Technical note

Summary of AWRI closure trials and other investigations into closure performance

Introduction

In 1999, the AWRI bottled a major trial comparing the performance of a wide range of wine bottle closures. The purpose of the trial was to conduct an independent assessment of closure performance to give winemakers robust data on which to base their decisions about closures. Since the 1999 trial, the AWRI has carried out number of additional closure trials in different wine matrices and has been involved in assessing data on closure-related wine faults from the International Wine Challenge. This article summarises some of the key lessons learned from closure studies over more than 20 years.

1999 AWRI Closure Trial

Background

The 1999 AWRI Closure Trial was bottled on 14 May 1999 with a high-quality Semillon wine packaged using 14 different closures: two grades of natural cork, two 'technical' or 'manufactured' corks, nine synthetic corks, and one screwcap. Great care was taken to ensure the trial was fair and impartial. Bottling was performed at a leading commercial bottling facility under strictly controlled conditions, with the manufacturers or suppliers of all closures except the screwcap present. The two grades of cork were those most used in Australia at the time and following extensive testing, were deemed to be representative of corks available in the marketplace. The technical corks and synthetic corks were supplied by the manufacturers, and the screwcaps were taken from the standard stock held at the bottling facility. Approximately 8,600 bottles were filled. A bottling-run of 300 bottles was performed for each of the non-screwcap closures, with the order in which the closures were used determined at random. One bottling run of approximately 800 bottles was then performed with the screwcap, followed by second 300-bottle runs for each of the non-screwcap closures, conducted in reverse order. Each bottle was given an identifying number, and stored inverted at 15°C. The storage position of each bottle within each pallet of wine, and the selection of individual bottles used for subsequent chemical and sensory testing, was determined by random number generation.

The results of testing performed up to 20 months post-bottling were peer-reviewed and published in 2001 (Godden et al. 2001), with later results and commentary included in 14 subsequent publications, including Godden (2001), Godden (2002) and Godden at al. (2005). Although it was anticipated that the trial would run for ten years, testing was terminated

after three years because the results were clear-cut, and because the mix of available closures in the marketplace changed markedly in a short space of time, partly because of the trial's findings. Several of the poorly performing closures were withdrawn from the market, others underwent major design changes, while some entirely new closures were introduced.

Results of chemical and sensory testing

Testing commenced six months after bottling and was repeated at three- or six-monthly intervals. Strong positive correlations were seen between how much sulfur dioxide (SO_2) was retained in the wine, the freshness of fruit characters and the lack of yellow/brown colour development. Sulfur dioxide is the major preservative in wine, and its retention over time is a key indicator of the closure's effectiveness.

The screwcap demonstrated superior performance to the other closures for the retention of SO_2, freshness of fruit, and lowest development of yellow/brown colour. This was followed by the two manufactured corks, and then the two grades of natural cork. While laboratory testing ceased after three years, a bottle of wine sealed with each of the closures was photographed at approximately two, five and ten years after bottling, with the bottles arranged in ascending order of colour development/descending order of SO_2 retention, from left to right (Figure 1). Very little change in the order of the wines in these photos was seen over time, with the screwcap and the 'Altec' manufactured cork (the forerunner of 'Diam'), maintaining superior performance over the longer term. Similar trends have been seen in subsequent AWRI closure trials with both red and white wines.

Figure 1. Images of wines from the 1999 AWRI Closure Trial, arranged from lowest to highest colour development at two, five and ten years after bottling

Reasons for differences in closure performance

The reason that retention of sulfur dioxide is a key indicator of closure performance is because SO_2 acts in wine as a sacrificial antioxidant. Once the SO_2 has been largely exhausted, further oxygen exposure leads to oxidation of the wine, with a loss of fruit characters, the formation of yellow/brown colour and the development of 'oxidised' aromas and flavours. The oxygen dissolved in the wine and trapped inside the headspace or closure when the bottle is closed is called the total package oxygen (TPO), and accounts for the initial loss of SO_2, which can be substantial. The SO_2 loss continues due to any oxygen subsequently entering the bottle via the closure, which is known as the oxygen transmission rate (OTR). The OTR is therefore an important determinant of how a closure performs over time.

A large range of OTRs is seen when different classes of closures are compared, as shown in Figure 2. Screwcaps have the lowest OTR but still vary depending on the lining used inside the cap. Saran/tin linings are most commonly used in Australia, with Saranex linings also available. However, it should be noted that the best performing natural corks have OTRs comparable to screwcaps. The other important factor related to OTR is the variability among closures of the same type. The variability in OTR among screwcaps is very low, which explains why the condition of different bottles of a wine sealed with screwcaps is usually very consistent. On the other hand, natural corks show a higher variability in OTR, resulting in less consistent performance.

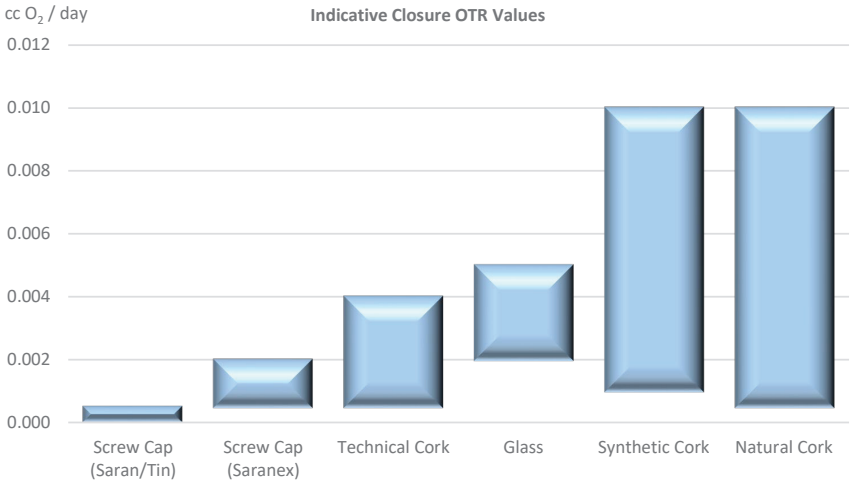

Figure 2. The range of oxygen transmission rates observed for different classes of wine bottle closures

Low OTR closures and 'reduction'

During the extensive sensory evaluation performed as part of the 1999 AWRI closure trial, a positive correlation was seen between retention of SO_2 and the extent of development of a 'reductive' character in the wine. Wines described as 'reductive' can exhibit aromas variously described as 'struck flint', 'burnt match', 'onion', 'garlic', 'rubber', 'egg' or 'rotten egg'. The identification of this potential problem led to researchers and winemakers developing a range of strategies to avoid it. Importantly, research has demonstrated that low OTR closures do not cause 'reductive' characters; however, if the wine has a propensity to become 'reductive' because of the way it was made, it is more likely to happen if low OTR closures are used. In this situation higher OTR closures may only modulate the level of reduction, rather than preventing it altogether.

The largest data set of faults in bottled wine has been generated by the International Wine Challenge (IWC). The data show that the percentage of wines rejected for reductive or 'sulfide' character is the same for wines sealed under natural cork, synthetic closures or screwcaps (Figure 3). Therefore, any assertion that 'reductive' characters are only a problem with low OTR closures is incorrect.

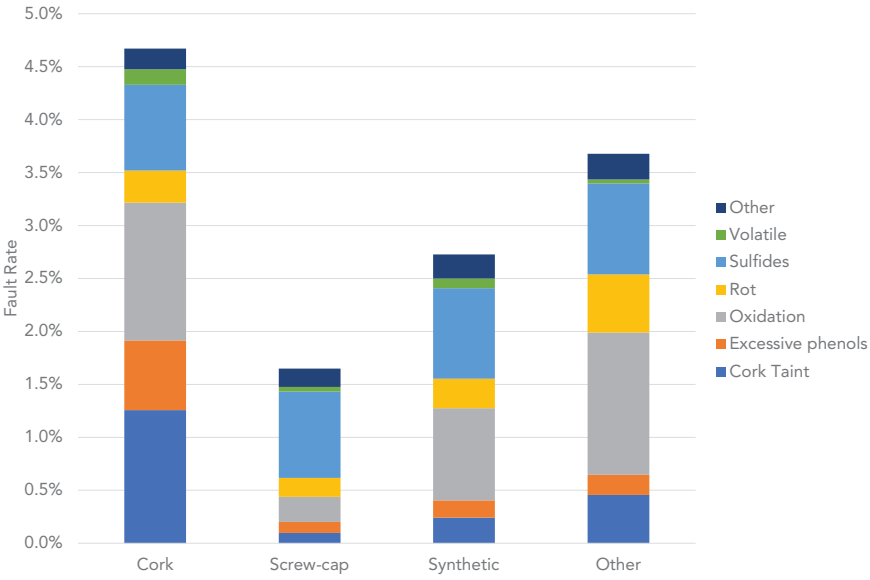

Figure 3. Percentages of wine faults observed in samples submitted to the International Wine Challenge between 2007 and 2017, broken down by wine closure type, n=117,732. The percentage of wines rejected for 'sulfide' characters is consistent across cork, screwcap and synthetic closures.

'Cork taint'

A major sensory problem associated with cork-based closures is 'cork taint', which is caused by chemical compounds formed by mould growing on the cork, either on the trees before the cork bark is harvested, or during processing. All four cork-based closures in the 1999 AWRI closure trial exhibited levels of cork taint well above the 1.3% shown in the IWC data (Figure 3). The 1.3% reported by the IWC is also well below the previously reported incidence of cork taint and suggests that cork industry initiatives to reduce the problem are having a positive effect. An analysis of cork-sealed bottles representing many wine styles from many countries used in AWRI Advanced Wine Assessment Courses in 1994, revealed a 5.5% incidence of cork taint (Leske et al. 1995), with subsequent analysis of 1,625 cork-sealed bottles used in AWACs between 2001 and 2003 revealing rates between 5% and 8% (Cowey and Godden 2004). A French publication (Chastaingt 2003) also reported a 'likely incidence' of cork taint in the French market of between 5% and 8%.

Screwcaps and wine development

A view is expressed by some people that red wines 'do not age properly' under screwcaps. While the AWRI has not examined this specific issue over the longer term, anecdotal observations indicate that red wines develop in much the same manner when sealed with screwcaps as they do when sealed with well-performing corks (i.e. individual corks that are free of cork taint and have low OTR). There are numerous red wines from Australia and New Zealand from early 2000s vintages onwards sealed with screwcaps, which invariably demonstrate that this is the case.

In November 2018, the AWRI sourced six red wines and two white wines which had been sealed with both natural cork and screwcap for use in two presentations made to a Great Wine Capitals meeting in Adelaide. The wines included a 2004 vintage Cabernet Sauvignon, a 2010 Shiraz, a 2010 Shiraz Viognier, a 2002 Riesling and a 2002 Chardonnay, plus a 2006 Pinot Noir sealed with both screwcap and Diam. Six bottles of wine under each closure were obtained, with three of each used in each presentation.

Four of 30 bottles sealed with natural cork exhibited cork-related taints. None of the six bottles sealed with Diam exhibited a closure-related taint. In addition, one bottle each of the three red wines sealed with natural cork was considered excessively oxidised and markedly different from the other cork-sealed bottles. Otherwise, there was little difference seen between the non-oxidised and non-tainted bottles of the four red wines sealed with cork, and the same wines sealed with screwcaps. It is also noteworthy that three bottles of the 2002 Riesling sealed under cork, which were neither excessively oxidised nor displaying cork-derived taints, were also very similar to the six bottles of that wine sealed with screwcap.

When small differences between the same wine sealed with different closures were identified, there was little or no consistency in audience preferences, assessed by show of hands, for wine sealed with either closure.

To summarise, for both the red and white wines used in these tastings, the best-preserved cork-sealed bottles were the equal of the screwcapped versions, with the converse also being true; in every case, all the screwcapped bottles were the equal of the best cork-sealed bottles.

Closure use in Australia

The *James Halliday Australian Wine Companion* is Australia's leading annual guide to Australian wine. Since 2007 the proportion of wines submitted for evaluation sealed with screwcap, natural cork or Diam has been published, and the figures are collated in Table 1.

Table 1. Closures used on Australian bottled wines submitted to the *James Halliday Australian Wine Companion* for the years 2007 to 2018

Year	Screwcap	Cork	Diam
2018	87.9%*	5.8%	4.7%
2017	90.0%	5.3%	3.1%
2016	88.4%	5.8%	4.5%
2015	90.7%	5.5%	3.1%
2014	91.7%	4.6%	3.0%
2013	91.0%	4.8%	3.2%
2012	85.0%	8.0%	5.0%
2011	84.0%	9.0%	6.0%
2010	79.0%	14.0%	5.0%
2009	68.0%	17.0%	5.0%
2008	65.0%	22.0%	6.0%
2007	51.5%	43%	5.5%

*97.3% of white wines

Australian winemakers have adopted screwcaps for approximately 90% of both their red and white wines because of screwcap's demonstrated superior consistency in preserving both red and white wine freshness without causing adverse sensory effects. Market-focused research has also found that Australian consumers prefer the flexibility and ease of use of screwcaps, including that no corkscrew is required, and that bottles are easily re-sealable (Atkin et al. 2007).

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Acknowledgements

The AWRI's communications are supported by Australia's grapegrowers and winemakers, through their investment body, Wine Australia, with matching funds from the Australian Government. The AWRI is a member of the Wine Innovation Cluster in Adelaide. The author thanks Halliday Wine Writing for assistance in providing data for this article.

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