Latest Developments in the Investigation of Smoke Derived Taint in Grapes and Wine

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Introduction

As Australia is facing a warming climate with increasing bushfire incidences the issue of smoke derived taint in grapes and wine has become a regular occurrence. Losses from smoke taint vary from year to year due to the unpredictable nature of bushfire events. Where significant smoke exposure occurs during sensitive periods of vine development the resultant wine is consequently unfit for purpose. Smoke taint in wine has resulted in financial losses and decline in product quality for several wine producers in Western Australia, Victoria and New South Wales with isolated incidences in other states. Smoke taint has also occurred in wine-grapes grown overseas and is an emerging issue for the wine-grape industry.

Wines made from grapes exposed to smoke exhibit various aroma characters with some smoke tainted wines containing ‘burnt’, ‘smoked meat’, ‘leather’, ‘disinfectant’, ‘charred’, ‘ashtray’ and ‘salami’ aromas. Smoke tainted wines are usually unpalatable and unfit for purpose therefore resulting in financial losses for the wine industry.

Due to the emerging nature of this issue, a lack of information exists as to the effects of smoke exposure on grapevines and the development of subsequent taint in wine. Few sources of published information exist. The following summary endeavours to address the lack of information on this issue and compiles recent developments in the area of smoke taint research.

Components of smoke

Smoke is a highly complex substance that is found to contain a multitude of compounds including carbon monoxide, carbon dioxide, ozone, polycyclic aromatic hydrocarbons, oxides of nitrogen and sulphur, volatile and semi-volatile organic compounds and particulate matter (McKenzie et al. 1994, Radojevic 2003). Many authors have found smoke to impact the organoleptic properties of foods and this is attributed to smoke derived volatile compounds, including phenols (Maga 1988, Guillén et al. 1995). Of these phenols, guaiacol and 4-methylguaiacol are important in smoke analysis due to their ‘smoky’, ‘toasted’, ‘ash’, ‘chemical’ and ‘phenolic’ aromas in food and in wines originating from oak barrel fermentation / storage (Baltes et al. 1981, Boidron et al. 1988, López et al. 1999). The analysis of guaiacol and 4-methylguaiacol in grapes, wine and vine material provides a mechanism for detecting the exposure of smoke to grapevines although it is noted that these are not the only compounds in smoke that may contribute to the sensory smoke taint. Analysis of guaiacol and 4-methylguaiacol is conducted by gas chromatography-mass spectrometry (GC-MS) equipment.

Field research

To investigate the issue of smoke derived taint in grapes and wine, researchers have developed a novel apparatus for the application of smoke to field-grown grapevines. This apparatus has been developed to enclose grapevines within tents whilst smoke is pumped from a smoke generating device into the tent that encloses the vines (Figure 1) (Kennison et al. 2008a). Tent frames are made of galvanized steel and covered with a greenhouse grade film (Solarweave) to allow the transmission of light to grapevines. Smoke is generated in a 50 L metal drum and forced into the tent by a remote controlled variable speed air pump.

Figure 1. Field smoke application apparatus showing smoke tent with vines enclosed (left) and smoke generator (right).

Research results

Research demonstrates the direct application of smoke to field-grown grapevines to result in the detection of smoke-like compounds (guaiacol and 4-methylguaiacol) in grapes and final wines (Kennison et al. 2008b). The presence of guaiacol and 4-methylguaiacol in grape samples is attributed to smoke exposure as these compounds were not found in samples from unsmoked (control) vines. Smoke exposure to grapevines also resulted in the detection of smoke-like aromas of ‘burnt rubber’, ‘leather’, ‘smoked meat’ and ‘disinfectant’ in resultant wines. These aromas were not discovered in wines made from fruit of unsmoked (control) vines.

Low levels of guaiacol and 4-methylguaiacol have been measured in grape samples in comparison to final wines that produce elevated levels of these compounds. Further investigation has revealed guaiacol and 4-methylguaiacol to release throughout the fermentation process resulting in elevated levels in wine (Kennison et al. 2008a). The level of smoke taint can therefore be underestimated in fruit samples. Ongoing research is investigating methods of sample preparation that provide a true estimate of the level of smoke taint.

Research has investigated the process by which smoke is assimilated and translocated by the vine to understand how smoke compounds can result in the grape berry and the final wine. Interestingly, initial research has found smoke compounds to reside within the skins of grape berries only and not within berry pulp (AWRI 2003, Kennison et al. 2009).

Timing of grapevine exposure to smoke

The timing of grapevine susceptibility to smoke uptake has been of major interest in the issue of smoke derived taint in grapes and wine. Little information has been available to detail the effect of smoke exposure to grapevines at key phenological stages of grapevine growth and development leading to uncertainty of outcome from the timing of smoke events. Recent research has investigated the effect of smoke application to grapevines at key growth stages (Kennison et al. 2009). Smoke has been applied to Merlot grapevines at shoots 10 cm, flowering, berries pea size, beginning of bunch closure, veraison, intermediate sugar, berries not quite ripe and harvest to investigate the sensory and chemical effects of smoke exposure. From this research, an understanding of the key timings of grapevine sensitivity to smoke exposure and the development of smoke taint in wine has been discovered (Figure 2).

Three distinct periods of grapevine sensitivity to smoke uptake have been discovered. The first period (P1) is characterized by a low potential for smoke uptake early in the growing season when shoots are 10 cm in length and at flowering. The potential for smoke uptake is variable during the second period (P2) from when berries are pea size through to 3 days post veraison. Grapevines show a low to medium sensitivity to smoke uptake during P2. During the third identified period (P3) from 7 days post veraison through to harvest grapevines have a high potential for the uptake of smoke compounds.

Cumulative effect of smoke

Vignerons have questioned the quantity of smoke exposure that is required to create a smoke taint effect in grapes and wine. Although research is ongoing in this area, it is interesting to note that a single heavy exposure of smoke (30% obscuration/m) to grapevines, at sensitive timings as previously indicated, for 30 min has resulted in smoke taint in wine. Research has further investigated the effects of repeated smoke applications to the same vines and has found repeated smoke applications to have a cumulative effect on the levels of smoke compounds and smoke aromas in wine (Kennison et al. 2008b). Therefore, repeated smoke exposures or smoke exposures for a long period of time results in an accumulation of smoke aromas and compounds in resultant wines.

Figure 2. Key periods of grapevine sensitivity to smoke exposure and the development of subsequent smoke taint aromas and compounds in wine. Information is derived from research investigating the direct application of smoke to field grown Merlot grapevines.

		Grapevine growth stage	**Potential for smoke uptake**
P1		Shoots 10 cm in length	Low
		Flowering	Low
P2		Berries pea size	Variable (low to medium)
		Beginning of bunch closure	Variable (low to medium)
		Onset of veraison to 3 days post veraison	Variable (low to medium)
P3	 	From 7 days post veraison to Harvest	High

Carry over from year to year?

Further queries have been raised as to whether smoke compounds can be exhibited in fruit one season after a heavy exposure to smoke. That is, are smoke compounds absorbed by the grapevines, stored and then released in fruit in the following season? Research has investigated the potential of this phenomenon to occur by applying repeated smoke applications to the same vines in one year only, measuring the level of smoke compounds and aromas in wines in the same year and then again in the following year (Kennison et al. 2009). Results showed high levels of smoke compounds and smoke aromas in wines made from fruit of vines exposed to repeated smoke applications although smoke compounds and aromas were not detected in wines made from fruit of the same vines in the year following the repeated smoke applications. Therefore, a carryover effect of smoke compounds from one year to another has not been demonstrated.

Other effects of smoke on grapevines

The application of smoke to grapevines has been found to affect grapevine functioning and development. For instance, repeated smoke exposures have resulted in the decrease of vine productivity by producing necrotic lesions on leaves (Figure 3) (Kennison et al. 2008b). Subsequently, fruit ripening capabilities of the vine are decreased. Interestingly, carryover effects of smoke can be detected in grapevine growth and production in the season following a heavy smoke exposure. Shoot length and fruit yield are significantly decreased in the season following repeated smoke applications (Kennison et al. 2009), effects which are not seen on unsmoked vines. Further investigations on the effects of smoke on grapevine leaf photosynthesis are also being conducted to assist with explaining this phenomenon.

Figure 3. Necrotic lesions evident on leaves exposed to repeated smoke applications (left) in comparison to vines that were not exposed to smoke with healthy leaves (right). Photos were taken at harvest.

Management Options

Little information is available as to the management options to reduce the effects of smoke in field-grown grapevines and wine. The Australian Wine Research Institute (2003) trialed vineyard based methods of reducing smoke taint and discovered that a management strategy of leaf removal, high volume cold water wash, hand harvesting and avoidance of leaf matter in the grape load was likely to minimise the taint. Also the taint could be reduced in the winemaking process by the pressing of whole bunches and the further division of juice into press fractions (AWRI 2003).

Pre-harvest testing of grapes for guaiacol and 4-methylguaiacol can be an effective mechanism to detect the presence of smoke taint and enhance the decision making process. Although, it is recommended that grape samples are prepared to release the maximum amount of guaiacol and 4-methylgauaicol leading to a better estimation of the taint in final wine.

Investigations of grapevine protective chemicals have revealed that acrylic polymers may reduce the presence of smoke compounds in fruit when applied prior to a smoke event (Kennison GWRDC report). Further investigation is required to understand longevity of protective chemicals and their effects on wine.

Future Research and Development

Substantial research is being conducted in Australia to investigate and mitigate the effects of smoke on grapes and wine. Research includes:

- Investigating the duration and density of smoke that is required to create a smoke taint effect;
- Use of vineyard based smoke detection systems (nephelometers) as a risk assessment tool for the detection and quantification of smoke;
- Investigation of the effects of smoke generated from a range of fuels on smoke taint;
- Investigation of the effect of smoke on a range of grapevine varieties;
- Analysis of compounds implicit in smoke that produce the smoke taint effect.

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References

Australian Wine Research Institute (2003). *Annual report 2003*. Glen Osmond, South Australia.

Baltes, W., Wittkowski, R., Söchtig, I., Block, H. and Toth, L. (1981) Ingredients of smoke and smoke flavour preparations. In *The Quality of Food and Beverages*, Charalambous, G. and Inglett, G. (Eds), Academic Press, New York, Vol. 2, pp. 1-19.

Boidron, J.N., Chatonnet, P. and Pons, M. (1988) Influence du bois sur certaines substances odorantes des vins. *Connaissance Vigne Vin* 22, pp. 275-294.

Guillén, M.D., Manzanos, M.J. and Zabala, L. (1995) Study of a commercial liquid smoke flavouring by means of gas chromatography/mass spectrometry and fourier transform infrared spectroscopy. *Journal of Agricultural and Food Chemistry* 43, pp. 463-468.

Kennison, K.R., Gibberd, M.R., Pollnitz, A.P. and Wilkinson, K.L. (2008a) Smoke-derived taint in wine: the release of smoke-derived volatile phenols during fermentation of merlot juice following grapevine exposure to smoke. *Journal of Agricultural and Food Chemistry* 56, pp. 7379-7383.

Kennison, K.R., Wilkinson, K.L. and Gibberd, M.R. (2009) Smoke application to field-grown grapevines at key phenological stages influences the concentration of compounds and smoke aromas in resultant wines. (manuscript in preparation).

Kennison, K.R., Wilkinson, K.L., Pollnitz, A.P., Williams, H.G. and Gibberd, M.R. (2008b) Effect of timing and duration of grapevine exposure to smoke on the composition and sensory properties of wine. (manuscript in preparation).

Kennison, K.R., Wilkinson, K.L., Williams, H.G., Smith, J.H. and Gibberd, M.R. (2007) Smoke-derived taint in wine: effect of postharvest smoke exposure of grapes on the chemical composition and sensory characteristics of wine. *Journal of Agricultural and Food Chemistry* 55, pp. 10897-10901.

López, R., Ferreira, V., Hernández, P. and Cacho, J.F. (1999) Identification of impact odorants of young red wines made with Merlot, Cabernet Sauvignon and Grenache grape varieties: a comparative study. *Journal of the Science of Food and Agriculture* 79, pp. 1461-1467.

Maga, J.A. (1988) *Smoke in Food Processing*, CRC Press: Boca Raton, Florida.

McKenzie, L.M., Hao, W.M., Richards. G.N. and Ward, D.E. (1994) Quantification of major components emitted from smouldering combustion of wood. *Atmospheric Environment* 28, pp. 3285-3292.

Radojevic, M. (2003) Chemistry of forest fires and regional haze with emphasis on Southeast Asia. *Pure and Applied Geophysics* 160, pp.157-187.