TOWARDS OFFERING WINE TO THE CONSUMER IN OPTIMAL CONDITION - THE WINE, THE CLOSURES AND OTHER PACKAGING VARIABLES.
A review of AWRI research examining the changes that occur in wine after bottling. PART 1.

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Abstract

An important outcome of the AWRI's research on wine closures is the recognition that when a wine is bottled under different closures, different wines begin to be created from that point onwards. Other workers have apparently expanded this concept to other bottling variables such as the filling height, the concentration of Free SO_2 at bottling, and the mixture of gases in the headspace of bottles post filling. The ability to link such variables to wine development post bottling creates the possibility of reliably predicting, and therefore optimising, wine development in bottle. This would enable wine producers to consistently offer wines to the market in optimal condition. As understanding of these factors increases, ever-tighter specifications for both closures and bottles may be set in order to minimise variation in wine development between bottles. The gap between reliable closure performance and wine producers' expectations of the manner in which closures need to perform, is smallest with manufactured closures. In particular, screwcaps have the proven ability to deliver the desired homogeneity. Technical corks, some synthetic closures, and novel closure technologies such as membrane barriers to oxygen and TCA for natural or synthetic corks, might all be able to deliver the tighter specifications demanded by wine producers, and the development of such technologies will inevitably continue. Understanding of the impact of the closure on wine development has been elucidated by the AWRI's various closure trials. The original trial commenced in May 1999 with the bottling of a Semillon wine under 14 different closures. Results of testing conducted at 60 and 63 months post bottling for five closures (roll-on tamper evident 'ROTE' or 'screwcap' closures, Altec and One + One technical corks, and 'reference 2' and 'reference 3' natural wine corks) showed that the ROTE and the Altec closures continued to retain a significantly higher concentration of SO_2 in the wine compared to the One + One and reference 2 cork closures, which in turn retained a significantly higher concentration of SO_2 in the wine compared to the reference 3 cork closures. Higher SO_2 concentration continued to show a strong negative correlation with optical density at 420 nanometers for all closures. Likewise, during sensory evaluation, ratings for *overall fruit aroma* and *citrus* aroma were strongly positively correlated with SO_2 concentration, and were negatively correlated with ratings for *oxidised*. Ratings for *struck flint* and *rubber* aroma were also, to a lesser degree, positively correlated with SO_2 concentration. In a second trial, a Semillon wine was bottled under screw caps with both a 'high' and a relatively 'low' concentration of SO_2, and at two filling heights. Sensory evaluation of the wine conducted two years post bottling showed no relationship between increased SO_2 concentration and ratings for *H_2S/cabbagey* aroma, and an inverse relationship between increased SO_2 concentration and ratings for *struck flint/rubber* aroma. However, it is considered possible that the elevated concentration of free SO_2 in the 'high SO_2' treatments (42 mg/L for the 'high fill height', and 39 mg/L for the 'low fill height' treatments respectively) might have interfered with the assessors' ability to evaluate the wines. Nevertheless, these data, and those from the first trial, suggest no causal relationship between increasing SO_2 concentrations and increasing ratings for 'reductive' characters during sensory evaluation. Additionally, in this second trial the varied ullage at the time of filling had no influence on ratings for *flint/rubber* and *H_2S/cabbagey* during sensory evaluation conducted two years post bottling, at either SO_2 concentration. In a third trial a

Chardonnay wine was bottled with screwcaps, and a portion of the wine was also sealed in glass ampoules in the absence of oxygen. Four years post-filling, the wine sealed by both methods received the same rating for the attribute *oxidised* during sensory evaluation, but the wine sealed in ampoules was rated significantly higher for the attribute *reduced*. Wine under both treatments had retained a similar concentration of SO_2.

The currently available stocks of some of the closures examined, and, therefore, their performance, might differ from those available when these trials commenced. Similarly, the closures have been used to seal only the wine types defined under the conditions described, and care should, therefore, be exercised when relating the results reported here to other wine types, or to wines stored in less than industry best practice storage conditions. Full details of the wine, the bottling procedures and storage conditions are contained in the Australian Journal of Grape and Wine Research *7 (2), 62-105.*

Any reference to 'Tage' closures in this presentation or in the publications referred to, are references to closures manufactured by APM in the USA, and not by Novembal in Europe. The closures were obtained from the Australasian agent, Esvin Wine Resources. The AWRI takes no position on the rights of APM or Esvin to manufacture or sell closures under the name 'Tage'.

Introduction

A key aspect of the success of the Australia wine industry, and of other non-traditional wine producing countries, has been a focus on the consumer and on delivering wine to them in optimal condition. Those employed in the Australian wine industry are working to ensure that this success continues. The recent and continuing shifts in the demographics of wine production and consumption around the world are resulting in increased market pressures for producers in many countries, but the future of those producers is to a large extent in their own hands. To paraphrase Alan Kay, the *inventor* of personal computing, *the best way for them to predict their future is to invent it.*

The Australian wine industry set itself a 25-year strategy to invent its own future, and that strategy document *Strategy 2025* (Winemakers Federation of Australia 1996) states that Australia will become the world's most influential producer of branded wine within that 25-year period. The industry is confident of achieving that objective. Those wine production regions that are facing a crisis of falling sales also require a strategic approach to address their problems, and a cornerstone of any such strategy *must* be to deliver wines to the market in the best possible condition. Packaging wine in a haphazard and unreliable manner would doom any such strategy to failure.

For those wine producing countries that are facing increased market pressures, the need to adopt modern bottling and packaging technologies is the most compelling and yet in many cases there is little apparent sign of it happening. Indeed, laws in some countries impede the adoption of such technology. For instance, some laws effectively rule-out the adoption of screwcap closures by denying wines bottled in such a manner the 'appellation' status to which they would otherwise have been entitled. Additionally, unlike in Australia, various regulations compel many producers to bottle and label wine at the site where it was made, in order to qualify for appellation or quality statements on their labels. This has the effect of condemning many otherwise sound wines to being poorly prepared for bottling, and to being packaged using antiquated equipment by people whose primary expertise is not wine bottling. In contrast, in Australia and New Zealand contract bottling by experts is common, and producers utilise the best equipment available which is operated by world-experts in the field. It is considered likely that this is contributing to the objective decisions that are being made by a growing number of wine consumers around the world, to purchase these bright, fresh, well-prepared and well-packaged wines. Meanwhile, in Australia, New Zealand and elsewhere, knowledge of how to optimise wine development post bottling is growing, and is being widely and rapidly adopted.

The subject of wine development post bottling is complex, and a large number of variables are involved which are interlinked in complex relationships. A complete understanding of the manner in which wine develops in bottle might be the 'Holy Grail' of wine research for many, as it is a key aspect of delivering wines to consumers in optimal condition. Gradual elucidation of some of the important factors indicates that in future it might be possible to reliably predict, and thereby optimise, wine development in bottle, and for the first time this might allow wine producers to be confident that they are offering their consumers wines in the best possible condition. As understanding of this subject grows, what might in future be achievable when closing the wine bottle is profound and exciting, and the potential market advantage to be gained by those who understand and apply such technology, cannot be overstated.

This paper, therefore, attempts to link together the research projects of several teams at The Australian Wine Research Institute (AWRI), which are providing insights related to wine development post bottling. This work goes beyond looking at the performance of different closures. While the closure is perhaps the most obvious variable that might influence wine development in bottle, it is only one factor. However, many of the other variables discussed are based on the premise of using closures that have lower and more consistent oxygen permeation than do traditional closures. The authors believe that in future most wine producers will be using closures that have lower and more consistent oxygen permeation than the closures that they currently use, and all producers should, therefore, already be defining the specifications of closure performance that they require, and be demanding closures that deliver to those specifications. The sooner that all producers the world-over

are demanding the same thing, the sooner that a range of closures that perform to those specifications will become available.

The AWRI closure trial

All producers strive to optimise the quality of their grapes in the vineyard, and to maintain and enhance that quality through winemaking. In spite of this, gross quality loss as a result of packaging routinely occurs and is apparently accepted by many in the world's wine industry. The starting point of the AWRI's work on wine packaging was to avoid this quality loss, by:

- helping to facilitate greater choice and greater reliability of closures and of other packaging materials;
- developing an understanding of the mechanisms by which quality is lost; and
- developing strategies to avoid that quality loss.

The stated objective of the original closure trial in 1998 was simply *"To facilitate greater choice and greater reliability of closures".*

The AWRI maintains a very positive relationship with stakeholders in the closure debate and senior technical personnel from the cork industry presented an excellent technical workshop at the *12th Australian Wine Industry Technical Conference*, which was staged in Melbourne in July 2004. While encouraging information was presented at that workshop, particularly relating to technical corks, the fact remains that the variability and tainting of wine that too often derives from traditional closures is inconsistent with the objective of confidently presenting wines to consumers in optimal condition. Much of our current understanding of wine development in bottle has only been gained by using screwcaps, and it is clear that the gap between our desired specifications of closure performance, and what closures are currently able to deliver, is smaller with screwcaps than with other closures.

Whilst on a purely objective basis it can be stated that screwcaps are currently the closure which most closely offers the possibility of offering wine to our consumers in optimal condition, it is inevitable that in future other closures that perform to the same specifications will become available. Technical corks are developing rapidly, and the results of trials conducted at the AWRI with prototypes of some novel technologies that are now commercially available, such as membranes for corks or synthetic corks that apparently lower oxygen permeation and act as a barrier to TCA, are very promising. For many applications, synthetic cork is already a well entrenched and accepted closure, as evidenced by the volume currently used, and the development of synthetic cork technology is sure to continue.

The promotion of the AWRI's trial results, particularly the success of screwcaps, remains part of the AWRI's strategy to achieve its stated objective of facilitating greater reliability and choice of closures, and provides all those involved in producing closures with a reference point.

Perhaps the most important outcome of the closure research at the AWRI is the postulate that one begins a process of creating different wines from the moment a wine is sealed with different closures. Accepting this proposition creates many exciting possibilities for the future of closing the wine bottle. More recently, other workers from Australian and New Zealand wine production and contract bottling companies have apparently expanded this concept of 'creating different wines' to other bottling variables. The *1st International Screwcap Closure Symposium* was held in New Zealand in November 2004, and papers and tastings were presented that supported this concept. It is apparent for instance, that bottling a wine under different commercially available screwcaps, each with slightly different oxygen permeation rates, might also result in 'different wines' being created. Further, tastings at the symposium indicate that in a Sauvignon Blanc wine, changing bottling variables such as the filling height by 5 mm increments or free SO_2 concentration by 5 mg/L increments, both created 'different wines' after time in bottle. The differences between the 'wines' were obvious to the first author, and were considered to be strongly related to the treatments that had been applied.

Figure 1 presents a graphical representation of the changes to the aroma profile of the Semillon wine used in the original AWRI closure trial 36 months after bottling, which can be attributed to the closures. This type of sensory evaluation is now being routinely conducted in the Australian wine industry by researchers, closure suppliers, wine producers and contract bottling companies, and demonstrates that the 'differences between wines' can be objectively quantified. To understand fully the significance of this concept, one also needs to appreciate that the 'differences' can be profound, and when tasting wines from the AWRI trials it can be difficult to come to terms with the fact that the 'wines' were once the same wine. In many cases it is apparent that the differences are of greater magnitude than those that might be attributable to many vineyard and winemaking variables.

These concepts have important implications. An understanding of the factors that determine the way in which wine develops in bottle will allow producers to manage them. Consequently, for the first time it might be possible to predict and influence the manner in which wine develops in bottle in a reproducible manner and the winemaker's role will thus continue after wine is bottled. This will enable wine producers to present wines to consumers that display the purest possible expression of their 'terroir', which in many situations is not the case at present.

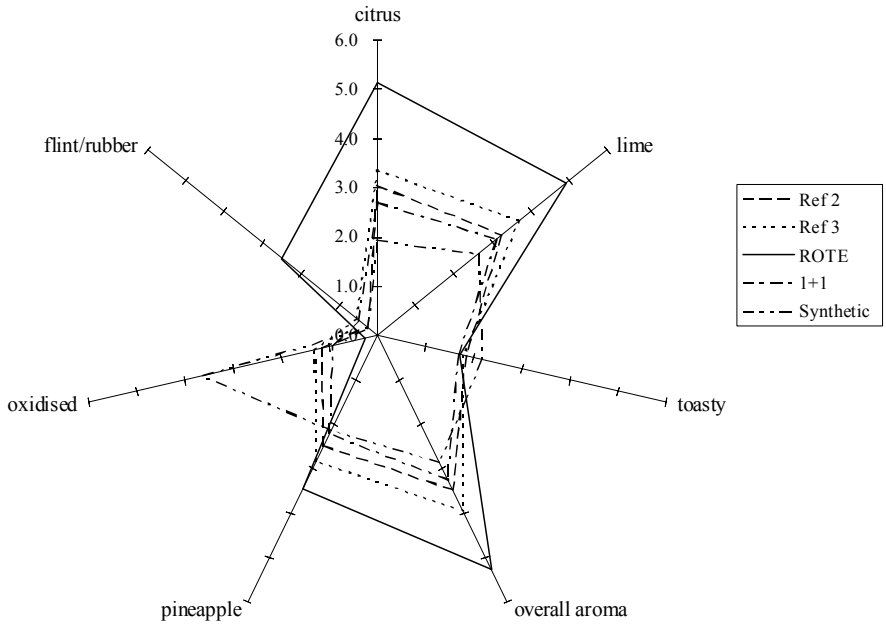

Figure 1. 'Spider plot' of descriptive sensory analysis of the AWRI closure trial Semillon wine conducted 36 months post bottling for selected attributes, rated on a scale of zero to nine.

Wine producers and contract bottlers in Australia and New Zealand are already defining the optimal bottling conditions for various wines, based on assessing the 'optimal' shelf life or cellaring potential of each wine. It is clear that those conditions, including the screwcap used, might be quite different for different wines and even for wines made from the same grape variety. For instance, it might be that for Riesling *x* with an optimal shelf life of 18 months, those conditions will be different than for Riesling *y* with an optimal cellaring potential of five years, which in turn might be different to Riesling *z* with an optimal cellaring potential of ten years. Once a full understanding of wine development in bottle is achieved, producers will have the ability to offer their products to consumers in optimal or 'perfect'

condition. This will be a powerful technology that has the potential to assist producers to increase their market penetration and market share.
It is to Australia's advantage, therefore, that so many wine producers in other parts of the world are apparently reluctant to also adopt alternative closure technologies and that regulations in some countries effectively impede the adoption of such technology. However, it must be considered likely that with time, other countries will also seize upon the potential power of this technology and also make the shift to more reliable closures. Indeed, it will be necessary for them to do so if producers in those countries are to be confident that they are presenting their wines to consumers in the condition that their winemakers intended, and also be in a position to defend their definitions of 'terroir'. Clearly, therefore, in the belief that producers the world over share a collective goal, the authors believe that the goal will be achieved more quickly if all producers adopt the technology together. The critical mass supplied by the traditional wine producing countries would ensure that closure and bottle manufacturers would be able to improve continually their products in response to the ever tighter specifications that are likely to be set.

Results of the initial AWRI closure trial up to 63 months post bottling
The original AWRI 'closure trial' commenced in May 1999, when a dry white Semillon wine was bottled under 14 different closures. The composition of the wine pre and post bottling is presented in Table 1.

Table 1. Wine composition at the time of bottling

Compositional variable	Value
Measures made immediately before bottling[a]	
Tartaric acid	3.8 g/L
Citric acid	0.1 g/L
L - malic acid	1.2 g/L
Lactic acid	0.1 g/L
Acetic acid	0.5 g/L
Glucose plus fructose	0.3 g/L
Laccase activity	Not detected
Pink colour	Not detected
Pinking susceptibility	4 au[b] x 10^3
Pinking precursor content	58 au x 10^3
Specific gravity	0.9929
Turbidity	0.17 NTU [c]
2,4,6–trichloroanisole, 2,3,4,6-tetrachloroansole, pentachloroanisole, 2,6-dichloranisole, 2,4-dichloranisole	None detected
Measures made after bottling[d]	
pH	3.1
Alcoholic strength	11.1 % v/v
Titratable acidity (at pH 8.2)	6.2 g/L as tartaric acid
Volatile acidity	0.58 g/L as acetic acid
Free SO_2	30 mg/L
Total SO_2	95 mg/L
OD_{420}	0.112 au[b]
Dissolved carbon dioxide	0.5 g/L
Ascorbic acid	42 mg/L

Adapted from Godden et al. 2001
[a] *analyses carried out on a tank sample*
[b] *absorbance units*
[c] *nephelometer turbidity units*
[d] *analyses made on bottled wine within 48 hours of bottling (mean, n=14 closures x 12 bottle replicates)*

Fourteen different closures were included in the trial, and details of the closures and their manufacturers/suppliers are provided in Table 2. It should be noted that the trial commenced before *Sabate Altec* and *Amorim Twintop* closures treated by the *Diam/ Diamond* or *ROSA* processes respectively, became available.

Table 2. The closures studied and their source

Closure name	**Type of closure**	**Source**
Aegis	Synthetic, moulded	Southcorp Packaging, Melbourne, Victoria
Altec (Not Diam/ Diamond)	Technical cork	Sabate USA, San Francisco, USA
Auscork	Synthetic, moulded	J. B. Macmahon Pty Ltd, Forestville, South Australia
Betacorque	Synthetic, moulded	Betacorque Limited, Blackwater, United Kingdom
ECORC	Synthetic, extruded	ECORC A.S., Oslo, Norway
Integra	Synthetic, moulded	Anthony Smith Australasia Pty Ltd, Regency Park, South Australia
Nomacorc	Synthetic, extruded	Newpak Australia Pty Ltd, Wingfield, South Australia
NuKorc	Synthetic, extruded	NuKorc Pty Ltd, Wingfield, South Australia
One + One 'Twintop' (Not ROSA)	Technical cork	Amorim Cork Australia Pty Ltd, Dandenong South, Victoria
Reference 2, 44 mm cork	Natural cork	Random sample of stock held by a major Australian wine producer
Reference 3, 38 mm cork	Natural cork	Random sample of stock held by a major Australian wine producer
ROTE (Screwcap) Auscap with aluminium liner	Screwcap	Auscap, Braybrook, Victoria
Supremecorq	Synthetic, moulded	Random sample of stock held by a major Australian wine producer
Californian 'Tage'	Synthetic, moulded	Esvin Wine Resources, Auckland, New Zealand

Both of the batches of natural cork were selected as random samples taken from stocks held by two large Australian wine companies. Each batch had been obtained by the wineries from leading Australian cork supply companies, which in turn had sourced the cork, as far as could be ascertained, from leading suppliers in Portugal. The corks had been hydrogen peroxide bleached, and any coating material or printing had been applied in Australia. Four large Australian wine companies independently graded each batch using their own assessment procedures. All four companies assessed each batch as being representative of the grades described by the respective cork suppliers.

The contract bottler of the trial supplied the screwcap closures, and of the remaining closures, all except Supremecorq were supplied directly by the manufacturers or agents of each closure, by invitation. Supreme Corq Inc. declined to participate in the trial, and accordingly did not provide a sample of its closures. As a consequence, the Supremecorq closures were taken as a random sample of stocks held by a major Australian wine producer. ECORC supplied closures, but subsequently indicated that it wished to withdraw from the trial.

Authors' note: Any reference to 'Tage' closures in this presentation or in the publications referred to, are references to closures manufactured by APM in the USA, and not by Novembal in Europe. The

closures were obtained from the Australasian agent, Esvin Wine Resources. The AWRI takes no position on the rights of APM or Esvin to manufacture or sell closures under the name 'Tage'.

All of the closures were used according to the specifications recommended by the suppliers of the closures. These were obtained from the published specifications where available, or from special instructions supplied by the manufacturers or suppliers of particular closures. Representatives of all but two of the closure suppliers, and of the cork industry, were present at the bottling.

The first results were published in the *Australian Journal of Grape and Wine Research* in July 2001 (Godden et al. 2001, Institute publication #666). Subsequent publications have updated the results as the trial has progressed, and are listed at the end of this paper.

Perhaps as an indication of the interest in, and importance of issues related to wine closures, results of the trial have been widely reported. Media monitoring conducted during the 18 months following the first publication of results revealed at least 220 articles in the print and electronic media, published in nine countries and in six languages, which directly referred to the trial. A search of the Internet using the Google search engine performed in December 2002 revealed hundreds of references to the trial.

Much of the media interest focussed on the performance of the screwcaps. It was no surprise that the screwcap closures performed so well in the trial, as the efficacy of these closures had been demonstrated in work conducted at the AWRI in the 1970s (Eric et al. 1976, (Institute publication #139), Rankine et al. 1980). Perhaps this focus on screwcaps was in part due to the coincidence of timing of the release of the results complementing the promotion of screwcaps by some producers of Riesling wines in the Clare Valley of South Australia and also the fledgling *Screwcap Initiative* in New Zealand, on which the press had already run stories. The authors consider that the results helped to add objectivity to the media debate, and an apparent change in the nature of closures reporting occurred post July 2001, with greater objectivity and science, and less subjectivity and emotion.

The trial continues, with wine sealed with five of the original fourteen closures (Altec, One plus One, Reference 2 and Reference 3 cork and screwcap) being examined from 2003 onwards.

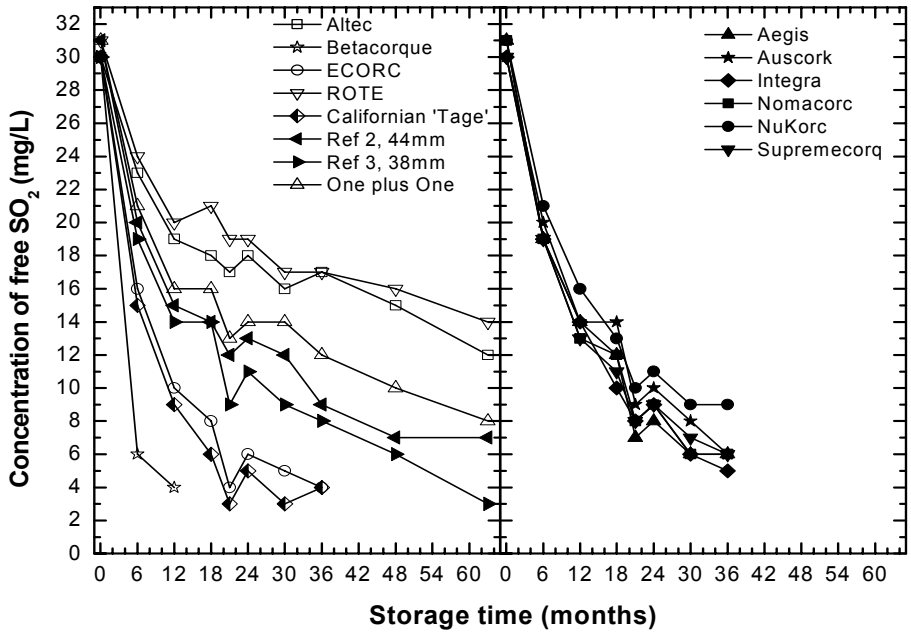

Figure 2. Mean concentration (n=12) of free SO_2 in wine sealed with each of the closures over time for bottles stored inverted.

Figure 2 plots the loss of free sulfur dioxide (SO_2) in wine sealed with each of the closures up to 63 months post bottling. The screwcap and Altec closures continue to retain significantly higher concentrations of SO_2 than the reference 2 and One + One closures, which in turn retain significantly higher concentrations of SO_2 than the reference 3 corks. Two of the synthetic closures, ECORC and Californian Tage, performed similarly, and retained less free SO_2 than the other commercially available synthetic closures. The remaining synthetic closures all performed very similarly. It should be noted that the trial commenced six years ago, and it is considered probable that, in general, the synthetic corks would retain greater SO_2 today than did the versions available when the trial commenced.

With minor exceptions, early trends in SO_2 data have become more pronounced over time. This strongly implies that the 1 and 2 mg/L differences in SO_2 concentrations between wine sealed with different closures recorded at 6 months post bottling were real differences, which were of later oenological and possibly commercial importance. Thus the 6 months post bottling SO_2 data proved to be strongly predictive of data recorded 24 months post bottling for the variables SO_2 concentration (R^2 = 0.89), optical density at 420 nm (OD_{420}) (R^2 = 0.90) and, to a lesser degree, ratings for *oxidised* during sensory evaluation (R^2 = 0.75), in wine sealed with each of the closures (means of 12 bottles, Betacorque excluded).

Throughout the trial, these three variables have strongly correlated for all of the closures. Figure 3 presents data for OD_{420} recorded from the same 12 intact bottles of wine sealed with each of the closures, over time. These data have been obtained using a modified spectrophotometer and novel analytical method developed at the AWRI (Skouroumounis et al. 2003, Institute publication number #731).

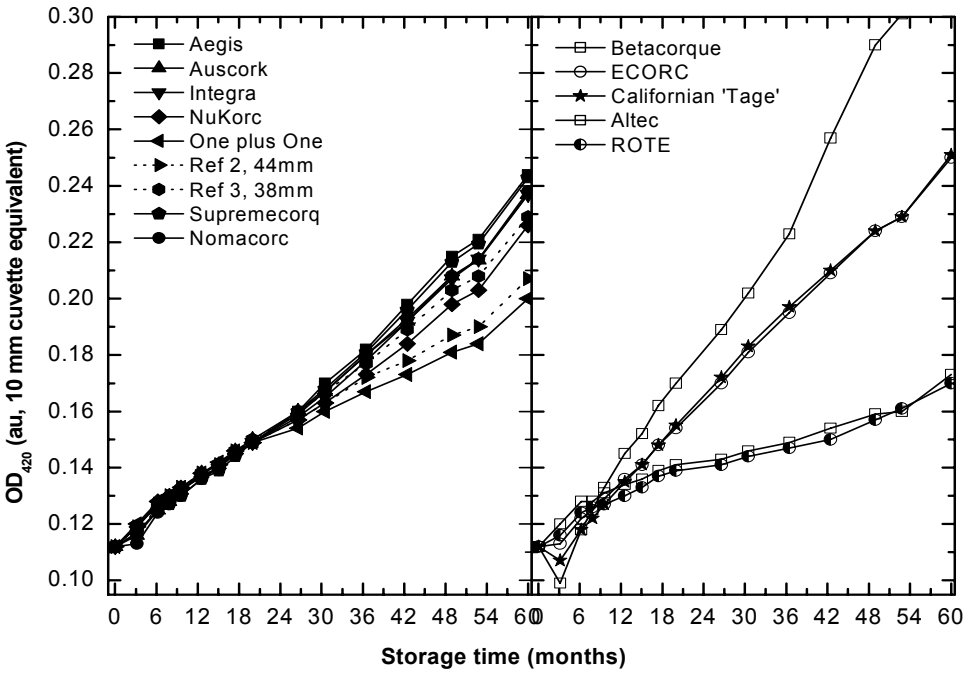

Figure 3. Mean (n=12) optical density at 420 nm in wine sealed with each of the closures over time for bottles stored inverted.

Wine sealed with the screwcap, being the closure that had retained the highest free SO_2 concentration, maintained substantially lower OD_{420} than wine sealed with the One + One and reference 2 corks. Similarly, ECORC and Californian Tage, two closures that had similarly low SO_2 retention up to 36 months post bottling, had almost identical ratings for OD_{420}.

The ability to quantify wine development in unopened bottles is a powerful technology to aid our understanding of the subject. Not only is this method being used as a research tool, commercial companies have also used it to sort batches of wine that demonstrate sporadic or random colour development between bottles. Additionally, further work at the AWRI in the field of NIR spectroscopy has also demonstrated the possibility of estimating many other wine components in unopened bottles, possibly including SO_2 concentration.

As with earlier testing, various sensory attributes continue to correlate strongly at 63 months with both SO_2 concentration and OD_{420} values, with higher ratings for *overall fruit* and *citrus* aroma correlating with higher SO_2 concentrations and lower OD_{420} values, and lower SO_2 concentrations and higher OD_{420} values correlating strongly with *oxidised* aroma.

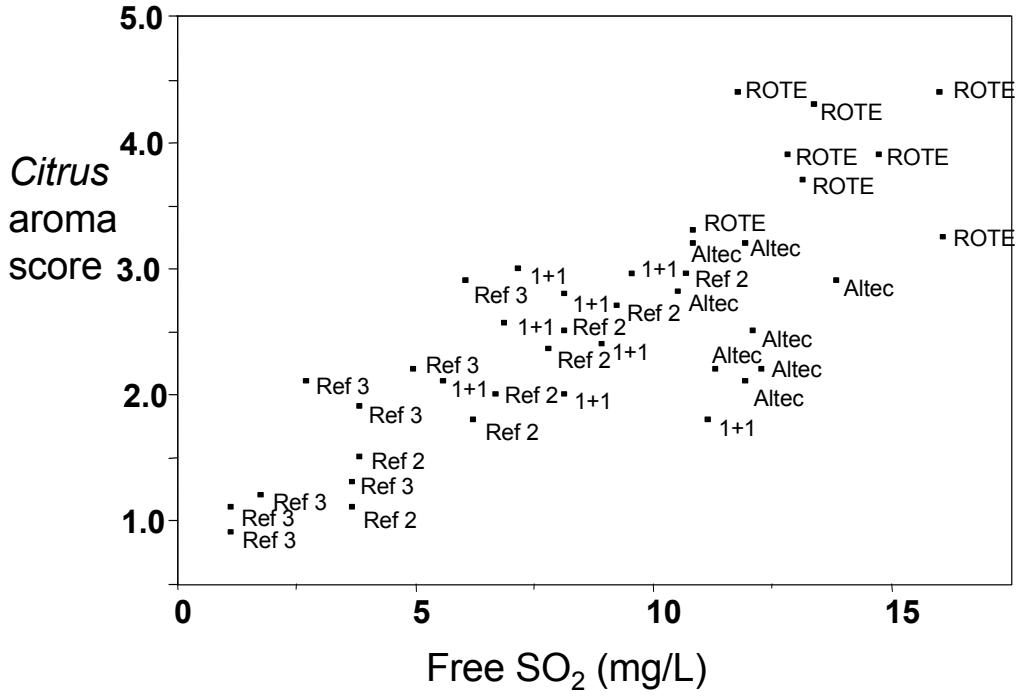

Figure 4. Relationship between Free SO_2 concentration (individual bottles) and mean scores for citrus (scale of zero to 9) during sensory evaluation conducted 63 months post bottling (ROTE = roll-on tamper evident screwcap, Ref 2 = Reference 2 cork, Ref 3 = reference 3 cork, 1+1 = One plus One).

Figure 4 demonstrates that the relationship between ratings for *citrus* (and for *overall fruit*, data not shown) and SO_2 concentrations, continues to be linear at 63 months post-bottling, except for the individual bottles that contained the highest concentrations of TCA, and for the screwcap bottle that was considered to exhibit the strongest *reduced* character. It is perhaps noteworthy that these relationships appear to have remained near-linear even in the range of what might be considered sub-optimal free SO_2 concentrations of less than 5 mg/L; perhaps again indicating that small differences in SO_2 concentration might be of oenological importance.

Notwithstanding greater SO_2 retention, lower colour development and superior sensory ratings, wine sealed with the screwcaps has been rated higher for the characters *rubber* and *struck flint* from 18 months post bottling through to the testing conducted 63 months post-bottling. The potential for wines with a propensity for 'reduction' to develop such characters if sealed with low oxygen permeation closures is an important issue, and is discussed in greater detail below. This is primarily a winemaking issue, and 'reduction' is not *caused* by the closure. While in some situations, all other things being equal, increased oxygen permeability of screwcaps or of other low permeation closures might diminish or avoid the development of *reductive* characters post bottling, the authors do not consider that this hypothesis should be used as an argument for changing the permeability of low permeation

closures. Rather, producers contemplating the adoption of low permeation closures should first consider if the winemaking techniques that they adopt lead to wines that are prone to 'reduction', and whether they are prepared to modify their winemaking to avoid this potential problem.

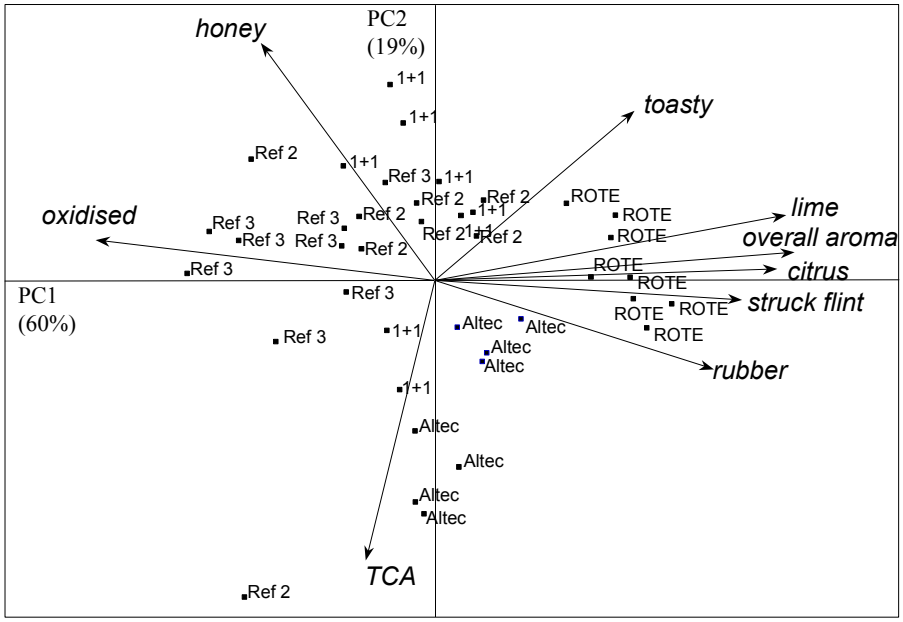

Figure 5. Biplot of principal components 1 and 2 for scores of sensory descriptive analysis of individual bottles, assessed at 63 months post bottling (ROTE = roll-on tamper evident screwcap, Ref 2 = Reference 2 cork, Ref 3 = reference 3 cork, 1+1 = One plus One).

Figure 5 presents data from sensory analysis conducted at 63 months post-bottling, for eight individual bottles of each of the five closures tested. Perhaps the most notable factor is the relatively tight grouping of the screwcap bottles compared to bottles sealed with the cork and, to a lesser extent, the technical cork closures. Additionally, the difference between the screwcap and other closures for the intensity of fruit characters appears to be increasing over time, compared with similar analysis conducted earlier in the trial (data not shown). It is also apparent, for instance, that despite very similar SO_2 concentrations wine sealed with the reference 2 and One + One closures are somewhat different in their *honey* and *toasty* characters, further illustrating the concept of creating 'different wines'.

Despite the Altec closure continuing to retain a high SO_2 concentration and low OD_{420}, virtually every bottle tested in the trial has been affected by TCA taint in a range of concentrations between approximately 1 and 1.5 ng/L. These concentrations were found to suppress the ratings of positive fruit attributes in the Semillon wine by approximately 40%, suggesting that concentrations of TCA as low as 1 ng/L have the potential to negatively impact on the consumer's enjoyment of wine. However, it should be noted that in a similar trial bottled in September 2002, no TCA has been detected in wine sealed with prototype Altec *Diamond*/*Diam* closures in the first two years following bottling (data not shown).

Part 2 of the article, including Acknowledgments and References, will be published in a later update of Infowine