A "Phenolic" Off-odour in White Table Wines: Causes and Methods to Diminish its Occurrence

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The quality of some Kerner table wines often is rated inferior owing to the presence of an objectionable odour designated as "medicinal", "elastoplast" (band-aid) or "phenolic". Occasionally this odour is also encountered in wines from other cultivars such as Gewürztraminer, Weisser Riesling, Muscat de Frontignan and Chenin blanc. The objectives of this study were to identify the compounds responsible for the off-odour and to establish possible relationships between their occurrence and vini-viticultural procedures. The component predominantly responsible for the "medicinal" odour was identified as *p*-vinyl guaiacol. This compound is known to be formed during alcoholic fermentation via decarboxylation of ferulic acid. Yeast strains, however, differed appreciably with respect to their ability to produce *p*-vinyl guaiacol. Most, if not all, of this component is apparently formed during alcoholic fermentation of grape juice. Only in one exceptional case was the presence of this odour detected in grapes from a crossing of Cruchen blanc x Servan blanc, which also contained relatively high levels of *p*-vinyl guaiacol. Wines made from grapes harvested at an advanced degree of maturity and in particular those exposed to sunlight, contained higher levels of *p*-vinyl guaiacol than did those from shaded grapes. Oxidation and subsequent treatment of grape juice with phenol-adsorbing fining agents such as activated charcoal, polyvinyl polypirrolidone, casein and gelatine (in combination with "kieselsol" and bentonite) led to decreases in the *p*-vinyl guaiacol levels and the concomitant "medicinal" odour intensity.

The cultivar Kerner is well known for its premium-quality table wines in Europe and South Africa. However, Kerner grapes from certain estates in the wine region Paarl, South Africa, consistently produced lower-quality wines. Such wines were usually rejected for purposes of certification as wines of origin and cultivar by panels of wine connoisseurs because of the presence of an unacceptable "medicinal" or "elastoplast" aroma, the origin of which has been erroneously associated with some form of contamination. Occasionally this odour is also encountered in wines from other cultivars such as Gewürztraminer, Weisser Riesling, Muscat de Frontignan and Chenin blanc. However, none of a large number of German Kerner wines and a few from South Africa exhibited this obtrusive odour. The inconsistent occurrence of the "medicinal" odour as well as the negative impact on wine quality prompted us to investigate its origin and identity as well as possible factors responsible for its erratic occurrence. These factors included region, degree of ripeness, exposure of grapes to sunlight, yeast strain used, fermentation temperature, free amino nitrogen content, oxidation of grape juice, use of phenol-adsorbing agents such as activated carbon, polyvinylpolypirrolidone, casein and gelatin and the addition of ferulic acid.

MATERIALS AND METHODS

Identification and quantification of off-odour components:

Freon extraction: Grape juices and wines were extracted with Freon-11 using the apparatus and extraction technique described by Marais (1986). 3-Decanol (100 µg/L) was used as an internal standard. After final concentration, the extracts were stored at -23°C prior to analysis.

Gas chromatography and gas chromatography-mass spectrometry conditions:

Carlo Erba HRGC: Gas chromatographic parameters: Column Quadrex/BTR (60 m x 0.32 mm ID x 0.25 µm df) fused silica capillary. Operating conditions: Injector temperature, 200°C, oven temperature programme, 60°C (5 min) x 1.5°C/min to 190°C, detector temperature, 240°C, carrier gas He, injection volume 1 µL, split ratio 30:1. For GC sniffing, the eluent was split 1:1 for simultaneous flame ionisation detection and odour assessment.

Finnegan 9610 gas chromatograph / 4600 Quadrupole mass spectrometer system: Gas chromatographic parameters: Column Quadrex/BTR (60 m x 0.32 mm ID x 0.25 µm df) fused silica capillary. Operating conditions: Injector temperature, 200°C, oven temperature programme, 60°C (5 min) x 1.5°C/min to 190°C, carrier gas He, injection volume 1 µL, split ratio 30:1.

Mass spectrometer parameters: Source temperature, 240°C; interface temperature, 210°C; manifold temperature, 105°C; ionisation current, 0.31 amps; acceleration potential, 70 eV, multiplier voltage 850, scanning range 35 to 450 amu, scan time 0.95s with a o.05s pause between scans.

Quantification of p-vinyl guaiacol using an internal standard method: A chemically pure standard solution of *p*-vinyl guaiacol (Oxford Chemicals, UK) was prepared and extracted with Freon 11 using 3-Decanol (TCI, Tokyo) as internal standard. The extract was analysed using the Carlo Erba GC operating conditions. An average response factor for *p*-vinyl guaiacol was calculated and used in the quantitative determination of the samples.

Sensory Evaluation: A panel of five trained judges rated the "medicinal" aroma intensity of the commercial and experimental wines on a structured 9-point scale according to which 1 = not noticeable, 3 = weak, 5 = medium, 7 = strong and 9 = very strong. Similar "medicinal" odour-free wines to which 250, 500, 750 and

1000 µg/L of *p*-vinyl guaiacol had been added were available to the panel during sensory sessions in order to enable panel members to familiarise themselves with this particular aroma at different concentrations in different wines.

Wines:

Commercial Kerner wines: Commercial Kerner wines exhibiting high and low intensities of the "medicinal" odour were collected for analysis. In the course of this study the "medicinal" off-odour was also periodically detected in wines from other cultivars, particularly Gewürztraminer, Weisser Riesling, Muscat de Frontignan and Chenin blanc. Such wines were also collected for analysis. In addition, juice and wine samples of a new crossing (Cruchen blanc x Serval blanc) exhibiting a strong "medicinal" odour were collected.

Experimental wines: Experimental wines were made in duplicate according to standard small-scale winemaking practices. These included cooling freshly picked grapes to 5°C before crushing, low-temperature (10°C) skin contact in the presence of limited sulphur dioxide (25 mg/L) and grape juice clarification by settling using a pectolytic enzyme preparative (Ultrazyme). Fermentation was conducted at 15°C using a commercial pure yeast culture (Anchor Yeast Vin 7). After fermentation, SO_2 (50 mg/L) and a sodium bentonite suspension (0.75 g/L) were added to each wine, which was then cold stabilised and finally racked and filtered. These wines were kept at 15°C until analysed for *p*-vinyl guaiacol and rated for "medicinal" aroma intensity.

Batches of Kerner juice from different origins were recovered and stored at -4°C in order to provide sufficient quantities of Kerner juice for additional studies on the formation of *p*-vinyl guaiacol and the intensity of the "medicinal" odour. Before using such samples, their capacity to yield wine with the medicinal off-odour was established by fermenting samples and sensorially testing such wines.

Wines from shaded and sun-exposed grapes at different grape maturities: For the purpose of studying the effect of shading of bunches by leaves as well as grape maturity, Kerner grapes from Lievland, Paarl were harvested at 18.8°B and at 23.5°B. Insufficient shading at the second picking did not permit harvesting of a properly shaded sample. At Grondves, Stellenbosch, both sun-exposed and shaded grape bunches were harvested at two maturity levels (20°B and 21.2 – 21.4°B). It should be noted that, although temperatures within the bunches were not recorded, the grape bunches in the Lievland vineyards were exposed to hotter conditions than those from Grondves. Not only were the bunches closer to the surface and therefore more exposed to heat radiated from the soil, but also the canopy of leaves was not as protected against the direct exposure to the sun rays. Furthermore, according to data from weather stations within 1-2 km from these vineyards, the Lievland vineyard is exposed to higher temperatures than the Grondves vineyard, the latter being better exposed to the prevailing cool sea breezes.

Wines from oxidised juice and juice treated with phenol-adsorbing agents: To test the effect of juice oxidation and phenol-adsorbing agents, one half of a juice which had been tested positively for its potential to produce the "medicinal" aroma was aerated to promote oxidation, whilst the other half was protected from oxidation. Aeration was performed by intermittently pouring the juice (at 15°C) from one container to another until the brown colour of the juice reached a maximum. Both reduced and oxidised samples were treated with relatively high doses of phenol-adsorbing agents *e.g.* gelatin (20 g/hL in combination with 2 g/hL kieselsol and 75 g/hL bentonite), casein (100 g/hL), PVPP (100 g/hL) and activated carbon (150 g/hL). The fining agents were regularly resuspended and finally allowed to settle overnight at 15°C after which they were removed by centrifugation. Fermentation was conducted in the same way as described above using a freshly rehydrated pure yeast culture, Anchor Yeast WE 372, which had been selected for its efficiency to produce *p*-vinyl guaiacol. The wines were treated as before.

Wines from juice fermented with different yeast strains: In view of the fact that *p*-vinyl guaiacol is formed by yeast during alcoholic fermentation, the capacity of a number of locally available commercial *Saccharomyces cerevisiae* strains to produce *p*-vinyl guaiacol was tested by fermenting samples of Kerner juice which hadtested positively for its potential to produce the "medicinal" aroma. These strains are listed in Table 5.

Wines from juice with added ferulic acid: In order to confirm the role of the concentration of ferulic acid, the *p*-vinyl guaiacol precursor in grape juice, different levels (2.0 and 10.0 mg/L) of ferulic acid (Sigma) were added to Kerner juice recovered from grapes produced at two locations in Paarl (KWV and Lievland). The two samples from Lievland 1990 vintage were fermented with the pure yeast cultures Lalvin L 2056 and Blastocel MW, respectively, whereas the samples from the 1992 vintage (KWV and Lievland) were all fermented with Anchor Yeast WE 372.

Wines from juice with increased free amino acid and fermented at 15°C and 25°C: The effect of fermentation temperature and the free amino nitrogen level of juice was studied by fermenting two different Kerner juice samples at two temperatures (15°C and 25°C) and at two levels of free amino nitrogen as obtained by addition of 750 mg/L diammonium phosphate. The two Kerner samples had been selected for their "medicinal" odour potential, one low and the other high. Anchor Yeast WE 372 was used as the pure yeast culture.

RESULTS AND DISCUSSION

Identification of off-odours component in Kerner wine extracts: Gas chromatographic fractionation of Freon 11 extracts permitted sniffing of volatile fractions as they emerged from the GC column. Only one fraction exhibited the typical "elastoplast" or "medicinal" odour. The mass spectrum of the main component present in the "medicinal"-containing fraction matched that of *p*-vinyl guaiacol. GC-MS analysis of an authentic sample confirmed this identification.

According to Dubourdieu *et al.* (1989), *p*-vinyl guaiacol is formed via enzymatic decarboxylation of ferulic acid by yeast during alcoholic fermentation. Since the completion of our research, additional findings have been reported on the formation of *p*-vinyl guaiacol. Chatonnet *et al.* (1993) proved conclusively that *Saccharomyces cerevisiae* possesses a type-(E) enzymic activity, substituted cinnamate carboxy-lyase, which is capable of transforming, by non-oxidative decarboxylation, the phenolic acids in grape must, namely (E) *p*-coumaric and (E) ferulic acids, into vinyl phenol and vinyl guaiacol respectively. This endocellular activity is only expressed during alcoholic

fermentation. According to Grando *et al.* (1993), these volatile phenols are formed primarily from the two phenolic acids rather than their tartaric esters. The nuclear gene called POF 1 (phenolic off-flavour) that confers to the yeast the ability to decarboxylate the phenolic acids was identified by Meaden & Taylor (1991).

Peleg *et al.* (1992), utilising a model solution simulating orange juice, provided evidence that *p*-vinyl guaiacol is also formed from ferulic acid in the absence of yeast and alcoholic fermentation. Although the production of *p*-vinyl guaiacol via chemical decarboxylation in Kerner grapes or wine can as yet not be ruled out, it is highly unlikely that such a contribution would be significant. Firstly, the "medicinal" odour as such could not be detected in Kerner juice, whereas it was prominently displayed in the freshly made corresponding wines. Secondly, no increase in the intensity of this aroma was noted during storage of any of the experimental Kerner wines.

Identification of off-odours components in Cruchen blanc x Servan blanc crossing: The grapes of an experimental crossing, *Vitis vinifera* L. cvs. Cruchen blanc x Servan blanc made at the Department of Viticulture, University of Stellenbosch, in the early 1970s exhibited an unusual, unmistakable, medicinal flavour never before encountered in South African grapes, and hence did not receive a cultivar status. The GC-MS analysis of Freon 11 extract of the juice not only confirmed the identity of *p*-vinyl guaiacol, but also of eugenol, which has a spicy aroma and is the main aroma constituent of cloves (Morrison & Boyd, 1959; Kollmansberger & Nitz, 1994). A high concentration *p*-vinyl guaiacol (1998 µg/L) was also determined in wine of this variety. Although the presence of *p*-vinyl guaiacol in wine can normally be attributed to the enzymatic decarboxylation of ferulic acid during fermentation, there is now conclusive evidence that *p*-vinyl guaiacol also occurs at relatively high levels in the berries of at least one grape variety. This finding, albeit of a rare phenomenon, supports the evidence provided by Peleg *et al.* (1992) that *p*-vinyl guaiacol could also be formed in the absence of yeast and alcoholic fermentation.

Perception concentration of *p*-vinyl guaiacol in white wine: By adding increasing increments of authentic *p*-vinyl guaiacol to young Weisser Riesling and Chenin blanc wines which did not display any "medicinal" aroma, it was assessed that at an addition of 1000 µg/L this compound was consistently recognised for its typical "medicinal" aroma by all of the judges. However, when the same dosage was added to bottle-aged Weisser Riesling and Kerner wines with intense and more complex aromas than young white wines, recognition of its typical aroma was not possible, apparently because of the masking effect of maturation bouquet compounds. Such variability in the perception threshold of a compound in wine, also referred to as recovery threshold, can be attributed to variability of composition between wines. It therefore only has an indicative value, yet this value is of significance, since it indicates the concentration at which the odour of a substance can be perceived above the aroma of a wine (Chatonnet *et al.*, 1993). These authors reported a perception value of 440 µg/L and a limit perception threshold of 570 µg/L for *p*-vinyl guaiacol in white table wine, the latter value being the level at which more than 50% of the tasters rejected the wine on account of its "medicinal", phenolic off-odour.

***p*-Vinyl guaiacol in other varietal wines:** The occurrence of *p*-vinyl guaiacol was, however, not limited to Kerner wines only. In fact, it is present in most wines, but seldom at levels high enough to display a "medicinal" aroma. In a few commercial wines produced in relatively hot regions of South Africa from other cultivars, particularly Gewürztraminer, Weisser Riesling, Muscat de Frontignan and Chenin blanc, the typical "medicinal" odour was also very pronounced. The *p*-vinyl guaiacol contents of such samples fell within the range of concentrations (456-1287) µg/L found in Kerner wines with pronounced medicinal odours (Table 1).

Factors affecting *p*-vinyl guaiacol formation:

Wine type and region: Kerner wines from Germany, where vineyards are known to be cooler than most in South Africa, did not exhibit any recognisable "medicinal" odour, whereas several from South African producers, in particular those from two estates viz. Lievland and Backsberg, in one specific macroclimatic region often contained relatively high *p*-vinyl guaiacol levels and were rated high in "medicinal" odour intensity (Table 1).

Microclimatic, exposure of grapes to sunlight, and grape maturity: The *p*-vinyl guaiacol content of wines made from shaded grapes at 18,8°B from the hotter location (Lievland) was practically of the same order of magnitude as that of the cooler location (Grondves, Stellenbosch) as seen in Table 2. However, wines made from sun-exposed early-harvested grapes at 18.8°B contained almost twice as much *p*-vinyl guaiacol in the case of the hotter Lievland vineyard. The median "medicinal" aroma intensity ratings were also higher for the latter wines. These differences were similar, but more marked in wines made from more matured sun-exposed grapes from the second picking. The effect of climate on *p*-vinyl guaiacol content appears to be of particular interest. Whereas wines made from the hotter Lievland vineyards showed a marked increase from the early to the late harvested sun-exposed grapes, no marked change was noted in

TABLE 1

"Medicinal" odour intensity ratings and *p*-vinyl guaiacol (PVG) content of South African Kerner wines.

Origin	Rating[1)]	PVG (µg/L[2)]
Nederburg Kerner 1983	4	61
Nerderburg Kerner (SLH)[3)] 1989	2	136
Lievland Kerner (SLH) 1989	4	316
KWV Kerner 1981	5	456
Backberg Kerner 1989	6	818
Lievland Kerner SLH 1986	7	1 287

[1)] Median of 10 ratings on a 9-point scale where 1 = not noticeable and 9 = very strong.

[2)] Average of duplicate analyses.

[3)] Special late harvest.

TABLE 2

Effect of region, degree of ripeness and exposure to sunlight on "medicinal" odour intensity ratings and *p*-vinyl guaiacol (PVG) concentrations in Kerner wines.

Region	Sugar °Balling	Exposure to sulnight	"Medicinal" intensity rating[1])	PVG (µg/L)[2])
Lievland	18.8	Shade	4	191
	18.8	Sun	5	852
	23.5	Sun	8	1 003
KWV	20.0	Shade	3	226
(Grondves)	20.0	Sun	4	483
	21.2	Shade	4	361
	21.4	Sun	2	405

[1]) Median of 10 ratings.

[2]) Average of duplicate analyses.

the case of the cooler Grondves vineyards. Although the difference in the degree of ripeness could have had an effect, it would appear as though wines made from Kerner grapes in the cooler location contained lower *p*-vinyl guaiacol levels and accordingly were rated lower in "medicinal" odour intensity. This observation probably offers an explanation for the absence of the "medicinal" odour in Kerner wines from the much cooler vineyards of Germany.

Oxidation: Since grape juice oxidation normally gives rise to the polymerisation and concomitant precipitation of phenols, it was anticipated that such a treatment could possibly lead to reduced *p*-vinyl guaiacol content in wines. However, the opposite effect was noted as is shown in Table 3. In every case, aeration followed by oxidation led to an increase in the *p*-vinyl guaiacol content. These increases varied according to the origin of the grapes as well as the particular yeast strain used, and in the case of the Lievland Kerner were of sufficient magnitude to have caused increases in he "medicinal" aroma intensity with concomitant adverse quality effects. It therefore seems advisable to limit excessive aeration and oxidation of grape juice in the case of Kerner and other cultivars which under specific conditions tend to yield wines containing relatively high levels of *p*-vinyl guaiacol.

TABLE 3

Effect of oxidation on Kerner grape juice on *p*-vinyl guaiacol (PVG) content of wine.

Vineyard	Yeast Strain	PVG (µg/L[1])		
		Control	Oxidised	Increase
Grondves	Achnor Yeast WE 228	670	740	70
Grondves	Anchor Yeast WE 372	962	1103	141
Lievland	Lalvin 2056	560	794	234
Lievland	Blastocel K	563	989	426

[1]) Average of duplicate analyses.

Phenol-adsorbing fining agents: Since activated carbon and polyvinylpolypirrolidone (PVPP) are insoluble in wine and casein becomes insoluble as it is added to juice or wine, these agents ought to be the most efficient adsorbents for the removal of low molecular weight phenolic compounds such as ferulic acid. Gelatin, being soluble in white wine, ought to be co-precipitated by fining agents such as kieselsol and bentonite in order to remove low molecular weight phenols effectively.

Although the activated carbon treatment of the juice reduced the *p*-vinyl guaiacol content and the "medicinal" aroma intensities of the wines (Table 4) very effectively in both non-oxidised and oxidised samples, the corresponding wines were colourless and neutral. For this reason much lower but less efficient dosages ought to be used in practice. The reduction in *p*-vinyl guaiacol levels and "medicinal" aroma intensity by PVPP and casein did not occur according to expectations, although relatively high doses of these agents had been used. Rather surprising was the marked reduction in the "medicinal" aroma

TABLE 4

Effect of oxidation and fining of juice with phenol adsorbents on *p*-vinyl guaiacol (PVG) content and "medicinal" odour intensity of Kerner wines.

Treatment[1]) Oxidised juice	PVG (µg/L)[2])	% Reduction in PVG concentration	"Medicinal" aroma intensity[3])
Control	1103	–	7
Activated Carbon	120	89	1
PVPP	711	36	4
Casein	531	52	6
Gelatin + Kieselsol + Bentonite	486	56	2
Unoxidised juice			
Control	962	–	3
Activated Carbon	70	93	1
PVPP	903	6	5
Casein	894	7	4
Gelatin + Kieselsol + Bentonite	835	13	2

[1]) Dosage levels (g/hL): casein and PVPP 100, activated carbon 150, gelatin 20, kieselsol 2, bentonite 75. Yeast strain: WE 372.

[2]) Average of duplicate analyses.

[3]) Median of 10 ratings.

intensity and the *p*-vinyl guaiacol levels by the gelatine-kieselsol-bentonite fining at standard dosages.

From the percentage reduction in *p*-vinyl guaiacol content it is clear that PVPP, casein and the combined fining of gelatine, kieselsol and bentonite were much more effective in removing the precursors of *p*-vinyl guaiacol in the oxidised juice than in the unoxidised juice. This may be ascribed to the fact that phenol oligomers formed by oxidative polymerisation upon aeration were more readily adsorbed than the unoxidised monomeric forms such as ferulic acid, for example. Since oxidation of grape juice without subsequent fining gave rise to higher *p*-vinyl guaiacol levels in wine, oxidised juice from grapes with a high *p*-vinyl guaiacol potential ought to be fined before fermentation.

It is clear that the efficiency of fining agents for removal of *p*-vinyl precursors from the grape juice should not be evaluated without also taking into account the effect on wine quality. At this stage it appears as though activated carbon is most efficient, but unfortunately not with respect to wine quality. Other fining agents, *e.g.* gelatine-kieselsol-bentonite, will be more appropriate from a wine quality point of view.

Yeast strain and fermentation conditions: The different capacities of various yeast strains to decarboxylate ferulic acid to *p*-vinyl guaiacol are clearly reflected by the *p*-vinyl guaiacol concentrations as well as the "medicinal" aroma-intensity ratings as presented in Table 5. These results emphasise the significance of interactions between yeast strain and grape variety, which may affect wine quality appreciably. It would therefore make sense to select a yeast strain with a low *p*-vinyl guaiacol-forming potential, *e.g.* Anchor Yeast Vin 11, Anchor Yeast WE 14 and Zymaflor VL 1, to ferment grape juice from Kerner and other high ferulic acid-containing cultivars, particularly those from the hot regions. Strains such as 71 B, EC 118, and Anchor Yeast WE 372 should preferably not be used in the latter cases.

Effect of ferulic acid: p-Vinyl guaiacol is known to be formed by enzymatic decarboxylation of ferulic acid during alcoholic fermentation (Dubourdieu *et al.* 1989). This was confirmed by the addition of different levels of ferulic acid to Kerner grape juice samples from two origins and two vintages and fermentation with different yeast strains. According to Table 6, all of the wines obtained from juice samples, to which 10 mg/L ferulic acid had been added, received the maximum "medicinal" odour intensity ratings of 9 points each. The variation in increases of *p*-vinyl guaiacol per mg/L ferulic acid added clearly reflects the decarboxylation potential of different yeast strains. This is also demonstrated by the *p*-vinyl guaiacol concentrations as well as "medicinal" odour ratings of wines made from the same juice, but fermented by different yeast strains (Table 5).

Grando *et al.* (1993) demonstrated that POF(–) in comparison with POF(+) strains only formed small amounts of *p*-vinyl guaiacol in a synthetic medium supplemented with ferulic acid. They also found that Traminer wines produced by fermentation with POF(–) strains contained a very high residual level of free ferulic and *p*-coumaric acids in comparison to wines produced by fermentation with POF(+) strains. Use of POF(–) strains is therefore strongly recommended as the sensorial contribution of volatile phenols can be detrimental to wine quality.

Fermentation temperature and free amino nitrogen: Increases in

TABLE 5

Effect of yeast strain on "medicinal" odour intensity ratings and *p*-vinyl guaiacol (PVG) concentrations in Kerner wines.

Species	Strain	"Medicinal" intensity rating[1)]	PVG (µg/L)[2)]
Saccharomyces	Hefix 1000	5	890
cerevisiae	Anchor Yeast N96	5	813
	Lalvin 734	4	734
	Anchor Yeast (Vin 11)	3	616
	Blastocel MW	6	591
	Lalvin L 2506	5	575
	Anchor Yeast (WE 14)	3	509
	Blastocel Kappa	1	–
	Anchor Yeast (WE 372)	7	–
	Anchor Yeast (WE 228)	3	–
	Zymaflor VL1	2	35
	71 B	8	954
	Anchor Yeast (Vin 7)	8	659
	EC 118	7	843
Saccharomyces	Hefix 2000	5	823
bayanus	Blastocel V5	5	810
	AEB	4	616
Saccharomyces bayanus/cerevisiae	Oenol Vit Bc	6	764

[1)] Median of 10 ratings.

[2)] Average of duplicate analyses.

TABLE 6

Effect of ferulic acid addition[2)] to Kerner grape juice and yeast strain on *p*-vinyl guaiacol (PVG) content of wine.

Vineyard	Yeast	*p*-Vinyl guaiacol (µg/L)[1)]		
		Control	Control & Ferulic Acid (FA)[2)]	Increase per mg/L FA added
Lievland '90	Lalvin L2056	794	833	19.5
Lievland '90	Blastocel MW	989	1 062	36.5
KWV Paarl '92	Anchor Yeast WE 372	1 103	6 326	522.3
KWV Paarl '92	Anchor Yeast WE 372	962	5 791	482.9
Lievland '92	Anchor Yeast WE 372	1 092	5 962	487.0

[1)] Average of duplicate analyses.

[2)] Ferulic acid dosage: 2 mg/L in case of 1990 samples, 10 mg/L in case of 1992 samples.

TABLE 7

Effect of fermentation temperature and free amino nitrogen on *p*-vinyl guaiacol (PVG) content and "medicinal" odour intensity of Kerner wines.

Low Fan Must[1)]		Fermentation Temperature (°C)	PVG (µg/L)[2)]	"Medicinal" intensity rating[3)]
A	No DAP added	15	686	8
B		15	23	2
A		25	453	7
B		25	23	2
A	DAP added[4)]	15	559	8
B		15	40	3
A		25	600	8
B		25	32	5

[1)] FAN = Free amino nitrogen.

[2)] Average of duplicate analyses.

[3)] Median of 10 ratings.

[4)] Diammonium phosphate dosage: 750 mg/L.

fermentation temperature from 15° to 25°C and free amino nitrogen by addition of 750 mg/L diammonium phosphate to Kerner juice prior to fermentation did not result in consistent changes in "medicinal" odour intensity and the *p*-vinyl guaiacol concentration (Table 7).

CONCLUSIONS

The production of *p*-vinyl guaiacol appears to be primarily dependent on two factors, *viz*. the concentration of its precursor, ferulic acid, in the grape berries and the decarboxylation of this acid by the yeast strain. Based on this mechanism of formation of *p*-vinyl guaiacol and the levels reported, it can be concluded that the ferulic acid levels are closely related to the grape cultivar, the climate, exposure to sunlight and grape maturity. Therefore in relatively hot regions, protection of grape clusters from exposure to sunlight by proper canopy management, together with early harvesting, would lead to a reduction in ferulic acid levels and therefore in *p*-vinyl guaiacol. Strong consideration should also be given towards planting Kerner in relatively cool regions only.

A reduction in ferulic acid content of juice with the aid of phenol-adsorbing fining agents, with the exception of activated carbon, cannot be recommended unless the juice is strongly oxidised. However, apart from the time and cost involved, winemakers would not normally resort to a practice of deliberate oxidation of grape juice in their attempts to make highly reductive fruity wines.

The use of POF(–) yeast strains, particularly in the case of grapes rich in ferulic acid, is strongly recommended.

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