Managing phenolics in white wine

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Introduction
The conventional approach of most winemakers in the New World is to minimise or control phenolic levels in white wines. This comes from observing that white wines high in phenolics lack fresh varietal flavours, can be astringent, have a bitter, hard finish and are prone to oxidation and rapid ageing. The management of phenolic levels in white wines may be achieved by prevention and/or amelioration strategies.

Prevention
To avoid making highly phenolic juices and wines, winemakers need to be aware of the viticultural parameters that can influence phenolic levels. Likewise, harvest logistics, juice extraction techniques and juice clarification may also impact on phenolic levels in juices and resulting wines.

Viticultural parameters
Grape variety
Grape varieties vary in their genetic ability to accumulate phenolic compounds as they ripen. (Singleton and Trousdale 1983, Waterhouse 2002). In 2003 various batches of mechanically harvested grapes were sampled on arrival at the Rowland Flat winery. The juice from these grape bins was analysed for total phenolics (absorbance units at 280 nm) and Table 1 shows that Muscat Gordo Blanco recorded relatively high total phenolics compared to Semillon. The varietal contrasts in total phenolics between Semillon and Muscat Gordo Blanco and Chardonnay shown in Table 1 are quite valid when one considers that these batches had similar harvest logistics.

Wind and bird damage
Grapes that suffer damage from hot winds or birds can have elevated levels of phenolic compounds. This can be caused by skin breakdown, and through berry dehydration and shrivel, which raises the ration of skin or pomace to juice volume.

Disease
Fungal pathogens that cause grape skin damage, berry desiccation or restriction in berry size can also elevate phenolic levels in resulting juice and wine. Stummer et al. (2005) found elevated phenolic levels in Chardonnay grapes infected with powdery mildew. The high level of phenolic compounds observed in Botrytis affected juices is due to skin breakdown as well as high levels of berry desiccation.

Maturity
Grapes accumulate total phenolics as they ripen. This may explain, in part, why some white and sparkling winegrapes harvested at lower maturity levels show less browning potential and have the ability to age relatively slowly.

Berry size
As discussed earlier, small berry size increases the likelihood that white musts and juices will have elevated levels of phenolics because the ratio of skin and pomace to juice volume has been increased.

White grapevines that experience poor flowering resulting in 'hen and chicken' clusters can run the risk of producing juices high in phenolics. In contrast, vineyards that are managed, so as to produce healthy lush canopies can often produce large size berries, especially if flowering and fruit set is favoured by seasonal conditions. A vineyard management approach consistent with achieving larger berry size in white cultivars may involve pre-veraison irrigation and fertigation.

The best outcome for minimising phenols in white winemaking is to have healthy, flavouresome, large-sized berries.

Sun exposure
White berries that become sunburnt show a distinct browning of the grape skin, which is related to the increase in phenolic level. Price (1975) showed the link between sun exposure and quercetin levels in Pinot Noir. More recently, Crothers (2005) has shown that sun exposure and sunburn in Chardonnay grapes are linked with higher total phenolics. Interestingly, Crothers found that highly sun exposed Chardonnay grapes have about six times the quercetin levels of shaded or control clusters. These results are shown in Table 2.

Summary
The viticultural parameters discussed above which influence the level of phenolics in berries can, to a reasonable extent, be controlled or managed. Disease- and damage-free clusters with large berries, grown under dappled light conditions, should result in white grapes with relatively low phenolic potential for the variety involved and for the maturity level at harvest.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Ave (a.u.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscat Gordo</td>
<td>4.40</td>
</tr>
<tr>
<td>Chardonnay</td>
<td>3.26</td>
</tr>
<tr>
<td>Riesling</td>
<td>2.47</td>
</tr>
<tr>
<td>Sauvignon Blanc</td>
<td>1.42</td>
</tr>
<tr>
<td>Semillon</td>
<td>1.31</td>
</tr>
</tbody>
</table>

Table 1. Total phenolic concentration in absorbance units (a.u.) in juice from mechanically harvested grape loads, 2003 vintage

<table>
<thead>
<tr>
<th>Parameter (units)</th>
<th>Vintage</th>
<th>Control clusters</th>
<th>Highly exposed clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total phenolics (a.u.)</td>
<td>2003</td>
<td>2.86</td>
<td>3.96</td>
</tr>
<tr>
<td>Total phenolics (a.u.)</td>
<td>2004</td>
<td>1.57</td>
<td>2.57</td>
</tr>
<tr>
<td>Quercetin conjugates (mg/L)</td>
<td>2004</td>
<td>3.02</td>
<td>17.25</td>
</tr>
<tr>
<td>Caftaric esters (mg/L)</td>
<td>2004</td>
<td>31.32</td>
<td>46.59</td>
</tr>
<tr>
<td>Coutaric acid esters (mg/L)</td>
<td>2004</td>
<td>15.68</td>
<td>29.34</td>
</tr>
</tbody>
</table>

After Crothers (2005)
Harvest logistics

Much of the following discussion is concerned with mechanical harvesting. However, a few points can be made regarding hand harvesting and phenolic extraction. Hand harvesting has the potential to deliver undamaged clusters to the winery. The full advantages of hand harvesting may not be realised regarding phenolic extraction if any of the following occur: vigorous and numerous transfers of clusters from picking baskets and collection bins to transport bins in the vineyard; failure to exclude or sort damaged clusters from healthy clusters; harvesting on a very hot day; long delays in transporting grapes to the winery, especially if the clusters are stored in large, poorly ventilated grape bins, where pressure and heat (some derived from respiring grapes) may cause juicing and skin breakdown.

The great majority of white grapes in Australia are mechanically harvested and various harvesting conditions and logistics can influence the resulting phenolic levels in juices and wine. These include temperature, use of SO₂, degree of berry damage caused by machine harvesting, degree of berry damage caused by bin handling/tipping in the vineyard, and time delay between harvest and delivery to the winery.

Temperature and time

Many winemakers believe that temperature and time are key factors that influence the degree of phenolic extraction with mechanically harvested grapes. In the Orlando Wyndham Group (OWG), commercial grade white cultivars will not be harvested if the minimum night time temperature exceeds 20°C, and for premium grade fruit the harvest temperature cut-off is lowered to 15°C.

In 2004, bench top trials were conducted at Orlando-Wyndham to study how harvest logistics and associated methods could influence phenolic extraction in mechanically harvested grapes. In one trial clusters of Chardonnay grapes were destemmed and partly crushed in bearers to stimulate the damage caused by mechanical harvesting. Sulphur dioxide was added at 50 ppm and the static extraction of total phenolics into the juice phase was observed over time and at two temperatures: 14°C and 25°C. Figure 1 shows the results of this trial.

The difference in phenolic extraction between the two temperatures may be marginal at first but appears to diverge more significantly after four hours of skin contact. This trial may underestimate the extraction of phenolics in a normal harvest and transport situation, where extra mechanical damage is involved.

Use of sulphur dioxide in mechanically harvested grape loads

Sulphur dioxide is not only lethal to bacteria and yeasts, it can also be lethal to plant cells, causing loss of vacuole membrane integrity. A similar bench top trial in 2004 investigated the role of SO₂ in the extraction of phenolics from partly crushed Chardonnay grapes.

In this trial, the static extraction of total phenolics was observed at 25°C at three SO₂ rates: nil, 50 ppm (standard) and 100 ppm (double). These results are shown in Figure 2.

At all time points, more phenolics were extracted from SO₂-treated berries, and the differences between treatments became more obvious after four hours of skin contact time.

Mechanical damage during harvest and transport

The degree of mechanical damage inflicted on berries during mechanical harvesting may influence juicing levels and extraction of phenolics. Modern harvesters that have a gentle fruit removal action, combined with skilled operators, can reduce berry damage and inclusion of MOG (materials other than grapes). Likewise, logistics that avoid repeated tipping, e.g. from collection bins to transport bins, also decrease the amount of mechanical damage to harvested berries. The rigidity of truck suspension and quality of road surfaces may also influence the degree of mechanical damage and juicing in mechanically harvested grapes.

Juice extraction techniques

Once grapes arrive at the winery, various methods can be used to extract juice. As with harvest logistics, the degree of mechanical damage to berries, temperature and time are key factors that impinge on phenolic extraction. Techniques of juice extraction include whole bunch pressing, draining and pressing of destemmed berries as well as destemmed and crushed berries. The pumping of must in must lines, draining equipment and methods, how pressures are loaded, the separation of free run juice from pressings juice, the use of additives, and the role of juice oxidation all play a role in the extraction and retention of phenolic compounds.

Whole bunch pressing

It is well documented that whole bunch pressing provides juice with fewer solids and lower phenolic levels compared to conventional crushing and draining (Gössinger et al. 1999). However, these advantages may only apply to fruit that can be hand harvested.
Conventional crushing and draining
For mechanically harvested white grapes at OWG, loads are destemmed but not crushed, and whole or part berries are pumped via must chillers [which reduce must temperatures to 5°C] to tank presses that are used as static draining. Static draining, including tank presses, have the ability to produce free run juices lower in total phenolics and solids compared to continuous draining that cause more mechanical damage to berry skins. All whitegrape processing sites within OWG exclusively use tank presses as static draining for all varieties and for all quality grades of fruit.

Must line diameter and design
Must line design which relates to winery design and layout can influence the pressure required to pump musts from crusher pits to tank presses. Optimal systems for low phenolic extraction will pump down hill, over short straight distances and through large diameter pipes. The pressure drop over 50 meters of horizontal must line delivering 45000L of must per hour can fall from 139Kpa to 5.9 Kpa if the diameter of the must line is increased from 75mm to 150mm (Policki, P. personal communication, 2005).

Press loading and draining methods
Modern tank presses can be top-loaded by pumping must through open doors or by pumping must through an axial valve which is positioned in the middle of the tank cylinder end. Various trials of press filling and draining were conducted at OWG in 2003. Some of these results are shown in Table 3.

Top filling involved pumping must through an extra 8 meters of must line with sharp bends, and at delivery, the must would fall 2.5 meters into the press. The mechanical damage caused by this method of loading may have contributed to the higher phenolic concentration in free-run juice. The loading method that gave the lowest phenolic level utilised axial filling with one rotation half way through to lower resistance pressure on the incoming must. Further, rapid draining facilitated by three gentle rotations, to clear screens, reduced skin contact time.

Free-run and press juice fractions
The decision to ‘make the press cut’ at OWG is based on sensory criteria. Figure 3 shows a typical pattern of how total phenolics rise as the free-run and then pressings fractions are extracted from a must line with sharp bends, and at delivery, the must would fall 2.5 meters into the press. The mechanical damage caused by this method of loading may have contributed to the higher phenolic concentration in free-run juice. The loading method that gave the lowest phenolic level utilised axial filling with one rotation half way through to lower resistance pressure on the incoming must. Further, rapid draining facilitated by three gentle rotations, to clear screens, reduced skin contact time.

Juice clarification
The extent of juice clarification prior to ferment may influence the phenolic level in the finished wine. If grape solids contain intact plant cells which can break down during fermentation, this may release phenolic substances into the wine. Most reports on white wines made from juices containing large quantities of grape solids focus on the fermentation aroma outcomes, rather than report elevated phenolic levels. (Singleton et al. 1975, Tromp 1984, Karagiannis 2002). However, Singleton et al. (1975) observed that white wines made from high solid juices were more astringent and bitter compared to control wines made from clarified juices.

At OWG, all white varieties are fermented with low levels of grape solids to enhance fresh varietal aromas.

Amelioration
Juice and wine fining are the main methods used to lower phenolics. Fining should be seen as a secondary process to the prevention strategies discussed earlier, because fining is costly and may cause flavour-stripping.

Fining at the juice stage, rather than the wine stage, may have several advantages: removal of bitter and astringent phenolics early in the winemaking process, targeting rogue batches of highly phenolic juice and thus avoiding higher rates of fining for finished blends of wine, and reducing the flavour-stripping effects of fining at the wine stage. Research has shown that phenolic glycosides are more resistant to protein fining than their non-polar aglycones (Donovan 1998). If similar chemistry applies to wine flavour precursors, then fining at the juice stage is strategic in preserving wine flavour.

Table 3. Total phenolic concentration (a.u.) in free-run sparkling Chardonnay juice for various loading and draining methods

<table>
<thead>
<tr>
<th>Loading method</th>
<th>Rotations during filling</th>
<th>Rotations during draining</th>
<th>Filling and draining time (minutes)</th>
<th>Total Phenolics (a.u.) in free-run juice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top fill</td>
<td>0</td>
<td>2</td>
<td>260</td>
<td>3.0</td>
</tr>
<tr>
<td>Axial fill</td>
<td>0</td>
<td>2</td>
<td>240</td>
<td>1.5</td>
</tr>
<tr>
<td>Axial fill</td>
<td>1</td>
<td>3</td>
<td>145</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Figure 3. Total phenolic concentration (a.u.) and juice extraction (litres per tonne) of Adelaide Hills Chardonnay grapes, 2004 vintage

Additions of pectolytic enzymes, SO2, and use of passive juice oxidation and hyperoxidation of juice
Pectolytic enzymes added at the crusher may soften or macerate crushed fruit, giving rise to higher juice yields but with higher phenolic levels. At OWG, pectolytic enzymes are added post-press to avoid this possibility.

SO2 additions to raw juice may prevent juice browning and preserve fresh flavours, but may also extract additional phenolic compounds from any fragments of grape skin contained in the juice. The role of oxidation in removing phenolics from juices is complicated. Cheynier (1991) observed that Chardonnay juices that were passively oxidised retained their phenolic composition if SO2 was added soon after the oxidation had occurred. This was explained by the fact that the quinones formed during oxidation were reduced with the addition of SO2 thus preventing their condensation into larger polymers. In contrast, hyperoxidation with delayed or no addition of SO2 allows quinone condensation and the removal of phenolics by the precipitation of brown polymers. At OWG, all white pressing juices are hyperoxidized with no addition of SO2 prior to fermentation.
One disadvantage of juice fining is that fining trials are difficult to interpret with high levels of sugar interfering with perceptions of astringency and bitterness. Overfining with protein fining agents can result in flavour-stripping and may cause higher levels of bentonite use. Trials at OWG (data not shown) have shown that soluble skim milk proteins are heat-labile and directly contribute to heat haze. In contrast, hydrolysed gelatin proteins are not heat-labile but have the ability to competitively inhibit the removal of heat-labile grape proteins by bentonite. Thus, any skim milk proteins or gelatin proteins remaining in wine after juice or wine fining will increase the amount of bentonite required to render wines heat-stable.

Wine fining is the last resort in managing phenolic levels, however it does provide for the fine-tuning of wine structure, taste/flavour and mouthfeel.

**Future directions**

If low phenolic white wines continue be what the market desires then systems should be engineered to secure this outcome. Where possible, poor or unreliable human decisions should be removed from critical control points where phenolic pick-up can occur.

There are many ways that further market and scientific research would allow winemakers to appropriately manage phenolic levels in white wines. This research may address some interesting questions such as:

- Are the best white wines low in phenolics?
- Will consumers always want low phenolic white wines?
- Are most flavour compounds and their precursors found in grape skins? If so, can we find novel ways of separating them from unwanted co-extracts?
- What are the sensory impacts of different phenolics in white wines?

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**References**


