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Varietal response to smoke exposure

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This article summarises the key results from major smoke taint-related research undertaken by The University of Adelaide and AWRI in recent years.

The incidence of bushfires resulting in vineyard exposure to smoke has increased in Australia and the US, Canada, South Africa and elsewhere, typically where wine regions are situated in hot climates. Some countries, including Australia, also employ prescribed burning programs to manage the risk of bushfires, and this can also result in vineyard exposure to smoke during the berry ripening period. Smoke exposure can be detrimental to grape and wine quality, with wines made from heavily smoke-affected grapes exhibiting a range of undesirable smoky and ashy characters. In some cases, this has led to a significant reduction in wine quality and, consequently, financial losses for grape and wine producers.

In 2009, The University of Adelaide established a smoke taint research project investigating the effects of vineyard exposure to smoke on the quality of grapes and wines and, in particular, evaluating the capacity of viticultural and winemaking techniques to ameliorate smoke taint in wines. This project was funded by the Australian Research Council as a Linkage Project, in which the cash and in-kind contributions of four industry partners - the Yalumba Wine Company, Brown Brothers, Treasury Wine Estates and the Department of Primary Industries and Resources of South Australia - were leveraged for government funding. The research team comprised Dr Kerry Wilkinson, Dr Renata Ristic, Professor Stephen Tyerman, Dr Sigfredo Fuentes and Dr Roberta Bei, from The University of Adelaide, Dr Daniel Cozzolino, from the Australian Wine Research Institute (AWRI), and Louisa Rose, chief winemaker from the Yalumba Wine Company.

In the first year of the project, a range of winemaking techniques were evaluated, including different yeast strains for fermentation of smoke-affected grapes, the effect of duration of skin contact time (i.e., rosé vs. red-style winemaking), and the addition of oak chips or tannins. These trials found that while different yeast strains did modify the sensory properties of smoke-affected wines to various degrees, none could completely mitigate smoke taint. Furthermore, reduced skin contact lessened the intensity of smoke attributes, while additions of oak and tannins increased wine complexity, allowing the smoke taint to be partially masked (Ristic *et al.* 2011). The fruit used in the winemaking trials comprised Shiraz grapes sourced from a vineyard located in Victoria and exposed to smoke from bushfires in 2009, and Grenache grapes sourced from a vineyard in the Barossa Valley. The Grenache grapevines were exposed to straw-derived experimental smoke approximately seven days after veraison, following experimental conditions developed by Kennison and colleagues (Kennison *et al.* 2008). Field experiments conducted in Western Australia on Merlot grapes indicated that seven days post-veraison was the most critical development stage for smoke uptake; with successive applications of smoke to Merlot grapevines yielding wines with the highest intensity of smoke taint (Kennison *et al.* 2009). Anecdotal evidence from industry following the 2009 Victorian bushfires suggested that the intensity of smoke taint detected in wine might be dependent on grape variety, with Pinot Noir, Sangiovese, Chardonnay and Cabernet Sauvignon thought to be more susceptible varieties than Shiraz and Merlot. Smoke-affected grape samples were collected from a number of regions and exposed to smoke for different durations. Chemical and sensory analysis revealed considerable variation in the concentrations of smoke-derived volatile phenols and the intensity of smoke-related sensory attributes for different grape varieties. The varietal response of grapevines to smoke exposure, therefore, remained unclear.

In 2010, an extensive trial involving seven grape varieties was conducted to investigate the physiological and biochemical responses of different grape varieties to smoke exposure. Three white varieties, Chardonnay, Pinot Gris, Sauvignon Blanc, and four red varieties, Merlot, Shiraz, Cabernet Sauvignon and Pinot Noir, grown in either the Adelaide Hills or at The University of Adelaide's Waite Campus were utilised. Grapevines were exposed to straw-derived experimental smoke approximately seven days after veraison for a duration of one hour. A range of viticultural and physiological measurements were performed on control and smoke-affected grapevines to characterise grapevine physiology. Smoke exposure was found to cause stomatal closure, resulting in reduced photosynthesis. While some varieties, e.g., Sauvignon Blanc, Pinot Noir and Pinot Gris, recovered relatively quickly, others, particularly Merlot, required almost two weeks to fully restore stomatal function. However, no differences in vegetative growth, leaf area or pruning weight were observed between control and smoked grapevines; albeit very small differences in berry weight and yield were observed for all varieties. Furthermore, the rate of sugar accumulation was similar across all varieties. This was in contrast to previous findings reported by Kennison and colleagues (Kennison *et al.* 2009), who observed lower total soluble solids content in fruit harvested from smoke-affected Merlot grapevines, compared with control grapevines. While vegetative growth and fruit load were not affected by smoke exposure in the varietal trial, the sensitivity of Merlot to smoke exposure was expected to be reflected in berry and/or wine compositional differences.

Wines were made from fruit harvested from control and smoke-affected grapevines of each variety, and the extent of smoke taint assessed chemically by quantification of volatile phenols and their glycoconjugates (Dungey *et al.* 2011, Parker *et al.* 2012) and sensorially by descriptive analysis (DA). The concentration of guaiacol glycoconjugates present in the control

fruit ranged from 37µg/kg (for Sauvignon Blanc) to 602µg/kg (for Shiraz). Levels were considerably higher in smoke-affected fruit, ranging from 253µg/kg (for Pinot Noir) to 1978µg/kg (for Shiraz). Control wines ranged from 8µg/L (Pinot Gris) to 334µg/L (Shiraz), while levels in smoke-affected wines ranged from 111µg/L (for Pinot Noir) to 1480µg/kg (for Shiraz). The glycoconjugate pool remaining after fermentation was considered a potential source of additional guaiacol that could be released with time as wine ages. Guaiacol, which is still considered a key marker of smoke taint, was present in control Merlot, Cabernet Sauvignon and Shiraz wines. Guaiacol levels ranged from very small amounts (less than 2µg/L) in smoke-affected Chardonnay and Sauvignon Blanc wines, to 20µg/L in Cabernet Sauvignon and 26µg/L in Shiraz wines made from smoke-affected grapes. Based on compositional data, i.e., the high concentrations of guaiacol and its glycoconjugates, the intensity of smoke taint was expected to be highest in smoke-affected Shiraz wines.

Descriptive sensory analysis was performed using a sensory panel comprising 12 trained judges convened from staff and students from The University of Adelaide and AWRI. The panel assessed the intensity of a range of smoke-related sensory attributes, including 'smoke', 'cold ash' and 'burnt rubber' aromas, 'smoky' flavour and 'ashy aftertaste'. Wines were also rated for the intensity of 'fruit' aroma and flavour. Red wines were found to exhibit a higher intensity of smoke taint; Cabernet Sauvignon was the most smoke tainted, followed by Pinot Noir, Merlot and Shiraz. Among the white wines, Pinot Gris was considered the most affected, then Sauvignon Blanc and Chardonnay (Figure 1). Interestingly, the 'fruit' aroma and flavour of smoke-affected Shiraz, Merlot and Chardonnay wines were not significantly diminished. This might indicate that the flavour complexity of certain grape varieties may influence the perception of smoke-related sensory attributes.

The results demonstrate the limitations in predicting the sensory impact of smoke taint in wines from grape and wine compositional data. This can be partially attributed to the presence of volatile phenols, particularly guaiacol, as natural components of some grape varieties. Furthermore, there was no apparent correlation between the concentration of individual volatile phenols or guaiacol glycoconjugates and the intensity of smoke taint in wines. For example, Shiraz contained relatively high

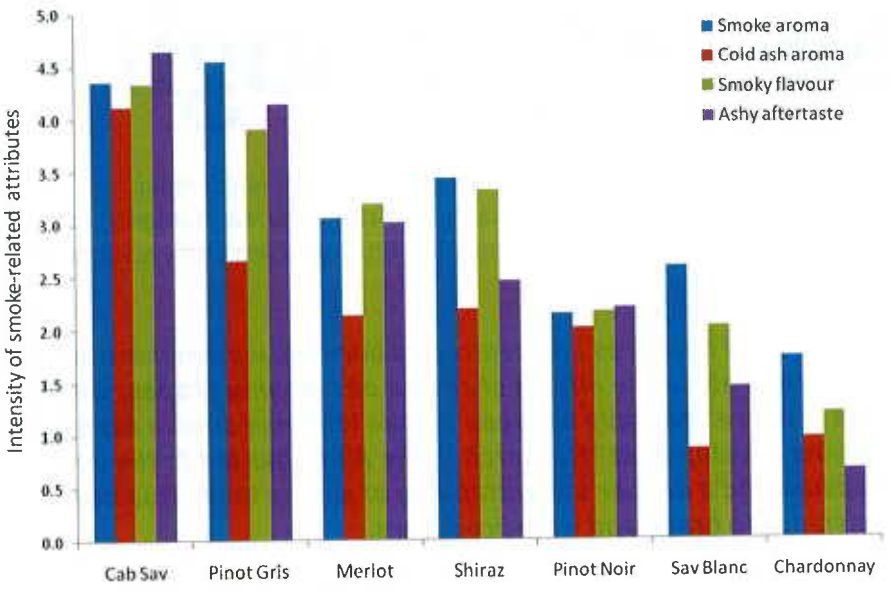

Figure 1. Mean ratings for smoke-related sensory attributes. Each value is the mean score from three fermentation replicate wines that were presented to 12 judges in two replicate sessions.

concentrations of guaiacol compared with the other varieties studied, but the increase due to smoke exposure was only three-fold. In contrast, the greatest increases in volatile phenol content occurred in Pinot Gris (30 x) and Merlot (20 x). Further work is, therefore, required to ascertain the background levels of volatile phenols that occur naturally in different grape varieties before benchmark values can be suggested for the assessment of smoke taint in different grape varieties. We have previously demonstrated the capacity of certain winemaking techniques (Ristic *et al.* 2011) and methods of amelioration (Fudge *et al.* 2011, Fudge *et al.* 2012) to mitigate the intensity of smoke taint in wines, but the glycoconjugate pools remaining in wines after treatment can allow the taint to return as a wine ages. As such, further research is also required to better understand the biochemistry involved in the glycosylation and metabolism of smoke-derived volatile phenols and their glycoconjugates.

ACKNOWLEDGEMENTS

In addition to the industry partners mentioned in the article, the authors thank Nepenthe, Adelaide Hills, for its generous in-kind contributions through the provision of the trial site and fruit, and accommodation of researchers' activities in the vineyard. We would also like to thank Yoji Hayasaka, Kerry Pinchbeck, Anthea Fudge and the Australian Wine Research Institute's Commercial Services Laboratory for performing grape and wine analysis, Andrew Markides of Lallemand, Australia, for the provision of yeast and winemaking consumables, and members of the sensory panel for their invaluable contributions and enthusiasm during the wine sensory studies.

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