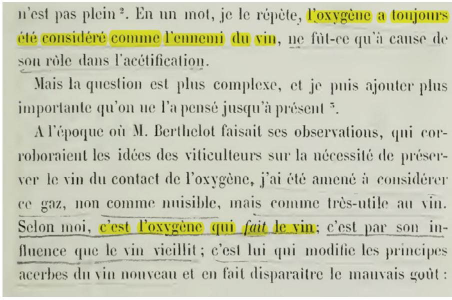
Technical notes

Introducing and measuring oxygen during active ferments

The quest to understand the role that oxygen plays in winemaking is as old as the history of oenology itself. Many modern articles on oxygen in winemaking will quote Louis Pasteur who, in acknowledging previous wisdom that described oxygen as the enemy of wine, proposed the opposing view that oxygen is what *makes* (Pasteur's italics) wine ("C'est l'oxygene qui *fait* le vin"). In this influential work, Pasteur demonstrated that a given amount of oxygen was needed to allow a wine to mature correctly. A slow and progressive addition of oxygen was advised over a sudden and rapid addition – perhaps he was already imagining micro-ox?


n'est pas plein [2]. En un mot, je le répète, l'oxygène a toujours été considéré comme l'ennemi du vin, ne fût-ce qu'à cause de son rôle dans l'acétification.

Mais la question est plus complexe, et je puis ajouter plus importante qu'on ne l'a pensé jusqu'à présent [3].

A l'époque où M. Berthelot faisait ses observations, qui corroboraient les idées des viticulteurs sur la nécessité de préserver le vin du contact de l'oxygène, j'ai été amené à considérer ce gaz, non comme nuisible, mais comme très-utile au vin. Selon moi, c'est l'oxygène qui *fait* le vin; c'est par son influence que le vin vieillit; c'est lui qui modifie les principes acerbes du vin nouveau et en fait disparaître le mauvais goût:

Figure 1. Extract from Pasteur's Etudes sur le vin (2nd edition) 1875

What is often overlooked by those revisiting this work is that Pasteur was the first to realise that must aeration influences the future quality of a wine as well as being essential for a vigorous fermentation. To demonstrate this, in an experiment conducted in 1864, he exposed a volume (335 L) of crushed fruit to air in a refrigerated tub for three days, raking over the surface twice a day, before racking it off to barrel; his control must was run to barrel without prior aeration. The result of this trial demonstrated that the wine made from oxygen-exposed must was 'good to drink', having lost any 'green', or 'unripe' characters, and was also less 'acerbe', an adjective encompassing taste sensations of 'bitter', 'tart' and 'pungent'. He further went on to applaud those wineries whose crushing and pressing techniques introduced oxygen into the must before fermentation.

After 150 years the role of oxygen in winemaking is still of great relevance. The AWRI has embarked on a four-year project applying new technology to answer some age-old questions:

- What is the oxygen requirement of a must, over and above the requirements for a healthy yeast population?
- What is the importance of the timing of the oxygen addition?
- How can oxygen be measured to ensure the right amount is added?
- How can oxygen be delivered most efficiently into must?

The answers to the first two questions are being investigated in a series of laboratory-based experiments and pilot-scale winery trials which form the backbone of the AWRI's current wine and oxygen project. This article will instead focus on possible answers to the third and fourth questions – how to measure oxygen and how to deliver it.

Measuring oxygen in an active ferment

The measurement of dissolved oxygen (DO) in finished wines is not new to the wine industry and several types of DO meter have been available for some time. The Orbisphere 3650 is standard equipment in most bottling labs and handheld meters, such as the Hach HQ, can be used to measure tank DO prior to bottling or even headspace oxygen during ullage management. The Orbisphere is best suited to use with finished wine and in the lab because of the possibility of membrane fouling. Depending on the model, handheld devices also do a reasonable job, provided that they are frequently calibrated, preferably using a two-point calibration[1].

Another DO-measuring technology uses luminescence and is often referred to as LDO – this is the system used in the AWRI bottling line oxygen audits. More robust DO probes are also available which are better suited for use on the cellar floor, particularly when built into pump-over rigs. The AWRI has been using stainless steel probes – routinely used in the brewing industry – with a stand-alone monitor mounted in 2′ and 3′ fittings. This set-up has enabled the determination of DO during juice and wine transfers and in large scale aeration trials with a commercial venturi.

Another innovative device that has been trialled is a small DO datalogger (operated on two AA batteries with a standard digital camera memory card) which can be deployed in a tank and left to monitor DO over several hours, days or weeks before recovery and data download. With this device it has been possible to monitor the DO inside a press during both inert and normal aerobic press cycles (Figure 2).

However, just getting a value for DO is not the whole story. As yeast are voracious consumers of oxygen, a DO measurement made in an active ferment may not accurately represent how much oxygen is being delivered. Equally, the oxygen consumption by oxidation of phenolic compounds, particularly in red wines, may also compromise the ability to take a meaningful DO reading. In addition, the CO_2 evolving from a vigorous fermentation can easily sparge out the oxygen dissolving into the must and give a low value. This therefore does make

[1] The 0% O_2 calibrant can be made by dissolving 1 g sodium sulfite (Na_2SO_3) and 0.5 mL cobalt nitrate (0.1 g/L) in 100 mL water. The 100% O_2 calibrant is made by sparging water with air using an air-pump with a glass-frit (or airstone, normally used in aquariums), creating a multitude of small air bubbles, while stirring the solution. Switch off bubbling and stir for 10 minutes prior to measurement to prevent oversaturation.

measuring DO a challenge. The best option is to measure DO before and immediately after an air introduction device to assess the amount of oxygen introduced.

Ways to introduce oxygen into an active ferment

In wineries that grow their own yeast cultures for inoculation, aerating juice using a stainless sinter or frit fed by compressed air is common, although the aim of such an array is to saturate the solution (typically around 8 mg/L O_2). In white winemaking, in-tank spargers, either ceramic or stainless steel, can be easily deployed and fed with compressed air. However, for red winemaking the options need to be more varied depending on the fermenter used, whether open, Potter/SWAP (sweeping arm Potter) or Vinimatic.

It is generally believed that open fermenters are largely oxidative and anecdotal evidence suggests that reductive aromas are less common when such fermenters are used. However the blanket of carbon dioxide that exists above the cap will prevent any substantial aeration even when vigorously plunged. A pump-over with fanning/spraying or using an irrigator placed higher than the top of the fermenter will be needed to introduce oxygen from outside. Potters/SWAPs are essentially closed systems and as such need active methods for getting oxygen into the system. The open pump-over tub is widely used but again the blanket of CO_2 may prevent effective aeration if an inclined plane or screen is not included in the set-up. A submerged air-stone or sparger fed by compressed air would improve the aeration; however this is less convenient.

Fitting some sort of air bleed into the pump-over system either before or after the pump may prove to be more convenient and a number of options are available (Figure 3). Placed on

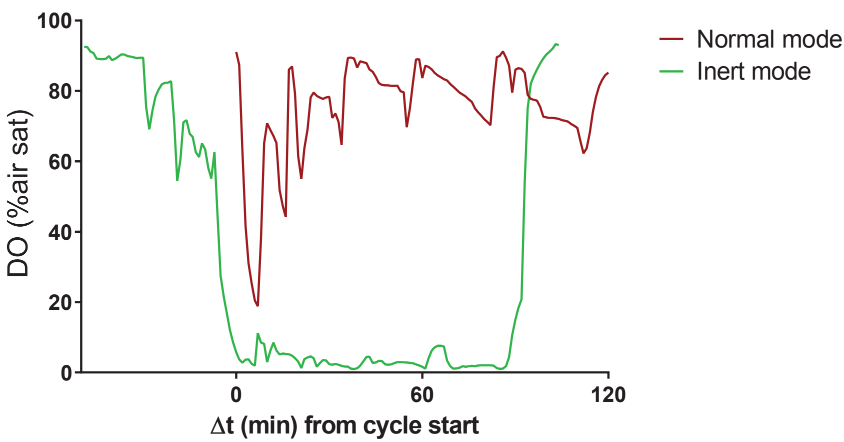


Figure 2. Dissolved oxygen measured inside a membrane press during inert and aerobic cycles

the suction side of the pump, a small opening will create a venturi effect, sucking air from outside, and avoiding the need for a compressed air feed. Many people use this set-up for introducing additives or yeast into the tank, however when it is only sucking in air this might cause the pump to cavitate and greatly increase the risk of rotor burn out. Of course this is essentially the same as the common practice of 'cracking the fitting' (i.e. just loosening the hose fitting on the suction side of the pump) which has similar risks. If an in-line sparger is used on the suction, the aeration is just as effective and the cavitation risk is slightly reduced. An air-draw tube is another option constructed of a cylinder of sintered metal (typically available with 20 or 40 micron pores) which looks like a standard hose union fitting. The disadvantage of this is that air is continuously drawn through the fitting while the pump is on; placement of the fitting is also important as head pressure could force liquid to bleed out once the pump is turned off. A safer option for the pump is to have the in-line sparger on the delivery side of the pump and blow compressed air into the flow of liquid, although this does incur additional infrastructure costs.

Another option that protects the pump is to use a commercially available venturi air injection system. A venturi device introduces a restriction in the flow which causes an increase in fluid velocity but drops its pressure at the narrowest end. An air inlet at right angles to the flow is placed at this point where the restriction ends, sucking in air to the flow of liquid. This can be placed on the delivery side of the pump as long as a non-return valve is placed at the air inlet. Alternatively, the venturi device can be placed just before the irrigator.

Figure 3. Examples of fittings used to deliver oxygen to ferments – venturi injector (left), in-line sparger (middle) and air-draw tube (right)

Table 1 presents DO measurements recorded before and after use of four options for oxygen delivery. It can be seen that 'cracking the fitting' and an open tap on the suction side of a pump result in the highest (and very similar) DO concentrations, followed by the in-line sparger and then the airdraw tube. As understanding grows of the oxygen requirements of different types of fermentations, this information will allow winemakers to tailor their oxygen delivery to achieve optimum results.

Table 1. DO values using different methods suitable in a small to medium sized winery

Device	DO before (% air sat)	DO at steady-state (% air sat)
Airdraw tube (20 μm frit) attached to bottom tank valve	1.1	2.3 – 8.8 %
In-line spargers (~2 μm frit) attached to pump suction inlet	1.0	21.5 %
Open tap on pump suction	2.5% (uninoculated juice)	35.6 %
'cracking the fitting'	4.0 %	37.3 %

References

Pasteur, L. (1875) Etudes sur le vin: ses maladies, causes qui les provoquent, procédés nouveaux pour le conserver et pour le vieillir (2nd Edition), Librarie F. Savy, Paris (www.archive.org/details/tudessurlevins00past)

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