Micro-oxydation: a large winery case study

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Introduction
Milburn Park is part of Cranswick Premium Wines and is located at Mildura in NorthWest Victoria. In 2002 the company as a whole had a 43,000 ton crush with 26,000 of that being from Milburn Park. This report concerns only the operations on the Milburn Park site, although micro-oxydation is also used on the Griffith site. This site has been used for contract processing, which accounted for about 14,000 tonnes, and as a bulk production facility. Wine is also produced and bottled for the Salisbury Estate and Milburn Park labels, as well as for several Buyers Own Brands.

The majority of the fruit intake is red, with Cabernet Sauvignon being the dominant variety. However it also includes Shiraz, Merlot, Ruby Cabernet and an increasing number of small lots of ‘alternative’ varieties, all grown locally. There is also fruit from South Australia: Cabernet, Shiraz and Merlot from Wrattonbully and Langhorne Creek.

Until recently the bulk processing capacity has been utilised by one very large producer. This has involved mainly red grapes, and has on a few occasions, utilised any spare micro-oxydation capacity. With new contract customers the range of processing options has expanded from the basic options, for example crushing to tanker, white ferment to post centrifuge and red ferment to cold stability. Milburn Park has done some experimental work with maceration times and tannins, and will continue to expand the ability to process small batches.

The impetus to try micro-oxydation came when Krister Jonsson joined Cranswick in 2001. He had observed the effects of the large canopies on red varieties, particularly Cabernet Sauvignon, and felt that the characteristics of the fruit, combined with the need to prepare the wines for early marketing, made the wines ideal candidates for micro-oxydation. These wines often had a pronounced herbaceous aroma, accompanied by a thin body and often poor colour. The intention was to use micro-oxydation to reduce the herbaceous characteristics, build structure and integrate the oak. It was accepted that barrel maturation could achieve the same combination, but at the price-point of the wine this investment could not be justified. At the same time the move away from chips to tank staves began, and the slower pick-up of flavour from staves allowed a synergistic combination of the two operations, with micro-oxydation ‘synthesising’ barrel maturation.

Contracts were exchanged with Air Liquide for an Oenodev 5-head unit, which was delivered in time for the 2001 vintage. Under this agreement Milburn Park also received technical support from Wine Network Consulting (WineNet), without which we would not have achieved a fraction of what has been possible. Much of the micro-oxydation work that was to be done in that first year was to be post-malolactic fermentation (MLF), though there were some trials pre-MLF. A second 5-head unit was purchased, from Gas Process Control, before the start of the 2002 vintage as it was felt that there was insufficient capacity for enough of the wines to benefit.

Definition of micro-oxydation
It is accepted that oxygen applied at varying rates and at different times in the development of a wine is given a different processing name. If applied at high rates under skins during fermentation, it constitutes ‘macro-aeration’. If applied at moderate rates after the alcoholic fermentation and before malolactic fermentation, it may be referred to as ‘macro-oxydation’. This paper is not going to make distinctions between these, as in the view of the winemakers involved, using the equipment constitutes micro-oxydation.

In addition to these areas of oxygen use for red winemaking, a Chardonnay must was hyper-oxidised before fermentation, and three sticking alcoholic ferments were helped to completion by the measured addition of oxygen. It is the complete range of ‘treatments’ available that demonstrates the approach to oxygen additions. In any situation where an accurately measured dose of oxygen could be considered to be beneficial, ‘micro-oxydation’ will be considered.

Micro-oxydation theory
It is not the intention of this paper to discuss in detail the theory behind the reason that micro-oxydation pre-MLF creates beneficial changes to a wine. In order to be complete, however, it is necessary to give a simplified version of the changes. The levels of anthocyanin in the wine peak early in fermentation and then gradually reduce with increasing concentration of ethanol. These anthocyanin levels will continue to fall as the wine ages, with a particularly steep decline as a result of the SO₂ addition post-MLF. The time where most significant gains in colour stabilisation may be made is in the period before the SO₂ addition. Anthocyanins can be stabilised by connecting them to a tannin molecule, either by using furfurals extracted from oak or acetaldehyde. It is the aim of micro-oxydation to create this acetaldehyde in a controlled manner so that opportunities for the stabilisation of colour are maximised. The added oxygen oxidises phenols
to quinones, which in turn produce hydrogen peroxide. This leads to the formation of acetaldehyde by the oxidation of ethanol, which is then used in the complexing reaction between tannin and anthocyanin molecules. This complex is more highly coloured, has a more purple hue and is less susceptible to the bleaching effects of sulphur dioxide (Zoecklein et al 1999). At the same time the size of these tannin anthocyanin complexes is limited and so the complex remains in solution (Lemaire 2000).

Other effects of micro-oxygenation include the building of body in a wine with a simultaneous rounding out and softening of the tannin structure. This has the effect of making these wines appear over-structured, which prepares them for further maturation. Certain green characters may also be removed, although this is less predictable.

**Pre-MLF micro-oxygenation**

Pre-MLF micro-oxygenation started with an assessment of the wine for treatment; a rate was established based on the impression of the weight and colour of the wine. As a principle, a deeper coloured wine is treated at a higher oxygen rate than a paler wine.

After a wine had been assessed and the rate decided, the unit was run at that rate until the presence of aldehyde became evident on the nose. The oxygen rate was then reduced to allow the wine to start to utilise the aldehyde. When it was evident that the aldehyde level was diminishing, the rate was once again increased until a balance was achieved between aldehyde production and its utilisation. These oxygen rates were usually between 30–60 mL/L/month, although there were incidences of wines needing considerably higher rates before any aldehyde became evident. This was taken to mean that the wine needed far higher rates than originally assessed, and so the treatment of the wine was revised.

If the wine had insufficient tannin to allow the anthocyanins to complex successfully, tannin additions were made at the start and at any subsequent intervals when it was felt that tannin levels had fallen too far. With increasing experience these tannin additions moved away from topping up the levels in a wine that had become too soft, to adding tannin with the anticipation that this addition would be used up. This gave us the guarantee that there was always a sufficient supply of substrate to utilise the acetaldehyde, and continue the bridging reaction (Lemaire 2000, McCord 2001, WineNet 2002).

The period of treatment was not fixed at the start, and depended upon the evolution of the palate more than on colour or any other chemical analyses.

The control of temperature is also important as this affects the rate that the wine assimilates the aldehyde. Micro-oxygenation may be carried out over a temperature range of 12–18°C with aldehyde assimilation being quicker toward to top end of this range (Lemaire 2000, McCord 2001) (Tony Prichard pers. comm.). Temperature was used to delay the onset of malolactic fermentation, which allowed more time for treatment. The initial aim was for 16–18°C to reduce the risk of excess aldehyde build-up. With experience this has been reduced to 13–15°C. Below 12°C there is a significant risk of accumulating dissolved oxygen (DO) in the wine, with none of the benefits of micro-oxygenation.

**Pre-MLF micro-oxygenation in 2001**

Although the intention was to only micro-oxygenate post-MLF in the first year of operation, it was seen that great benefits were to be had from some pre-MLF treatment. The approach was therefore cautious, using conservative rates and in small tanks, keeping the greater portion of the wine as a control where possible. The fruit used for these trials was locally sourced and from one of Milburn Park’s growers.

The size of the tanks caused some difficulty with respect to the liquid head, which needed to be a minimum of 2.5 metres (Oenodev 2001) to guarantee that the oxygen bubbles would have dissolved. Only a couple of small tanks fitted this criterion, so the remainder of the tanks was about 20kL.

The oxygen rates used for the 2001 vintage trials show a similar pattern for each variety. Initially the oxygen rates were set high to build obvious aldehyde, and then decreased to maintain the aldehyde at a minimum level. In most cases there was a second oxygen rate increase when the aldehyde had dropped below threshold. This second peak was smaller than the initial starting rate.

DO measurements were originally taken for these trials but were abandoned, as the data appeared to be entirely random and led to alarmist responses. Information has been received from several sources (Tony Prichard pers. comm.) (WineNet 2001) confirming observations that the cellular DO meter was too inaccurate to permit adjustments to oxygen rates on the basis of DO measurements. As an alternative we were advised to make all oxygen rate adjustments on the basis of organoleptic analysis alone.

A second, and more serious concern, was a ‘mousy’ character that developed in several of the treated wines after about a week. This character has since been referred to as ‘transient mouse’, as distinct from mousiness due to the presence of acetyl-1, 4, 5, 6-tetrahydropyridine in the wine as a result of infection with Brettanomyces or lactic acid bacteria (Margalit 1997). This transient mouse character has been explained as possibly due to yeast cell wall lipid oxidation (WineNet 2001) and is entirely reversible. It did lead to some serious concerns, several sleepless nights and the reaction by one of the winemakers who had been less involved in the trials, that we “had ruined some of our best wine”. The transient mouse character did subside and all was forgiven.
Though unaware of it at the time, subsequent experience has suggested that it is far less easy to control rates of addition in a smaller tank with comparatively minor changes in oxygen rate, apparently resulting in huge variations in the level of aldehyde. Wine held in larger tanks seemed to respond more predictably to oxygen rate changes, although this could be the effect of increased confidence brought about through experience.

Colour measurements were taken after the trials but it was not possible to draw any firm conclusions from the data; a problem also experienced by Church Road Winery in New Zealand (Mitchell 2002).

**Pre-MLF micro-oxygenation 2002**

After the success of the trials in 2001, pre-MLF micro-oxygenation was made a part of the winemaking process for all 2002 Milburn Park and Salisbury grade wines. Batch size increased from a minimum of 22kL, up to 140kL. Treatment was for a longer period, approximately 4 weeks at oxygen rates of up to 80mL/L/month, with an average 30mL/L/month (Figure 2).

The period of time between the end of alcoholic fermentation and the onset of MLF is the busiest time for micro-oxygenation, as there are higher levels of anthocyanins available in a wine, before the addition of SO2 leads to anthocyanin binding and discoulouration. The number of micro-oxygenation heads was doubled before the start of vintage, but even with 10 heads working full time there was insufficient capacity in the period immediately post-vintage.

The wine quality in 2002 was considerably better than in the previous year, and that, combined with increased confidence in applying micro-oxygenation, enabled us to work the wines harder, and for longer. The longer ripening season also brought fewer problems with green characters, thus goals for the wine was building structure and stabilising colour, rather than using micro-oxygenation as a remedy for under ripe fruit. The batches of 2002 wine treated pre-MLF included Shiraz, Merlot and a split trial of Cabernet Sauvignon, all grown locally by the same grower. The Merlot, Shiraz and a portion of the Cabernet received micro-oxygenation with tannin supplements. One portion of the Cabernet was kept as a control, and the third portion received micro-oxygenation whilst on second use staves (Figure 2).

The main guide for these wines was the development of an appropriate palate weight and the suppleness of the tannins. At this stage it was not the goal to produce a finished wine, but rather to prepare the wine for further maturation or élevage. This built the structure of the wine up with an expectation that either barrel ageing or further micro-oxygenation post-MLF would later soften it. The decision of when to stop was therefore largely arbitrary, as it was not known what the ideal structure would be, or how much more could have been achieved through further treatment. It should also be pointed out that the winemakers involved were not necessarily in agreement. Input from a Bordeaux trained winemaker (Berrouet) who did not necessarily prefer the treated wines was gladly received. His view was that with appropriate ageing in barrel, similar levels of structure would be obtained. However he did concede that he would rack barrels more frequently than was Milburn Park’s practice as he observed it.

The starting rates were all set around 40mL/L/month and revised from there. These starting rates might have been set higher with the additional confidence from acetaldehyde monitoring, or from accurate DO meter data. It was anticipated that the wines would have taken a short time to show any aldehyde, but three of the batches took longer than had been expected, therefore the oxygen rates were revised upwards after a week (Figure 2). When the aldehyde became evident the oxygen rates were eased back. The reason for this initial under-estimation of the oxygen requirements was due to the quality of the wines in 2002. The long cool growing season meant that the wines were all darker and more intense than had been seen previously. Accordingly, the 2002 vintage wines were able to take more oxygen before aldehyde was showing, and they were able to utilise the aldehyde to form the anthocyanin-tannin complex at a faster rate. It is probable that acetaldehyde was being produced during the early part of this treatment, but it did not show because it was being utilised so quickly.

A gain this year the ‘mousy’ character was seen on some wines but this was expected, it caused less concern, and did not lead to an abrupt end to the treatment as it had the previous year.

It took a week before there was a hint of aldehyde in the Merlot, but two oxygen rate increases were required before the aldehyde could be ‘surfèd’ or controlled. A requirement of aldehyde management is that it has to be sufficiently evident so that increases and decreases are obvious. Operating at the sensory threshold makes it impossible to detect these changes. Figure 3 shows that changes in oxygen rate are not reliably followed by a corresponding change in aldehyde. This element of uncertainty highlights the need for daily monitoring.

The Shiraz batch, the lightest of the wines treated pre-MLF, was slightly sulfidic at the start of treatment. It appears that there were no changes in the wine until after the sulfides have been removed (or at least lowered in concentration) by the oxygen (see Figure 4). Once the sulfide had been removed aldehyde was produced more readily than in the Merlot or Shiraz wines and remained in spite of several decreases in oxygen rates. The abrupt drop in
aldehyde on the 19th April was due to the start of MLF.

The length of these trials was not fixed, although the onset of MLF would certainly have set a maximum time limit. MLF was delayed by reducing the temperature in these micro-oxygenation treatment tanks to between 13°C and 15°C. The data for the un-planked Cabernet (Figure 5) demonstrated that temperature can become a critical point if the cooling overshoots, as it can lead to high levels of dissolved oxygen. The oxygen rates on the un-planked Cabernet were reduced until the tank was warm again two days later. In the meantime a small rate of oxygen addition was maintained to keep pressure in the diffuser unit.

Both of the Cabernet wines had obvious hydrogen sulfide on the nose, which took more than a week to be removed. The un-planked Cabernet required an oxygen rate of 80mL/L/month overnight before it began to show aldehyde, with the rate subsequently decreased to an optimum of about 30mL/L/month (Figure 5). The planked batch lost its sulfide more quickly (Figure 6) and so started building aldehyde sooner than the un-planked batch. It also required lower oxygen rates throughout its treatment to maintain the aldehyde. During the treatment the un-planked wine received three separate tannin additions, equivalent to a single addition of 40ppm. The planked batch needed far less, probably due to the tannin pick-up from the wood.

All of these 2002 wines were destined for further treatment; either barrels or in tank on staves with post-MLF micro-oxygenation. Some of the planked and some of the control Cabernet batches went to barrels. The balance was blended together on staves and received a further 12 weeks of micro-oxygenation.

One further trial was carried out on a Ruby Cabernet while it was still fermenting under the cap. Oxygen was added through a sparger set in the racking valve (it was considered too difficult to install it through the cap with the auto-irrigators in place) at a rate equivalent to 110mL/L/month for
a period of 5 days. This addition started in the last 3 Baumé of fermentation, and continued until pressing. This rate led to the production of large amounts of acetaldehyde. It is unfortunate that due to pressure on tank space this lot was unable to be kept separate from the rest of the Ruby Cabernet. Afer bulking up, the aldehyde had disappeared within a couple of days.

**Post-MLF micro-oxygenation**

Post-MLF, the gains to be had from micro-oxygenation have been less impressive, though still worth the effort. There is a lower level of anthocyanin available for complexing due to the bleaching effects of the SO₂ addition that the wine received after completion of MLF. MLF itself is not the cut off point, as it would still be possible to micro-oxygenate the wine at the pre-MLF rates until the SO₂ addition. However there would be dangers involved, the most significant of which would be the encouragement of Brettanomyces, but there is also the fact that any excess acetaldehyde would remain in the wine without MLF to help its removal (Vinovation website).

With the completion of MLF and the accompanying SO₂ addition, the wine was settled and racked with the aim of achieving 100NTU. The clarity is important, as the lees are able to absorb large quantities of oxygen that might otherwise go into the desirable reactions. While this is not a danger in itself, it could lead to confusion when setting and adjusting rates, and more importantly, would result in wasted time. The wine was racked onto new or second use oak staves at between 10% and 20% barrique surface area equivalent. The separate portions were treated for 13 weeks at slightly different rates, with the anticipation that it will continue to 3–5mL/L/month, with the anticipation that it will continue for a further 4 weeks before oxygen rates will be reduced in preparation for weaning. The blend has received less oak than the varietals, all have received tannin additions where required. The treated blended wine has a more intense herbaceous character with oak flavours, though herbal or eucalyptus characters are more pronounced. Apart from the Langhorne Creek Cabernet mentioned, there has been some success softening the herbaceous character in several Cabernet and Merlot wines.

A trial, still in progress, is being carried out this year on a blend. The Salisbury Cabernet Merlot is a large blend, about 400kL, which is usually close to a 60-40% blend. Being treated at 3–5mL/L/month, it has been receiving treatment on planks at 20% equivalent, and have recently been weaned off in preparation for blending. Both of these rates required to retain the balance of the wine. If the wine was to justify the use of barrels it would need to be in barrel for much of that 9 months.

Micro-oxygenation is also an effective way of removing or softening some of the herbaceous characteristics of underripe fruit, though herbal or eucalyptus character are more likely to be exaggerated as a result of using this technique. As yet we are not in a position to comment regarding our wines, as this technique has only been used for two years. However the wines that have been treated, Salisbury

**Figure 6. Pre-MLF micro-oxygenation rates applied over an approximate four week period in 2002 to a Cabernet Sauvignon wine whilst on second use staves (left axis) and the perceived aldehyde and sulphide in the wine as recorded by tasting score (right axis).**
Merlot 2001 and Salisbury Cabernet Merlot 2001, which are now in bottle appear to be holding up better than they might have done in the past. The anthocyanin-tannin complex is more stable, and more deeply coloured, (Lemaire 2000) than free anthocyanin, and so the colour is less likely to brown, and the additional tannin that has been added to build up the body as part of the treatment has shown no evidence of beginning to dry out.

Use of micro-oxygenation to unstick alcoholic ferments

The use of the micro-oxygenation to restart a stuck fermentation came about through desperation. Figure 7 shows data for the first Chardonnay ferment that stuck in 2002. There was also a second Chardonnay and a couple of slow red ferments.

For the Chardonnay ferment shown in Figure 7, the initial progress was fine, but after 5 weeks there was still half a Baumé to go. Yeast uses the equivalent of between 4–6mL oxygen during fermentation (Lemaire 2000, Winen et al. 2002). This is best applied at peak fermentation rate. It was deduced that this amount of oxygen could be added without risking any oxidation, particularly as the wine still had a high turbidity due to the suspension of the lees. Yeast lees, whether viable or not, have a huge capacity to absorb oxygen, and therefore act as a buffer to oxidation. It was decided that, despite the uncertainty that oxygen supplied to cells that were already assumed to be dead would give any benefits; two trial additions would be made while a restart culture was prepared. The first blue bar in Figure 7 shows this. The rate of oxygenation was set at 20mL/L/made in two additions for 8 hours over two days, making a total addition of 0.44mL/L.

It is doubtful if this first attempt made any difference, although failing to compensate for temperature differences when reading the hydrometer led to the belief that it had. After this first addition the restart culture was added as planned and the fermentation continued slowly until it stuck again at 20g/L of residual sugar. At this stage it was decided that there was little to lose by trying a more extended addition of oxygen, so a rate of 5mL/L/month (or 0.16mL/L/day) was chosen, the assumption being that there were still viable cells that had survived from the re-inoculation. If this population proved too weak there was confidence in the ability of the yeast hulls to absorb any surplus. This addition continued for 9 days before it was felt that there was sufficient momentum for the ferment to finish. A residual sugar of 1.2g/L was achieved 5 days later (Figure 7).

The response to the oxygen addition by the second slow Chardonnay ferment was quicker, and as a result, a restart culture was not required. Treatment was started at 1.2° Baume at 5mL/L/month. The ferment was dry in less than two weeks with very little extended ferment character.

This approach to stuck ferments also had some success with red ferments, although there is a danger that this could encourage bacterial spoilage which could lead to high volatile acidity (VAc) and Brettanomyces (Winen et al. 2002). In the future a more active approach could involve the application of oxygen for a few days soon after peak ferment rate has been achieved, thus retaining a higher viable cell count for the later stages of fermentation.

Practical considerations

In most cases the cellar does not need to have any involvement in micro-oxygenation, as it has little impact on cellar operations. When additions are required, attempts are made to ensure that they are grouped together in a single operation so that the wine is left as undisturbed as possible. In order that the cellar-hands are alerted to this possibility, signs are placed on the tank doors. These prompt them to check for any other operations that might be pending.

Most of Milburn Park tanks have full insulation and a brine jacket, and so the control of temperature is not usually a problem. Any warming that is required is carried out through the use of a ‘tube-in-tube’ heat exchanger.

Copper sulphate additions are eliminated during treatment and the requirement for top up additions of sulphur dioxide is minimised by adding an extra 15ppm total SO₂ before the start of micro-oxygenation, thus preventing a ‘two steps forward, one step back’ treatment.

More recently Milburn Park has stopped the sparging of wines under micro-oxygenation during operations, as there appeared to be a noticeable lag before there was any further progress with the wine. This decision was based on the observation that wines saturated with carbon dioxide (CO₂) during transfers would spend a day or more with a foamy surface as the CO₂ was displaced from the wine by the oxygen bubbles. This is particularly noticeable when starting treatment immediately after the end of the alcoholic fermentation. The DO during these unprotected transfers has been monitored, and any slight rises in DO that have occurred have disappeared by the following day.
Equipment
A part from the winemaking aspects of micro-oxygenation there are more practical elements to operating the equipment that may provide complications. The dosing unit and gas bottle would usually be sited under cover and on the ground. Both units at Milburn Park are under cover, and at opposite ends of the winery and both have their gas bottles next to them. When the first was installed it was believed that micro-oxygenation would only occur in certain designated tanks, and single hoses were laid to these tanks with outlets attached to the catwalk from a manifold set-up close to the unit. When further tanks were needed extension hoses were attached to these. Some of these ‘connecting hoses’ remained attached to their various sections of catwalk as a permanent fitting, others move depending on the tank.

There are several problems with this arrangement. Only one person knows where all of the spaghetti runs to, and the line to one tank might include three or four connectors, each capable of leaking. The main problem is that there are pressure losses over any length of hose, and that those become exaggerated once any line exceeds the guide length of 200 metres. These problems combine to make it impossible to find smaller leakages, particularly on tanks running at low rates. This has happened with the result that there has not been any flow through the sinter unit in the tank. Some of these problems may be addressed by locating the dosing unit closer to the tanks, either centrally in the tank hall or upon the catwalk as recommended by Stavvin, with the gas bottle at ground level. Whether this approach solves the problem depends on the approach to dosing.

There are two different approaches to dosing oxygen accurately: The units from Oenodev, Sage and Parsec may be grouped together, as may Stavvin and Gas Process Control. Milburn Park has systems that follow both of the approaches described, and both approaches have their strengths and weaknesses.

The first group uses twin solenoid valves in series to fill a fixed volume, and then to discharge that measured volume into the delivery line to the sinter. Increasing the frequency of the pulses then varies the rates. The second group uses different approaches to produce a measured but constant flow.

The Oenodev unit is dependent on temperature in the dosing reservoir for its accuracy, as gas masses are dependent on temperature and pressure for accurate measurement. For this reason it was recommended that the unit be sited under cover where temperature variations are minimised. A small error on each individual pulse could lead to a significant variation in the actual dose, especially when temperatures can get to 45°C during the day.

The concern over the pulses of gas is less serious, as under usual operation, these pulses are close enough together that they can be considered a continuous delivery. This pulsed delivery does cause problems at start up, as it can take some time for there to be sufficient pressure in the hose to overcome the head pressure in the tank. The solution to this has been simple; the unit has been set to its maximum rate, while the sinter is being placed in the tank and then revised to the intended setting.

The ceramic sinters, while giving a very fine mousse that the sinter has occurred most often when the pressure release has blown out unnecessarily, but has also occurred while running at low rates with untraceable leaks in the line. The most serious blockage was resistant to the prescribed cleaning methods, forcing the use of the ultrasound bath in local jewellery manufacturers with a mild acid.

This system has a pressure release that blows out at about 2.5 bar. This is intended to prevent a blocked ceramic from damaging the unit, but it also means that tall tanks have the stone operating in the top third of the tank. Below this the head pressure is too much for the safety. Different results are therefore possible depending on whether tank samples are taken from the top or the bottom of the tank.

The second unit at Milburn Park was provided by Gas Process Control (GPC) which provides a constant flow of gas from finely calibrated ‘floating ball’ flow meters. It is in the nature for a floating ball to wander, which it does, but not over enough of a range to cause concerns over the actual delivery of the gas. A nother concern has been raised over the apparent variation in the flow meter reading over the course of a day, as the gas density varies with the temperature. This leads to a lower reading in the hotter part of the day as the density increases and the flow is apparently reduced; however the mass delivery remains the same. The solution adopted to solve this problem is to pick the same time of day to revise the settings. Mid-morning was chosen, as this is when the temperature is considered close to the daily average. The advantage with the volumetric delivery is that it is not subject to pressure losses with longer hoses. This makes it practical for a larger site, as the distance from the tanks to be treated is not restricted.

An Excel based calculator performs the calculation of the setting on the flow meters. This is less sophisticated than the Oenodev that sets only the rate and the tank size in hectolitres to catch the unwary, and is calculated by the PLC in the unit. The GPC calculator requires the rate required, which has been adjusted for volume flow rate from a mass flow rate in mg/L/month, tank volume, depth of sinter and the daily length of the micro-oxygenation period. By using the timer the micro-oxygenation can be set so that it occurs only during the day. Thus it can be checked more easily, or it can be turned off and left to run continuously if the tanks are of sufficient volume. The GPC unit at Milburn Park was placed deliberately so that it was servicing tanks that ranged in size from 99kL to 140kL. With tanks this size the unit runs continuously. This system uses larger hoses to deliver the oxygen to the sinter heads, but to allow the concerns of winemakers over the possibility of siphoning; a non-return valve has been fitted to each head.

The sinters for all systems are essentially a way of ensuring that the oxygen will dissolve fully. Many of the systems rely on steel sinters, the Oenodev system has a ceramic sinter, and the purpose of these is to minimise the size of the bubble produced. These hang over the neck of the tank and use the hose as supply and support. This gives rise to a problem with the tank neck seal. There has been an evolution in the approach to this problem at Milburn Park. The first tanks were fitted with a two-piece connector that went through the lid or neck, the sinter was then attached on the inside of the tank. These fittings were expensive, and as different tanks were used each time with lids that were not compatible, the cost to fit out more tanks became unacceptable. The current system uses a foam rubber collar that sits between the lid and the neck. The hose runs
through the collar where it is protected from being crushed and the lid has a good seal with only minor adjustments. The material for the hoses is also important. As they are carrying a food additive and are submerged in the wine, they must be food safe, and should also be UV resistant. Many of the original hoses were clear nylon, which is widely available. It is now known that this type of hose has a plasticiser in it, which may be extracted by ethanol and so leach into the wine (Brian Nagle of Gas Process Control, pers. comm.). These are being replaced with low-density polyethylene (LDPE) which comes in a range of colours, for identification purposes, and has all of the required properties. All of the fittings used should be food grade stainless steel as they are in contact with pure oxygen.

**Record keeping**

As an indirect result of Milburn Park's experimental approach to micro-oxygenation, a recording system was required. This was initially based on the record book that came with the unit from Oenovend as a part of the support package from WineNet. That recorded the date, the dosing rate, the temperature and any analyses, usually SO₂, with a comment section. There was a separate sheet for recording notes on the wines that included a scoring system for colour intensity, hue and clarity; sulphides, aldehyde, vegetal, fruit and development, on the nose; fruit, acid, astrignency and greenness on the palate and an indication of the development of the tannins.

Under the guidance of David Ramonduet, who was our consultant from WineNet at the time, we started to use a sheet that applied to a single wine that held the information from both of these sources as well as including analyses such as: NTU, free and total SO₂, pH and titratable acidity. Most of these records rely on the scoring of traits using a subjective scale. This gives rise to problems with terminology where the same term may be used by two people to mean different things. This problem can be sorted out by having some continuity among tasters, and with practice. Terminology might be difficult with flavour descriptors, but tannin development caused even greater problems. The range of descriptors provided by WineNet: green, hard, supple and dry which later included melted, round and firm, caused some difficulty. The solution was to adopt the terms of the ‘Mouthfeel Wheel’ (Gawel et al. 2000) which gave descriptors that covered the range of tannin textures and so provided tasters with more choice, and a standardised language.

The reason that subjective data must be recorded is that there is very little analytical data that may be used to monitor the technique. DO can only be reliably taken with the Orbisphere, and having also trialled it, it has been found that it does provide some control to what is a potentially dangerous process (Prichard pers. comm., WineNet 2002). Under investigation is the possibility of building a lower specification micro-oxygenation unit, with help from GPC, for working under skins at the end of the alcoholic ferment.

In order to achieve this expansion there must be a financial justification. As a facility well used to contract work, it would be logical to consider contracting out our skill in this area and using this to justify the expansion. This is an area that has sufficient interest but there is little expertise available.

Milburn Park would like to improve the analysis of wines under treatment. At present spectrophotometry is used to measure the success of wines after treatment. If meaningful results could be gained, this analysis could be used to help direct the levels of treatment and become an integral part of the process, instead of a justification after the event. It might have a part to play in the allocation of units by identifying which wines might show the most appropriate structure for micro-oxygenation.

Dissolved oxygen-monitoring needs to be improved, as this would take away a large element of the risk involved in using higher doses. It is fortunate that a DO meter with the ability to measure DO to within a few ppb exists, unfortunately the cost attached is enough to dissuade most accountants. Having spoken to wineries that have used the Orbisphere, and having also trialled it, it has been found that it does provide some control to what is a potentially dangerous process (Prichard pers. comm., WineNet 2002).

One surprising thing noticed whilst the Orbisphere was on trial at the winery; the DO of the wines being micro-oxygenated at that time, post-MLF, was lower than that of the DO of undisturbed wines in storage. This has been attributed to the active consumption of oxygen of these wines during micro-oxygenation that might allow the prediction of any return to reductive aromas, or to select wines that might be appropriate for treatment.

As Thierry Lemaire revealed in his presentation at the 11th Australian Wine Industry Technical Conference (Lemaire et al. 2002) tasters are not reliably measuring acetaldehydes. Even when it is recognised, not all of what is perceived as aldehyde may necessarily be acetaldehyde. If...
the ability of full-bodied wines to conceal acetaldehyde were considered, then it would be beneficial to be able to measure accurately; preferably in tank as it is considered too unstable for accurate laboratory analyses. Reliable acetaldehyde analysis would enable the winemaker to make the building phase of micro-oxygenation more reliable and more time efficient as the dose could be tuned with greater confidence.

With more wines receiving micro-oxygenation on oak staves, the handling of staves in tank should be improved. With many systems already around, and more evolving, no doubt there will be a user friendly, manageable system that will be easy to clean, and that will allow the use of agitators on tanks that have them fitted. In order to protect the fine delivery hose from damage by loose planks it was necessary to suspend the sinter inside a length of tube hung by light steel chain from the inside of the tank neck. Improvements to the stave mounting system would make this unnecessary.

A further area that could be investigated would be in using the accurately measured application of oxygen to eliminate sulfides without using copper. The presence of reductive aromas can be taken as an indication that the wine in question is in need of some oxygen, and its addition at this stage would not only treat the symptom, sulfides, but also the problem; the reductive environment in the wine. This would be particularly beneficial during fermentation when it could be used to replace further additions of DAP (Robert Paul pers. comm.).

The experimental treatment of white wines on lees is also an area that might be of interest, especially if it were to be used to treat the harsher, phenolic character of press wines.

Conclusion

Milburn Park is committed to the continued use of micro-oxygenation as a winemaking tool. It is accepted that there is a great deal to learn about the range of applications and the benefits that might be achieved. The results that we have achieved on wines treated so far are exciting, and have received favourable comments. We look forward to expanding our knowledge and range of techniques further to find appropriate applications and to integrate these into the winemaking philosophy.

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