

# Oak alternatives: a balance between science and finance

Kerry L. Wilkinson, Sijing Li and Anna M. Crump

School of Agriculture, Food and Wine, The University of Adelaide,  
PMB 1, Glen Osmond SA 5064, Australia

Corresponding author: kerry.wilkinson@adelaide.edu.au

## Introduction

Oak maturation plays an important role in the production of most red wines and many white wines, enhancing both physical attributes (colour and stability) and sensory properties (aroma, flavour and astringency). However, oak is an expensive raw material, and barrels contribute significantly to production costs, in terms of both capital investment (i.e. barrels) and labour associated with cellar management. The cost of maturation depends on several factors, including the origin of oak wood (i.e. French vs. American), the size of barrels, the duration of maturation, the proportion of wine subjected to oak maturation and the age of barrels (i.e. new vs. used)<sup>1</sup>.

In their *Costs of Wine Maturation*<sup>1</sup> case study, Wine Australia suggested the retail price of wine needed to double to meet the 104.5% cost increase associated with maturing wine for 2 years in new French oak barrels (Table 1). Therefore, while barrel maturation is still preferred for the production of premium wines, the range and application of alternative oak products (e.g. oak chips, shavings and powders) has increased considerably, as more rapid and economical methods of oak maturation.

**Table 1.** Cost effect of maturation.

Description	Cost to make \$/per case	Cost increase compared to no oak (%)	Retail price to achieve 50% gross margin \$ per 750mL bottle
No oak	99.97	-	40.00
One year in new French oak	160.32	60.4	64.00
Two years in new French oak	204.43	104.5	82.00

Adapted from Wine Australia, 2007<sup>1</sup>.

Examples of the use of oak alternatives and their impact on wine composition and sensory properties are presented in this paper, together with results from a recent study investigating consumers' knowledge of and attitudes towards the role of oak in winemaking. Techniques that extend the utility of oak offer industry real opportunities to gain competitive advantage, through reduced production costs. Thus, an innovative method by which old barrels can be 'recycled' and utilised as a previously untapped source of high quality oak for the preparation of alternative oak products will also be described.

## Contribution of oak wood to wine aroma and flavour.

Oak was originally used for wine maturation because it was readily available in parts of the world where wine was being produced (i.e. France and America), but over time oak was found to impart desirable aromas and flavours to wine, due to the extraction of oak derived volatile compounds<sup>2</sup>, including those shown in Table 2. The composition of oak wood is influenced by both species and geographical origin<sup>3</sup>, but thermal degradation of wood macromolecules (i.e. lignin and hemicellulose) during toasting results in the formation of oak volatiles<sup>4-6</sup> (Table 2). The concentration of these volatiles can be measured in either oak

wood to determine its flavour potential or in wine to determine the impact of oak maturation. Sensory analyses can also be used to determine the contribution of oak to wine aroma and flavour.

**Table 2.** Several important oak derived volatile compounds, their aroma descriptors<sup>7,8</sup> and reported concentrations in untoasted and toasted French and American oak wood<sup>4-6</sup>.

Oak volatiles	Descriptors <sup>a</sup>	Concentrations (µg/g)			
		untoasted French oak <sup>b</sup>	toasted French oak <sup>c</sup>	untoasted American oak <sup>b</sup>	toasted American oak <sup>c</sup>
<i>cis</i> -oak lactone	coconut, woody	11.5	nd–11.4	49.2	12.3–47.9
<i>trans</i> -oak lactone	coconut, celery	6.8	nd–6.8	4.7	3.3–5.3
guaiacol	smoky, burnt bacon	tr	2.3–18.5	tr	4.2–13.5
4-methylguaiacol	smoky	nd	1.3–10.2	nd	0.9–7.9
eugenol	clove, spicy	-	0.7–2.3	-	4.2–6.1
vanillin	vanilla	7.9	53–190	9.5	42–140

tr = trace levels (i.e. <1 µg/g); nd = not detected.

<sup>a</sup> Descriptors from Günther and Mosandl, 1986<sup>7</sup> and Boidron et al. 1988<sup>8</sup>.

<sup>b</sup> Data from Campbell et al. 2005<sup>4</sup>.

<sup>c</sup> Data from Campbell et al. 2005<sup>4</sup>, Fernández de Simón et al. 2010<sup>5</sup> and Alañón et al. 2012<sup>6</sup>.

### Evaluating alternative oak maturation regimes.

A recent study investigated the influence of different methods of oak maturation on the composition, sensory properties and consumer acceptance of wine<sup>9</sup>. A combination of traditional and alternative oak maturation regimes were used to age two Cabernet Sauvignon wines: a 2009 Cabernet Sauvignon from Padthaway, aged in 900 L Stakvats for 12 months; and a 2011 Cabernet Sauvignon from Eden Valley, aged in 225–300 L barrels, 4550 L stainless steel tanks or 1000 L plastic tanks for 4 months. Stakvat vessels comprised stainless steel, stainless steel with high density polyethylene (HDPE) panels or stainless steel with oak panels. Toasted French oak chips were added (at 2 g/L) to stainless steel and stainless steel/HDPE Stakvats. Maturation of the 2011 Eden Valley Cabernet Sauvignon in stainless steel and plastic tanks was performed with and without the addition of toasted French oak staves (at 1.4 m<sup>2</sup>/KL).

Following maturation, wines were analysed by gas chromatography-mass spectrometry to determine the concentrations of several key oak volatiles (Table 3) and by descriptive analysis with a trained panel of judges to determine the intensity of various aroma and palate attributes (Figure 1). This enabled the influence of each maturation regime on wine composition and sensory properties to be determined. Consumer acceptance of a subset of wines was also determined.

Similar concentrations of oak volatiles were observed in wines aged in Stakvats, irrespective of the type of Stakvat; i.e. stainless steel, stainless steel/HDPE or stainless steel/oak. Oak volatiles were also detected in wines aged in either barrels or in stainless steel or plastic tanks with the addition oak chips; but barrel aged wines had considerably higher concentrations of *cis*- and *trans*-oak lactone and lower concentrations of vanillin than other oaked wines. Wines aged in stainless steel or plastic tanks without oak chips contained little or no oak derived volatiles, as expected. Differences observed between the oak volatile concentrations of different wines most likely reflect differences in the type of oak used for maturation, as well as the different rates of oak addition and durations of maturation. Nonetheless, compositional analysis confirmed the presence of oak volatiles in wines made using both traditional and alternative oak maturation regimes.

**Table 3.** Concentrations of oak volatiles present in Cabernet Sauvignon wines following maturation.

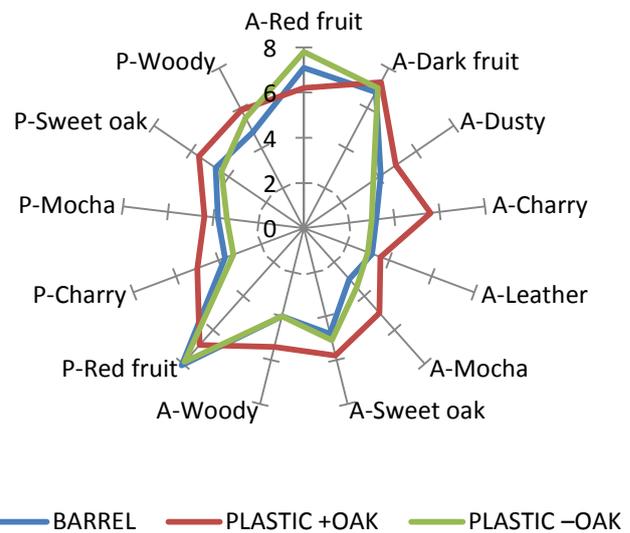
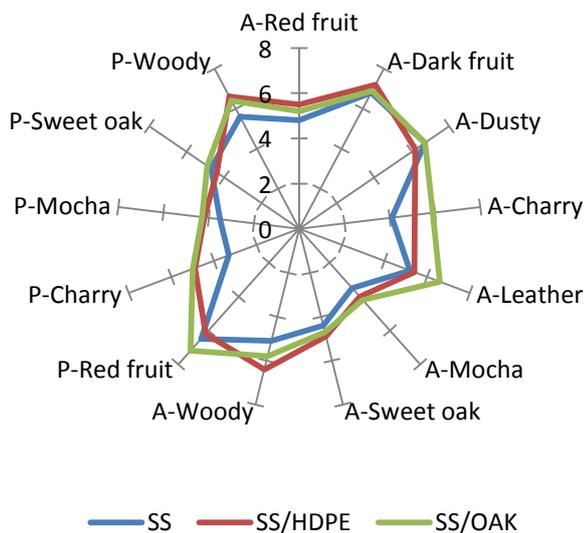
	Concentrations ( $\mu\text{g/L}$ )					
	<i>cis</i> -oak lactone	<i>trans</i> -oak lactone	guaiacol	4-methyl guaiacol	eugenol	vanillin
<b>2009 Padthaway Cabernet Sauvignon</b>						
aged for 12 months in Stakvats	121–128	23–29	7–8	4–11	nd–12	54–153
<b>2011 Eden Valley Cabernet Sauvignon</b>						
aged for 4 months in oak barrels	99	79	4	1	6	123
aged for 4 months in stainless steel or plastic tanks without oak chips	nd	nd	3–4	nd	nd	6–20
aged for 4 months in stainless steel or plastic tanks with oak chips	30–47	24–46	27–33	15–16	nd–6	242–313

nd = not detected.

Descriptive analysis subsequently confirmed the presence of perceptible oak aromas and flavours. The 2009 Cabernet Sauvignon exhibited intense aged notes, i.e. *leather* aroma, as well as *woody* aroma and flavour. Surprisingly, the sensory profiles of the wines aged in Stakvats were quite similar, consistent with compositional data. In contrast, more distinct differences were observed between the sensory profiles of 2011 Cabernet Sauvignon wines. The barrel aged wine and unoaked wine aged in a plastic tank gave quite similar sensory profiles; whereas the wine aged in a plastic tank with oak chips had apparent oak aromas and flavours (i.e. *cherry*, *mocha* and *woody* notes).

**2009 Padthaway Cabernet Sauvignon**

**2011 Eden Valley Cabernet Sauvignon**

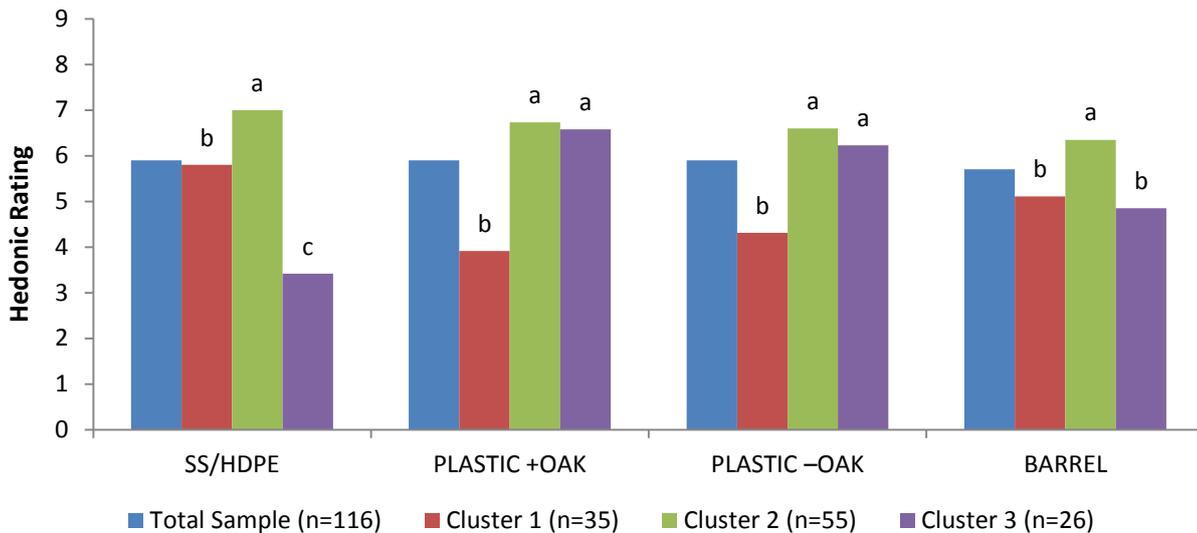


**Figure 1.** Sensory profiles of selected Cabernet Sauvignon wines following maturation.

Consumers (n=116) were then asked to rate their acceptance of a subset of wines, comprising the 2009 Cabernet Sauvignon aged in a stainless steel/HDPE Stakvat (with the addition of oak chips) and the 2011 Cabernet Sauvignon aged in either oak barrels, or in plastic tanks with or without the addition of oak staves (Figure 2). Collectively, the total sample (i.e. all 116 consumers) gave the wines very similar scores, which ranged from 5.7 to 5.9 (out of 9). However, considerable variation was observed between consumers'

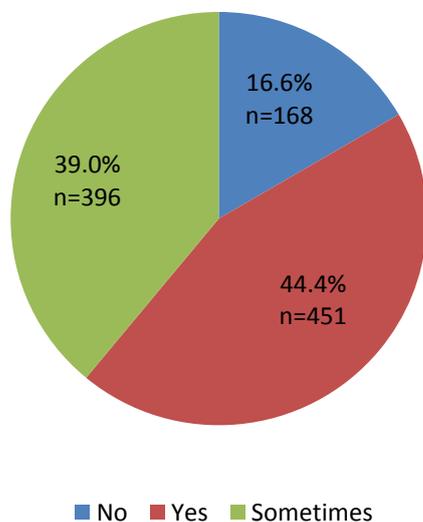
individual preferences, so cluster analysis was performed on the basis of hedonic scores, and three distinct consumer segments were identified. The first cluster (n=35) liked the stainless steel/HDPE Stakvat wine most, but wasn't especially accepting of any wine. Cluster 2 (n=55) quite liked all of the wines; while Cluster 3 (n=26) liked the wines aged in plastic tanks (irrespective of whether oak staves were added or not) but did not particularly like the barrel aged or Stakvat wines. These results demonstrate the variation in consumers' preferences for wine, but also that wines aged using oak alternatives were liked by some segments of the consumer market.

**Figure 2.** Consumer liking of selected Cabernet Sauvignon wines.



**Evaluating consumer attitudes towards oak maturation regimes**

In a different study, consumers' knowledge of and attitudes towards the role of oak in winemaking was investigated<sup>10</sup>. Most consumers were found to have a fairly limited understanding of the oak maturation process and a significant proportion (>10%) believed wine was always aged in oak barrels. Importantly, of the 1015 consumers surveyed, the vast majority (83.4%) enjoyed drinking oaked wines, at least sometimes (Figure 3). Furthermore, whilst these consumers generally agreed the use of oak chips 'doesn't sound romantic' compared to barrel maturation, they also 'don't care how wine is made as long as it tastes good'<sup>10</sup>.



**Figure 3.** Proportion of consumers surveyed (n=1015) who enjoy drinking oaked wines.

Consumers' knowledge regarding the use of oak in winemaking was found to influence their attitudes towards wines made using oak alternatives, as well as their preferences for oak maturation of wine (Table 4), and four distinct oak knowledge segments were identified following cluster analysis. One segment (Cluster 4) comprised consumers who were quite knowledgeable about oak maturation and who held strong opinions regarding the impact of oak on wine quality and negative attitudes towards the use of oak alternatives. These consumers had a stronger preference for French oak (than American oak) and considered themselves capable of differentiating wines aged in oak barrels or with oak alternatives (Table 4). They valued traditional barrel maturation and were willing to pay the associated higher price per bottle. In contrast, another segment (Cluster 1) comprising less knowledgeable consumers did not have strong opinions regarding the maturation of wine. These consumers had no preference for French vs. American oak and did not believe they could differentiate wines based on oak maturation (Table 4); instead, they were accepting of the use of oak alternatives, provided wine quality was not compromised.

**Table 4.** Consumer preferences for oak maturation of wine.

	Oak knowledge segments (%)			
	cluster 1 (n=461)	cluster 2 (n=133)	cluster 3 (n=141)	cluster 4 (n=112)
<b><i>Prefer French or American oak</i></b>				
Not sure/no preference	92.6	75.9	79.5	41.1
French	6.5	21.1	17.0	56.3
American	0.9	3.0	3.5	2.7
<b><i>Able to tell the difference between wine made in barrel or with alternatives</i></b>				
No	90.9	78.9	78.0	25.9
Yes	9.1	21.1	22.0	74.1

Adapted from Crump et al. 2014<sup>10</sup>.

### **Evaluating the potential for old oak barrels to be recycled**

The volatile compounds extracted from oak wood during maturation are finite and diminish with time<sup>11</sup>. As a consequence, oak barrels need to be replaced routinely; typically every 5 or 6 years. An innovative method of recycling old barrels was investigated as a means of extending the utility of cooperage oak and reducing overall production costs.

Used French and American barrels were disassembled and the resulting staves processed to produce oak battens (approximately 900 x 70 x 6 mm). Briefly, this involved removing the wine-affected inner portion of each stave and then splitting the remaining oak lengthways into battens, which were subsequently toasted over far infrared (FIR) heating elements. Extracts were then prepared by soaking shavings taken from each batten in 20% aqueous ethanol. Extracts were analysed by gas chromatography-mass spectrometry to determine the concentrations of several key oak volatiles (Table 5) and compared with concentrations reported for new toasted oak wood (Table 2), in order to determine the flavour potential of recycled oak wood.

Considerable variation was observed in the concentrations of oak volatiles present in individual recycled oak wood samples (Table 5), albeit variation is similarly observed in new oak wood. Nonetheless, most of the oak derived volatiles measured occurred at concentrations comparable to those reported for new oak wood<sup>4-6</sup> (Table 2). As such, reclaimed oak wood can indeed impart oak aroma and flavour to wine and old oak barrels can therefore be recycled as a source of oak wood for the preparation of alternative oak

products. The barrel reclaim process typically generates 60 oak battens with an approximate surface area of 8 m<sup>2</sup> for every 225 L barrel, at a cost of \$150 (i.e. between 10 and 20% the cost of a new barrel). Thus, the barrel reclaim process is not prohibitively expensive.

*In press: Australian Society of Viticulture and Oenology 2015*

**Table 5.** Concentration of oak volatiles in toasted samples of French and American reclaimed oak.

Oak Samples	Concentrations ( $\mu\text{g/L}$ )					
	<i>cis</i> -oak lactone	<i>trans</i> -oak lactone	guaiacol	4-methyl Guaiacol	eugenol	vanillin
reclaimed French oak <sup>a</sup>	nd–33.4	nd–73.1	1.5–11.6	0.8–4.9	2.7–7.7	58–115
reclaimed American oak <sup>b</sup>	nd–65.5	nd–9.1	0.8–12.3	0.6–5.6	2.3–6.2	70–137

nd = not detected

<sup>a</sup>Values are means from 24 replicates; <sup>b</sup>Values are means from 22 replicates.

Table 6 provides a simple cost comparison for maturation of wine (90,000 L per year for 9 years, i.e. 810,000 L total) in either American or French oak barrels (300 L hogsheads) vs. stainless steel Stakvats (900 L) containing reclaimed oak (30 battens/Stakvat). The calculations assume: maturation of wine for 12 months; that American and French oak barrels cost \$900 and \$1,500 each respectively; that barrels are replaced every 3 years (due to diminished oak volatiles); that Stakvats cost \$5,000 each, and will last at least 20 years; and that the reclaimed oak battens obtained from one hogshead (at a cost of \$150) provide sufficient oak for two Stakvats (albeit in reality, winemakers might prefer more or less oak, depending on wine style). Ongoing cellar management costs have not been considered, but should be less for management of 100 Stakvats than for management of 300 barrels.

The capital investment associated with traditional barrel maturation is considerable and contributes \$1.00–\$1.67/L to the overall cost of wine production. The use of alternative oak maturation regimes significantly reduces the required capital investment; in the case of Stakvats and reclaimed oak, maturation costs were only \$0.70/L.

**Table 6.** Cost comparison for wine maturation using traditional oak barrels vs. maturation with stainless steel Stakvats and reclaimed oak.

Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Cost	
									Total	/L
<b>American oak barrels (300 x 300 L @ \$900 each)</b>										
\$270K	–	–	\$270K	–	–	\$270K	–	–	\$810K	\$1.00/L
<b>French oak barrels (300 x 300 L @ \$1500 each)</b>										
\$450K	–	–	\$450K	–	–	\$450K	–	–	\$1,350K	\$1.67/L
<b>Stakvats (stainless steel with reclaimed oak battens; 100 x 900 L @ \$5000 each)</b>										
\$500K	–	–	–	–	–	–	–	–	\$568K	\$0.70/L
\$7.5K	\$7.5K	\$7.5K	\$7.5K	\$7.5K	\$7.5K	\$7.5K	\$7.5K	\$7.5K		

## Conclusion

Traditional barrel maturation remains the preferred method of oak maturation for the production of premium wines, but oak alternatives are increasingly being used as more rapid and economical methods of oak treatment of wines at lower price points. The research presented here demonstrates that alternative oak maturation regimes are certainly capable of imparting oak derived volatile compounds, and oak aroma and flavour to wine. Furthermore, although different segments of the consumer market have distinctly different wine preferences, wines aged with oak alternatives were accepted by several consumer segments. Consumers' knowledge of the role of oak maturation influenced their attitudes towards wines

made with oak alternatives; more knowledgeable consumers weren't overly accepting of the use of oak alternatives, but less knowledgeable consumers were, provided wine quality was not compromised.

There are clear economic benefits to be gained from the improved utility of oak during winemaking. The use of oak alternatives enables winemakers to reduce production costs, particularly for wines at lower price points; while the potential for old barrels to be recycled as a source of high quality oak wood has now also been demonstrated. Hopefully these results give winemakers greater confidence in oak alternatives, and enable industry to address the increasing costs associated with wine production; i.e. an issue considered to be a high priority for the wine sector.

### Acknowledgements

The authors thank the industry partners who participated in these research projects through the provision of wine and/or oak samples. The valuable contributions of collaborators, in particular Dr. Trent Johnson, Dr. Daniel Cozzolino and Associate Professors Sue Bastian and Paul Grbin (University of Adelaide), Dr. Yoji Hayasaka (The Australian Wine Research Institute) and Mr. Peter Warren (Ausvat Pty. Ltd.), are also gratefully acknowledged. Anna Crump thanks the Australian Grape and Wine Authority for financial support.

### References

1. Winemakers Federation of Australia. **2007**, Wine Australia: Directions to 2025.
2. Maga, J.A. The contribution of wood to the flavour of alcoholic beverages. *Food Rev. Int.*, **1989**, *5*, 39-99.
3. Doussot, F., De Jéso, B., Quideau, S. and Pardon, P. Extractives content in cooperage oak wood during natural seasoning and toasting; influence of tree species, geographic location, and single tree effects. *J. Agric. Food Chem.*, **2002**, *50*, 5955-5961.
4. Campbell, J.I., Sykes, M., Sefton, M.A. and Pollnitz, A.P. The effects of size, temperature and air contact on the outcome of heating oak fragments. *Aust. J. Grape Wine Res.*, **2005**, *11*, 348-354.
5. Fernández de Simón, B., Cadahía, E., Muiño, I., Del Álamo, M. and Nevares, I. Volatile composition of toasted oak chips and staves and of red wine aged with them. *Am. J. Enol. Vitic.* **2010**, *61*, 157-165.
6. Alañón, M.E., Díaz-Maroto, M.C. and Pérez-Coello, M.S. Analysis of volatile composition of toasted and non-toasted commercial chips by GC-MS after an accelerated solvent extraction method. *Int. J. Food Sci. Tech.*, **2012**, *47*, 816-826.
7. Günther, C. and Mosandl, A. 3-Methyl-4-octanolid - "Quercuslacton, whiskylacton" - Struktur und eigenschaften der stereoisomeren. *Liebigs Ann. Chem.*, **1986**, 2112-2122.
8. Boldron, J.N., Chatonnet, P. and Pons, M. Influence du bois sur certaines substances odorantes des vins. *Conn. Vigne Vin*, **1988**, *22*, 275-294.
9. Crump, A.M., Johnson, T.E., Wilkinson, K.L. and Bastian, S.E.P. Influence of oak maturation regime on composition, sensory properties, quality and consumer acceptability of Cabernet Sauvignon wines. *J. Agric. Food Chem.*, **2015**, (in press, accepted 14<sup>th</sup> January 2015).
10. Crump, A.M., Johnson, T.E., Bastian, S.E.P., Bruwer, J. and Wilkinson, K.L. Consumers' knowledge of and attitudes toward the role of oak in winemaking. *Int. J. Wine Res.*, **2014**, *6*, 21-30.

11. Towey, J. P. and Waterhouse, A. L. The extraction of volatile compounds from French and American oak barrels in Chardonnay during three successive vintages. *Am. J. Enol. Vitic.*, **1996**, *47*, 163–172.

In press: Australian Society of Viticulture and Oenology 2015