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Terpene Response to Pressing, Harvest Date, and Skin Contact in *Vitis vinifera*

Andrew G. Reynolds[1], Douglas A. Wardle[2], and Marjorie Dever[2]
Agriculture Canada Research Station, Summerland, B.C. V0H 1Z0, Canada

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Abstract. Vitis vinifera **L. cultivars Müller-Thurgau, Muscat Ottonel, Gewürztraminer, and Kerner were studied for 1 year to document changes in fruit terpene levels from berry stage to free-run and press-juice stages. Substantial amounts of free volatile terpenes (FVTs) and potentially volatile terpenes (PVTs) were lost between berry and juice stages. PVTs were higher in press juices of 'Gewürztraminer' and 'Muscat Ottonel' than in free-run juices. In another experiment, juices from 'Miiller-Thurgau', 'Muscat Ottonel', 'Kerner', 'Optima', 'Pearl of Csaba', and 'Siegerrebe', harvested 10 to 20 days after a designated initial harvest date, contained higher FVTs and PVTs than initially. A third experiment with 'Kerner', 'Müller-Thurgau', 'Optima', and 'Siegerrebe' found highest FVTs and PVTs in juices from grapes subjected to skin contact compared with grapes crushed and immediately pressed. Sensory evaluation showed aroma differences between wines from free-run and press juices of 'Miiller-Thurgau' and 'Muscat Ottonel', aroma and flavor differences due to harvest date for all cultivars except 'Pearl of Csaba', and aroma and flavor differences due to skin contact for 'Siegerrebe'.**

Terpenes are partly responsible for the floral and muscat aromas and flavors of grapes. Viticultural techniques such as trellising and vine spacing (Reynolds and Wardle, 1991) and basal leaf removal (Reynolds and Wardle, 1989, 1991) influence berry and juice terpene composition, which, in turn, may affect the wine's sensory properties. Other considerations, such as harvest date (Marais, 1987; Marais and van Wyck, 1986), use and duration of skin contact (Bayonove et al., 1976; Cordonnier and Bayonove, 1981; Marais, 1987; Marais and Rapp, 1988; Marais and van Wyck, 1986), and press treatment (Bayonove et al., 1976; Cordonnier and Bayonove, 1979, 1981; Kinzer and Schreier, 1980), have affected terpene concentration significantly in juice and wine.

Many muscat and intensely flavored winegrape cultivars (e.g., 'Pearl of Csaba', 'Siegerrebe', and 'Optima') grown in the Okanagan Valley, B.C., present winemaking problems due to their fruit maturation patterns. In warm years, it may be necessary to harvest these cultivars at low soluble solids concentrations (<17° 'Brix) and titratable acidity (<6.0 g·liter^{-1}) and high pH (>3.50). In many cases, wines made from such fruit may lack varietal character, but delayed harvest could produce wines with a high potential for microbial instability. Extended skin-contact time and using a higher proportion of pressed juice may increase juice and wine terpenes, but these practices are not well accepted by many winemakers.

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[1]Research Scientist.

[2]Research Assistant.

The objectives of these experiments were to assess the effect of harvest date, pressing, and skin contact on the concentration of free and bound terpenes in the juices of several *Vitis vinifera* cultivars and to relate these data to sensory descriptors of the wines.

Effect of press fraction (Expt. 1). Three 100-berry and three 250-berry samples of 'Müller-Thurgau', 'Muscat Ottonel', 'Gewürztraminer', and 'Kerner' were collected randomly on 6 Oct. 1987 from five-vine plots in the Agriculture Canada Research Station, Summerland, B.C., cultivar collection and stored at -40C until analysis. Fruit harvested for winemaking were stored for 24 h at 2C, crushed in a destemmer-crusher, and given skin contact for 24 h at 2C without sulfite. Fruit were pressed on a hydraulic rack and cloth press with a maximum pressing capacity of 21 ,100 kPa. Approximate juice volumes for 'Müller-Thurgau', 'Muscat Ottonel', and 'Gewürztraminer' were 16, 12, and 16 liters (free-run fractions) and 27, 16, and 11 liters (press fractions), respectively. Free-run and press-juice fractions were blended for 'Kerner'; total volume was 8 liters.

Juices intended for winemaking were sulfited to 50 mg free S_2O_5/liter, stored for 24 h at 2C, racked, kept at 15C for 16 h, then inoculated at a rate of 3% (by volume) with ST61 yeast (provided by C.M. Duitschaever, Univ. of Guelph, Ont.) grown in 'Riesling' juice. Three 250-ml juice samples were collected from each pressing treatment for each cultivar before inoculation and stored at -40C until analysis. Each treatment within cultivar was fermented at 15C as two replications in 12-liter glass carboys. Fermentation was stopped when residual sugar was ≈1.5%, after which wines were cold-stabilized at -1C for 3 weeks, racked, and stored at 2C until bottling.

A 50-g subsample from each 100-berry sample was subjected to the nonvolatile acid extraction procedure of Mattick (1983), and titratable acidity (TA) was determined on the obtained extracts using a Brinkmann Titroprocessor ensemble (Metrohm , Herisau, Switzerland). The rest of the sample was juiced, and soluble solids concentration (°Brix) and pH were measured on settled juice using an Abbé refractometer (AO Instruments, Buffalo, N.Y.) and a pH meter (model 825MP; Fisher Scientific, Vancouver, B.C.), respectively. °Brix of the juice samples and pH of the juice and wine were measured in the same manner as those of the berries. Juice and wine TA was measured using the method of Amerine and Ough (1980) using the titrator ensemble noted. Ethanol in the wines was measured using a gas chromatograph (model HP5700; Hewlett-Packard, Mississauga, Ont.). Wines were analyzed after bottling.

Free volatile terpenes (FVTs) and potentially volatile terpenes (PVTs) were determined on two 100-g subsamples of homogenate from the 250-berry samples and on two 100-ml subsamples from each juice sample. The distillation and quantitation procedure used was a modification of the Dimitriadis and Williams (1984) method described by Reynolds and Wardle (1989). Distillation was carried out on a steam distillation unit (model JD-2115; Scientific Glass Apparatus Co., Bloomfield, N.J.), and FVT and PVT levels were determined calorimetrically using a spectrophotometer (model DMS 100; Varian, Georgetown, Ont.).

Wines were tasted by eight experienced wine tasters on 29 May 1989 after 12 months of bottle storage. Seven wines ('Müller-Thurgau', 'Muscat Ottonel', and 'Gewürztraminer', each free-run and press; and 'Kerner') were presented in a random order as 50-ml portions in tulip-shaped clear glasses. The two fermentation replications were presented at separate tastings. Tasters were required to rate the flavor and aroma of each sample according to eight descriptors: muscat, lychee, citrus, green apple, floral, astringent, vegetative, and spicy. Panel members were trained using representative samples of each flavor descriptor (Table 1). A score sheet with 50-mm line scales for each descriptor was used.

Triangle tests also were performed on 'Müller-Thurgau', 'Muscat Ottonel', and 'Gewürztraminer' wines on 20 Nov. 1990 using 10 tasters to ascertain if differences existed between free-run and press treatments. Tasters were asked to identify the odd sample in each case, based exclusively on aroma and flavor, from a trio of wine samples containing two duplicate samples and one odd sample. Tasters assessed aroma and flavor separately and also were asked to identify whether the odd or duplicate samples had the most muscat and most floral aroma, flavor, or both. Muscat and floral references are indicated in Table 1. Sample order was randomized for each taster and rerandomized between aroma and flavor assessment.

Statistical analysis for this and the two accompanying experiments was carried out using SAS's (SAS Institute, Cary, N.C.) Gen-

Table 1. Wine descriptors and standards used by tasters in our experiments.

Descriptor	References used
Muscat	
Aroma	Two drops each of linalool, geraniol, nerol, and citral in 10 ml 95% ethanol, diluted to 100 ml with distilled water.
Flavor	Commercial 1987 'Pearl of Csaba' wine.
Lychee	
Aroma and flavor	Lychee nut juice (canned).
Citrus	
Aroma	Two drops of citral in 10 ml of 95% ethanol, diluted to 100 ml with distilled water. Fresh lemon and lime wedges.
Flavor	Lemon extract (1 ml) in 200 ml of neutral white wine.
Green apple	
Aroma	Apple extract (1 ml) in 10 ml of 95% ethanol, diluted to 100 ml with distilled water. 'Granny Smith' apple cubes.
Flavor	Apple extract (1 ml) in 200 ml of neutral white wine.
Spicy	
Aroma	Black pepper, allspice, nutmeg, cinnamon, and whole cloves (1 g each) in 10 ml of 95% ethanol.
Flavor	No reference used.
Floral	
Aroma	Two drops each of linalool and geraniol in 10 ml of 95% ethanol, diluted to 100 ml with distilled water.
Flavor	Two drops each of linalool and geraniol added to 200 ml of neutral white wine. Commercial 'Riesling' wine.
Vegetative	
Aroma	Infusion of grape leaves in 10 ml of 95% ethanol, added to 200 ml of neutral white wine.
Flavor	Experimental 'Semillon' wine.
Astringent	
Aroma	No reference required.
Flavor	Grape tannin (2 g) in 200 ml of neutral white wine.

eral Linear Models procedure. Data were analyzed using treatment × block (within cultivar) as an error term and treatment × cultivar × block as an error term on data pooled across cultivars. Triangle-test data were analyzed using a one-tailed ***t*** test.

Juices of the four cultivars tended to be higher in °Brix and lower in TA, FVTs, and PVTs than their berries (Table 2). Enzymatic breakdown of pectins and amylopectins in the grape skins during skin contact could have accounted for the increased °Brix from the berry to juice stage, while tartrate precipitation during skin contact, or acids resident in the skins, may have accounted for reduced TA. FVT and PVT levels decreased substantially between the berry and juice stages. During skin contact, therefore, some of the terpenes in the skins (Gunata et al., 1985) could not be extracted effectively; hence, FVT and PVT levels decreased. Juice pH was not affected consistently between the berry and juice stages.

°Brix was slightly lower and TA slightly higher in press juice of 'Gewürztraminer' compared to the free-run fraction, but pressing did not affect juice °Brix and TA levels overall (Table 2). Pressing also did not affect juice pH and FVT levels. 'Muscat Ottonel' and 'Gewürztraminer' (and across all cultivars) juice PVTs were highest in the press fractions. Increases in terpenes in successive press fractions were reported by Cordonnier and Bayonove (1979, 1981) and Kinzer and Schreier (1980). TA, pH, and ethanol in the wines showed no consistent response to pressing (data not shown). Ranges of those variables in the wines were TA, 5.8 to 7.4 $g\cdot liter^{-1}$; pH, 3.37 to 3.50; and ethanol, 12.7% to 14.2%.

Tasters could distinguish between free-run and press wines of 'Müller-Thurgau' and 'Muscat Ottonel' based on aroma (Table 3). There were no perceived differences in aroma between the treatments of the 'Gewürztraminer' wines, nor were there significant differences between the treatments based on flavor only (data not shown). For 'Muscat Ottonel', higher juice PVTs could have led to a greater flavor reservoir in the press wines for FVT liberation during aging (hence more floral aroma), but the small treatment differences in 'Gewürztraminer' juice PVTs apparently were not adequate to evoke a sensory response.

Tasters also found no differences between the treatments within cultivars for most of the descriptors, with the exception of spicy for 'Muscat Ottonel' aroma and flavor (data not shown), which was higher in press wines. Fruitiness (sum of muscat, lychee, citrus, and green apple) in 'Muscat Ottonel' press wines also was substantially higher than in the free-run treatment, as was total flavor (sum of all descriptors except astringent). When the tasting scores were pooled across treatments to compare cultivars, 'Muscat Ottonel' had the highest levels of citrus and terpenic (sum of muscat, lychee, citrus, floral, and spicy) and total flavor (data not shown). This result was expected, considering the high FVT and PVT levels in the juice. We were surprised, however, that differences could not be detected among cultivars, despite substantial differences in juice FVTs and PVTs.

Effect of harvest date (Expt. 2). Six cultivars (Müller-Thurgau, Muscat Ottonel, Kerner, Optima, Pearl of Csaba, and Siegerrebe) growing in five-vine plots in the research station cultivar collection were chosen in 1988 to investigate the effect of delayed harvest on fruit composition (especially FVTs and PVTs) and wine quality. Vines were trained to a Y-shaped divided canopy (Reynolds et al., 1992) and the two canopies were kept separated by shoot positioning. Two harvest dates (early and late) werechosen for each cultivar. The design was a randomized complete block

Table 2. Composition of berries and free-run and press juices of 'Müller-Thurgau', 'Muscat Ottonel', 'Gewürztraminer', and 'Kerner', 1987.

Cultivar	Sample source	°Brix	Titratable acidity ($g\cdot liter^{-1}$)	pH	Free volatile terpenes ($mg\cdot liter^{-1}$)	Potentially volatile terpenes ($mg\cdot liter^{-1}$)
Gewürz-traminer	Berry	20.3	8.7	3.43	1.50	2.10
	Free-run juice	22.5	7.2	3.48	0.91	1.75
	Press juice	22.4	7.4	3.50	0.85	1.91
	Contrast (berry vs. juice)	**	***	NS	**	**
	Contrast (free run vs. press)	*	***	NS	NS	**
Kerner	Berry	22.5	10.5	3.15	1.00	3.24
	Juice	24.0	7.9	3.18	0.78	2.33
	Significance	*	**	NS	*	*
Müller-Thurgau	Berry	19.4	9.6	3.35	0.77	2.23
	Free-run juice	20.9	5.1	3.42	0.88	1.93
	First-press juice	21.0	5.3	3.41	0.86	1.81
	Contrast (berry vs. juice)	**	***	**	NS	*
	Contrast (free run vs. press)	NS	*	*	NS	NS
Muscat Ottonel	Berry	19.6	8.1	3.49	2.78	7.85
	Free-run juice	19.6	6.0	3.32	1.30	3.62
	Press juice	20.9	5.9	3.34	1.36	3.91
	Contrast (berry vs. juice)	NS	***	**	***	***
	Contrast (free run vs. press)	NS	NS	NS	NS	*
All cultivars						
	Contrast (berry vs. juice)	***	***	NS	***	**
	Contrast (free run vs. press)	NS	NS	NS	NS	*

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 3. Results of significant triangle tests (N = 10) comparing aromas of *Vitis vinifera* wines vinted in 1987 from free-run (FR) or press (P) juice, 15 Nov. 1990.

Cultivar	Correct responses	Correct respondents[z] (no.) Strongest muscat FR	P	Strongest floral FR	P
Müller-Thurgau	7*	2/7	3/7	6/7**	1/7
Muscat Ottonel	7*	2/7	4/7	4/7	2/7

[z]Based on a one-tailed *t* test.
*,**Significant at $P \leq 0.05$ or 0.01, respectively.

with each vine within a five-vine plot designated as a block, and the early and late-harvest treatments were assigned randomly to one of the two canopies within the vine. The criteria for the early harvest dates were subjective (palatability) and objective [fruit composition indexes (°Brix, TA, and pH)] and satisfied the British Columbian grape-maturity standards (Vielvoye, 1991) for 100% commercial maturity. Late-harvest dates took place from 10 to 20 days after the early harvest dates.

Fruit were harvested from the appropriate cultivars and treatments and handled in the same manner as in Expt. 1. Grapes werepressed to 21,100 kPa, and the free-run and press fractions were blended. Two fermentation replications were used for each treatment within cultivar. Wine was made as previously described.

Berry samples were not retained for analysis in Expt. 2, but two 250-ml juice samples were collected at pressing and stored at -40C until analyzing for °Brix, TA, pH, FVTs, and PVTs. Wines also were analyzed after bottling for TA, pH, and ethanol. Methods of juice and wine analysis were as described.

Differences between the aroma and flavor of the early and late-harvest treatments within each cultivar were ascertained through triangle tests; 15 experienced tasters participated. Wines were evaluated on 14 Jan. 1991, after 18 months of bottle storage. Tastings were conducted in the same manner as the 1990 tasting in Expt. 1. Muscat and floral references are indicated in Table 1.

Using British Columbian commercial grape-maturity standards as a guideline (Vielvoye, 1991), theoretical monetary values (based on °Brix, TA, and pH) of early harvested 'Müller-Thurgau', 'Muscat Ottonel', 'Kerner', 'Optima', 'Pearl of Csaba', and 'Siegerrebe' were 120%, 110%, 110%, 90%, 100%, and 70%, respectively, of the base prices for those cultivars. Low TA and high pH in 'Siegerrebe' were caused by delaying the early harvest until a reasonable °Brix level was obtained. 'Optima' was harvested too early in error. Thus, five of six cultivars had attained commercial maturity by their initial harvest dates.

Late harvesting increased °Brix, pH, FVTs, and PVTs and reduced TA (Table 4). All cultivars also experienced a reduction in wine TA and an increase in ethanol and wine pH with delayed harvest. Delaying harvest by the number of days specified in this experiment would have resulted in a 30% increase in commercial value for 'Optima', a 10% increase for 'Kerner' and 'Siegerrebe', no increase for 'Müller-Thurgau', and a 10% loss for 'Muscat Ottonel' and 'Pearl of Csaba'.

Increases in °Brix and pH and decreases in TA during fruit maturation are well documented (La Rosa and Nielson, 1956; Marais, 1987; Marais and Van Wyck, 1986). However, in the case of terpenes, many researchers (Bayonove and Cordonnier, 1970; Dimitriadis and Williams, 1984; Hardy, 1970; Wilson et al., 1984) have reported a plateau or decrease in their concentration in berries after attaining commercial maturity. Under British Columbian conditions, FVTs and PVTs may continue to increase after full maturity is reached in terms of °Brix, TA, and pH. Another significant observation is that small increases in °Brix may lead to large FVT and PVT increases, which should contribute to greater varietal character. Because these observations may have important organoleptic and commercial implications, maturity standards will need careful revision to accommodate these facts.

Tasters found differences in aroma between wines from early and late-harvested grapes for all but 'Pearl of Csaba' (Table 5). The nature of these differences was more muscat aroma in late-harvested 'Siegerrebe'. Based on flavor, tasters could not discriminate between early and late-harvest treatments in 'Muscat Ottonel', 'Pearl of Csaba', and 'Siegerrebe', but found more floral flavor in late-harvested 'Optima'. The bulk of these significant differences can be ascribed to higher FVTs or PVTs in the initial juices. 'Muscat Ottonel' and 'Siegerrebe' produced significant organoleptic responses despite a lack of treatment differences in juice FVT, suggesting that bottle storage allowed some hydrolysis of PVTs to their odor-active precursors.

Effect of skin contact (Expt. 3). In 1989, four of the six cultivars used in Expt. 2 ('Müller-Thurgau', 'Kerner', 'Optima', and 'Siegerrebe') were chosen to investigate the impact of skin contact on juice composition and wine quality. The 'Muscat Ottonel' and 'Pearl of Csaba' vines used in 1988 died in Winter 1988-89, while the other four cultivars suffered varying degrees of winter injury and concomitant loss in yield potential. Grapes were harvested on 25 Sept. ('Siegerrebe'), 28 Sept. ('Optima'), and 4 Oct. ('Müller-Thurgau' and 'Kerner').

Fruit were crushed as previously described,

Table 4. Effect of harvest date on juice and wine composition[z] of six *Vitis vinifera* cultivars, 1988.

Cultivar	Harvest date	Juice °Brix	Juice TA (g·liter^{-1})	Juice pH	Juice FVT (mg·liter^{-1})	Juice PVT (mg·liter^{-1})	Wine TA (g·liter^{-1})	Wine pH	Wine Ethanol (%)
Kerner	5 Oct.	16.6	8.5	3.21	1.88	2.27	7.7	3.21	9.6
	24 Oct.	18.3	8.1	3.35	2.21	2.38	7.3	3.32	11.0
	Significance	***	NS	***	***	NS	***	***	***
Müller-Thurgau	5 Oct.	18.0	8.8	3.17	1.64	1.59	8.1	3.19	11.2
	24 Oct.	18.5	7.5	3.32	1.96	1.46	6.8	3.36	12.7
	Significance	***	***	***	*	NS	***	***	***
Muscat Ottonel	5 Oct.	16.8	7.0	3.32	1.56	4.74	6.2	3.31	9.8
	24 Oct.	17.9	6.5	3.42	1.76	5.65	5.9	3.40	12.7
	Significance	***	**	***	NS	**	***	***	***
Optima	19 Sept.	15.5	10.3	3.02	1.27	2.24	9.1	2.97	9.8
	5 Oct.	19.4	9.4	3.16	1.38	2.48	8.1	3.16	11.2
	Significance	***	***	***	**	*	***	***	***
Pearl of Csaba	9 Sept.	18.2	7.3	3.45	2.34	5.04	6.3	3.45	9.7
	19 Sept.	17.5	6.3	3.46	2.06	5.73	6.1	3.43	11.3
	Significance	***	***	***	*	*	***	***	***
Siegerrebe	9 Sept.	17.7	4.5	3.75	1.74	4.11	4.0	3.74	10.8
	9 Sept.	19.7	4.2	3.89	1.63	5.75	4.1	3.87	12.8
	Significance	***	**	***	NS	***	***	***	***
All cultivars									
	Significance	**	***	***	**	**	*	***	***

[z]TA = titratable acidity, FVT = free volatile terpenes, PVT = potentially volatile terpenes.
NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 5. Results of triangle tests (N = 15) comparing wines vinted from six *Vitis vinifera* grape cultivars, each harvested early and late, 1988.

Cultivar	Correct responses	Correct respondents[z] (no.) Strongest muscat Early	Late	Strongest floral Early	Late
		Aroma			
Kerner	13***	3/13	5/13	6/13	6/13
Müller-Thurgau	9*	5/9	2/9	2/9	5/9
Muscat Ottonel	10**	3/10	1/10	2/10	5/10
Optima	11***	2/11	4/11	4/11	5/11
Pearl of Csaba	7[NS]				
Siegerrebe	11***	3/11	7/11**	4/11	4/11
		Flavor			
Kerner	15***	4/15	5/15	3/15	7/15
Müller-Thurgau	10**	1/10	2/10	3/10	3/10
Muscat Ottonel	6[NS]				
Optima	10**	0/10	2/10	1/10	6/10*
Pearl of Csaba	5[NS]				
Siegerrebe	7[NS]				

[z]Based on a one-tailed *t* test.

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

and half of the volume of crushed grapes was given 24 h ('Optima'), 72 h ('Siegerrebe'), or 264 h ('Müller-Thurgau' and 'Kerner') of skin contact without sulfite at 2C. The rest of the fruit (crush-and-press) was pressed immediately and treated as in Expt. 2, except Steinberg yeast (Red Star Co., Milwaukee) was used instead of ST61. Crushed grapes subjected to skin contact were treated during and after pressing in the same manner as the crush-and-press grapes. Two 250-ml juice samples were collected from each treatment within cultivar at pressing and stored at -40C until analysis for °Brix, TA, pH, FVTs, and PVTs. Two, 12-liter fermentation replications were maintained for 'Optima' and 'Siegerrebe'. Insufficient volumes of 'Kerner' and 'Müller-Thurgau' juice were available for winemaking treatments.

Berries and juices were analyzed as described for Expt. 1. Wines were analyzed after bottling for TA, pH, and ethanol as in Expt. 1.

Wines were tasted in Feb. 1992 after 20 months of bottle storage. Differences between the crush-and-press and skin-contact treatments were ascertained by 12 experienced tasters using triangle tests. Tastings were conducted as in Expt. 2. Muscat and floral references are shown in Table 1.

Using skin contact reduced juice and wine TA and increased juice and wine pH and juice FVTs, PVTs, and ethanol (Table 6). Reduced TA, as in Expt. 1, may be explained by some precipitation of tartaric acid during skin contact, while elevated FVTs and PVTs in skin-contact juices could be ascribed to greater extraction of FVTs and PVTs by skin contact. This phenomenon was observed by Marais (1987), Marais and Rapp (1988), and Marais and Van Wyck (1986) on several *V. vinifera* cultivars in South Africa, although Rapp et al. (1985) could not demonstrate an increase in wine terpenes in response to varying skin-contact times.

Tasters could distinguish ($P \leq 0.05$) between the crush-and-press and skin-contact treatments for 'Siegerrebe' based on aroma (15/24) and flavor (14/24). Skin-contact wines seemed to contain the most floral aroma (8/15), a result that corresponded well with the higher juice PVT levels. Tasters could not distinguish between treatments for 'Optima' wines, despite higher juice FVTs and PVTs in the skin-contact treatment (data not shown).

Data presented in these three somewhat-related experiments provide strong evidence that calorimetric determination of monoterpenes can be used to 1) more accurately assess grape maturation than conventional harvest indexes and 2) predict or define the degree of varietal character in wines of some cultivars. Instances of a lack of correlative relationships between monoterpene levels and taster response may be ascribed to stimulus error or to the variability commonly encountered in organoleptic analysis. This lack of correlation also can be explained by the analysis itself, since FVTs and PVTs do not provide a total explanation of the aroma and flavor of the grape cultivars studied here. Although more sophisticated techniques and equipment are available for monoterpene quantitation, the method used in this study should be considered for medium to large wineries or for research programs lacking funds or time for flavor research.

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Table 6. Effect of skin contact on juice and wine composition[z] of four *Vitis vinifera* cultivars, 1989.

Cultivar	Treatment	Juice °Brix	TA (g•liter⁻¹)	pH	FVT (mg•liter⁻¹)	PVT (mg•liter⁻¹)	Wine TA (g•liter⁻¹)	pH	Ethanol (%)
Kerner	Crush and press	23.0	12.8	2.92	0.79	2.02	---	---	---
	Skin contact	22.2	7.9	3.20	1.62	2.76	7.1	3.26	15.4
	Significance	***	***	***	***	***	---	---	---
Müller-Thurgau	Crush and press	23.2	9.4	3.22	0.93	2.30	---	---	---
	Skin contact	22.6	6.8	3.37	1.36	2.36	6.2	3.27	15.6
	Significance	***	***	***	**	NS	---	---	---
Optima	Crush and press	19.5	8.4	3.10	1.36	4.54	6.9	2.91	13.4
	Skin contact	20.3	6.9	3.21	1.75	5.07	6.0	3.16	14.2
	Significance	***	**	***	***	*	***	***	***
Siegerrebe	Crush and press	18.9	6.0	3.37	1.88	5.16	5.2	3.13	12.8
	Skin contact	20.6	6.5	3.44	2.04	6.10	4.6	3.28	13.1
	Significance	***	*	***	NS	**	***	***	*
All cultivars									
	Significance	NS	**	***	***	**	**	**	**

[z]TA = titratable acidity, FVT = free volatile terpenes, PVT = potentially volatile terpenes.

NS,*,**,***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

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