

## Effect of Variety, Ultraviolet Light Exposure, and Enological Methods on the trans-Resveratrol Level of Wine

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**Abstract.** *Resveratrol is one of the wine components related to moderate wine consumption and reduction of serum cholesterol levels. The standard addition method was used with a high pressure liquid chromatography procedure to calculate resveratrol levels. Grape variety, UV light exposure, enzyme addition, skin contact time, and the fining agents, carbon and PVPP, affected the resveratrol levels of wines from the white varieties, Chardonnay and Chardonel, and the red varieties, Cabernet Sauvignon, Cynthiana, and Noble. UV light exposure of the grape clusters significantly increased the resveratrol level in Cynthiana and Noble wine produced in 1994, but did not yield a consistent result in the other experiments from the 1995 and 1996 wines. Enzyme addition significantly increased resveratrol levels in Chardonnay wine but not Chardonel wine. Skin contact time influenced the extraction of resveratrol from the skin in the red varieties, but the maximum extraction time was dependent on the variety of the grapes. Carbon addition decreased the resveratrol level in Noble wine but not in Cynthiana in the 1994 wines. The addition of PVPP significantly lowered resveratrol level in Chardonel, Chardonnay, Cabernet Sauvignon, Cynthiana, and Noble wine. However, low levels of added PVPP addition did not cause significant loss of resveratrol.*

Wines contain a complex of phenolic components responsible for the overall color and flavor. Resveratrol is one of the phenolic compounds implicated in the health benefits associated with wine consumption. Moderate wine consumption has been shown to lower coronary artery disease, positively effect lipid levels in humans, and have cancer chemopreventive activity [1,2,3,5,6,8,9,10,11,12,13,17,18,24,35,36,39,44]. Since resveratrol was identified as a wine component by Siemann and Creasy in 1992, researchers have investigated many aspects of the winemaking process. However, winemaking is complex; many aspects in the process remain unexplored.

Resveratrol concentrations are high in red wines, while white wines contain less [16,23,26,27,29,32,34,38,41,45,47] primarily because resveratrol is found in the skin of grapes, and red wine is fermented on the skins. Goldberg *et al.* [16] analyzed over 100 white wines and found very few with resveratrol concentrations greater than 0.1 mg/L. The variety of grape plays an important role in resveratrol synthesis which may be genetically controlled [26]. In several studies, researchers determined that wines made from Pinot noir contain the highest level of resveratrol [16,28,40,47]. However, Soleas *et al.* [43] concluded that resveratrol levels were higher in Cabernet Sauvignon than in Pinot noir from Ontario-grown grapes. Furthermore, resveratrol levels in wines made from muscadines compared favorably with those made from other grape species [7,25,30].

Resveratrol was produced in the skin after W exposure and there was a negative correlation between resveratrol content of grape skin and berry development [4,19]. However, Muscadine grape seeds (*Vitis rotundifolia*) had higher concentrations of resveratrol than other berry parts [7]. Roggero and Garcia-Parrilla [37] determined that W exposure of the cut grape skins at 254 nm destroyed resveratrol, but this may have been related to the maturity and stage of senescence of the berry.

Resveratrol glucosides are a key component in commercial wines [14]. Jeandet *et al.* [20] demonstrated a rapid increase in resveratrol content of wine during the first 24 hours, after the addition of f3-D-glucosidase. Vrhovsek *et al.* [46] reported that Pinot noir must, fermented by yeast with high 13-D-glucosidase activity, significantly increased the level of resveratrol in the wine. In studies comparing commercial enzymes, resveratrol content increased in enzyme-treated red wines [40,48].

Resveratrol concentrations increased during fermentation on the skins but the amount extracted was dependent on the variety and enological conditions [21, 26,34,42,49]. The maximum level of resveratrol was obtained between three and eleven days from the first stages of fermentation. The extraction of resveratrol from the skin may be facilitated by the production of ethanol during the fermentation process [26].

Fining agents, such as bentonite, carbon, egg white (albumen), gelatin, and polyvinylpolypyrrolidone (PVPP) are used to remove haze, alter or remove odor, color, or taste, and aid in wine stability [31,50]. Bentonite, egg white, and diatomaceous earth had no major effect on resveratrol levels of wine [15,42]. Gelatin and silica gel removed resveratrol slightly but not significantly. High levels of activated carbon adsorbed both isomers of resveratrol. PVPP greatly reduced resveratrol levels in Pinot noir wine [41,46].

Three studies were designed to determine the effect of variety, UV light exposure, enzyme addition, skin contact

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time, fining with carbon and PVPP, and filtering on the resveratrol level of Arkansas wines. The white grape varieties, Chardonnay (*Vitis vinifera*) and Chardonel (French-American hybrid Seyval x Chardonnay cross), and the red grape varieties, Cabernet Sauvignon (*Vitis vinifera*), Cynthiana (*Vitis aestivalis*), and Noble (*Vitis rotundifolia*), were used for these studies. The objectives of these studies were:

**Study 1:** The effect of variety, W light exposure, enzyme addition, and the fining agent PVPP on resveratrol levels of Chardonel and Chardonnay 1995 wine.

**Study 2:** The effect of variety, W light exposure, skin contact time, carbon fining, and filtering on resveratrol levels of Cynthiana and Noble 1994 wine.

**Study 3:** The effect of variety, W light exposure, skin contact time, and the fining agent PVPP on resveratrol levels of Cabernet Sauvignon, Cynthiana, and Noble 1995 and 1996 wine.

## Materials and Methods

**Chromatography equipment and procedure:** Resveratrol levels were determined with HPLC instrumentation (Hitachi L-4200 W VIS Detector, L-6200 Intelligent Pump, and D-2000 Chromato-Integrator). A Phenomenex Bondclone 10  $\mu$ m Phenyl 300 X 3.9 mm column was used with a 20- $\mu$ L injection loop. A gradient of water adjusted to pH 2.5 by 0.6 M perchloric acid and methanol at flow rate of 1 mL/min was used for analysis [7]. A commercial standard of resveratrol was purchased from Sigma Chemical Co. (St. Louis, MO) and used as a standard for identification. Resveratrol was measured at a wavelength of 310 nm.

**Standard addition method:** The standard addition method [33] was used for the analysis of samples. A series of 10-mL flasks were used, and a volume of wine ( $V_U$ ) was added to the flask to determine the analyte concentration ( $C_U$ ). A known volume ( $V_S$ ) of the standard solution of concentration  $C_S$  was also added to each flask. The flasks were filled to the same total volume ( $V_T$ ). In accordance with Beer's Law, measured peak height of each flask was proportional to total analyte concentration as follows:

$$A = k(V_S C_S + V_U C_U) / V_T$$

where:  $V_S$  = volume of standard;  $C_S$  = concentration of standard;  $V_U$  = volume unknown;  $C_U$  = concentration of unknown;  $V_T$  = total volume; and  $k$  = proportionality constant.

The results were plotted with the volume of the standard added to each flask ( $V_S$  as the independent variable and peak height in centimeters as the dependent variable. The above equation fits a linear equation with the slope =  $kC_S / V_T$  and the intercept =  $kV_U C_U / V_T$ . Rearranging the equations above gives the following formula:

$$C_U = (\text{measured intercept} / \text{measured slope}) (C_S / V_U).$$

The standard addition method used in combination with the selected HPLC procedure was reproducible with no significant differences between the calculated resveratrol levels of the samples (data not shown).

**Grapes and wine:** Cabernet Sauvignon and Noble grapes were obtained from Post Familie Vineyards Altus, Arkansas, and Chardonel, Chardonnay, and Cynthiana grapes were obtained from the research vineyards at the Agricultural Experiment Station, University of Arkansas, Fayetteville, Arkansas, for the production of wines for these experiments. Grapes were hand-harvested and delivered to the University of Arkansas Food Science Department for processing on the same day.

Grape clusters were randomly separated into four: lots for each variety, and each treatment contained an equal weight of grapes. Two lots of grapes were exposed to UV light using a Black-Ray 254 nm short-wave UV light for a total of 10 minutes. The clusters were spread in a single layer on a 60 X 60 cm tray, exposed to UV light for five minutes, and then turned to expose for five additional minutes. The W light was suspended 30 cm above the tray and yielded an average illuminance of 30 ca. 11200 lux on the surface of the grapes. The grapes were then held at 21°C for 20 hours before processing. The controls were an equal weight of grapes not exposed to W light and held for the same time and at the same temperature.

After crushing and destemming, the must was placed in stainless steel fermentation tanks, pressed in a #25 Enrossi bladder type press (Enoagricol Rossi s.r.l., Calzolaro, Italy), and collected in glass carboys. All studies were inoculated with 71B yeast (Lallemand, Inc., Montreal, Canada) and fermented at 21°C. The fermented wine was racked three times to remove spent yeast cells and prevent the production of off-flavors.

After completion of fermentation (<0.5% residual sugar), sulfur dioxide ( $SO_2$ ) was added as potassium metabisulfite to each treatment at a rate of 175 mg/l, to prevent oxidation and spoilage. For each study and year, wine was bottled in 114-mL glass bottles with screw caps and stored in the dark at 21°C until analyzed. The standard addition method of analysis was used to determine resveratrol levels of the wine 1 samples. Individual study differences are listed below.

**Study 1:** Chardonel and Chardonnay grapes were harvested in 1995. After destemming and crushing, Rohapect D5L pectolytic enzyme (Scott Laboratories) was added at a rate of 15 mL/919 kg of crushed grapes and held for 30 minutes on the skins before pressing. The juice was collected into carboys and cold-settled overnight at 2°C. The juice was racked, and laboratory analysis indicated Chardonel had 0.75 mg tartaric acid/100 mL of juice, 23.1° Brix, and a pH of 3.51 and Chardonnay had 0.58 mg tartaric acid/ 100 mL of juice, 20.2° Brix, and a pH of 3.53. The titratable acidity was adjusted to 0.75 mg tartaric acid/100 mL of juice in the Chardonnay variety. The juice was inoculated with yeast and fermented.

After completion of fermentation and SO<sub>2</sub> addition, each treatment, Control Enzyme, Control No Enzyme, W Enzyme, and UV No Enzyme, for each variety was treated with the fining agent PVPP at four levels (level 0, 1, 2, and 3) with two replications. The type of PVPP used was Polyclar®VT (GAF Chemicals Corporation). The recommended maximum amount of 0.96 g/L was used for level 3 of PVPP [50]. Level 2 was half of level 3 resulting in half of the recommended maximum amount (0.48 g/L). Level 1 was half of level 2 resulting in one-fourth of the recommended maximum amount (0.24 g/L). Level 0 was the control which received no fining agents. After 24 hours following the addition of PVPP, the wines were filtered, bottled, and stored until analyzed.

The treatment design was a 2 x 2 x 2 x 4 factorial in a completely randomized design with two replications. The factorial treatment design contained four factors, variety (Chardonal and Chardonnay), UV light exposure (Control and UV light), enzyme addition (No Enzyme and Enzyme), and PVPP addition (0, 0.24, 0.48, and 0.96 g/L). The analysis was carried out by Statistical Analysis System PROC GLM procedure. Treatment means were separated by least significant difference (LSD). Since there was no variability in the replications in either Chardonnay or Chardonal wine, the results were analyzed as main effects with the interactions as the error term.

**Study 2:** Cynthiana and Noble grapes harvested in 1994 were destemmed, crushed, and placed in fermentation tanks. Laboratory analysis of the must samples indicated Cynthiana had 0.98 mg tartaric acid/100 mL of juice, 19.9° Brix, and a pH of 3.41. Noble had 0.75 mg tartaric acid/ 100 mL of juice, 17° Brix, and a pH of 3.24. The soluble solids of both varieties were ameliorated to 21° Brix. The must was inoculated with yeast and fermented. The grapes were then further divided into two skin contact times, with one batch-fermented on the skin until dryness (0° Brix) and the other batch-held seven days on the skins after reaching 0° Brix. The must was then pressed, and the wine was collected into carboys.

After completion of fermentation and SO<sub>2</sub> addition, each treatment, Control Dry, Control Extended, UV Dry, and UV Extended, for each variety was divided into a control sample (no treatment), a fined sample (activated deodorizing carbon fined at a rate of 0.06 g/L of wine), a filtered sample (filtered with a polyvinylidene fluoride 0.45µm filter), and a fined and filtered sample. The wine was bottled and stored until analyzed.

The treatment design was a 2<sup>5</sup> factorial in a completely randomized design with two replications. The factorial treatment design contained five factors, variety (Cynthiana and Noble), UV light exposure (Control and UV light), skin contact time (Dry and Extended), carbon fining (No Fining and Fining), and filtering (No Filtering and Filtering). The analysis was carried out by Statistical Analysis System PROC GLM procedure. Treatment means were separated by LSD.

**Study 3:** Cabernet Sauvignon, Cynthiana, and Noble grapes harvested in 1995 and 1996 were destemmed, crushed, and placed in fermentation tanks. Laboratory analysis was performed and listed as follows:

Variety	Year	% Tartaric acid	°Brix	pH
Cab. Sauvignon	1995	0.74	17.9	3.56
Cynthiana	1995	0.95	20.0	3.47
Noble	1995	0.66	14.4	3.29
Cab. Sauvignon	1996	0.99	16.5	3.25
Cynthiana	1996	1.15	20.0	3.43
Noble	1996	0.41	18.0	3.36

The soluble solids of all varieties and years were ameliorated with cane sugar to 21° Brix. The must was inoculated with yeast and fermented. The grapes were then further divided into two skin contact times, with one batch fermented on the skin until dryness (0° Brix) and the other batch held three days on the skins after reaching 0° Brix. The must was pressed and collected into glass carboys.

After completion of fermentation and SO<sub>2</sub> addition, each treatment, Control Dry, Control Extended, UV Dry, and UV Extended, for each variety was further treated with the fining agent PVPP at different levels with two replications as in Study 1. After 24 hours following the addition of PVPP, the wines were prefiltered, bottled, and stored until analyzed.

The treatment design was a 3 x 2 x 2 x 4 factorial in a completely randomized design with two replications for each year. The factorial treatment design contained 4 factors, variety (Cabernet Sauvignon, Cynthiana, and Noble), UV light exposure (Control and UV light), skin contact time (Dry and Extended), and PVPP addition (0, 0.24, 0.48, and 0.96 g/L). The analysis was carried out by Statistical Analysis System PROC GLM procedure. Treatment means were separated by LSD. Means were further separated using estimate and contrast statements.

**Results and Discussion** The wines in this study were produced to determine how variety, UV light exposure, and other common winemaking procedures affect the resveratrol levels of finished wine. The UV light exposure was used to simulate stress conditions to the vine prior to processing. Enzyme addition was used to break down the pectin in the cell wall of grape clusters to promote juice release from the flesh and extract phenolic compounds from the skin. Skin contact time was used to influence the extraction of colors, flavors, and other components during fermentation of the grape must. The addition of fining agents, such as carbon and PVPP, is used commercially to alter the color or remove off-flavors in the wine, and filtering the wine prior to bottling is used in the final stages of the winemaking process.

**Study 1:** The white wine produced had extremely low levels of resveratrol. The mean resveratrol levels from Chardonel wine with no PVPP addition was 0.0181 mg/L while the mean for Chardonnay was 0.0287 mg/L. The low resveratrol levels could result from the lack of fermentation on the skins or naturally low levels in these varieties. Ultraviolet light exposure significantly increased resveratrol levels in Chardonel wine, while enzyme addition significantly increased resveratrol levels in Chardonnay wine.

Grapes exposed to W light then processed into wine had higher resveratrol levels (0.0143 mg/L) than wine from the control (0.0124 mg/L) in Chardonel. Resveratrol has been shown to be produced in the skin of grape berries in response to W irradiation. Not only is variety a major factor in the synthesis of resveratrol from W exposure but also the maturity of the grapes which may correspond to the lack of resveratrol synthesis by Chardonnay grapes [4,19,37]. Thus, UV irradiation of the grapes yields complex results especially when the grapes are fermented on the skins.

Grapes with enzyme addition then processed into wine had higher resveratrol levels (0.0156 mg/L) than the control (0.0111 mg/L) in Chardonnay wine. Although enzyme addition aids in pectin degradation in grape clusters to increase the release of juice from the flesh, the extraction of resveratrol from the skin could be enhanced by the fermentation of the white wines on the skins instead of directly pressing the must. Lamuela-Raventos *et al.* [26] theorized that the extraction of resveratrol from the skin may be based on the production of ethanol during the fermentation process. The basis of this theory is that resveratrol is more ethanol soluble than water soluble, so as the ethanol level increases during fermentation the resveratrol is extracted from the skins. Another key factor in the addition of commercial enzymes is the purity of the enzymes which could contain enzyme activities similar to those produced in the later stages of *Botrytis* infection that cause the degradation of grape enzymes responsible for the formation of resveratrol [22].

The addition of PVPP significantly lowered resveratrol content in both Chardonnay and Chardonel wine ( $p < 0.0001$ ) (Fig. 1). In Chardonel wine, the resveratrol levels decreased from 0.0187 mg/L in level 0 to 0.0086 mg/L with the addition of PVPP at a rate of 0.96 g/L in level 3. In Chardonnay wine, the resveratrol levels decreased from 0.0287 mg/L in level 0 to 0.0034 mg/L with the addition of PVPP at a rate of 0.96 g/L in level 3. The resveratrol level in the control was significantly higher than level 2 and level 3 in both varieties. In Chardonel wine, the control was not significantly different from level 1; but in Chardonnay wine, the control was significantly different from level 1.

PVPP complexes with phenolic compounds, such as resveratrol, by hydrogen bond formation between the carbonyl groups of PVPP and the hydroxyl groups. Sieman and Creasy [41] also noted significant removal of resveratrol by PVPP in white wines. However, their research on PVPP was limited, and this research shows that increases in PVPP reduce resveratrol levels in the wines. The results indicate that the addition of low levels of PVPP in wine can be used without the significant removal of resveratrol.

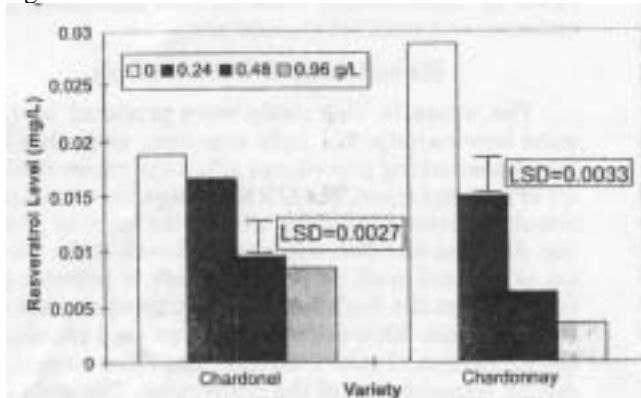


Fig. 1. Effect of PVPP Level on the resveratrol level of Chardonel and Chardonnay wines.

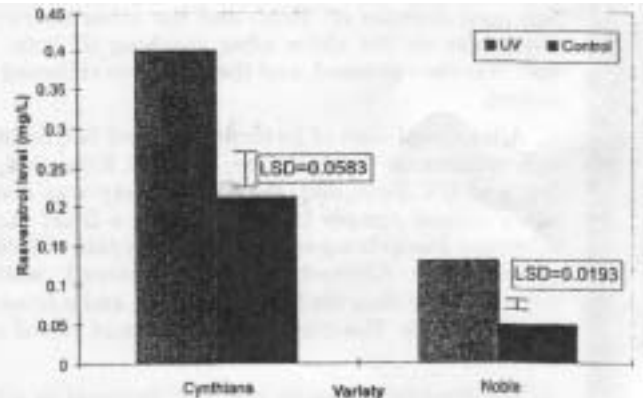


Fig. 2. Effect of UV light exposure of clusters on the resveratrol level of Cynthiana and Noble wine.

**Study 2:** Resveratrol content was significantly higher in Cynthiana wine than in Noble wine ( $p < 0.0001$ ). Resveratrol levels were variety-dependent. The mean resveratrol level of Cynthiana was 0.3066 mg/L while the mean level for Noble was 0.0906 mg/L. The difference in the resveratrol levels of the varieties is also dependent on the maturity of the grapes at harvest. Since each variety had a large difference in mean values, the results were analyzed by variety.

Ultraviolet light exposure was a significant factor within wines from both varieties ( $p < 0.0001$ ). Exposure to UV light caused the induction of key enzymes to the formation of resveratrol. Grapes exposed to UV light and then processed into wine had higher resveratrol levels than those grapes not exposed in both Cynthiana and Noble wine (Fig. 2). The resveratrol levels for Cynthiana wine were 0.4007 mg/L for the W exposed clusters and 0.2125 mg/L for the control. Mean resveratrol levels for Noble wine were 0.1314 mg/L for the UV-exposed clusters and 0.0484 mg/L for the control. This research showed that the increased production of resveratrol in the grapes can result in a corresponding increase in resveratrol in the wine.

In Cynthiana wine, there was a significant interaction between UVV light exposure and skin contact time ( $p = 0.0009$ ). The synthesis of resveratrol has been shown to occur in the skin of the berries and is dependent on the maturity of the berries which may explain the difference of the effects within the different varieties. Wine produced from the extended skin contact time had higher (0.2865 mg/L) resveratrol levels than the wine produced from the dry skin contact time (0.1385 mg/L) for the control group. However, the dry skin contact time had a higher mean resveratrol level (0.4389 mg/L) than the extended skin contact time (0.3624) for the UV exposed treatment. The interaction could result from the maximum production of resveratrol occurring in the UV treated grapes, followed by extraction into the wine, and then degradation or transformation of resveratrol. Fining and filtering did not significantly reduce resveratrol levels in Cynthiana wine, possibly due to the presence of other complex phenolic compounds which interfere with the removal of resveratrol or the low level of carbon addition.

Table 1. Significance level of the effect of UV light exposure (UV), skin contact time (SCT), polyvinylpyrrolidone (PVPP) levels, and interactions on resveratrol levels of Cabernet, Cynthiana, and Noble wine from 1995 and 1996.

Variety and Year	UV	SCT	PVPP	UV × SCT	UV × PVPP	SCT × PVPP	UV × SCT × PVPP
Cabernet 1995	ns*	0.0306	0.0001	0.0068	0.0185	0.0121	ns
Cynthiana 1995	ns	0.0001	0.0001	ns	ns	ns	ns
Noble 1995	0.0001	0.0004	0.0001	0.0001	ns	0.0164	ns
Cabernet 1996	ns	0.0001	0.0001	0.0012	0.0032	ns	0.0001
Cynthiana 1996	0.0002	0.0003	0.0001	ns	ns	ns	ns
Noble 1996	0.0001	0.0074	0.0001	ns	0.0015	ns	ns

\* Not significant ( $p \leq 0.05$ ).

Carbon fining significantly reduced resveratrol levels in Noble wine ( $p = 0.0302$ ). The mean resveratrol level after carbon fining of Noble wine was 0.0789 mg/L, while the mean resveratrol level for wine with no carbon fining was 0.1031 mg/L. There was also a significant interaction among UV light exposure, fining, and filtering ( $p = 0.0054$ ). In the UV exposed treatment Noble wine with carbon fining, the mean resveratrol level of the filtered

sample was slightly lower than the unfiltered sample, whereas, in the UV exposed treatment of wine with no carbon fining, the resveratrol levels of the filtered wine were higher than in the unfiltered sample. This difference could be due to oxidation of the wine prior to the analysis. Resveratrol levels of both carbon fining treatments for the filtered and unfiltered control wine were similar.

Table 2. Factors that result in the highest resveratrol levels in Cabernet Sauvignon, Cynthiana, and Noble 1995 and 1996 wines.

Variety and year	Light =	SCT =	PVPP=	Resveratrol level (mg/L)
Cabernet 1995	UV	Dry	0 g/L	0.3704
Cynthiana 1995	UV	Dry	0 g/L	0.4166
Noble 1995	Control	Dry	0 g/L	0.4159
Cabernet 1996	UV	Dry	0 g/L	0.5275
Cynthiana 1996	Control	Dry	0 g/L	2.6974
Noble 1996	UV	Dry	0 g/L	0.1188

**Study 3:** The significance of the main effects and interactions were evaluated for Cabernet Sauvignon, Cynthiana, and Noble wine produced in 1995 and 1996 (Table 1). The results were analyzed by variety and year. PVPP addition and skin contact time significantly affected resveratrol levels of wine produced from all varieties in both years. The interaction of UV light x skin contact time x PVPP addition was not a significant factor in all varieties in both years except for Cabernet Sauvignon produced in 1996. The main effect of UV light exposure and the two-way interactions showed no pattern in terms of

significance, thus, indicating that UV irradiation yields complex results.

Table 3. Factors that result in the lowest resveratrol levels in Cabernet Sauvignon, Cynthiana, and Noble 1995 and 1996 wines.

Variety and year	Light =	SCT =	PVPP=	Resveratrol level (mg/L)
Cabernet 1995	Control	Extended	0.96 g/L	0.1931
Cynthiana 1995	UV	Extended	0.96 g/L	0.1851
Noble 1995	Control	Extended	0.96 g/L	0.027
Cabernet 1996	Control	Extended	0.96 g/L	0.3043
Cynthiana 1996	UV	Extended	0.96 g/L	1.5473
Noble 1996	Control and UV	Dry and extended	0.96 g/L	0.0

The combination of factors which yielded the highest and lowest resveratrol levels was evaluated (Table 2, 3). A dry skin contact time and no PVPP addition yielded the highest resveratrol levels in all varieties and years. An extended skin contact and 0.96 g/L PVPP addition yielded the lowest resveratrol levels in all varieties and years except Noble 1996 which contained 0 mg/L of resveratrol in both the Dry and Extended skin contact time. Thus, the highest level of PVPP completely removed resveratrol from Noble wine.

Further examination of the effect of UV exposure and skin contact time on resveratrol level of 1995 and 1996 wines with no PVPP addition yielded

varying results (Fig. 3). This agrees with other research which found that resveratrol concentrations increased during fermentation on the skins, but the amount extracted was dependent on the variety and enological conditions [22,26,34,42,49]. In the highest and lowest resveratrol levels, the UV light exposure did not yield a constant result which may be due to the maturity of the grapes at harvest. Thus, for these varieties a dry skin contact time allowed for the maximum extraction of resveratrol from the skins with degradation or transformation of resveratrol occurring as a result of extended skin contact.

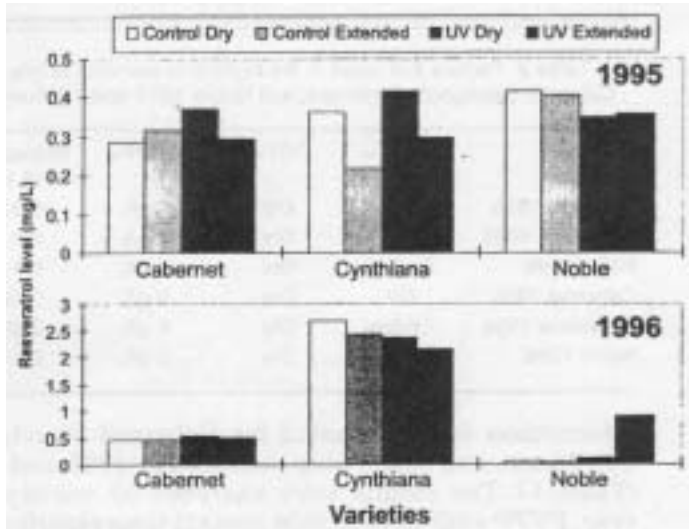


Fig. 3. Effect of ultraviolet exposure and skin contact time on the resveratrol level of Cabernet Sauvignon, Cynthiana, and Noble 1995 and 1996 wine with no PVPP addition.

Regardless of the skin contact time and UV exposure, PVPP addition significantly lowered the resveratrol level in all varieties and years (Fig. 4, 5). This research shows that as the addition of PVPP increases in wine from all years and varieties so does the removal of resveratrol from the wine. However, the results indicate that the addition of low levels (0.24 g/L) of PVPP in red wine can be used without significant removal of resveratrol in the wine, depending on the grape variety.

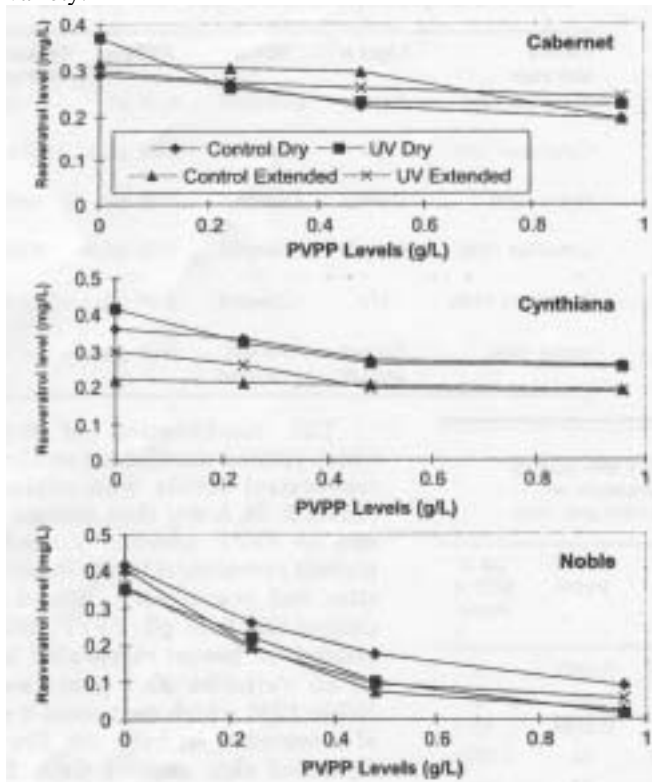


Fig. 4. Effect of PVPP on resveratrol levels of 1995 Cabernet Sauvignon, Cynthiana, and Noble wines treated with different UV light exposure and skin contact time.

## Conclusions

Three studies were done to evaluate the effects of variety, W light exposure, enzyme addition, skin contact time, and the fining agents, carbon and PVPP, on the resveratrol level of wine. The wine from the white varieties, Chardonnay and Chardonel, had low levels of resveratrol. Wine from the red varieties, Cabernet Sauvignon, Cynthiana, and Noble, had higher levels of resveratrol than white wines. Since resveratrol levels in wines differed according to variety, the data were statistically analyzed by variety in all studies.

LTV light exposure of the grape clusters significantly increased the resveratrol levels in Cynthiana and Noble wines produced in 1994, but did not yield a consistent trend in the other experiments. Enzyme addition significantly increased resveratrol levels in Chardonnay wine but not in Chardonel wine. The effect of enzyme addition in combination with fermentation on the skins on resveratrol levels in white varieties should be investigated. Skin contact time influenced the extraction of resveratrol from the skins of the red varieties. However, the maximum extraction time was dependent on the variety of the grapes.

The fining agents, carbon and PVPP, reduced the resveratrol level of wine. Carbon addition decreased the resveratrol level of Noble wine, but not of Cynthiana, in the 1994 wines. This could be due to the low level of carbon that was used or interfering compounds present in Cynthiana wine. PVPP addition lowered resveratrol level in all varieties. However, low levels of PVPP addition can be used without the significant removal of resveratrol from the wine. Besides variety, the year of production and the maturity of the grape at the time of harvest influence the resveratrol level of the resulting wine. Several of the factors analyzed yielded complex and varying results.

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