The Australian Wine Research Institute

Fact Sheet
CLOSURES AND PACKAGING

Understanding total package oxygen

What is total package oxygen (TPO)?

Total package oxygen (TPO) is the total concentration of oxygen present in a packaged wine at the time of packaging. For standard glass 750 mL bottles, there are three potential sources of oxygen:

1. the dissolved oxygen (DO) in the wine when the bottle is filled
2. the oxygen present in the headspace when the closure is applied
3. the oxygen encapsulated in the closure itself.

Once a wine has been bottled, additional oxygen may still enter the bottle via diffusion through the closure. The rate of this diffusion is governed by the oxygen transmission rate (OTR) of the closure. For alternative packaging, such as bag-in-box or aluminium cans, the principal of TPO is similar to that defined above.

Why is TPO important?

TPO has been shown to have a significant impact on wine development and shelf life. High TPO concentrations can lead to premature oxidation of the wine during bottle ageing, affecting wine flavour and aroma. If bottling TPO levels are not well controlled, the impact of TPO can be more significant than that of oxygen ingress through the closure over the life of the wine.

Contributors to TPO

1. Dissolved oxygen (DO)

The concentration of DO present in wine at bottling can be influenced by the preparation techniques used, filtration processes and method of transfer to the filler bowl. During filling, DO can increase due to poor inert gas cover and pre-fill bottle purging, high filling temperatures and line stoppages. Dissolved oxygen concentrations can be reduced prior to filling by judicious use of sparging with an inert gas (typically air/nitrogen/CO_2 then follow up sparge with nitrogen), although this practice can also affect the concentration of volatile aroma compounds present in the wine.

2. Headspace oxygen (HO)

Headspace oxygen is predominantly determined by the efficiency of the inert gas flushing (if used) applied to the empty bottles before filling and to the headspace in the bottle after filling. It is important to ensure that the bottling line is well maintained. In particular, it is important that seals on individual filling heads and pumps are functioning correctly and do not allow the ingress of air. Most modern bottling lines are able to achieve displacement of approximately 60-80% of the oxygen from the headspace, resulting in reasonably low HO values of around 0.8-1.5 mg/L. The total amount of oxygen present in the headspace is governed by the ullage volume (the space between the upper surface of the wine and the closure). The headspace (ullage) volume under a screw-cap is greater than under cylindrical closures such as natural, synthetic or technical corks.

3. Oxygen encapsulated in the closure

Contributions to TPO from oxygen encapsulated in the closure itself occur predominantly when using cylindrical closures such as cork. The concentration of encapsulated oxygen can be significantly higher than that contained in the headspace, depending on the type of closure used. The mechanisms through which oxygen trapped within the lenticels of cork closures diffuse into the headspace of a bottled wine are not well understood, but partial pressure gradients are likely to dictate that this occurs during the first few months after bottling.

Screw caps can introduce a significant volume of oxygen into the headspace unless the cap space underneath is specifically dosed with an inert gas, such as nitrogen, immediately prior to application. The total volume of a standard screw-cap, including the skirt, is approximately 40 mL, compared with the internal headspace volume of approximately 10 mL, when a standard fill height of 32 mm is applied during bottling. On application, a degree of mixing between the two environments would be expected. If cap dosing is not applied, this can significantly increase the TPO at bottling.

Relative contributions of headspace and dissolved oxygen to TPO

Total package oxygen is a relatively new concept in the wine industry, with many producers still focusing on dissolved oxygen (DO) concentration in wine during bottling. An extensive benchmarking study of Australian bottling lines carried out in 2010 found that the relative contributions of HO and DO oxygen to TPO varied significantly among different bottling lines, with HO typically accounting for more than 60% of the TPO (Figure 1).

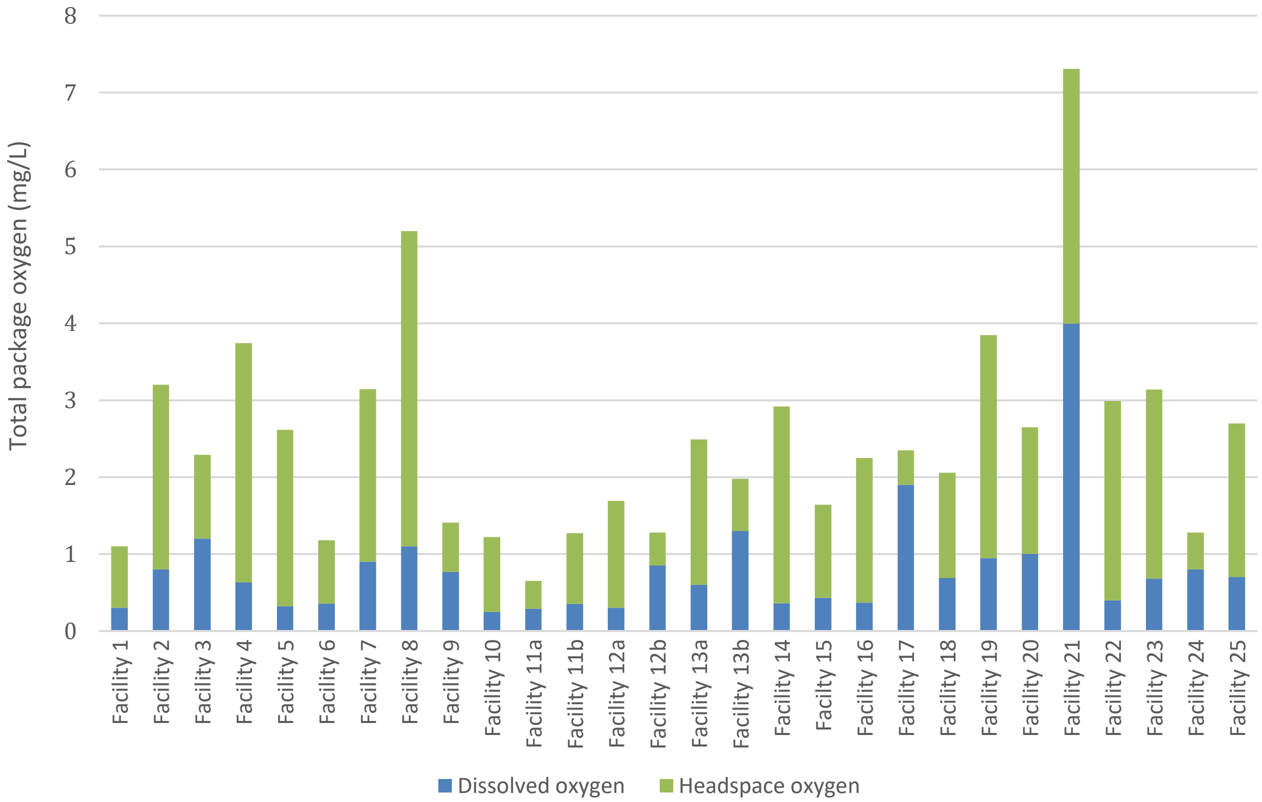

Figure 1. Measured total package oxygen levels in wines packaged on 25 different Australian bottling lines, showing contributions of headspace and dissolved oxygen

Table 1 presents the relative contributions of the oxygen present at bottling (TPO) and the oxygen that diffuses through the closure over time, for wines packaged with different oxygen levels. For wines with high initial oxygen level, the TPO can dominate the total oxygen exposure for the wine, resulting in an extremely short shelf life. When best practice oxygen management techniques are employed (low initial oxygen level), the oxygen contribution entering through the closure becomes more significant and the wine will have a longer shelf life.

Table 1. Relative contributions of TPO and closure OTR to total oxygen exposure over a one-year storage period, with the projected shelf life of the wine, following bottling under different oxygen levels

TPO Case Studies	TPO (mg/L)	Closure OTR contribution (mg/L)	Total oxygen exposure (mg/L)	Total oxygen exposure due to TPO	Projected shelf-life (months)
LOW (<1.0 mg/L)	0.2	2.2	2.4	8%	27
MEDIUM (1.0 – 3.0 mg/L)	1.9	2.1	4.1	47%	8
HIGH (> 3.0 mg/L)	4.7	2.0	6.7	70%	6

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Measuring TPO

There are many ways to measure the concentration of DO and HO in wine, in order to determine the TPO concentration; however, the majority of these methods require destructive testing. The TPO concentration can, however, be determined using a non-destructive technique. This relies on the use of oxygen sensitive sensors (dots) that fluoresce when illuminated using an excitation light source (supplied through an optical fibre). The strength of the fluorescence is dependent on the amount of oxygen present in the environment surrounding the sensor (see Figure 2). The sensors can be affixed to the inside body and the neck of a bottle, to directly measure DO and HO respectively.

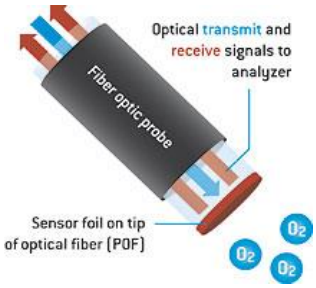

Figure 2. Measurement principle for non-destructive testing of oxygen concentration

The AWRI has also developed a method for estimating TPO in wine using a modified dissolved oxygen (DO) measurement (the TPO calculator). The method allows the oxygen present in the headspace to be incorporated into the measurement, by shaking of the sample for a short period (five minutes), measuring the increased DO concentration and then adjusting this figure to account for bottle neck internal diameter, ullage volume (fill height) and wine temperature. The TPO calculator is available from the packaging solutions page on the AWRI website and is free to access.

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Further reading

Winemakers' Federation of Australia (2015) *Wine Packaging Guideline: Guidelines for the Use of Wine Packaging*. Available from: https://www.agw.org.au/assets/technical-and-packaging/WFA-Wine-Packaging-Guidelines-May-2015.pdf