Managing oxygen ingress at bottling

Vince O'Brien[1] and Chris Colby[2] with Mai Nygaard

INNOVATION FOR SUCCESS

In this column we present results from cutting-edge research that sheds light on a significant wine quality issue confronting the wine sector: management of oxygen ingress in bottles. This research involved benchmarking how well current oxygen management practices are being performed at bottling in selected wineries in Australia. The Australian Wine Research Institute (AWRI) Commercial Service and Nomacorc, using its proprietary PreSens technology for oxygen measurement in wine bottles, conducted the study. Consequently, we invited Mai Nygaard, Nomacorc's business and brand development manager, to co-author this article with us.

OXYGEN, FRIEND OR FOE?

Keeping oxygen out of wine is like trying to stay dry in a swimming pool!

Oxygen can have a significant impact on wine style. Low oxygen ingress levels typically tend to lead to wines displaying elevated fresh fruit attributes, an absence of developed characters such as toasty and honey attributes, and a tendency to form undesirable reduced characters. On the other hand, too much oxygen can lead to subdued fresh fruit characters, the development of stewed and cooked fruit along with other developed attributes, the absence of reduced characters and the early onset of undesirable oxidised attributes.

Oxygen's impact is so dramatic that the same wine exposed to slightly different oxygen levels at and after bottling can result in completely distinct products.

For example, closure benchmarking studies widely published in the literature repeatedly demonstrate that oxygen impacts significantly on wine style (Skouroumounis *et al.* 2005, Godden *et al.* 2005, Godden *et al.* 2001 a,b,c, Francis *et al.* 2003)

Furthermore, a survey of 2598 wines at the 2008 Royal Adelaide Wine Show revealed that approximately 130 wines had reductive or oxidised characters significant enough to impact on the perceived quality of the wines (2% reductive and 3% oxidised). These results are consistent with observations at the 2006, 2007 and 2008 International Wine Challenge in London, where fault analysis revealed that almost half of all wine faults were oxygen management related, with approximately 2% of the wines being reductive and 1-2% oxidised (Harrop 2008).

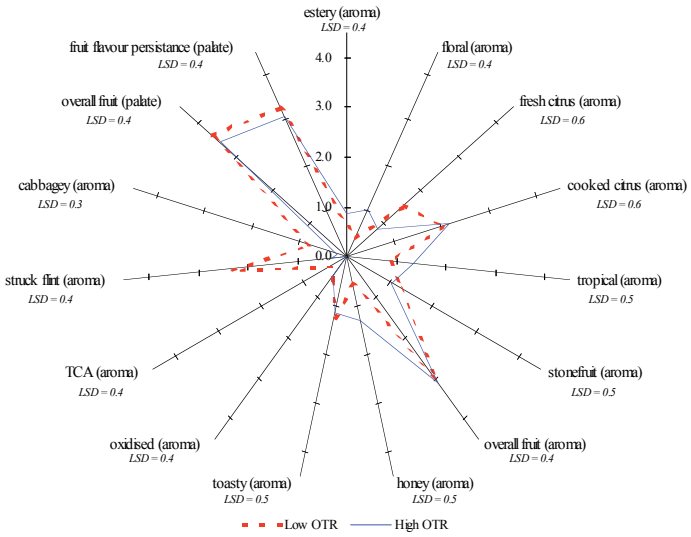

Figure 1. Example of a sensory evaluation of a Semillon wine under two different closure OTRs. Data collected 18 months post-bottling (AWRI Commercial closure trial 2008).

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The development of reductive characters in wines was discussed in our column in the September/October 2008 issue of this journal, and will not be discussed further other than to state that evidence such as that shown in Figure 1 shows significant levels of reductive attributes can develop in a wine, subsequent to bottling under a closure with low oxygen transmission rate (OTR), despite the wine being adequately copper-fined prior to bottling. Low molecular weight sulfide compound analysis of the wines in Figure 1 have shown trace amounts of the compound methanethiol (rotten cabbage, burnt rubber, putrid attributes) were present in the wine under the low OTR closure that were not present in the other wines showing no reductive characters (AWRI Commercial closure trial 2008).

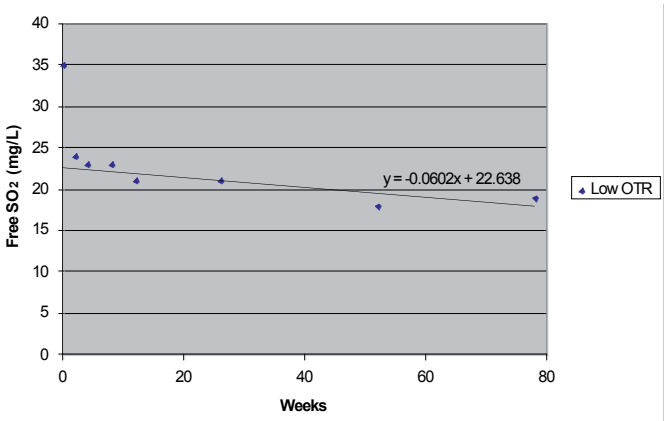


Figure 2. Free SO_2 decay subsequent to bottling with a low OTR closure. The initial free SO_2 content at the time of bottling was 35mg/L.

The shelf life of a wine is typically dictated by the onset of oxidised characters in a wine, which can be associated with, as a rough rule of thumb, free SO_2 levels dropping to less than 10mg/L in the wine. At this point, insufficient free SO_2 is available to bind newly-formed oxidised compounds, allowing them to have a detrimental effect on wine flavour and aroma. The majority of red and white wines have free SO_2 levels around 30-35mg/L at bottling. Given that 1mg/L of oxygen leads to the depletion of approximately 4mg/L free SO_2 (Boulton *et al.* 1996), it only takes a total of 5mg/L of oxygen before oxidised characters will develop in the wine. Obviously, serious quality implications will occur at far smaller amounts of oxygen ingress due to wine style changes, particularly with many fruit driven wine styles.

In summary, the effect of oxygen ingress at and after bottling is critical because it:

- impacts on wine style
- can cause the onset of wine faults
- determines wine shelf life
- presents carefully crafted products to the market place in the form that winemakers intend, which can only be achieved with effective control of oxygen ingress levels.

Furthermore, effective management of oxygen levels in wine involves providing a desired wine style for drinkers at the point of consumption. Too little oxygen can lead to the development of reduced characters or the slow onset of desirable developed attributes. Too much oxygen can cause premature loss of fresh fruit characteristics and the development of oxidised attributes.

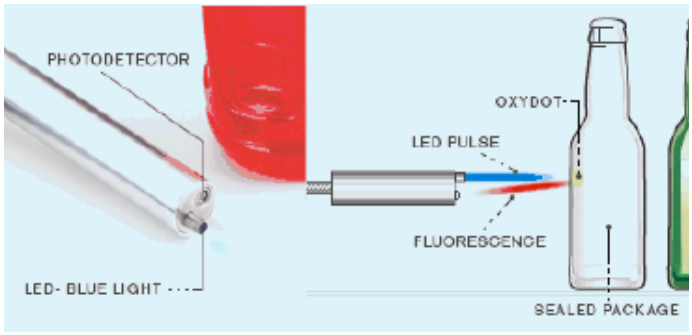
BOTTLING OPERATIONS

One of the largest sources of oxygen ingress into wine occurs during bottling operations. Figure 2 shows a typical decay of free SO_2 in wine after bottling, for a wine bottled under a low OTR closure. The figure shows approximately 50% of the decline in free SO_2 before the wine's shelf life is reached (based on a 10mg/L limit), occurring within one month of bottling. The rapid initial rate of free SO_2 decline can be attributed entirely to oxygen entrained in the wine and headspace at bottling due to the near anoxic seal this closure provides.

Given free SO_2 is depleted rapidly shortly after bottling, associated with its role in 'mopping up' oxidation products in the wine, it is not surprising we see effects such as bottle shock. Bottle shock is a term used to describe the loss in flavour and aroma intensity in many wines immediately after bottling. Usually a wine's concentration of flavour and aroma attributes recover over a period of one to several months, however, we suspect it might only achieve a reduced intensity and a slightly altered wine style.

BOTTLING LINE AUDITS USING 'PRESENS' TECHNOLOGY

In collaboration between the AWRI Commercial Service and Nomacorc, three bottling line audits were conducted using a novel technology called the PreSens, depicted in Figure 3. Nomacorc is the distributor of PreSens and has previously validated this technology in similar studies in Europe. The PreSens uses the oxoluminescense principle to provide reliable measurements of headspace oxygen levels and wine dissolved oxygen levels through the technical capability tied up in the oxygen sensor spot. A light-emitting diode (LED) provides a blue light exitation pulse to the oxygen sensor spot, which returns a fluorescent red light signal indicative of the oxygen



(a) (b)

Figure 3. PreSens technology and wine bottle application (PreSens/ Nomacorc, 2008). (a) The photodetector. (b) Illustrates application for measurement of oxygen in a bottle containing an oxoluminescent 'oxygen sensor spot'.

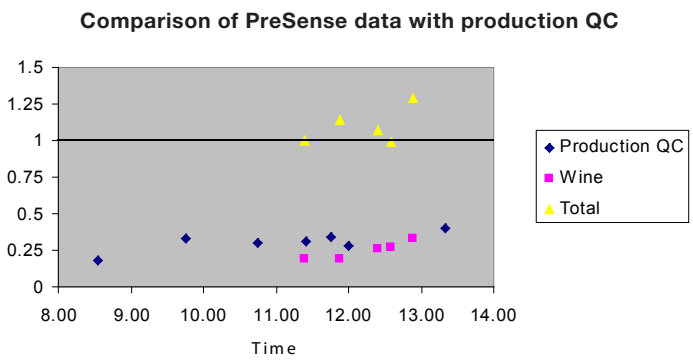


Figure 4: Oxygen data collected during a bottling run at a commercial winery. PreSens data include dissolved oxygen (wine) and dissolved +headspace oxygen (total).

concentration. Two oxygen sensor spots are glued inside a bottle, one in the headspace region and one in the side of the bottle as depicted, which can be passed down bottling lines under standard operating conditions.

The technology was applied at three different bottling lines during October and November 2008. Two lines were commercial operations, while the third was a smaller experimental bottling line with no vacuum applied. Results from a bottling audit performed during a run on a commercial bottling line are shown in Figure 4.

The results shown in Figure 4 highlight the following:

- similar dissolved oxygen (DO) values in the wine were obtained using the PreSens and the winery's Orbisphere
- dissolved oxygen levels in the wine were well below the production quality control set point of 1mg/L
- oxygen levels in the wine headspace contributed to the total level of oxygen in the bottle, resulting in it slightly exceeding the quality control set point

Results obtained from all three audits are depicted in Figure 5 which show:

- the total oxygen ingress at bottling varies significantly between different bottling lines
- most of the oxygen entrained in the bottle resides in the headspace.

HEADSPACE MANAGEMENT

The botting line audit results suggest that in many bottling facilities, a large amount of oxygen is entrained into the bottle in

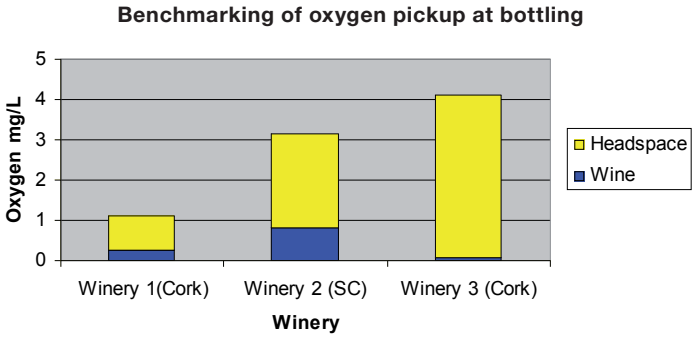


Figure 5: Summary of bottling audit results from three different bottling lines.

the headspace. Table 1 shows potential levels of oxygen in an untreated headspace and the resultant impact these oxygen levels could have on free SO_2 levels in the bottle. Obviously, these levels of oxygen have a significant impact on the shelf life of the wine and are likely to have a significant impact on wine quality.

Current technologies used to manage headspace oxygen levels at bottling include the following:

- nitrogen gas sparging followed by filling and closure application in a nitrogen blanketed environment
- nitrogen gas sparging pre- and/or post-filling
- liquid nitrogen sparging pre- and/or post-filling
- CO_2 snow drop pre- and/or post-filling
- vacuum.

It is our experience that the performance of these technologies varies dramatically depending on how well the process is engineered and controlled. Most oxygen quality control strategies used in bottling lines only record the dissolved oxygen levels in the wine, leaving the headspace oxygen levels unmonitored. This is a risky approach given the aforementioned results.

Table 1. Potential headspace oxygen levels.

750mL bottle	Screwcap	Cork (headspace - 15kPa)
Ullage (mL)*	10	10
O_2 (mL)	2.1	1.8
O_2 (mg/L)	3.9	3.3
SO_2 loss (mg/L)	15.6	13.3

* Note values selected purely for illustration purposes highlighting the potential impact of no headspace treatment and the relatively minor impact of pulling a vacuum under a cork.

TAKE-HOME MESSAGE

Managing oxygen ingress at bottling is critical to controlling wine quality and shelf life. Three bottling line audits conducted using the PreSens technology showed a large part of the oxygen getting into a wine at bottling exists in the headspace, a component which goes unmonitored in many bottling lines.

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