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MICRO-OXYGENATION PRINCIPLES

Micro-oxygenation is a technique that involves the addition of controlled amounts of oxygen into wines. The goal is to simulate the effects of barrel-ageing in a controlled way and lower production costs through reduction of barrel requirements. Currently, this technique is widely used around the world in combination with tannins and oak alternatives, as a way to improve stability and the organoleptic qualities of wine.

Micro-oxygenation induces oxidation reactions with phenolic compounds. These reactions lead to the formation of stable color pigments while improving mouthfeel and structure. The speed/rate of oxygen additions is important for this technique, as rapid exposures to high doses of oxygen can quickly result in the accumulation of both oxygen and acetaldehyde, which can lead to oxidation and browning. The goal of micro-oxygenation is to allow small doses of oxygen to slowly be consumed through polymerization reactions, thus avoiding oxygen accumulation. By providing a lower dose of oxygen than the amount consumed by the wine, this will reduce the possibility of oxygen accumulating in the wine. Throughout every micro-oxygenation treatment, the most important parameters to monitor closely are dissolved oxygen, volatile acidity, Free SO_2 content and temperature, in conjunction with sensory evaluation to best fine tune the addition rate.

Timing of Treatment	O_2 Dosage	Typical Duration
During Fermentation @ 1/3 Sugar Depletion thru 2/3 Sugar Depletion	1 – 3 mg/L/Day 10 – 15 mg/L Total	Apply for 60 – 240 minutes 1-4 times during fermentation
Between AF - MLF	1 – 3 mg/L/Day	4 – 10 Days
Post MLF	0.5 – 3 mg/L/Month 0.5 – 2 mg/L/Month 0.5 – 1 mg/L/Month	1 – 3 Months 3 – 6 Months 6 – 12 Months

Stage 1: Alcoholic Fermentation (~10 – 15 mg/L Total Addition)

NO SO_2 REQUIRED

Goals: Stimulate production of unsaturated long chain fatty acids and sterols by yeast, which improves overall yeast health and fermentation kinetics.

Application: During fermentation, application is prior to the end of the exponential growth phase or after completion of first 1/3 of fermentation. Later additions can also help eliminate reductive characters that may appear during the second part of fermentation. Oxygen applied with active yeast present will be consumed rapidly by yeast and will produce minimal reactions with tannins.

Recommended Analysis: YAN, Malic Acid, Volatile Acidity (VA)

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Stage 2: Between Alcoholic Fermentation (AF) & Malolactic Fermentation (MLF) (~1-3 mg/L/DAY and ≤ 15 mg/L Total Addition)

NO SO_2 REQUIRED, ADDITION OF STAB MICRO M PRIOR TO APPLICATION WILL DELAY THE ONSET OF MLF

Goals: Stabilizing color compounds, improving structure and minimizing herbaceous and reductive characters. Application during this stage produces acetaldehyde as a product of the reaction of ethanol with oxygen. This compound acts as a bridge in polymerization reactionsof tannins with free anthocyanins, creatingmore stable condensed color compounds. Micro-oxygenation during this stage can be used to develop and improve structure as well as reduce potentially detrimental herbaceous and reductive characters. There is also a significant impact on tannin structure and intensity, due to tannin polymerization, which leads to softer (less astringent) and fuller tannin perception.

Application: It is preferred to begin treatment soon after completion of alcoholic fermentation, before the addition of SO_2 and/or prior to beginning malolactic fermentation. Typical application lasts between 4 to 10 days, with a total of 8 to 15 mg/L supplied and should be stopped immediately at the onset of MLF, which will be indicated by a shift in pH or a decrease in malic acid content. Performing analysis prior and post treatment is recommended to see development of stabile color.

Recommended Analysis: Total SO_2, VA, pH, Malic Acid, Lactic Acid, DO, Acetaldehyde, Absorbance at 280/420/520/620, Color Profile (CIELab)

Product Recommendations:

- ***Tannins*:** Enartis Tan E to keep the tannin/anthocyanin ratio in balance when there is an abundance of free anthocyanins, in order to promote polymerization reactions for color stability and structure.
- ***Oak Alternatives*:** Incanto Range of oak products (1-4 g/L) to add aromatic complexity and develop mid-palate, mask green/herbaceous characters and integrate oak aromas and flavor.

Control **Micro - OX**

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Stage 3: Post-MLF during Maturation (Average rate 0.5-2 mg/L/MONTH and Total rate typically 10-30 mg/L)

SO_2 ADDITIONS REQUIRED, MAINTAIN FSO2 20-25 MG/L DURING APPLICATION

Goals: Improve mouthfeel as well as develop and integrate aromas. Winemakers prefer to utilize micro-oxygenation at this stage to simulate barrel ageing with oak alternatives for flavor development. Typical oxygen transfer rates in barrel vary from 30 mg/L/*year* in new barrels to less than 10 mg/L/*year* in two year old neutral barrels.
Application: At this stage the O_2 dosage is reduced to a tenth of the rate used prior to SO_2 addition, to allow the slow reaction of oxygen with wine and create highly complex aromas, while reducing the potential for oxidation. Weekly sensory analysis should be documented and wine analysis of volatile acidity (VA), SO_2 and dissolved oxygen (DO) are required to monitor dosage and progression of the micro-oxygenation treatment.

Recommended Analysis: Free & Total SO_2, VA, DO, Wine Phenolic Panel (HPLC), Color at absorbances 280/420/520/620, Color Profile (CIELab), Redox potential

Product Recommendations:

- ***Tannins:*** Enartis Tan E and Enartis Tan Microfruit (5-15 g/hL) for wines with low tannin content to promote polymerization reactions for color stability and structure.
- ***Yeast Derivatives:*** Surli One or Surli Round (10-20 g/hL) to reduce astringency and green/herbaceous characters by enhancing mid-palate and softening of tannins.
- ***Oak Alternatives:*** Incanto Range of oak products (1-4 g/L) to add aromatic complexity and develop mid-palate, mask green/herbaceous characters and integrate oak aromas and flavor.

What are the recommended parameters to monitor throughout micro-oxygenation treatment?

Temperature: Temperature impacts the solubility of oxygen and speed of reactions in wine. Temperatures between 59-68˚F (15-20˚C) are appropriate for treatment. Temperatures less than 55˚F (13˚C) can lead to accumulation of dissolved oxygen due to the increase of oxygen solubility and decrease the speed of wine consumption. Above 68˚F (20˚C), oxidation reactions occur faster, increasing the risk of premature ageing. Typical temperature during treatment is ~59°F (15°C).

Dissolved Oxygen (DO) mg/L: Oxygen should be added in a manner that does not cause an accumulation of dissolved oxygen. Monitoring DO twice weekly throughout the application will help make adjustments to level of treatment and find the appropriate dosage rate for each wine. Maintaining DO levels below 0.8 mg/L for red wine is recommended.

Free SO_2 (FSO_2) mg/L: This parameter should be monitored in wines treated after MLF once SO_2 has been added. A rapid decrease in Free SO_2 indicates too high of an oxygen addition rate or potential microbial spoilage. During maturation, average Free SO_2 should be maintained above 20 mg/L. Research has shown that 1 mg/L of oxygen depletes 4 mg/L Free SO_2 (Boulton et al. 1996), however it should be noted that if there is headspace in the tank, Free SO2 can interact with headspace oxygen, depleting at an expedited rate. Consistent monitoring can help ensure that any movement of Free SO_2 level can be addressed.

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Volatile Acidity (VA) g/L: Volatile acidity should be monitored during the treatment. An increase in VA could be an indicator of bacterial spoilage and high levels of oxygen. Micro-oxygenation in wines with high VA levels is not advised.

Acetaldehyde: Acetaldehyde is a byproduct of wine oxidation and serves as a bridge between unstable color pigments and tannin. This bridge helps bind color and tannin, forming long-lasting or stable color. The process of stabilizing color also has a softening effect on the astringency of wine. A build-up of acetaldehyde indicates there is more production of acetaldehyde occurring through oxidation, rather than color stabilization or bridging reactions occurring. Significant increases in acetaldehyde levels indicate that the amount oxygen being applied needs to be reduced or that the micro-oxygenation needs to be suspended.

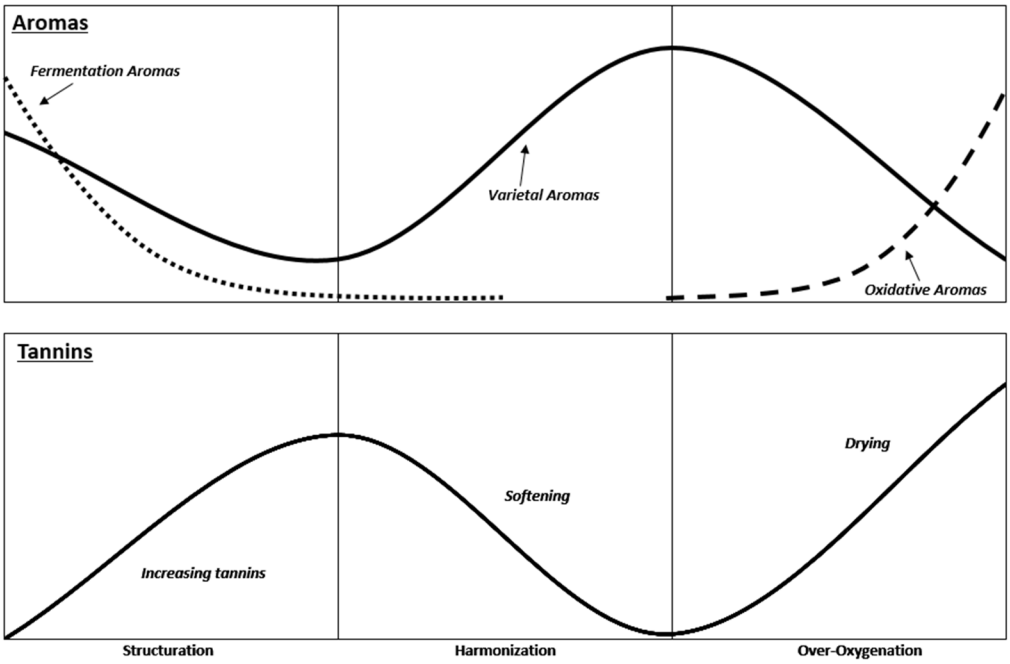
Color Profile: Measurement of color using CIELab-based color identification can differentiate between minor shifts as the wine ages. Understanding the progression of color throughout the treatment of wine allows the reproduction of results between vintages and the recognition of potential issues.

Phenolic Compounds: Phenolic measurement can provide information about the potential for a wine to be treated with oxygen, as well as to guide on starting dosage.

Turbidity (NTU): High turbidity can decrease the effectiveness of treatment as dissolved oxygen will be consumed by yeast lees instead of wine components.

Tasting and Sensory: During micro-oxygenation treatment, tasting and sensory analysis is crucial to fine tune the oxygen dosage. Therefore, the optimal oxygen dosage of micro-oxygenation should be adjusted based on the evolution of the above parameters and weekly sensory evaluation. With micro-oxygenation during ageing, wines go through three stages that can be distinguished by changes in aroma and tannin appearance:

- ***Structuring:*** Structuring can happen pre or post MLF. During this phase, wine tannins become more reactive and aggressive as the degree of polymerization increases tannin astringency. This change is combined with the degree of aromatic complexity.
- ***Harmonization:*** This stage is marked by the formation of a fuller, rounder palate. Tannins become less reactive and are softer throughout the mouth. Aromas integrate more fully while increasing in complexity.
- ***Over Oxygenation:*** This stage is when the treatment has gone too far. Mid palate becomes thinner and tannins are dryer, resulting from excessive polymerization and increasing development of aldehyde/oxidase aromas and flavors. Tasting is the best way of checking the results and deciding when it's time to stop treatment.



Adapted from (Parish *et al.*, 2000)