Micro-oxygenation

of red wine

Background

Red wine production typically involves numerous chemical and biochemical transformations of grape and oak-derived compounds during (*Table 1*):

1. yeast fermentation;
2. malolactic fermentation; and
3. wine maturation.

Oxygen is an important component of the wine maturation process, contributing to chemical aging reactions. Techniques and equipment have been developed to augment the addition of oxygen into wine.

Micro-oxygenation

Wine micro-oxygenation is the controlled addition of oxygen during the winemaking process. The wine consumes the oxygen through preferred chemical reaction. The micro-oxygenation process allows complete mass transfer from the gaseous to the dissolved state, as long as rates of addition are lower than the capacity of the wine to consume the oxygen.

The development of micro-oxygenation was originally aimed at improving the body, structure and fruitiness of red wines with high levels of tannins and anthocyanins. This was achieved by mimicking the wine maturation that occurs in oak barrels, through a slow oxygenation process. This stimulates the aldehyde-cross linkage of polymeric tannins and production of stable pigments.

Stainless steel tanks fitted with a system of micro-oxygenation can replace expensive oak barrels, and can provide the required amount and rate of oxygen for these reactions to occur over a reduced period of time.

Systems

There are two key systems for the controlled addition of oxygen into wine:

1. **Bubble plume diffusion**. Utilises a ceramic diffuser through which oxygen is periodically injected into the wine tank as a stream of very fine bubbles, creating a bubble plume (*Figure 1*).
2. **Permeable membrane diffusion**. A semi-permeable tubular membrane is pressurised and permeates oxygen across the membrane and into the wine (*Figure 2*).

Each system has its limitations and merits, which are highlighted in *Table 2*.

Table 1 Chemical and biochemical transformations of grape and oak-derived compounds during microbial fermentation and maturation in red wine production.

Microbial fermentation or wine maturation phase	Chemical or biochemical transformation
Yeast fermentation	Transforms sugars into ethanol Extracts aroma compounds
Malolactic fermentation	Further transforms aroma compounds Modifies structure De-acidifies Stabilises colour
Wine maturation	Further transforms aroma compounds Generates body and structure Stabilises wine colour Reduces astringency

Table 2 Features of the two main micro-oxygenation systems.

	Bubble plume diffusion	Permeable membrane diffusion
Oxygen supply to wine	periodic	continuous
Oxygen quality/form	allows gaseous oxygen to dissolve	permeation of dissolved oxygen
Oxygen phase transition	in the wine	in the membrane
Gas pressure	variable	constant
Tank size suitability	large only, >2.5 m high	small to large

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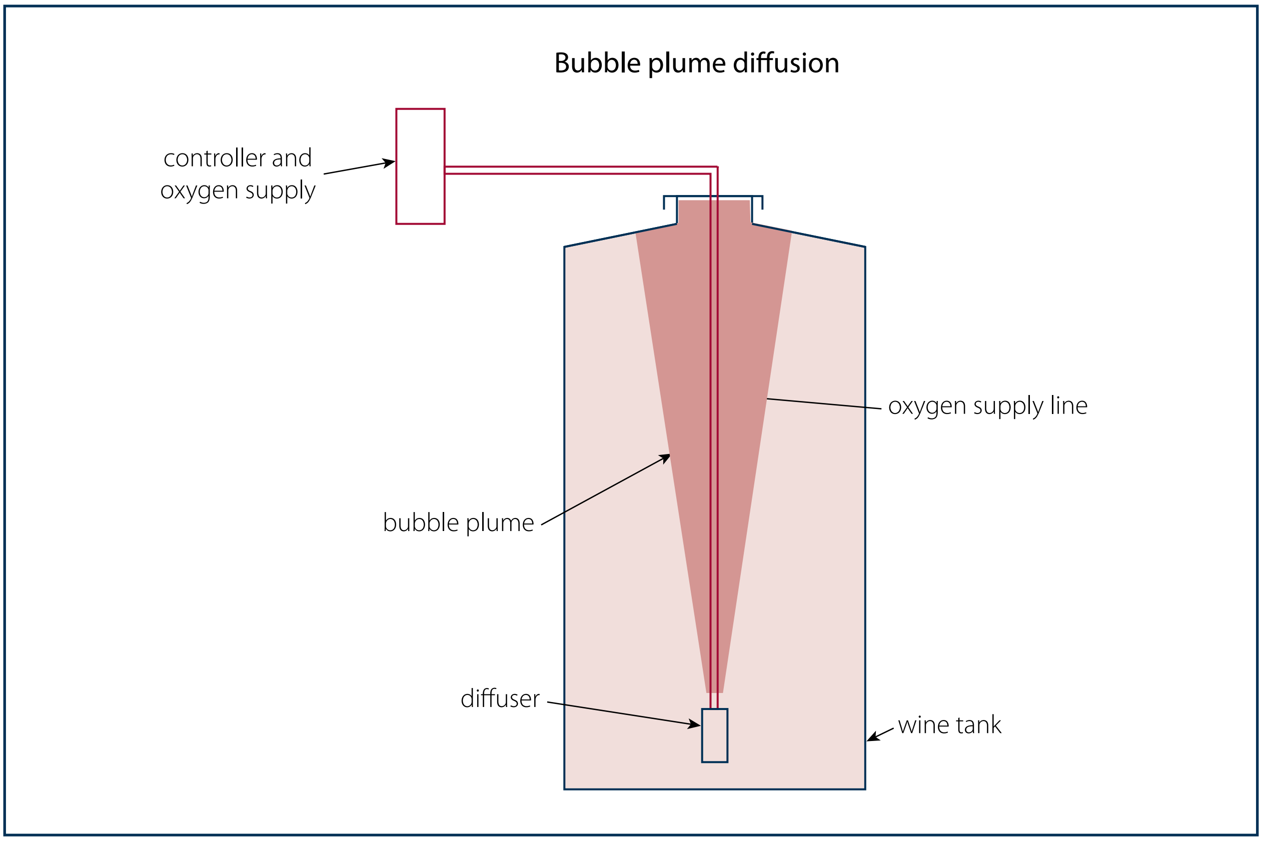

Figure 1 Illustration of bubble plume diffusion, where a very fine plume of oxygen bubbles is injected into the wine periodically (not to scale).

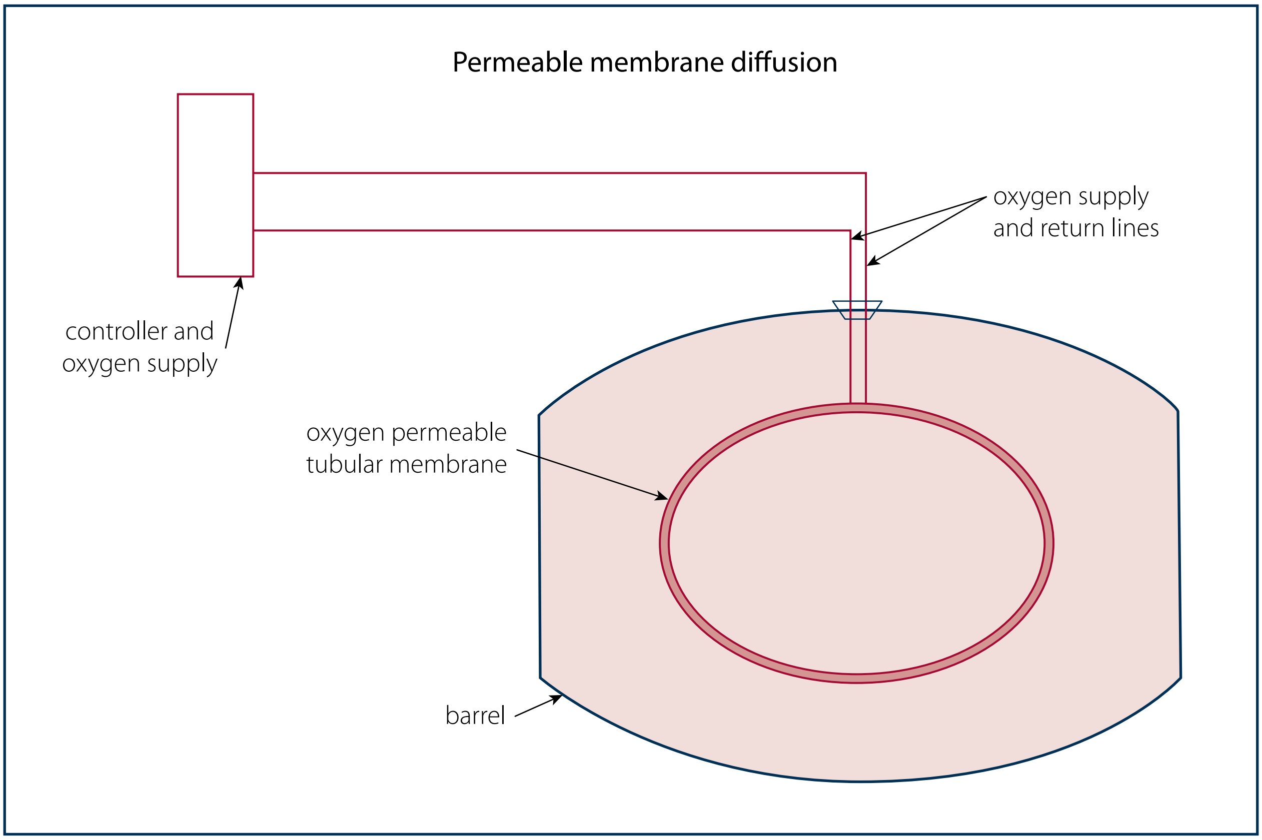

Figure 2 Illustration of permeable membrane diffusion: oxygen under pressure permeates a membrane into the wine tank (not to scale).

Complex control units are used in commercial bubble plume diffusion devices to manage micro-oxygenation dose rates and duration.

Rates and duration

Dose rate and oxygen quantity are the most critical aspect of successful micro-oxygenation to ensure that the wine does not accumulate dissolved oxygen. When oxygen is added above the wine's capacity to consume it, excess oxygenation can lead to:

- oxidation related aldehydes that can reduce sensorial qualities; and
- oxygen accumulation in the head space of the storage vessel, which may lead to growth of aerobic spoilage micro-organisms.

The stage of wine production at which micro-oxygenation is started can also influence recorded rate and quantity of added oxygen (*Table 3*). At early stages there are a range of oxygen consuming species including grape derived phenolic material, yeast hulls, and wine solids. These necessitate the addition of higher rates of oxygen, compared with post malolactic fermentation stages. While there does not seem to be any clear varietal trend, total oxygen amount was higher in those studies that added it to varieties with high flavonoid content (*Table 3*).

Table 3 Micro-oxygenation dose rates and estimated total oxygen addition in a range of wine varieties from different studies.

	Pre-malolactic fermentation micro-oxygenation			Post-malolactic fermentation micro-oxygenation		
Grape variety	**Dose (mg/L/month)**	**Dose (mL/L/month)**	**Duration (days)**	**Dose (mL/L/month)**	**Duration (days)**	**Total oxygen addition (mg/L†)**
Blend (not stated)	4				140	18.4
Cabernet Franc		40–80	10–14			24.4
Cabernet Sauvignon	2–36	2–80	10–30	1–10	84–183	4.9–123.9
Mencia		40–68	17–23	2	30	38.5–60.5
Merlot		2–80	6–112	3	275	10.8–38.6
Monastrell		5–10	21–44	2–5	50–116	7.8–33.1
Montepulciano				2–5	183	17.1–42.9
Pinot Noir		30	10	2–4	214	10.5–20.0
Pinotage	1.5–5				60–140	4.0–30.0
Sangiovese	4–8			1–9	90–183	4.8–47.2
Shiraz	3	5–90	10–25	1–3	67–252	6.3–97.0
Tempranillo		7.5–66	15–23			25.0–58.8
Tinta del Pais		35–66	19–20	1–3	85	6.9–58.8
Tinta de Toro		35–66	19–20			32.8–58.8
Valpolicella				2–5	183	17.1–42.9

† calculated value

Monitoring

The quantification of wine chemical parameters and sensorial assessment can provide wine makers with guidelines to ensure optimum micro-oxygenation conditions for wine maturation while inhibiting undesirable microbial growth. Wine attributes and target specifications for micro-oxygenation are listed in *Table 4*.

Note

Sampling bias when monitoring wine from large non-homogenised tanks may occur due to the uneven exposure of the wine to the dissolved oxygen from bubble plume devices. Furthermore, there may also be inconsistencies in dissolved oxygen monitoring from sensors lowered into the bubble plume, or from the intermittent injection of oxygen from these devices.

Table 4 Attributes important for monitoring micro-oxygenation.

Attributes	Target specification for micro-oxygenation
Dissolved Oxygen	0.1–0.3 mg/L and constant
Temperature	12–18°C
Sensorial	Avoid drying out tannins
Acetaldehyde	None detected by sensory
Turbidity	<100 nephelometer turbidity units

Daily use of experienced tasters for sensorial analysis of micro-oxygenation wines is seen as critical for appropriate decision making in the management of oxygen additions to wine. The major sensorial attributes of wine that are affected by micro-oxygenation are:

- colour;
- concentration of aldehyde;
- astringency; and
- fruitiness.

Micro-oxygenation

review undertaken by the National Wine and Grape Industry Centre

Project	Micro-oxygenation of red wine: techniques, applications and outcomes
When and where	2010 and 2011, Wagga Wagga NSW
Collaborators	Leigh Schmidtke, NWGIC, Andrew Clark, NWGIC and Geoff Scollary, The University of Melbourne
Funding	Domaine Chandon, Victoria

The outcomes of micro-oxygenation in red wines can be divided into sensorial and chemical attributes.

Sensorial attributes

Trends of the sensorial results suggest that the outcomes of micro-oxygenation are varied according to the compositional attributes of the wine before oxygen addition. There have been numerous reports of sensorial enhancements to wine after micro-oxygenation including:

- increase in fruitiness;
- lowering of herbaceousness and reductive characters; with
- increase in the fullness and round palate structure.

Chemical attributes

Compounds considered important in the production of varietal and herbaceous aromas (including terpenes, lactones, esters, vanillins, higher alcohols and volatile phenols) were monitored for eight months after pre-malolactic fermentation micro-oxygenation of Cabernet Sauvignon and Tempranillo. No changes in concentrations were recorded that corresponded to any improved wine aroma for these tested varieties. Micro-oxygenation treated wines from two vintages of Mencia and Tinto de Toro consistently showed lower levels of furfural, cis-whiskey lactone and eugenol, and higher concentrations of vanillin and guaiacol compared to control wines.

Wine spoilage

Oxygenation of wine could lead to an increase in the presence and growth of organisms associated with wine spoilage. Aerobic microbial organisms such as *Acetobacter* (AAB) and *Brettanomyces* were found to be at higher levels in micro-oxygenation wines from two trials, the latter organism abundance correlated to decreased free sulfur dioxide concentration. The addition of sulfur dioxide during the trial reduced viable numbers of *Brettanomyces*.

Wine colour

Red wine colour is influenced by many different compounds, including:

- anthocyanins,
- flavonols, and
- pyranoanthocyanins.

Anthocyanins are monomeric compounds that are the principle colour agents in red wine, and accumulate from grape skin and pulp extraction during the winemaking process. Anthocyanins can react with other flavonoids to form new coloured compounds with 2, 3 or more subunits. The flavonoids are typically other anthocyanins, flavonols (e.g. (+)–catechin), or pyranoanthocyanins. Polymeric material can also be formed in reactions involving acetaldehyde acting as a bridge between anthocyanins, flavonols etc. Micro-oxygenation has been linked to increased levels of coloured compounds formed from anthocyanin/flavonol bridging, as well as an increased rate of formation of pyranoanthocyanins (e.g. vitisin-B) through enhanced acetaldehyde production, giving a brick-red colour.

Future research

While there are several commercial micro-oxygenation devices on the market, the results for large scale trials suggest that dissolved oxygen distribution through the tank is inconsistent, and may contribute to a lack of desired sensory outcomes. This may also reduce the changes in chemical attributes that support sensorial improvements from micro-oxygenation. Future research should consider the improvement of the:

1. Consistency of oxygen addition in commercial sized tanks, and the monitoring of chemical attributes during the process.
2. Clarification of the tactile sensorial properties of anthocyanin derivatives formed during micro-oxygenation. This may help explain a perceived improvement in astringency of micro-oxygenated wines.
3. Understanding of acetaldehyde existence in the presence of free sulfur dioxide in wine.
4. Understanding of competing reactions occurring within wines following micro-oxygenation.

Further information	www.nwgic.org

Schmidtke, L.M., Clark, A.C. and Scollary, G.R. (2011). Micro-oxygenation of red wine: techniques, applications and outcomes. *Critical Reviews in Food Science and Nutrition* **51**(2): 115–131.

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