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Food Chemistry 92 (2005) 729–736
Food Chemistry
www.elsevier.com/locate/foodchem

Preliminary study of resveratrol content in Aragón red and rosé wines

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Received 9 February 2004; received in revised form 31 August 2004; accepted 31 August 2004

Abstract

A survey of resveratrol content in wines of the four Aragón designations of origin (Borja, Cariñena, Calatayud and Somontano) was carried out. Concentrations of *trans*- and *cis*-resveratrol isomers of 98 commercial wines of the four designations of origin, from several vintages, were analyzed by means of reverse-phase high-performance liquid chromatography. Concentration of *trans*-resveratrol ranged from 0.32 to 4.44 mg/l in red wines and from 0.12 to 2.80 mg/l in rosé wines. *cis*-Resveratrol levels ranged from 0.20 to 5.84 mg/l in red wines and from 0.02 to 3.17 mg/l in rosé wines. The grape variety influenced resveratrol contents in wines from the different regions. The highest *trans*/*cis* ratios were found in Somontano (4.50) and Calatayud wines (2.90), both of the Tempranillo variety. However, a discriminant analysis applied to the concentrations did not show significant differences between young red wines nor between rosé wines of the four designations of origin.

Keywords: Wine; Resveratrol; HPLC; Discriminant analysis

1. Introduction

Resveratrol (3,5,4′-trihidroxyestilbene) is a stilbene phytoalexin and a natural compound of grape vines. Its production increases in response to stress of the plant (Creasy & Coffee, 1988; Langcake, 1981) or fungal infection (Lamuela-Raventós & Waterhouse, 1993), among other causes. It appears in grapes (Creasy & Coffee, 1988; Jeandet, Bessis, & Gautheron, 1991) as well as in wine (Goldberg et al., 1995a; Jeandet, Bessis, Sbaghi, & Meunier, 1994; Lamuela-Raventós & Waterhouse, 1993;Mattivi, 1993a; McMurtrey, Minn, Pobanz, & Schultz, 1994; Pezet, Pont, & Cuenat, 1994; Roggero & Archie, 1994; Siemann & Creasy, 1992). The growing interest in *trans*-resveratrol is the result of its claimed role in protecting against coronary heart disease (Mattivi, 1993a, 1993b; Seigneur et al., 1990; Siemann & Creasy, 1992). This potential effect could be due to the ability of resveratrol to inhibit low-density lipoprotein oxidation (Frankel, Waterhouse, & Kinsella, 1993), eicosanoid synthesis (Pace-Asciak, Hahn, Diamandis, Soleas, & Goldberg., 1995; Ruf, 1999) and bloking platelet aggregation (Bertelli et al., 1995; Pace-Asciak et al., 1995), a process that plays an important role in the progression of atherosclerosis, as well as in the final occlusive events leading to myocardial infarction and stroke. It also reduces the levels of triacylglycerol and protects the liver from lipid peroxidation (Shan, Yang, He, Shao, & Zhang, 1990). It has been found to act as a significant antioxidant (Frankel, Waterhouse, & Teissedre, 1995; Murcia & Martínez-Tomé, 2001), and, moreover, possesses anti-inflammatory and anticancer properties: it inhibited the development of preneoplastic lesions in carcinogen-treated mouse mammary glands in culture, and inhibited tumorigenesis in a mouse skin cancer model (Fremont, 2000; Jang et al., 2000). All

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0308-8146/$ - see front matter
doi:10.1016/j.foodchem.2004.08.034

these effects on human health justify the interest in studying this substance.

In addition to the *trans*-isomer, first detected, other forms of this trihydroxystilbene have been found only in wine. The next to be described was *cis*-resveratrol (Goldberg et al., 1995a; Jeandet, Bessis, Maume, & Sbaghi, 1993; Soleas et al., 1995), which in some wines is in higher concentration than the *trans*-isomer (Jeandet, Bessis, Sbaghi, Meunier, & Trollat, 1995; Soleas et al., 1995). Later, the piceid (3-β-glucoside) of *trans*-resveratrol was identified (Jeandet et al., 1994; Roggero & Archie, 1994). Piceid was isolated and structurally characterized in the roots of the medicinal plant *Polygonum cuspidatum*, used in Asia as a treatment for atherosclerosis (Kimura, Okuda, & Arichi, 1985; Shan et al., 1990), and was used for confirming its presence in grape skin (Waterhouse & Lamuela-Raventós). The glucosides of both isomers were also reported as red wine constituents (Goldberg et al., 1995; Lamuela-Raventós, Romero-Pérez, Waterhouse, & de la Torre- Boronat, 1995). Nowadays the presence of the piceids: the 3-β-glycoside of *trans*-resveratrol together with its isomer *cis*-, is of a great importance and appears to be one of the beneficial factors conferring a protective effect against cardiovascular disease through red wine ingestion (Adrian et al., 2000; Martınez-Ortega, Garcia Parrilla, & Troncoso, 2000; Waterhouse & Lamuela-Raventós, 1994). Their concentration can be of the same order of magnitude or even superior to that of the free forms (Ribeiro de Lima et al., 1999; Romero-Pérez, Lamuela-Raventós, Waterhouse, & de la Torre-Boronat, 1996), and the effects of these derived forms on health can be very important (Kimura & Okuda, 2000).

Since *cis*-resveratrol has not been detected in grape skins or juices, it appears to be formed from the isomerization of *trans*-resveratrol or the breakdown of resveratrol polymers during skin fermentation (Roggero, 1996; Soleas et al., 1995).

Resveratrol contents in red wines are higher than those present in rosé wines; likewise rosé wines present a higher resveratrol level than white wines (Mattivi, 1993b). This difference in concentrations is linked to the winemaking process, especially to the contact of wine with the solid parts of the grape, since resveratrol is found in the skin but not in the flesh (Creasy & Coffee, 1988).

Many studies have been carried out on the contents of *trans*-resveratrol in red wines. Among them, the following may be indicated: Jeandet et al. (1993) obtained an interval of resveratrol content ranging from 0.4 to 2.0 mg/l in French wines; in Italian wines, Mattivi (1993b) measured concentrations up to 7.17 mg/l in wines from Trentino and Dell'Oro, Cravero, and Moraglio (1997) found a mean resveratrol concentration of 2.09 mg/l in wines from Piedmont. McMurtrey et al. (1994) studied California wines, obtaining a mean content of 0.99 mg/l; Lamuela-Raventós et al. (1995) obtained results ranging from 0.60 to 8.00 mg/l in Spanish wines, and Goldberg et al. (1995b) found mean concentrations of 3.16 mg/l for Canadian wines, 1.47 mg/l for Californian and Australian wines, 1.21 mg/l in South America wines and 1.76 mg/l for Italian wines. They also reported mean contents of 2.88 and 3.89 mg/l for Beaujolais and Bordeaux wines. In Spanish and Portuguese wines they found a mean of 1.64 mg/l.

Japanese wines appeared to have a very low content of *trans*-resveratrol (0.08–0.244 mg/l, Okuda & Yokotsuka, 1996). Recently, Greek wines were also studied (Kallithraka, Arvanitoyannis, El-Zajouli, & Kefalas, 2001), the levels being between 0.550 and 2.534 mg/l, similar to those of Spanish, Italian, Portuguese, French and Californian wines. Finally, Baptista, da Tavares, and Carvalho (2001) reported a comparison between red wines from the Portuguese mainland vs Azores Islands, showing higher resveratrol levels for the Azorean wines (3.36 mg/l) than for Portuguese mainland wines (1.56 mg/l).

In rosé wines, this compound presented an average level of 0.41 mg/l in Spanish wines, ranging from 0.07 to 1.06 mg/l (Romero-Pérez et al., 1996), very similar to those described by Mattivi (1993b) in Trentino wines, ranging from 0.05 to 1.19 mg/l.

For the *cis*-isomer, fewer reports have emerged. Jeandet et al. (1993) reported range of 0.19–1.30 mg/l in Burgundy wines; Lamuela-Raventós et al. (1995) found range of 0.11–2.48 mg/l for Spanish red wines and Gonzalo et al., (1997) obtained an average of 1.33 mg/l in Cataluña red wines. Ribeiro de Lima et al. (1999) found the highest mean value (2.6 mg/l) in Portuguese red wines. In Spanish rosé wines, an average of 0.41 mg/l was obtained by Romero-Pérez et al. (1996), who considered different types of grape varieties, while an average of 0.58 mg/l was found by Gonzalo et al., 1997) in Cataluña wines.

According to Goldberg et al. (1995b), the climatic conditions of Bordeaux and Ontario make their wines have higher resveratrol concentrations than those from Spain or from Italy, which are subject to warmer and drier conditions. However, they found that Rhone Valley wines have high resveratrol contents, although it is a warm and dry region. To explain this apparent contradiction, they suggested that these differences of concentrations between wines from regions of climatic similarity were due to the intrinsic resveratrol-synthesizing capacity of the different cultivars employed.

Not only can environmental factors affect resveratrol contents, but also the concentration of resveratrol in wine varies considerably and appears to depend on the grape variety. Lamuela-Raventós et al. (1995) found, in Spanish red wines made from Pinot noir grapes, a high level of *trans*-resveratrol, averaging 5.13 mg/l compared to 2.43 mg/l for Garnacha, 1.42 mg/l for Cabernet

Sauvignon and 1.33 mg/l for Tempranillo. The *cis*-resveratrol levels were also higher for Pinot noir (1.12 mg/l), followed by Garnacha (0.43 mg/l), Cabernet Sauvignon (0.29 mg/l) and Tempranillo (0.28 mg/l). In Californian wines, Cabernet Sauvignon appeared to have the lowest levels of *trans*-resveratrol (2.55 mg/l) (Goldberg et al., 1995; Lamuela-Raventós & Waterhouse, 1993; McMurtrey et al., 1994). Likewise, Roggero and Archie (1994) found, in French commercial red wines, higher concentrations in Cabernet Sauvignon (1.1 mg/l) than in Garnacha (0.3 mg/l).

At the present time there are no reports in the literature about *trans* and *cis*-resveratrol content in wines from Aragón. As far as the authors are aware, for Spanish wines, there is only one recent study (Rodriguez-Delgado et al., 2002) concerning only the *trans*-resveratrol content in different wines of some designations of origin from the Canary Islands.

Our work corresponds to a two-year project, the aim of which was to determine the *cis*- and *trans*-isomer resveratrol concentrations in red and rosé wines produced in the four designations of origin of Aragón (Borja, Calatayud, Cariñena and Somontano), and to characterize them, depending on the resveratrol content. Although we have knowledge of the above-mentioned importance of glucosides in recent years, in this report we will only comment upon them, leaving their study for later research.

Making the most of these results we also investigated the grape variety and vintage effects in each designation of origin. Finally, we carried out a discriminant study on wines of the same vintage (young wines), considering all designations of origin together, in order to find whether there were significant differences among the wines of these designations of origin.

2. Materials and methods

2.1. Standards

trans-Resveratrol was purchased from Sigma Chemical Co. The *cis*-resveratrol standard was prepared by UV-irradiation of *trans*-resveratrol for 2 h in a UV box at 254 nm (model Saga).

2.2. Samples

The samples were 98 bottled commercial wines from different grape varieties and vintages of the four designations of origin of Aragón, analyzed during 2 years of study. This sampling represents more than 80% of the production. Most rosé wines were from Garnacha. Red wines were made from the grape varieties Garnacha, Tempranillo, Cabernet Sauvignon and Moristel. The rest of the red wines were blends of some of these varieties and constitute most of the aged wines. Red and rosé winemaking and red wine-ageing processes are similar in all Aragón wineries. All rosé wines were young. Red wine samples were separated into two groups: young wines (Y), not matured in cask, and aged wines (A), matured in cask. The number of samples of these aged wines is not very high, because not all wineries carry out ageing processes as, generally, Garnacha red wines have no ageing potential.

2.3. HPLC analysis

The analysis was carried out using an HPLC system, KONTRON (Model 440), with a diode array UV–visible detector controlled by an Acer 486 PC with KONTRON Data System 450-MT2/DAD Series software. A reversed-phase column Tracer Nucleosil,C_{18} 120 (25×0.4 cm), 5 μm particle size, with a precolumn (1×5 cm) of the same material was used; the column heater temperature was maintained at 40 °C. Injection was performed by means of a Rheodine injection valve (Model Valco C6W) with a 100 μl fixed loop coupled to an autosampler (Model 360).

The elution was performed under binary gradient conditions. Pump A: glacial acetic 12 in water (pH 2.4) and Pump B: phase A/acetonitrile (20:80). The gradient profile was 0 min 18% B; 11 min, 18% B; 18 min, 23% B; 31 min, 100% B. The flow-rate was 1.5 ml/min.

The eluate was monitored at two different wavelengths, 285 and 306 nm, where *cis*- and *trans*-isomers have absorbance maxima, respectively.

2.4. Analysis of data

A SPSS 10.0 statistical package was used for this analysis. An initial exploratory analysis was carried out to compare the results of the four designations of origin. The Turkey–Kramer multiple range test was applied to compare resveratrol concentration means. A discriminant analysis was applied to the *trans*-, *cis*- and total resveratrol concentrations, after checking the validity of this procedure by estimating the skewness and kurtosis indices of the data sets.

3. Results and discussion

Fig. 1 shows the chromatogram relevant to a red wine, where the peaks of *trans*- and *cis*-resveratrol are signaled. These peaks appear at 16.6 and 23.5 min, respectively. Other compounds, such as *trans*- and *cis*-piceid are shown (7 and 13.5 min), but they have not been quantified because they were not a matter of study for us at that moment.

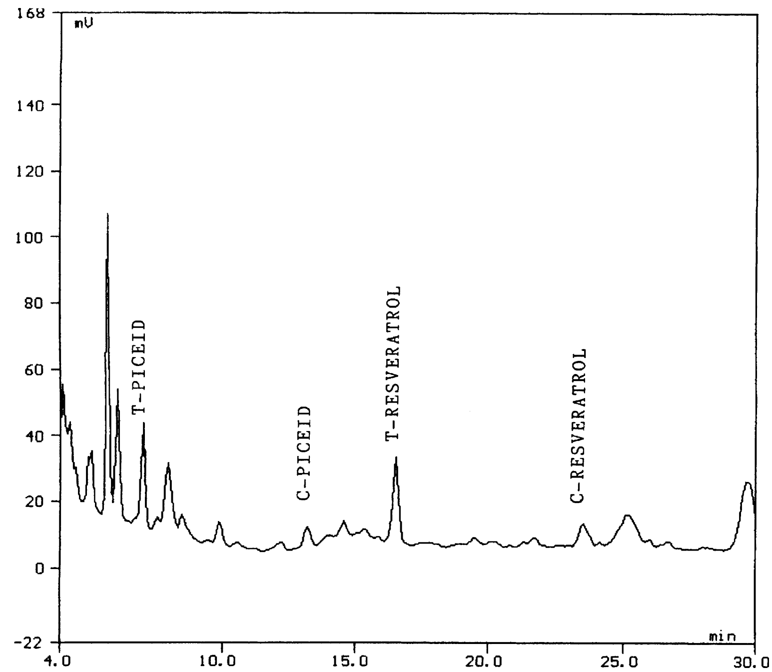

Fig. 1. Chromatogram of a red wine obtained by separation on a 5 μm C18 column using a mobile phase of 20% glacial acetic in water/80% acetonitrile at a flow rate of 1.5 ml/min, monitoring the eluant at 306 nm. Retention times: *trans*-resveratrol, 16.6 min; *cis*-resveratrol, 23.5 min.

Results of *trans*- and *cis*-resveratrol contents in red and rosé wines, respectively, are shown in Tables 1 and 2. Means and standard deviations of the concentrations are expressed in mg/l. For most red wines, these results are similar to those found by Goldberg et al. (1995b) and also Jeandet et al. (1993), Kallithraka et al. (2001), Lamuela-Raventós et al. (1995) and Mattivi (1993b). However, our mean contents are lower than those shown in wines from the Canary Islands (Rodríguez-Delgado et al., 2002), despite the presence in these wines of two very similar varieties, such as "listan negro" (from Canary Islands) and Tempranillo (from Spanish mainland).

If the concentrations of both isomers among designations of origin are compared, the Calatayud wines stand out for their high content in both isomers. These concentrations reach nearly twice the values of the others and the differences were significant in *trans*- and total resveratrol contents.

Table 1
Concentrations of resveratrol in red wines (mg/l)

	trans-Resveratrol	*cis*-Resveratrol	Total resveratrol
D.O.[b]	Means ± SD[c]	Means ± SD[c]	Means ± SD[c]
Borja (*n* = 24)	1.01 ± 0.45[1a]	0.74 ± 0.62	1.74 ± 1.02[13]
Calatayud (*n* = 19)	2.33 ± 1.06[2]	1.27 ± 1.12	3.60 ± 1.73[24]
Cariñena (*n* = 13)	1.43 ± 0.39[1]	1.38 ± 1.38	2.81 ± 1.40[34]
Somontano (*n* = 18)	1.21 ± 0.59[1]	0.65 ± 0.43	1.86 ± 0.93[13]

n = total number of samples.
[a] Means within a column followed by a different number are significantly different at the 0.05 level as determined by the Tukey–Kramer test.
[b] D.O., designation of origin.
[c] SD, standard deviation.

Table 2
Concentrations of resveratrol in rosé wines (mg/l)

	trans-Resveratrol	*cis*-Resveratrol	Total resveratrol
D.O.[b]	Means ± SD[c]	Means ± SD[c]	Means ± SD[c]
Borja (*n* = 6)	0.47 ± 0.30[1a]	0.51 ± 0.13	0.99 ± 0.21
Calatayud (*n* = 7)	1.21 ± 0.89[2]	1.34 ± 1.09	2.54 ± 1.51[1]
Cariñena (*n* = 5)	0.50 ± 0.25[1]	0.72 ± 0.43	1.12 ± 0.42
Somontano (*n* = 6)	0.38 ± 0.17[1]	0.47 ± 0.56	0.85 ± 0.72[2]

n = total number of samples.
[a] Means within a column followed by a different number are significantly different at the 0.05 level as determined by the Tukey–Kramer test.
[b] D.O., designation of origin.
[c] SD, standard deviation.

The higher content of resveratrol in Calatayud wines could be due to a more extreme environmental stress of the vineyards, because they are located at a height of about 800 m, while the height of the other designations of origin is lower and their climatic conditions are warmer.

On the other hand, we have grouped the wines, depending on their grape variety. *trans*-, *cis*- and total resveratrol concentrations are shown in Table 3. Red blended wines presented different amounts from those in varietal wines of the same designation of origin. This result could be due to the different climatic conditions of each vintage and/or to the effect of ageing, as has been

Table 3
Resveratrol contents (mg/l) depending on their cultivar for each designation of origin

D.O.[b]	Type	Grape variety	*trans-R*	*cis-R.*	Total R	Ratio (t/c)
Borja	Red (*n* = 24)	Tempranillo (*n* = 4)	0.55[1a]	0.28[1]	0.83[1]	1.96
		Garnacha (*n* = 7)	0.83[1]	0.35[1]	1.18[1]	2.40
		Cabernet Sauvignon (*n* = l)	0.70	0.28	0.92	2.50
		Blended (*n* = 12)	1.28[2]	1.15[2]	2.44[2]	1.10
	Rosé (*n* = 6)	Garnacha (*n* = 6)	0.47	0.51	0.99	0.92
Calatayud	Red (*n* = 19)	Tempranillo (*n* = 7)	2.46	0.86	3.32	2.90
		Garnacha (*n* = 7)	2.57	2.05	4.62	1.25
		Blended (*n* = 5)	1.82	0.75	2.75	2.40
	Rosé (*n* = 7)	Tempranillo (*n* = 3)	0.76	0.70	1.46	1.10
		Garnacha (*n* = 4)	1.76	1.15	2.91	1.53
Cariñena	Red (*n* = 13)	Tempranillo (*n* = l)	1.65	1.22	2.87	1.40
		Garnacha (*n* = l)	1.27	1.12	2.39	1.10
		Cabernet Sauvignon (*n* = l)	0.92	1.01	1.93	0.90
		Blended (*n* = 10)	1.50	1.50	3.00	1.00
	Rosé (*n* = 5)	Garnacha (*n* = 5)	0.49	0.72	1.22	0.70
Somontano	Red (*n* = 18)	Tempranillo (*n* = l)	1.80	0.40	2.20	4.50
		Moristel (*n* = 2)	1.60	0.92	2.52	1.70
		Cabernet Sauvignon (*n* = 2)	1.04	0.61	1.66	1.70
		Blended (*n* = 13)	1.13	0.64	1.77	1.70
	Rosé (*n* = 6)	Cabernet Sauvignon (*n* = l)	0.64	1.56	2.20	0.40
		Blended (*n* = 5)	0.32	0.26	0.58	1.20

n = total number of samples.
[a] Means with in a column followed by a different number are significantly different at the 0.05 level as determined by the Tukey–Kramer test.
[b] D.O., designation of origin.

indicated by other authors (Goldberg et al., 1995b; Roggero, 1996). In Borja and Calatayud red wines, the grape variety Garnacha had higher amounts of these compounds than did the grape variety Tempranillo. These results are in agreement, qualitatively, with those found by Lamuela-Raventós et al. (1995). In Borja red wines, significant differences were found in resveratrol concentrations between single-varietal Tempranillo wines and blended wines and between Garnacha and blended wines, whereas very little difference was detected between Tempranillo and Garnacha wines; however between Calatayud red wines, significant differences were not detected. In other designations of origin, the multiple range test is not useful, because some groups have only one sample. In spite of this unrepresentative sampling, we can observe, in Cariñena and Somontano red wines, that the lowest levels were found in Cabernet Sauvignon for both designations of origin. The highest *trans*/*cis* ratio was found in Somontano (4.50) and Calatayud wines (2.90), both of the Tempranillo variety. Generally, high ratios of *trans*/*cis* isomers support the ideal that resveratrol is produced as a *trans*-isomer and that the *cis*-isomer is derived by isomerization of the *trans*-isomer, mainly during fermentation, but this phenomenon is not clearly understood (Baptista et al., 2001).

Rosé wines contain lower resveratrol amounts than red wines, as other authors have reported (Mattivi, 1993b; Romero-Pérez et al., 1996). Calatayud rosé wines are again those that presented the highest resveratrol contents and a higher ratio of *trans*/*cis* than Borja and Cariñena wines. On the other hand, in Borja and Cariñena rosé wines of the grape variety Garnacha, the *trans*/*cis* proportions are opposite to those of Garnacha red wines, because the *cis*-resveratrol content is higher than the *trans*-resveratrol content. The same occurs with the variety Cabernet Sauvignon in Somontano rosé wines.

Table 4 shows the comparison of resveratrol content between young wines and the different aged red wines. There were appreciable reductions of *trans*-, *cis*- and total resveratrol concentrations in aged wines in the Somontano and Calatayud designation of origin, as did other authors (Jeandet et al., 1991; Lamuela-Raventós et al., 1995). However, in Borja and Calatayud aged wines, these concentrations were slightly higher. Due to the fact that, in the two years duration of this project, it was not possible to carry out an ageing study of a wine, we cannot report about its effect on resveratrol content. Therefore, these differences in resveratrol contents could be attributed to the different climatic conditions of each vintage.

In order to see whether the differences of resveratrol concentrations could be used to characterize each designation of origin, a discriminant analysis was applied to *trans*-, *cis*- and total resveratrol contents. First, red wines and rosé wines were considered separately. No discriminant variables were found in rosé wines.

Table 4
Average concentrations of resveratrol for red wines with different ageing (mg/l)

D.O.[a]	No. samples	Wine ageing[b]	*trans*-Resveratrol	*cis*-Resveratrol	Total resveratrol
Borja	17	Y	0.93	0.66	1.60
$n = 24$	7	A	1.18	0.91	2.09
Calatayud	15	Y	3.09	1.61	4.69
$n = 19$	4	A	1.66	0.96	2.62
Cariñena	6	Y	1.48	1.11	2.59
$n = 13$	7	A	1.43	1.60	2.95
Somontano	10	Y	1.57	0.85	2.42
$n = 18$	8	A	0.62	0.39	1.01

n = total number of samples.
[a] D.O., designation of origin.
[b] Y, young wines; A, ageing wines.

A discriminant analysis among designations of origin was then applied to all red wines. Only the *trans*-resveratrol variable was selected, because a high correlation ($r > 0.7$) between *trans*-resveratrol and total resveratrol was found, whilst *cis*-resveratrol was rejected as a discriminant variable. A much lower correlation ($r \approx 0.3$) was found between *trans*- and *cis*-isomers. A very low percentage of correctly classified cases was found (47.39%).

In order to avoid data dispersion, the analysis was repeated, considering only young red wines. *trans*-Resveratrol content was again the most discriminating variable. Similar correlations between *trans*-resveratrol and total resveratrol and between *trans*- and *cis*-resveratrol were found. The percentage of cases correctly classified reached 60.40%, as can be seen in Table 5.

Because of the high resveratrol content in Calatayud wines, which could lead to a biased statistic, the discriminant analysis was applied only to the other three designations of origin, obtaining a percentage of correctly classified cases of 63.60%, which was similar to the previous results.

In every analysis, Cariñena and Somontano wines presented the worst classification. Most of these wines were assigned to other designations of origin (Table 5). Although geographical origin often seems to be a determinant factor in the level of resveratrol in wine (Siemann & Creasy, 1992), our results show that there is not an acceptable discrimination among the wines of the different designations of origin of Aragón. A similar result was found by Rodríguez-Delgado et al. (2002) in 58 red wines of different designations of origin from the Canary Islands.

Table 5
Classification results for young red wines (%)

	1	2	3	4	total
1	13	0	1	3	17
	76.5[a]	0.0[a]	5.9[a]	17.6[a]	100[a]
2	1	10	2	2	15
	6.7[a]	66.7[a]	13.3[a]	13.3[a]	100[a]
3	1	0	2	3	6
	16.7[a]	0.0[a]	33.3[a]	50.0[a]	100[a]
4	3	2	1	4	10
	30.0[a]	20.0[a]	10.0[a]	40.0[a]	100[a]

Discriminant analysis results using *trans*- *cis*- and total resveratrol as variables. Columns indicate predicted group membership. Files indicate the actual group.
[a] Classification expressed in percentage. Designation of origin: 1 – Borja; 2 – Calatayud; 3 – Cariñena; 4 – Somontano.

4. Conclusions

For Aragón wines, resveratrol concentrations were formed of the same order of magnitude as those found by other authors in wines from California, Australia, Italy and Portugal (Goldberg et al., 1995b; Mattivi, 1993b), France (Jeandet et al., 1993) and, Greece (Kallithraka et al., 2001), but lower concentration than those found in wines from the Canary Islands (Rodríguez-Delgado et al., 2002) and Azores Islands (Baptista et al., 2001); both archipelagoes have in common an Atlantic climate with mild temperatures throughout the year.

Young Calatayud wines present the highest resveratrol concentrations of the four designations of origin. Concentration of resveratrol appears to be influenced by grape variety, Garnacha being the most outstanding grape variety in wines of Aragón. In Garnacha rosé wines, the *trans*/*cis*-resveratrol ratio is opposite to that of Garnacha red wines, which could be due to the different winemaking processes that contribute to *cis*-isomer formation. Because resveratrol contents in Aragón aged red wines appeared to be highly variable, it is possible that resveratrol contents of these wines are principally influenced by the climatic conditions of each vintage. According to the discriminant analysis by resveratrol content, there is no appreciable discrimination among wines from the four Aragón designations of origin, as was found in red wines from the Canary Islands.

Acknowledgements

The authors wish to express their gratitude to the Diputación General de Aragón (DGA) for the financial support (PCA 1594 project) and to the Canary Islands Government for the grant to Manuela Abril.

They also thank the wineries and the Consejos Reguladores de Denominación de Origen of Borja, Cariñena, Calatayud and Somontano for supplying the samples.

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