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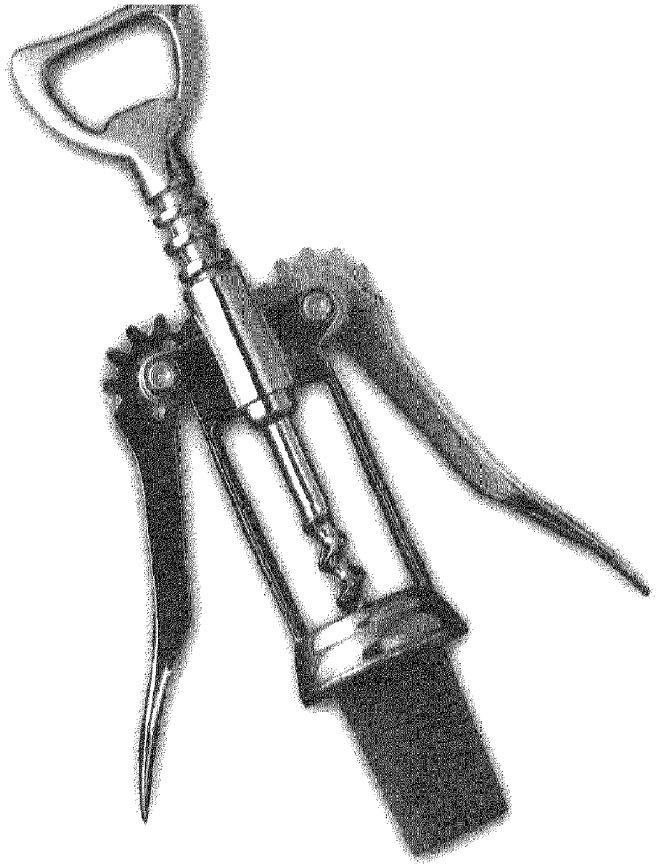

Close combat

The closure debate rumbles on, with not even the hint of an end in sight. Jamie Goode considers the latest evidence from the cork and screwcap camps

Let's begin with a rather stretched analogy. World War I was a terrible conflict that exacted a terrible human toll. Yet this otherwise disastrous war yielded a significant positive benefit for the aviation industry as both sides sought more effective warplanes to master the new arena of aerial combat. Since this time, military requirements for more lethal fighter aircraft and bombers with bigger payloads have driven the whole field of aviation forward.

The wine world is currently involved in its own war, although fortunately this one is rather less lethal. It's the war over cork and alternative closures. With the advent and rapid adoption of the screwcap, advocates of natural cork looked on their way to defeat. New developments in our understanding of what happens to wines after they are bottled mean this outcome is currently in some doubt, but the point of this analogy is that we should actually be

grateful for this sometimes bitter conflict over closures. Why? Because the debate on closures has fixed the attention of the wine world on the previously rather neglected science of post-bottling wine chemistry. Doesn't sound too exciting, does it? But post-bottling wine chemistry, including the winemaking interventions immediately preceding bottling, is currently hot. It's the new rock and roll.

Cork wars

The story of the cork wars is roughly summed up as follows. The distressingly high incidence of cork taint led many winemakers to seek alternative types of closure. The Australians, with their refreshing pragmatism and unwillingness to be bound by tradition, trialled screwcaps as an alternative to corks in the 1970s, but this venture failed – largely because of consumer non-acceptance of what was deemed a low-status closure, not because the screwcaps didn't work.

Fast forward to the mid-1990s, when the desire for alternatives to cork gathered fresh momentum, again driven by the Australians. Plastic corks were tried and gained some market acceptance, and screwcaps were also revisited. This time, the wine world was substantially less hidebound by tradition, and in the UK, New Zealand and Australia at least, consumers seemed to adopt alternative closures without too much of a problem. Wine journalists, frustrated by cork taint, joined the chorus calling for more experimentation with these alternatives. The cork industry, faced with indisputable evidence about cork taint, began to abandon its PR strategy of denial and smokescreens, and some of the more clued-up cork producers initiated serious efforts to deal with the problem.

In Australia, a revolution was initiated by the producers in a small region of South Australia, who banded together and released a sizeable proportion of their 2000 vintage wines under screwcap. New Zealand then took up the baton as key advocate of screwcaps, and now leads the way: it held the first-ever screwcap symposium in November 2004. Approximately 10% of the entire production of 2004 bottled wine in Australia is sealed with screwcaps. In New Zealand, this figure has increased from 1% in 2001 to 70% in 2004, a startlingly rapid uptake.

A pivotal point in the closures discussion occurred in 2001 with the publication of a research paper by scientists from the Australian Wine Research Institute (AWRI). The paper reported results 20 months into a large, ongoing study comparing the performance of a range of closures sealing the same Semillon wine. Four observations stood out from this first publication, and have been re-emphasised with each round of fresh results – the latest were from 63 months post-bottling. First, screwcaps provide a seal against oxygen entry that is tighter than that of natural cork. Second, natural cork shows a wide variation in oxygen transfer characteristics. Third, the synthetic corks included in the trial have the highest gas permeability and are suitable only for wines destined for early drinking. Fourth, the wines sealed with screwcaps display a 'reduced' character, due to the presence of sulfur compounds (commonly known as 'reduction').

The significance of this publication was that it shifted the debate onto new ground, and brought some solid, independent data into a field that had been dominated by anecdotal evidence and studies by groups with vested interests. Now, the key question became whether a tighter seal than that provided by cork is desirable, and whether red wine in particular needs the very small amount of oxygen transmission permitted by the average cork for successful ageing to occur. And does the tighter seal provided by screwcaps lead to problems with reduction? The focus had shifted very firmly onto post-bottling wine chemistry.

Dr Alan Limmer, a chemist-turned-

winemaker at Stonecroft Winery in New Zealand, believes the closure discussion 'gets to the core of what ageing wine is all about'. 'This may sound self-evident, but in fact it opens a Pandora's box of post-bottling wine chemistry, which in turn is directly connected to the pre-bottling chemistry,' Limmer says. 'The more we understand about this chemical process, the better we will understand what we need from closures.'

Peter Godden of the AWRI echoes these sentiments: 'It is important to understand that the changes that occur in wine after bottling, which can be attributed to the closure and other bottling variables, are profound and can be of far greater magnitude than many vineyard and winemaking variables.' Indeed, at the New Zealand screwcap symposium, data in his presentation backed this idea up: 63 months after bottling, the same Semillon wine in the AWRI closure trial is clearly taking rather separate developmental trajectories under the different closures.

With this change of focus, siren voices have emerged, predicting that the shift to screwcaps is premature. Of course, we are all frustrated with cork taint, the level of frustration usually correlating with the length of time elapsed since the last time we opened a decent bottle only to find it tainted. But do we really know how wines develop under the tighter seal of the screwcap? How good are the data indicating that wine ageing is totally anaerobic? And how common are reduction defects in screwcapped wines? These are important questions for those considering switching to screwcap, and ideally they need to be answered by data and not just conjecture.

Terms of engagement

Before we begin this discussion, we need to remember that screwcaps aren't all equal. The cap itself functions merely to hold a piece of wadding or lining material tightly in apposition to the smooth surface of the rim of the bottle neck. It is the surface layer on the wadding material that determines the permeability of the screwcap. Two types are currently used for wine, a metal layer (normally tin) coated with Saranex (PVDC; polyvinylidene chloride), and Saranex combined with polyethylene without the metal layer. The former provides a very tight seal that allows very little oxygen through; the latter allows a reasonable amount of oxygen permeation. The screwcaps used in Australia and New Zealand are almost all tin-lined, whereas in Europe both liners are used, with many fast-rotation wines having the more permeable Saranex–polyethylene liners (these are easy to spot, as they are white as opposed to metallic).

The AWRI data show that the wines sealed with metal-lined screwcaps retain free sulfur dioxide better and develop more slowly than those sealed with other closures. Corks vary more than screwcaps and synthetics in this regard, but generally allow considerably less development than synthetics. The wines sealed with the synthetic corks included in the AWRI trial didn't do terribly well and developed very quickly, suggesting that these closures are suited only to fast-rotation wines. However, it should be pointed out that the trial used synthetics on the market in 1999. 'In many cases the current incarnations of those closures are very different, and they would all perform to a much higher standard now,' says Godden. 'As it was, many were fine up to 18 months. I would expect this to have increased to at least three years by now, and more than 95% of the world's wine is consumed within three years.'

Is oxygen needed for successful wine ageing?

Winemaker Jeffrey Grosset became frustrated at the insistence by many that oxygen was needed for the ageing of fine wines. Disillusioned with cork, he had

already committed to moving to screwcap, but from his perspective the critical question was whether it's best to use a metal-lined screwcap or one engineered to have a specific oxygen permeability, perhaps in line with that of a 'good' cork. So in a bold and forward-thinking move, he initiated the Australian Closure Fund to finance studies aimed at answering some fundamental questions. The first result of this initiative has been the publication of a study that was initiated back in 1997 by Southcorp, and reported by Allen Hart, now Southcorp's research and development winemaker. Released in February 2005, the study claims to show that oxygen is not necessary for ageing bottled wine. In fact, the study is a bit of a mish-mash of three different sets of data.

The core of the paper concentrates on the evolution of a 1996 Penfolds Bin 389 under different closures: a 44mm reference 2 natural cork, a tin-lined screwcap and two different synthetic closures. The bottles sealed with cork and synthetic closures were stored laid down, while the screwcap bottles were stored upright. Prior to bottling, the wine was aged in American oak for 14 months and was subjected to copper fining after fermentation to remove sulfide residues. The wine was subjected to chemical analyses while in bottle, and then at seven years post-bottling a thorough sensory analysis with trained panellists was carried out.

What do the results show? After seven years, the screwcapped bottles retain the highest levels of free and total sulfur dioxide, with the synthetics the lowest (no free sulfur dioxide left by 2002) and the corks intermediate between the two. There are no significant differences in colour density or colour hue changes among the various closures. In the sensory analysis, the results are very interesting. While the synthetics are significantly different from the other closures (more oxidised, more developed, less spicy and with less fruit intensity), the only significant difference between the screwcapped and cork-sealed bottles is that the screwcaps were significantly higher in 'reduced' characters. Various interpretations of these data can be made, but the most logical conclusions seem to be that: (1) synthetics are allowing larger amounts of oxygen into the wine, causing it to age more rapidly; (2) corks are sealing against oxygen entry very nearly as well as screwcaps; and (3) the only consequence of the tighter seal of screwcaps at this stage (given the small sample size – perhaps a larger one would have made more differences apparent) is the development of reduced aromas. The conclusion that the 389 in this trial has developed under screwcap similarly to the way it has under cork can also be supported by these data, although it's not the most obvious conclusion to emerge and must be made tentatively from such a small data set.

There are two other bits of data tagged onto these in this study. The first concerns a sensory analysis of four widely separated vintages (1984, 1987, 1994, 1999) of sparkling reds sealed with crown caps. This is an odd inclusion. First, we don't know anything about the state of these wines when they were bottled – for sparkling reds, varying development of the base wines may already have taken place. Second, we don't know anything about the permeability of the crown caps used – like screwcaps, their performance depends on the lining. 'The base wine is matured in cask for a time

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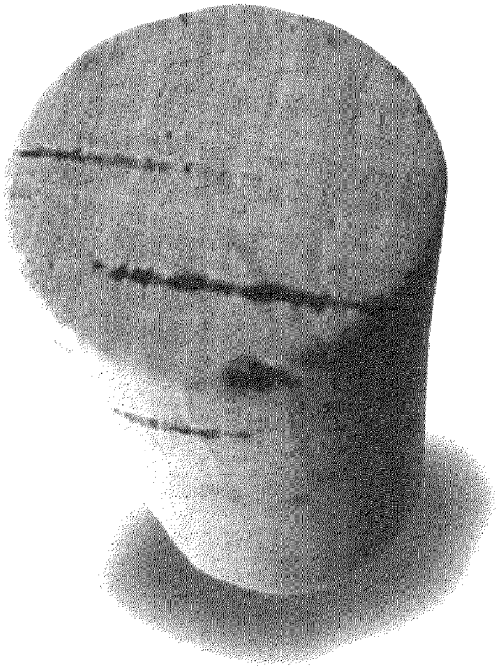
before tirage bottling,' explains Richard Gibson, previously general manager of technical services at Southcorp and now at consultancy Scorpex. 'No information is presented on how much development occurred in the wines from different vintages before they went into the bottle. And crown seals are not necessarily anaerobic seals – the liner is the key to performance. Liners have changed considerably over the years. Also, contrary to what is implied in the paper, oxygen can get into a sparkling wine bottle through a permeable seal, even when carbon dioxide is pushing out.'

Just how permeable are corks?

The second bundled-in data set concerns the permeability of cork. One of the figures in the paper presents data on the oxygen permeability of 35 randomly selected reference 2 corks. These data are collected by a measuring device called a Mocon machine: the corks are inserted into the necks of bottles, the necks are cut off and the Mocon measures the passage of oxygen through the inserted cork. It's a slow and expensive process. These data illustrate that there is a range of permeabilities, from just over $1cm^3$ to less than $0.001cm^3$ oxygen transfer per cork per day. Does this mean that corks exhibit a 1,000-fold variation in permeability? This conclusion, while currently being touted by some as a further nail in the coffin of cork, is a hard one to accept. First, the data show a distribution of permeabilities, with the majority of the corks falling between $0.01cm^3$/day and $0.1cm^3$/day. But beyond this, there is something odd about these results. In the same study, the synthetics showed a consistent permeability of around $0.01cm^3$/day, yet wines sealed with these closures develop much faster than corks. Indeed, while the Bin 389 trial showed a significant difference between evolution under synthetics and other closures, the screwcaps (which the Mocon found to have a consistent permeability of less than $0.001cm^3$/day) are not significantly different from the corks.

The explanation may lie in the nature of the Mocon measurements. 'The oxtrans results quoted are for a non-wetted cork in a Mocon machine,' explains Gibson. 'In my experience, Mocon oxygen transmission results for cork are consistent with performance in bottles stored upright. However, oxygen transmission of cork appears to be much lower and less variable when wine is in contact with the cork. The reasons for this are not well understood, and wetted cork oxygen transmission is not measurable by Mocon, but it has been demonstrated by experience and published



work that the incidence and degree of wine oxidation is higher in cork-sealed bottles stored upright than in bottles sealed with corks from the same batch laid down. The Mocon results for cork quoted in the ACF paper cannot be linked to the behaviour of the cork closures in the 389 trial. However, trials have shown that synthetics and screwcaps give similar oxygen transmission standing up and laid down. Links between the Mocon results and the behaviour of these closures in the 389 trial are likely to be valid.'

So the apparent conclusion of the paper – that because the 389 in bottles under screwcap and cork have developed similarly, and yet the Mocon oxygen transmission of cork is much higher than screwcap, oxygen is not a primary driver of red wine maturation – is a very long shot indeed. Besides, if corks really do exhibit 1,000-fold differences in permeability, no two cork-sealed examples of the same wine would resemble each other after several years in bottle. Alan Limmer points this out. 'If, in fact, we had a variation of 1000-fold at these levels, individual wines would be unrecognisable,' he says. 'They would reflect the cork more than the wine. And yet, we can generally agree on the character of a particular aged wine.' That said, there is clearly a level of variability between cork-sealed bottles that isn't seen with alternative closures, even when the bottles are laid down.

How prevalent are reduction problems with screwcap?

The shock conclusion of the AWRI closures trial was that wines sealed with screwcaps developed marked 'reduced' characters after some time in bottle, typically 12–18 months. This worry was re-emphasised by the appearance of reduced characters in the screwcapped bottles in the ACF study.

To understand the phenomenon of reduction we need to look at the chemistry of sulfur-containing compounds in wine. In brief, 'reduction' refers to the presence of volatile sulfur compounds in wine that are formed by reducing conditions (the relative absence of oxygen). These sulfur compounds originally come from the yeasts, which, under certain stressful fermentation conditions, will produce hydrogen sulfide. This can be transformed into thiols, including the smelly mercaptans, some more desirable than others. Depending on the redox state of the wine, there can be an interchange between mercaptans and disulfides.

What are we to make of the occurrence of reduced aromas in screwcapped wines? According to many of the screwcap advocates, these are a winemaking problem: it's up to winemakers to make sure that their wines come to bottling without any potential sulfur chemistry problems. There are two ways of going about this: managing fermentations more carefully so that fewer sulfur compounds are produced by the yeast, and copper fining, which is seen as a vital tool for removing potentially problematic sulfur compounds at bottling.

This is easier said than done. 'The issue

of reduction has come up again in the 389 trial,' says Gibson. 'While sulfide formation may be a winemaking issue, the wine in this trial was copper fined and matured in barrel under semi-aerobic conditions for a long period. The wine was clean at bottling. Despite this, something in the wine has formed a reduced character after bottling, but only under screwcap – not under the other seals.' The copper fining didn't work here. This is because while copper removes mercaptans, it doesn't eliminate disulfides, which can hang around unnoticed. Then, given the right redox conditions (in this case lack of oxygen under a super-tight closure), the result can be the development of smelly mercaptans. 'The quicker the sulfur dioxide level drops after bottling,' explains Limmer, 'the less chance of this disulfide reversion [to mercaptans] occurring.' He explains that this is why, given cork's variable oxygen transfer rate, some bottles can seem clean while others (with a much tighter seal) can seem closed or dirty. The other problem with copper fining is that it is not selective for bad sulfides. Some sulfur-containing compounds are beneficial for wine aroma. For example, there are some thiols that have recently been implicated in the varietal aroma of Sauvignon Blanc. You don't really want to strip these out with a copper fining. 'Copper fining is the ambulance at the bottom of the cliff, but it is almost all we have at the moment,' says Limmer. 'It is my concern that the inability to explain and control the sulfur compound issue under screwcaps is going to lead to a campaign to accept this fault as a benevolent trade-off for eliminating cork taint. In my view, both are unacceptable.'

Godden has a different perspective, though. 'We know of several wineries that had reduction problems when they first used screwcaps a few years ago and that as a result have now fixed their winemaking issues, especially focusing on fermentation management, and have got rid of the problem,' he explains. 'Screwcaps are clearly acting as a driver for better winemaking in many New Zealand and Australian wineries, and the number of commercial wines showing reduction plummeted from about 18 months ago. It will be interesting to assess the situation again when the wine show season gets under way in a few months' time, but my guess is that there will be fewer again.' He adds that 'not accepting that in most cases [reduction] is a winemaking issue is the thing that is likely to ensure that there are more reductive wines around for longer'.

Given the occurrence of disulfide reversion, and the fact that it is currently not possible to conduct ferments without the generation of at least some sulfur compounds, it seems unfair to blame the winemaking for all reduction problems under screwcap. It's possible to have a mercaptan-free finished wine that seems clean only for it to become reductive after bottling.

These conclusions are supported by findings presented by Godden at the Screwcap Symposium. A Chardonnay wine was stored in bottles sealed with corks and screwcaps, and also in hermetically sealed glass ampoules. The screwcap-sealed wine was rated higher than the cork-sealed wine for flint/rubber, the descriptor often used for reduced aromas. And the wine stored in the glass ampoule, with no oxygen entry at all, was rated even higher for these aromas.

The reason cork-sealed wines show lower rates of reduction is presumably because they allow a little more oxygen ingress, thus resulting in a redox potential that discourages the formation of smelly sulfur compounds. But it needs to be added that those corks that seal tightly will also cause reduction problems for wines with this propensity. It's not solely the preserve of screwcaps.

A different perspective

Let's approach this discussion from a different angle. Where the same wine has

been bottled under screwcap and cork, and some time later the two have been compared, an almost universal finding has been that the developmental trajectories of the two are different, even after a short time in bottle. In many cases the tasters have expressed a preference for the screwcapped wine. There seems a contradiction here between the conclusions drawn in the press release from the ACF study, which claims that this study demonstrates that red wines develop the same way under cork and screwcap, and the reports from tasters who say that wines taste better sealed with screwcaps. More likely than suggesting that all these tasters are deceiving themselves is the explanation that the ACF study lacked sufficient power (due to small sample size) to discriminate such relatively subtle differences. The striking observation here is that in the wine trade we like the way that fine wines develop under average-permeability, non-tainted corks. Tin-lined screwcaps are different, and this is not necessarily a good thing. If you have been making wines with a track record of ageing well in bottle and which sell for high prices, you aren't going to react too enthusiastically to someone suggesting you should use screwcaps that will change the way your wines develop in bottle and necessitate you changing your winemaking to avoid potential reduction problems. It's a bit like changing the foot to fit the slipper.

Conclusion: focusing on post-bottling chemistry

It is thus becoming clear that closure choice is a key variable in how wines develop in bottle. 'The screwcap/cork debate is not actually about screwcaps versus corks, it is about suitable post-bottling conditions to provide optimum chemistry for wine development,' says Limmer. The often heated discussion about corks and alternative closures has led scientists to begin to examine more closely the post-bottling behaviour of wine, previously rather a mysterious and myth-ridden subject.

Godden emphasises that 'the most important outcome of our trials is to demonstrate that by changing the closure one effectively creates "different wines", and that the differences between those wines can be profound'. But it is not just the closure that impacts on the post-bottling development of wine. 'Other workers are showing that the notion of "different wines" extends to bottling variables other than the closure: other bottling variables, such as filling height and sulfur dioxide concentration, may also effectively change a wine into "different wines" after time in bottle,' he says.

Just as wines differ in their chemical make-up, it is likely that there won't be a single closure for all wine types. The current area of focus does seem to be very firmly on closures, but perhaps in the future we'll be having animated discussions about the free sulfur dioxide levels at bottling, too. Godden points out that it is partly because of the consistent, tight specifications of the seal provided by screwcaps that we are able to have these discussions at all. 'We are only gaining these insights because we are using screwcaps; we would not have gained our current level of knowledge if we had continued to use only cork,' he explains. 'The gap between what we want a closure to do, and what closures are able to deliver, is currently smallest with screwcaps. We want all closures to deliver to the same high specifications. It is also likely that specifications will become tighter as our understanding grows – for all closures, including screwcaps. There will be little future for closures that cannot deliver to those specifications.'

There are several messages to take away from the discussions here. The ACF paper doesn't really prove what its sponsors claim it does. While wine ageing clearly

doesn't require very much oxygen transfer by the closures – the synthetics in this study are allowing too much for the long-term ageing of wine – in the highly reductive environment of a wine sealed by a metal-lined screwcap, sulfides can be a problem, and copper fining before bottling isn't the ideal solution.

Corks are variable, but the data suggesting that they show a 1,000-fold variation of permeability are perplexing and may not apply to bottles laid down rather than stored upright. If they really do, then we need to know why such a massive difference doesn't have a much bigger effect on the wine in the bottle. Godden suggests that cork may have an O_2-scavenging effect, which, if true, opens up new avenues for research.

For all its apparent shortcomings, however, the ACF paper has certainly sparked enthusiastic discussion within the wine community and may help to identify approaches that will lead to the answers that are being sought.

The picture that is emerging is complex, and it seems that there is a future for a range of closures, depending on the wine. It is becoming clear, though, that a glass ampoule, which would allow zero oxygen transfer, is not the ideal closure. Then the issue becomes one of just how much oxygen transfer is desirable? 'The future is to use oxygen ingress creatively, as small differences can have a big effect on how wine develops,' says Godden. He adds that 'the question of "does wine need oxygen to develop?" is pretty well redundant. The amount of oxygen required for optimal development will be different for each wine, and understanding this, and other bottling variables, is the next step. Several producers are already working actively on this.' It looks like the metal-lined screwcap, which many producers are currently putting their faith in, is not the complete solution because it may provide too tight a seal for many types of wine that have a propensity to become reduced, although this is something that might fairly easily be fixed. However, it would be unfair to leave readers with the impression that the majority of screwcapped wines have reduction problems, because it seems from anecdotal reports that they don't. The cork wars are certainly not over yet. ■

'Screwcaps are clearly acting as a driver for better winemaking in many New Zealand and Australian wineries'

Peter Godden, AWRI

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