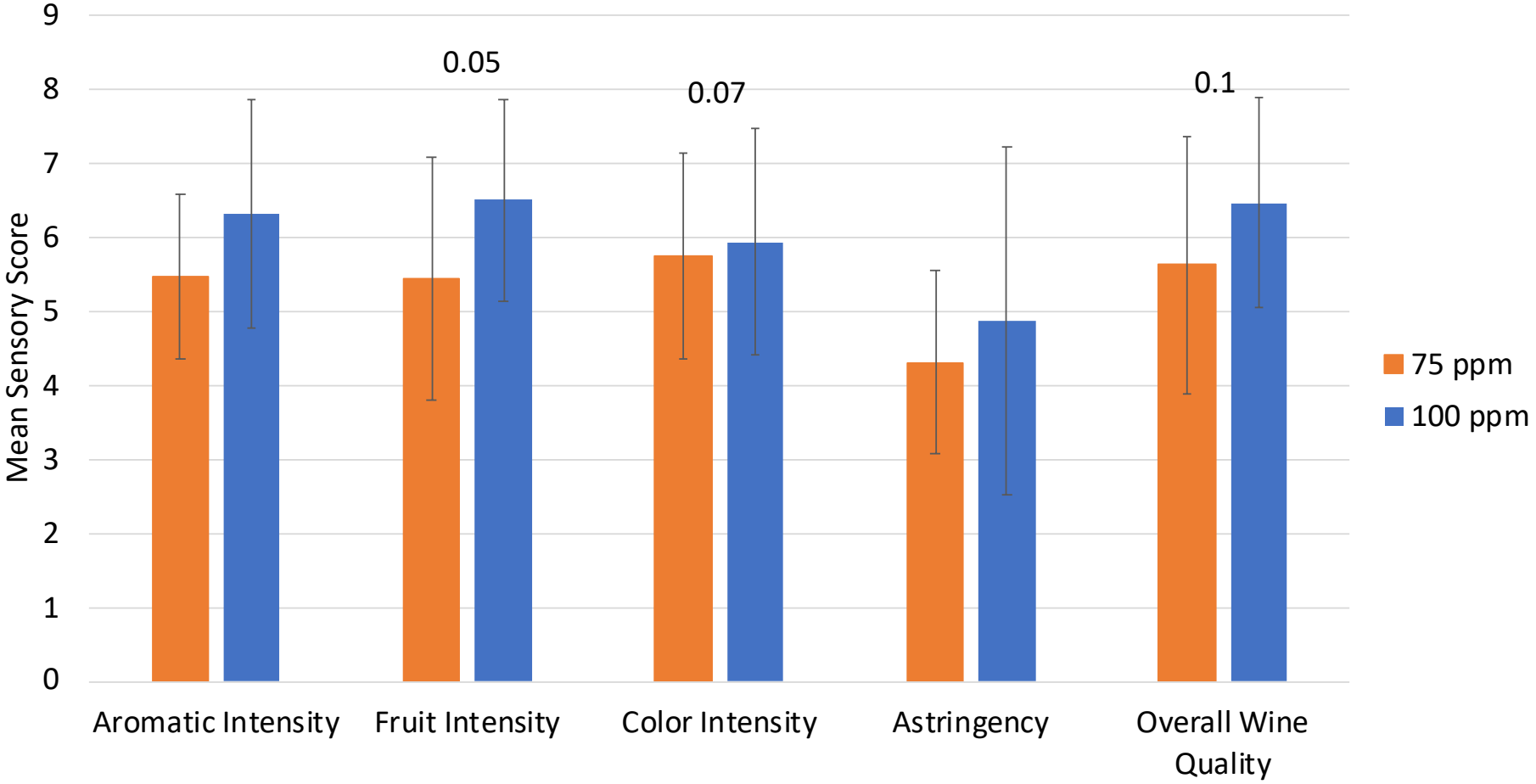
75 vs. 100 ppm
Delayed 14 days
2018 barrels

Piggot Vineyard

75 vs. 100 ppm
Delayed 14 Days
Neutral barrels

75 ppm (green) vs. 100 ppm (blue)




9
8
7
6
5
4
3
2
1
0
Mean Sensory Score
0.05
0.07
0.1
Aromatic Intensity
Fruit Intensity
Color Intensity
Astringency
Overall Wine Quality
75 ppm
100 ppm

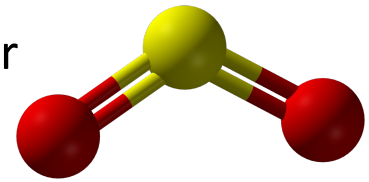
Post Fermentation SO_2 Experiments

Delaying SO_2 addition (7-14 days) led to lower overall total SO_2 and no film formation

Very high (100 ppm) initial SO_2 doses were more likely to achieve molecular targets

- Lower doses (30, 70) did not achieve targets until final month of aging
- 75 ppm still needed additions; 100 ppm did not

Wine with 100 ppm initial addition had higher sensory scores for favorable attributes (fruit intensity, color, overall quality).



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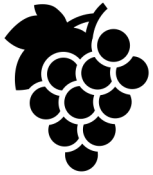	At the press	Antioxidant Antimicrobial	20-80 ppm antioxidant 50-100 ppm antimicrobial Yeast more resistant than bacteria	30 vs. 70
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	At bottling			

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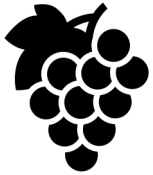	At the press	Antioxidant Antimicrobial	20-80 ppm antioxidant 50-100 ppm antimicrobial Yeast more resistant than bacteria	30 vs. 70
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	At bottling	Antioxidant	10-30 ppm for reds 20-30 ppm for whites 8-10 ppm for operations 5-6 ppm for TPO	

Total Package Oxygen

Total Package Oxygen at Bottling

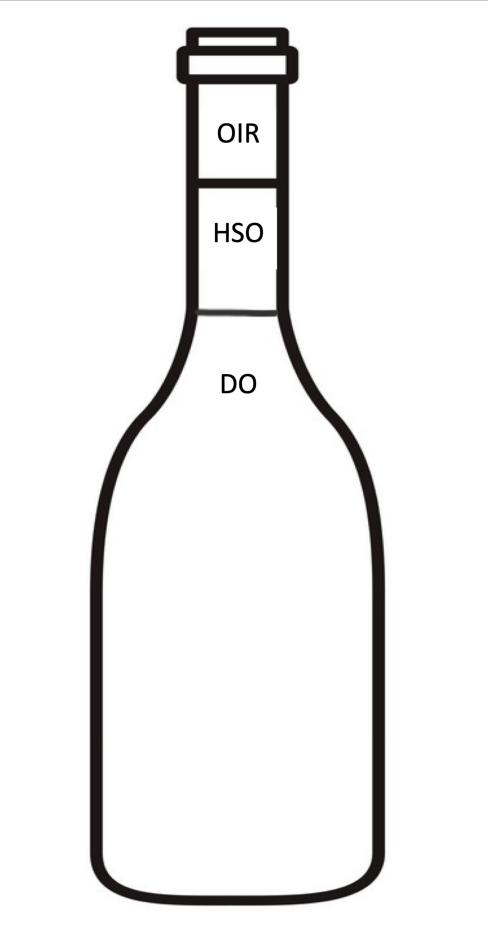
TPO = OIR + HSO + DO

Oxygen Initial Release - Air trapped in closure materials

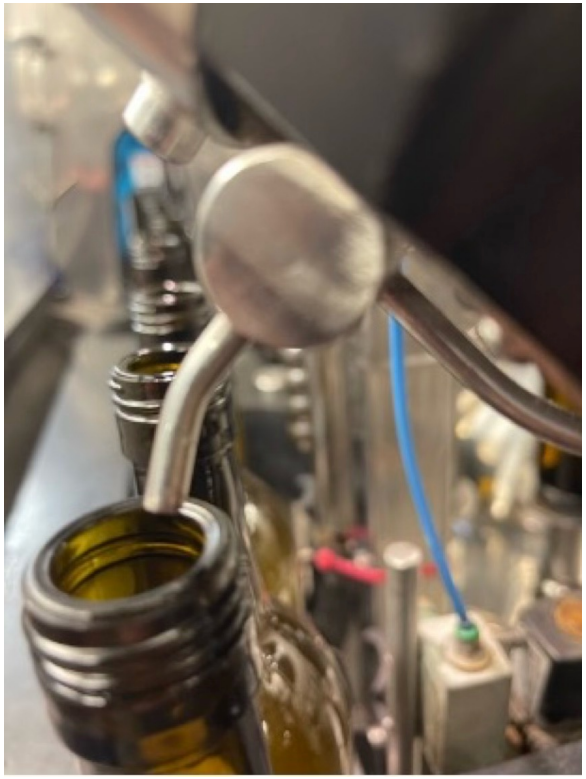
Headspace Oxygen - 60% of TPO from HSO (AWRI audit)
Depends on ullage, bottling line

Dissolved Oxygen – introduced during pre-bottling processes and during bottling

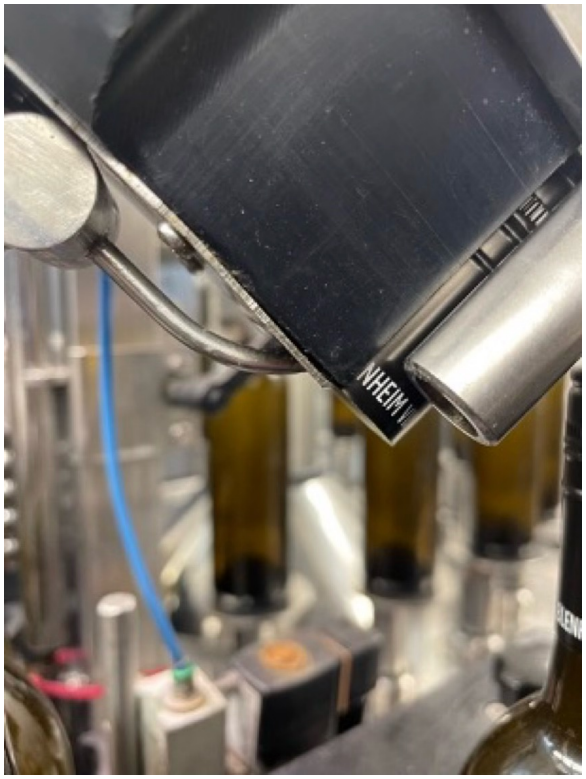
- Best < 1.0 mg/L for reds, <0.5 mg/L whites
- Increased with small lots, slow bottling or interruptions



Sparging the bottle

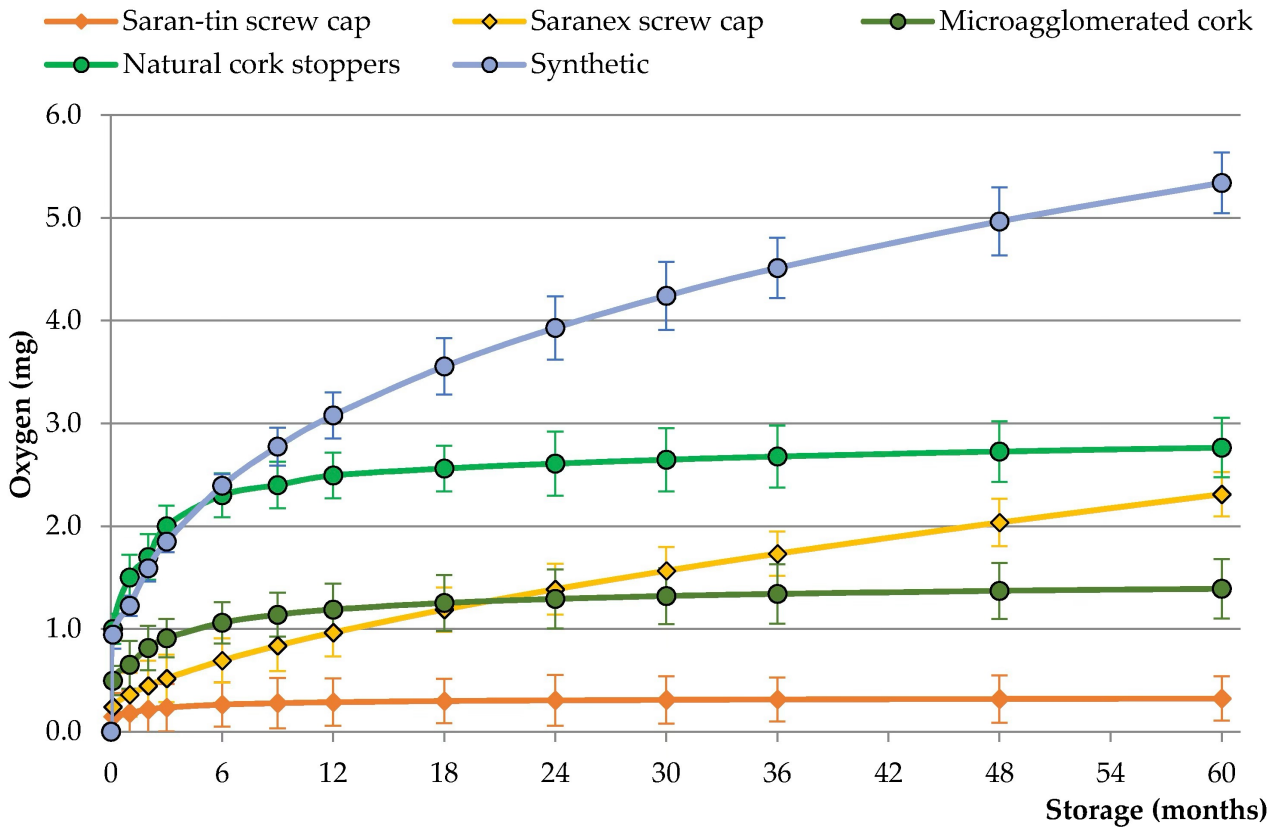


Sparging under the screwcap



(photo: Jason Collins, Hunter Bottling)

Oxygen during aging



(*Amorim, From: Wong 2020*)

What is a good target free SO_2 at bottling?

In Tank (before bottling)

Dissolved Oxygen, Free and Total SO_2

During Bottling:

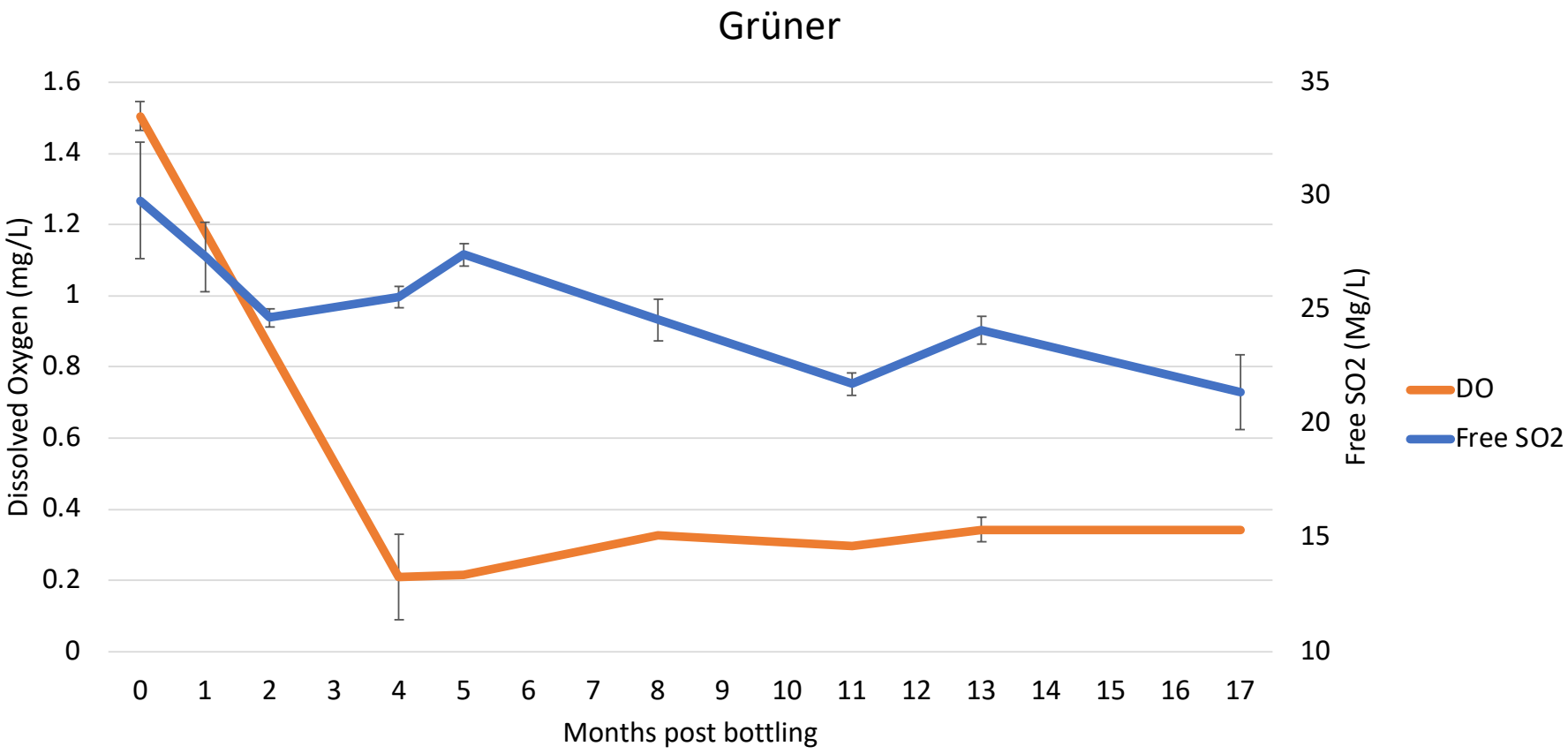
DO early, middle, late in the run

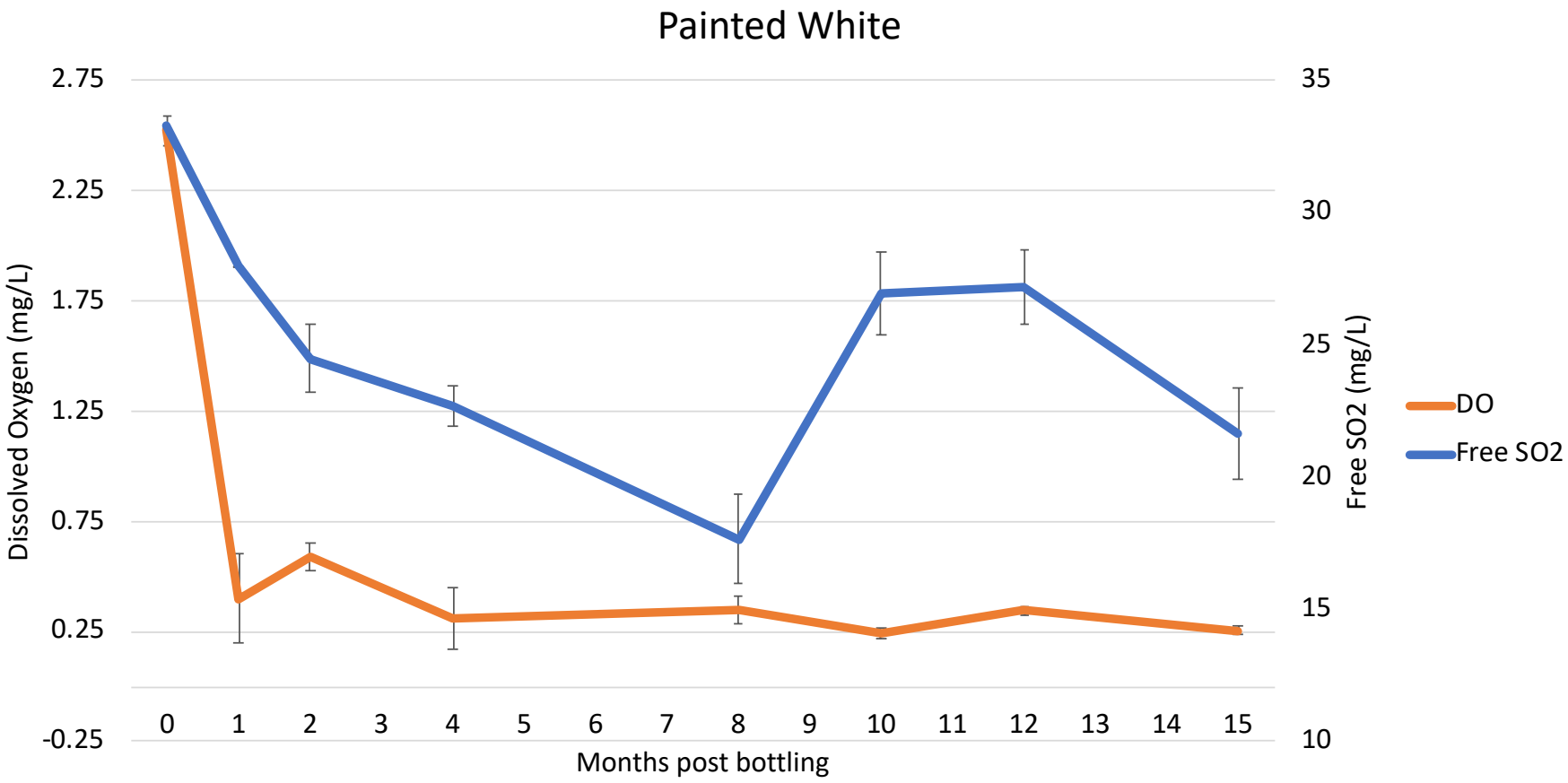
TPO* in triplicate mid run

Aging:

1, 2, 3 ,4, 6, 12 months*

DO, free and total SO_2 in triplicate


Grüner
Dissolved Oxygen (mg/L)
Free SO2 (Mg/L)
Months post bottling
DO
Free SO2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
10
15
20
25
30
35
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17


Painted White
2.75
2.25
1.75
1.25
0.75
0.25
-0.25
Dissolved Oxygen (mg/L)
35
30
25
20
15
10
Free SO2 (mg/L)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Months post bottling
DO
Free SO2

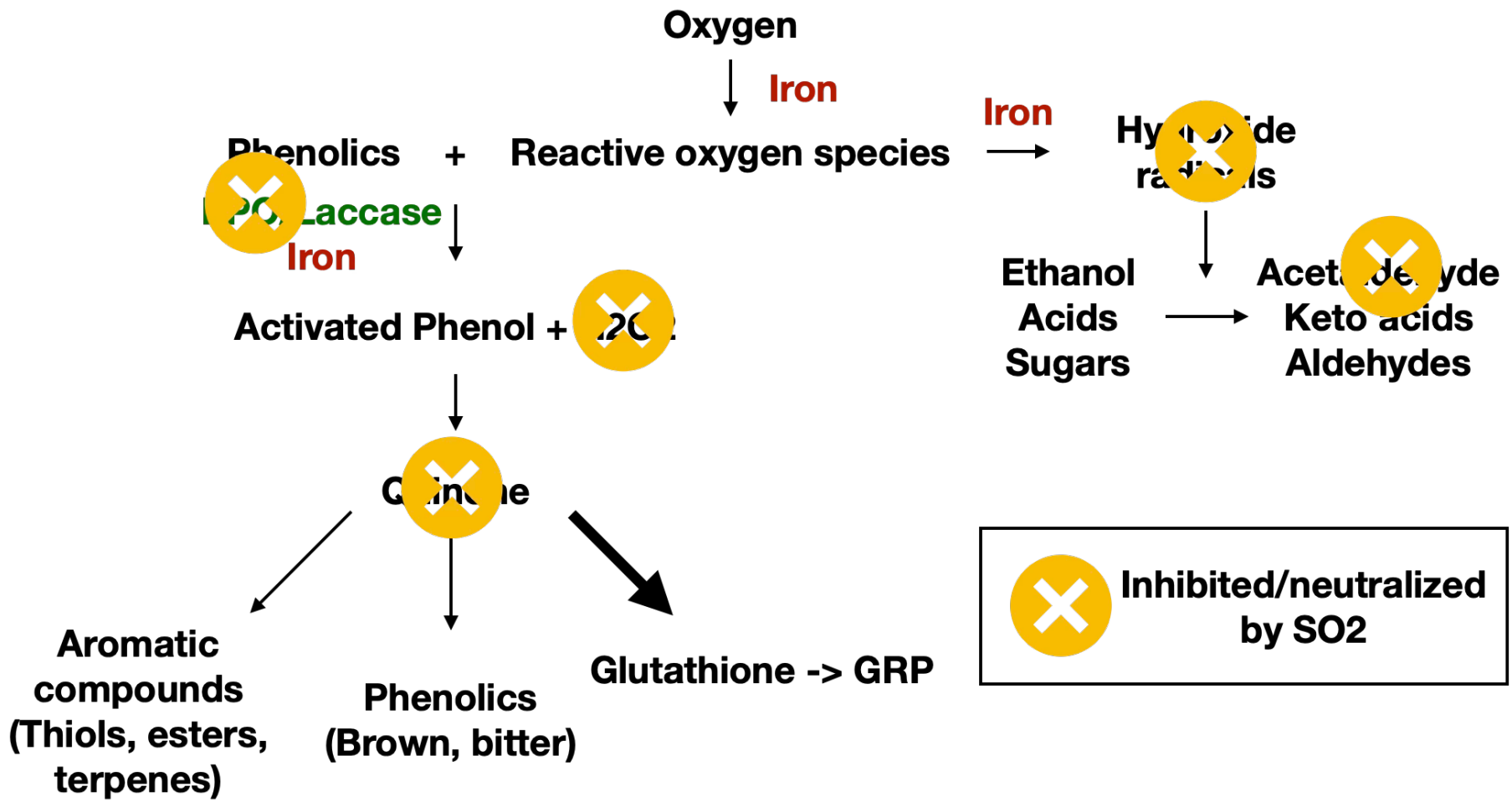
	Grüner	Cab Franc	Painted Wihte
TPO at bottling	3.3	2.53	4.6
Overall FSO_2 Change	8.4	5.6	11.7
FSO_2 change/month	0.49	0.47	0.78
FSO_2 change/month After 1st month	0.37	0.38	0.46
DO during aging	0.34	0.28	0.25

Free, Bound, and Total Sulfur Dioxide (SO_2) during Oxidation of Wines

Gavin L. Sacks,[1]* Patricia A. Howe,[2,5] Matthew Standing,[3,6]
and John C. Danilewicz[4]

Sulfur Dioxide–Oxygen Consumption Ratio Reveals Differences in Bottled Wine Oxidation

Andrew L. Waterhouse,[1]* Scott Frost,[1] Maurizio Ugliano,[2] Annegret R. Cantu,[1]
Bruce L. Currie,[1] Mauri Anderson,[1] Alexander W. Chassy,[1] Stéphane Vidal,[3]
Jean-Baptiste Diéval,[3] Olav Aagaard,[3] and Hildegarde Heymann[1]


Oxygen
Iron
Phenolics + Reactive oxygen species
Iron
Laccase
Iron
Activated Phenol +
Ethanol
Acids
Sugars
Keto acids
Aldehydes
Aromatic compounds (Thiols, esters, terpenes)
Phenolics (Brown, bitter)
Glutathione -> GRP
Inhibited/neutralized by SO2

Rapid White Wine Shelf-Life Prediction by Forecasting Free SO_2 Loss Post-Bottling

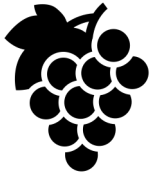
Miao & Waterhouse, AJEV vol 76, 2025

Developed a predictive equation for the rate of free SO_2 depletion during aging
Answers question ”How long will wine age before oxidation?”

Factors:

☑ Total Package Oxygen
☑ Initial Free SO_2
☑ Oxygen transmission through the closure

The presence of compounds that bind SO_2 and their ability to return it to the free SO_2 pool
The presence of other antioxidants in the wine (ascorbic acid, thiols, phenolics)

	Phase	Purpose	Effective Dose	At Blenheim
	At the press	Antioxidant Antimicrobial	20-80 ppm antioxidant 50-100 ppm antimicrobial Yeast more resistant than bacteria	30 vs. 70
	End of Fermentation	Antioxidant Antimicrobial	Brett: 0.8 ppm molecular Acetobacter: >50 ppm free, 0.9 mol Antioxidant >10 ppm in reds >20 ppm in whites	100ppm
	At bottling	Antioxidant	10-30 ppm for reds 20-30 ppm for whites 30-50 ppm for sweet wine 8-10 ppm for operations 5-6 ppm for headspace	

Acetaldehyde

Production

By-product of fermentation (intermediate between glucose and ethanol)(10-30 mg/L)

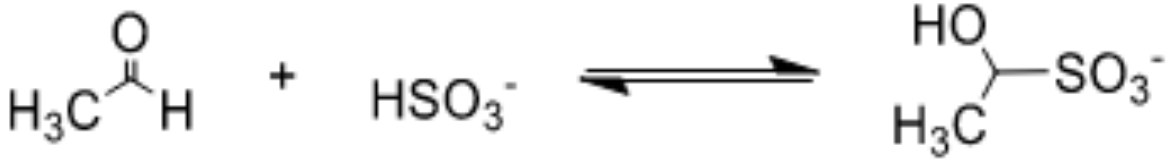
SO_2 at crush stimulates yeast to produce more acetaldehyde

Metal – catalyzed oxidation of ethanol during wine storage (slow)(20-75 mg/L)

Degraded by lactic acid bacteria in late stages of malolactic fermentation

Binds to acetaldehyde (1.5:1) more strongly than other carbonyls (pyruvic acid, α-ketoglutaric acid, galacturonic acid, glucose), but still reversible

Bruised apple, nutty, oxidized sensory impact (75 – 100 mg/L)



BLENHEIM VINEYARDS

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