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Aroma components of Galician Albariño, Loureira and Godello wines

by

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S u m m a r y : Wines of the three most interesting Galician white grape varieties have been deeply analyzed for three aroma categories: the volatile compounds, except for monoterpenols, the monoterpenols and the bound forms. Many compounds showed significant differences between the wine groups, as proved by Tukey's test, e.g. for methanol, *trans* and *cis* 3-hexen-1-ols and relevant ratio, benzaldehyde and 4-vinylguaiacol in the first category, and for the most part of compounds of the other two categories.

Loureira and most Albariño wines contain linalool and ho-trienol at a level of sensorial contribution. The relevant average terpene profiles show many similarites, especially for Albariño and particularly if considering the contents and relevant ratios of furan and pyran linalool oxide isomers, of ho-diendiols I and II and of geraniol. On the other hand differences could be stated for some compounds, mostly under the bound forms. Godello wines, with the poorest content of monoterpenols under both forms, are principally characterized by a marked level of bound benzaldehyde, with contemporary presence of a considerable average level of the free form.

PCA data treatments on both monoterpenols and aglycons from the bound forms, showed a good separation among the groups as well a good homogeneity and varietal correspondence of the wines.

K e y w o r d s : aroma compounds, monoterpenols, bound forms, Galician wines, classification.

Introduction

Particular attention has been devoted in the last years to the analytical characterization and to the quality improvement, especially through the skin-contact technique, of the varietal aroma of certain white wines from the northwest region of Spain, mainly of Albariño and Loureira cultivars, both typical for a floral note (ORTEGA HERNANDEZ-AGERO *et al.* 1991; ORRIOLS and MORENO CAMACHO 1992; PEREZ FERNANDEZ *et al.* 1992; GARCIA JARES *et al.* 1993).

An interesting presence of linalool in a concentration of 20-50 μg/l for Albariño musts and approximately 5-8 times more for Loureira musts was found. This compound contributes to the sensorial difference between the two products; the content of other monoterpenols like α-terpineol, geraniol, nerol and citronellol resulted not higher than 10-20 μg/l. Godello and other monovarietal Galician wines seem not to show any marked monoterpenic content and character (ORRIOLS *et al.* 1993).

In this research on the aroma components of wines of the mentioned varieties, we focused the attention principally to compounds possibly linked to varietal peculiarities, extending in particular the investigation to other monoterpenols and to the bound forms, with the aim to improve the characterization and classification of the wines.

Materials and methods

11 Albariño and 6 Godello wines of 1992 vintage, available on the market, and varietal products (3 Albariño, 2 Loureira - representative of a small production area close to the Portuguese border - and 1 Godello) obtained with the same technology in the experimental cellar of the Oenological Institute of Leiro, Spain, were analyzed in July and August 1993.

All samples, added with 250 μg/l of 2-octanol as internal standard, were submitted to a 10 h liquid-liquid aroma extraction with pentane-dichloromethane, 2:1, v/v, (quantification of most volatiles, in particular more polar fermentation products; 350 ml wine with 50 ml organic solvent - DRAWERT and RAPP 1968) and to a fractionation (100 ml wine) on XAD-2 resin of the free and bound aroma parts (according to GUNATA *et al.* 1985) modified by percoling the free forms with pentane/dichloromethane, 2:1, v/v (90 ml), and the bound with ethyl acetate/methanol, 9:1, v/v (80 ml), (VERSINI *et al.* 1993 a). Among the free forms from XAD-2 enrichment, only the monoterpenols were quantified. The bound fraction, concentrated to dryness, reacted for 12 h at 40 °C with Rohapect C enzyme (Röhm, Darmstadt) in 3 ml citrate buffer at pH 5, then added with the same internal standard and extracted three times with 3 ml pentane/dichloromethane.

All compounds from XAD-2 fractionations were quantified as 2-octanol, except for the diols evaluated as 2,6-dimethyl-3,7-octadiene-2,6-diol (ho-diendiol I).

G a s c h r o m a t o g r a p h i c a n a l y s e s : Methanol, higher alcohols, acetaldehyde and ethyl acetate were determined with a packed column by injection of the 1:1 distillate of the wine at pH 7 (SALVAGIOTTO *et al.* 1981).

Detailed GC and GC-MS analytical conditions for aroma extractes were reported previously (VERSINI *et al.* 1988). Some monoterpenols, above all those present in very small quantities or those for which the relevant peaks are not

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well resolved from others as often happens for *trans* and *cis* furan and *cis* pyran linalool oxides, nerol, 2,6-dimethyl-1,7-octadiene-3,6-diol (ho-diendiol II) and *trans* and *cis* 2,6-dimethyl-2,7-octadiene-1,6-diols (8-hydroxylinalool) under free forms, were quantified by happens GC-SIM/MS analysis, integrating specific ions and relating the values to those corresponding to other compounds found also by FID-GC.

In particular, all oxides were related to the *trans* pyran linalool oxide, the nerol to the geraniol and the ho-diendiol II, as well as the 8-hydroxylinalool isomers to ho-diendiol I.

Statistical evaluation of the data was carried out by using SAS package.

Results and discussion

Volatile compounds, except monoterpenols. In Tab. 1, the concentration variability of the compounds, which ranges generally within an interval typical for technologically well elaborated young fruity products, is considered in relation to the variety denomination category of wines. The significance of the discrimination level on the basis of the Tukey test, is also reported, taking into account for such comparison, in few cases, a more homogeneous subgroup of values purged from some outliers. Among the discriminating compounds and particularly those having values depending to a lower extent on fermentation conditions and that are almost unchanged during ageing, we would like to give prominence to the differences in *trans* and *cis* 3-hexen-1-ol and methanol contents.

The Albariño products prove to be characterized by a higher level of *cis* than of *trans* 3-hexen-1-ol. This fact has also been verified in 5 commercial Albariño wines from 1987, '88 and '89 vintages, but only at times in the literature (ORRIOLS and MORENO CAMACHO 1991, 1992). At variance, the Loureira and, except for one case, the Godello wines, present a more marked *trans* isomer, a tendency already found for Italian Soave wines obtained from the Garganega variety (MORET *et al.* 1987), for Traminer

Table 1

Volatile compounds, except for monoterpenols, in Galician wines. For each variety the number of samples, the mean content (x) and the standard deviation (σ) for each compound are reported; in few cases outliers or minority subgroups are evidenced. Possibly, the cases of significant (> 95 %) differences between the groups on the basis of the Tukey test, are indicated by using different letters in the right columns, each one referred to the cited varieties: A = Albariño, G = Godello, L = Loureira

COMPOUND (mg/l)	ALBARINO (14)		GODELLO (7)		LOUREIRA (2)		A	G	L
	x	σ	x	σ	x	σ			
METHANOL	34.5^{12}	4.86	21.3^{5}	5.60	19.5	2.79	a	b	b
	62.5^{2}	11.81	43.4^{2}	7.32					
1-PROPANOL	22.6	9.43	17.9	3.48	32.1	8.56			
2-METHYL-1-PROPANOL	28.1	11.41	27.4	5.73	32.9	14.57			
1-BUTANOL	1.72	0.501	1.76	0.331	1.75	0.354			
2-METHYL-1-BUTANOL	23.7	5.38	27.3	3.83	19.1	1.27			
3-METHYL-1-BUTANOL	148.7	26.66	149.2	19.30	78.9	3.04	a	a	b
1-HEXANOL	1.14	0.672	1.57	0.512	0.867	0.1732			
trans 3-HEXEN-1-OL	0.044	0.0169	0.124	0.0531	0.039	0.0021	a	b	a
cis 3-HEXEN-1-OL	0.130	0.0298	0.094	0.0237	0.016	0.0021	a	b	c
trans / cis 3-HEXEN-1-OL	0.344	0.1302	1.56^{6}	0.436	2.52	0.481	a	b	c
			0.361^{1}						
BENZYL ALCOHOL	0.050	0.0256	0.079	0.0327	0.010	0.0000	ab	a	b
2-PHENYLETHANOL	17.7	4.42	20.2	8.59	11.1	2.93			
3-METHYL-1-PENTANOL	0.040	0.0232	0.033	0.0151	0.010	0.0000			
3-ETHOXY-1-PROPANOL	0.29^{10}	0.193	0.34	0.291	3.7	1.43	a	a	b
	5.5^{4}	1.42							
3-METHYLTHIO-1-PROPANOL	1.35	0.723	1.64	1.125	1.83	0.287			
ACETALDEHYDE	50.6	24.54	52.9	26.48	13.0	2.05			
BENZALDEHYDE	0.005^{12}	0.0037	0.024^{6}	0.0079	0.006	0.0040	a	b	a
	0.053^{2}	0.0329	0.260^{1}						
ETHYL ACETATE	56.5	30.78	35.7	11.85	41.3	1.77			
1,3-PROPANEDIOL MONOACETATE	0.70^{10}	0.182	1.24	0.554	2.5	0.33	a	b	c
	2.7^{4}	1.64							
ISOBUTYL ACETATE	0.014	0.0041	0.017	0.0057	0.019	0.0099			
ISOAMYL ACETATE	1.91	1.935	1.33	0.571	1.40	0.001			
HEXYL ACETATE	0.165	0.1852	0.136	0.0587	0.196	0.0092			
2-PHENYLETHYL ACETATE	0.191	0.1083	0.102	0.0665	0.267	0.0219			
ETHYL BUTYRATE	0.136	0.0332	0.117	0.0350	0.110	0.0000			
ETHYL HEXANOATE	0.844	0.1475	0.777	0.1359	0.515	0.0071	a	ab	b
ETHYL OCTANOATE	0.919	0.1687	0.999	0.1569	0.550	0.0283	a	a	b
ETHYL DECANOATE	0.191	0.0579	0.289	0.0743	0.175	0.0212	a	ab	a
ACETOIN	5.8	6.34	7.2	12.09	0.54	0.233			
ETHYL PYRUVATE	0.25	0.171	0.096	0.0755	0.25	0.184			
ETHYL LACTATE	6.4^{9}	2.57	16.0	9.49	8.1	3.22			
	96.9^{5}	19.93							
DIETHYL SUCCINATE	1.09	0.900	1.23	0.525	0.360	0.0283			
DIETHYL MALATE	6.90	4.945	2.03	1.517	2.78	0.651			
γ-BUTYROLACTONE	4.5	1.21	4.1	0.84	3.4	1.12			
ETHYL 4-HYDROXYBUTYRATE	0.83	0.322	1.72	0.706	0.49	0.000	a	b	c
N-(3-METHYLBUTYL)ACETAMIDE	0.20^{13}	0.206	4.3^{5}	3.30	0.92	0.017	a	b	ab
	4.3^{1}		24.7^{2}	9.23					
4-VINYLGUAIACOL	0.028^{12}	0.0099	0.070	0.0184	0.004	0.0007	a	b	a
	0.084^{2}	0.0163							
4-VINYLPHENOL	0.109	0.0719	0.169	0.1235	0.004	0.0014			
ISOBUTYRIC ACID	0.68	0.398	0.58	0.212	0.58	0.177			
BUTYRIC ACIO	1.21	0.382	1.15	0.409	1.23	0.297			
ISOVALERIC ACID	0.59	0.168	0.65	0.174	0.28	0.042	a	ab	b
HEXANOIC ACID	4.67	0.811	4.83	0.675	3.34	0.028			
OCTANOIC ACID	6.95	1.271	7.67	1.360	5.31	0.177			
DECANOIC ACID	2.09	0.564	2.29	0.555	1.67	0.071			

(VERSINI *et al.* 1991) and Müller-Thurgau (VERSINI *et al.* 1994) wines as well as for those from other Rhine Riesling crossings (VOLKMANN 1989). A higher content of *trans* 3-hexen-1-ol and a lower content of fatty acid ethyl esters - this last aspect also coming out from our research - was found by GUEDES DE PINHO (1993) as typical of Loureira wines of the Vinho Verde region in Portugal, by comparing the products of this variety with others of that area. In our case, however, the average contents of the sum of the 3-hexen-1-ol isomers in Godello and Albariño wines are 3-4 fold higher than that in the less numerous samples of Loureira.

Also the average methanol content, but not that of 1-hexanol, is tendentially higher in Albariño wines than in the other types: this fact, together with the generally very low level of N(3-methylbutyl)acetamide, seems not to support a possible use of the skin contact technology (RAPP *et al.* 1985; BAUMES *et al.* 1989) only for Albariño winemaking.

We emphasize also the possible tendency to a higher level of 4-vinylphenol and 4-vinylguaiacol in Godello and Albariño wines than in Loureira, the relevant maximum values being in correspondence of those of methanol. Also the highest average level of benzaldehyde of ca. 25 µg/l in Godello wines - except one case with 260 µg/l at a possible sensorial relevance (our threshold evaluation is at 0.5-0.7 mg/l) - is to be stressed - in contemporary and very original remarkable presence of its bound form at about 70 µg/l (see below). The mentioned unusual presence of benzaldehyde in one Godello wine, as well as in one of the Albariños (75 µg/l), could be reasonably justified by the benzyl alcohol metabolism of some yeasts (DELFINI *et al.* 1991), or by the action of oxidase enzymes of *Botrytis cinerea* (GOETGHEBEUR *et al.* 1992), working at a more favourable pH than that of wines, like these, with progressed malolactic fermentation. Even if not evident in the final content in wines, these wines could probably have had a higher starting benzyl content than the others, as it is typical for products obtained with the skin contact technique (BAUMES *et al.* 1988), which can be inferred by the contemporary highest contents of methanol and N-(3-methylbutyl)acetamide in their groups.

The splitting of the Albariño wines in two groups as for the low and high levels of 3-ethoxy-1-propanol and 1,3-propanediol monoacetate suggests the prevailing of different yeasts in wine making, the high content being typical, e.g., for certain commercial *Saccharomyces bayanus* strains (unpublished results).

The highest average levels of diethyl malate and of ethyl lactate in Albariño products, can be linked to the typical high acidity and malic acid level (PEREZ FERNANDEZ *et al.* 1992), and therefore to the tendency to favour the malolactic fermentation during the wine-making process.

Free monoterpenols and enzymatically released aglycons. Considerations on the varietal flavour contributors As deducible from the values in Tab. 2, only Albariño and even more markedly Loureira wines, can be confirmed as floral-type products.

According to Meilgaard's suggestion of the sensorial contribution of a substance when its concentration is at least 20 % of the threshold unit (MEILGAARD 1975), linalool is verified as possible marker for the varietal character (TERRIER *et al.* 1972), because of an average value of about 40 µg/l - ranging, in fact, from 5 to 108 µg/l - for Albariño wines compared to about 130 µg/l for the Loureira. It is likely that these contents are inclusive of the contribution of the bound forms, which are easily hydrolyzable glycosides (GUNATA *et al.* 1986) being present, at the time of the analysis, only as residual traces (see aglycon part of Tab. 2). α-Terpineol, showing a generally higher content in correspondence to a higher level of linalool, should be mostly chemically derived from linalool itself and therefore implying its sensorial decrease. Ho-trienol, a lime scenting compound at about 60 µg/l in Albariño and about 60 % lower in Loureira group, and ho-diendiol I, producing ho-trienol and neroloxide during ageing (WILLIAMS *et al.* 1980) and, respectively, at a level of about 600 and 850 µg/l, are to be regarded respectively as further present and potential aroma contributors. In fact, according to SIMPSON (1979), the threshold level of ho-trienol is estimated at about 100 µg/l, like that of linalool.

For Godello wines, no aroma contribution can be found under the monoterpenols in both forms.

Analytical profile peculiarities - *Free forms*: If considering free monoterpenol profile similarities, Albariño and Loureira wines can be considered very close to the Rhine Riesling typology (RAPP *et al.* 1981; VERSINI *et al.* 1993 b). We recall the peculiarity of a small content of geraniol, nerol and citronellol with respect to the linalool, which is typical for all these products, but, principally, the very notable content of ho-diendiol I, clearly prevailing over ho-diendiol II expecially in Albariño and Rhine Riesling, and the dominance of *trans* pyran linalool oxide on the *cis* form as well as the similarity or the dominance of the *trans* pyran linalool oxide on the *cis* and *trans* furan linalool oxides, this last aspect being more remarkable in Loureira wines.

Focusing the attention on the variables more usually considered in literature (*trans* and *cis* furan and pyran linalool oxides, linalool + α-terpineol, ho-trienol, geraniol and ho-diendiol I and II), the Principal Component Analysis (PCA) was used to see the differences among the various samples and to determine which variables were principally involved. The projection on the plane of eigenvectors 1 and 2 (68.6 and 19.0 % of the total variance, respectively) shows a good separation among the varietal groups (Fig. 1). In particular eigenvector 1 is similarly charged by all the variables, while eigenvector 2 mostly by *trans* furan linalool oxide, ho-diendiol I and ho-trienol, opposite to *trans* and *cis* pyran linalool oxides, ho-diendiol II and geraniol.

Bound forms: As for the bound compounds profile (Tab. 2),Albariño and Loureira varieties present some interesting differences with respect to the Rhine Riesling type. Most Albariño wines, differently from Loureira and Rhine Riesling products, contain only traces of bound α-terpineol, p-menth-1-ene-7,8-diol and 2-*exo*-hydroxy-1,8-cineol.

Table 2

Free monoterpenols and aglycons of Galician wines: mean content (x) and standard deviation (σ) for each compound and variety group. Compounds with significant (> 95 %) differences between groups on the basis of Tukey's test are evidenced, as in Tab. 1

COMPOUND (µg/l)	ALBARINO (14) x	ALBARINO (14) σ	GODELLO (7) x	GODELLO (7) σ	LOUREIRA (2) x	LOUREIRA (2) σ	A	G	L
FREE MONOTERPENOLS									
trans FURAN LINALOOL OXIDE	6.8	3.20	2.0	1.16	11.3	0.57	a	b	a
cis FURAN LINALOOL OXIDE	2.1	1.00	0.9	0.58	5.6	0.88	a	b	c
LINALOOL	23.3[11] 82.0[3]	10.65 23.30	5.9	2.35	133.8	15.91	a	b	c
α-TERPINEOL	28.2	17.06	2.5	1.09	95.6	4.31	a	b	c
trans PYRAN LINALOOL OXIDE	12.5	6.34	1.0	0.59	81.5	2.12	a	b	c
cis PYRAN LINALOOL OXIDE	1.6	1.12	0.8	0.46	19.2	0.81	a	a	b
HO-TRIENOL	57.8	14.14	0.5	0.30	28.8	7.42	a	b	c
CITRONELLOL	1.5	1.14	1.7	1.14	0.4	0.14			
NEROL	4.4	3.68	2.4	0.94	21.2	5.23	a	a	b
GERANIOL	6.8	4.89	7.0	2.37	23.2	0.92	a	a	b
2,6-DIMETHYL -3,7-OCTADIENE-2,6-DIOL	581.3	180.39	9.4	6.10	862.0	79.20	a	b	c
2,6-DIMETHYL-7-OCTENE-2,6-DIOL	24.9	9.89	4.8	2.26	67.9	5.37	a	b	c
2,6-DIMETHYL-1,7-OCTADIENE-3,6-DIOL	6.2	8.60	0.5	0.20	51.7	27.12	a	a	b
trans 2,6-DIMETHYL-2,7-OCTADIENE-1,6-DIOL	4.6	2.16	1.6	0.86	10.8	3.89	a	b	c
cis 2,6-DIMETHYL-2,7-OCTADIENE-1,6-DIOL	23.3	16.27	4.0	2.98	9.5	4.95	a	b	ab
AGLYCONS									
trans FURAN LINALOOL OXIDE	52.1	12.29	6.7	3.90	54.8	16.62	a	b	a
cis FURAN LINALOOL OXIDE	13.0	3.52	16.7	7.87	2.8	1.48	a	a	b
LINALOOL	3.1	4.50	0.3	0.17	4.3	0.49			
α-TERPINEOL	2.1	2.60	0.3	0.18	10.7	3.32	a	a	b
HO-TRIENOL	3.8	1.44	0.3	0.25	1.4	0.71	a	b	b
trans PYRAN LINALOOL OXIDE	24.3	6.33	2.9	1.38	8.6	3.68	a	b	b
cis PYRAN LINALOOL OXIDE	2.0	1.38	1.5	0.84	0.6	0.49			
CITRONELLOL	0.5	1.00	0.2	0.21	0.2	0.00			
NEROL	3.3	1.53	1.9	0.80	1.3	0.07			
GERANIOL	26.1	7.14	17.6	4.83	6.0	5.37	a	b	b
trans GERANIC ACID	25.2	8.36	10.0	2.42	4.9	2.47	a	b	b
2-exo-HYDROXY-1,8-CINEOL	0.7	0.47	0.4	0.20	2.4	1.20	a	a	b
2,6-DIMETHYL -3,7-OCTADIENE-2,6-DIOL	52.2	18.49	1.5	0.87	79.0	14.14	a	b	a
2,6-DIMETHYL-7-OCTENE-2,6-DIOL	4.2	1.70	1.5	0.64	5.6	6.15	a	b	ab
2,6-DIMETHYL-1,7-OCTADIENE-3,6-DIOL	7.0	4.23	0.9	1.12	33.0	6.36	a	b	c
2,7-DIMETHYL-7-OCTENE-1,7-DIOL	7.8	4.29	3.8	1.33	3.6	2.76			
trans 2,6-DIMETHYL-2,7-OCTADIENE-1,6-DIOL	107.3	40.60	40.8	5.14	88.5	10.61	a	b	ab
cis 2,6-DIMETHYL-2,7-OCTADIENE-1,6-DIOL	310.8	94.92	39.4	17.81	56.0	0.00	a	b	b
3,7-DIMETHYL-2-OCTENE-1,7-DIOL	23.6	8.47	10.9	4.20	2.8	2.19	a	b	b
p- MENTH-1-ENE-7,8-DIOL	9.5	7.77	2.0	1.96	42.2	1.17	a	b	c
3-OXO-α-IONOL	191.7	65.30	126.4	46.96	88.8	21.57			
BENZALDEHYDE	1.4	2.14	68.0	14.52	1.2	0.07	a	b	a
BENZYL ALCOHOL	108.9	16.77	105.6	22.00	83.3	1.77			
2-PHENYLETHANOL	212.9	66.92	193.8	40.92	161.3	10.96			
1-HEXANOL	42.7	12.01	43.1	10.59	30.3	1.84			
trans 3-HEXEN-1-OL	0.3	0.20	1.0	0.46	0.8	0.18	a	b	ab
cis 3-HEXEN-1-OL	5.7	0.99	9.5	4.40	3.2	1.06	a	b	a
trans 2-HEXEN-1-OL	9.6	7.29	9.6	4.25	15.2	1.56			

Moreover, both aromatic Galician varieties, differently from Rhine Riesling, have more *trans* than *cis* furan linalool oxide, but only the Albariño products, more similarly to those of Rhine Riesling and differently from those of Loureira, show less bound ho-diendiol II and a remarkable content of *cis* 8-hydroxylinalool higher than the *trans* isomer. Such characteristics were confirmed by analyzing must samples.

As for bound terpenols in Godello wines and in view of a possible comparison with those of products from other neutral white grapes, we underlined for all the products, including that with *cis* 3-hexen-1-ol prevailing on the *trans* isomer, an interesting average content of *cis* furan linalool oxide at the same level of the geraniol and widely prevailing on the *trans* isomer. Furthermore, while non-significant quantities of α-terpineol and of its oxidation products like 2-*exo*-hydroxy-1,8-cineol and p-menth-1-ene-7,8-diol were found, considerable and similar contents of the *trans* and *cis* 8-hydroxylinalool were observed.

But, as a singularity for this variety, we put in evidence the average level of benzaldehyde at about 70 µg/l. Such peculiarity seems to be shared with another Spanish variety, not described here, the Maccabeo. The existence of a β-glucosidic linkage of benzaldehyde with glucose can be inferred because the bound form is well hydrolyzed also by using β-glucosidase from almonds (Sigma Chemical Co.).

It is evident that Albariño and Loureira products can be well discriminated from each other and from Godello products, which are poorer in terpenols. This fact is con-

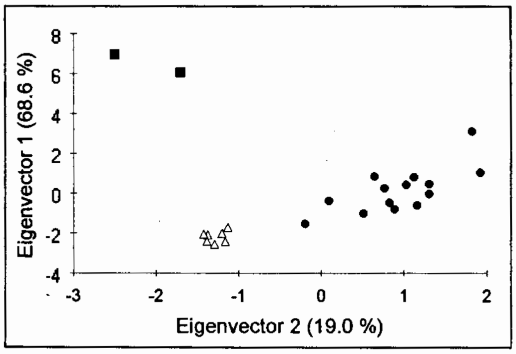

Fig. 1: PCA on 9 free monoterpenols (see the test). Data set wines: scores on eigenvectors 1 and 2. (●) Albariño, (Δ) Godello, (■) Loureira.

firmed by PCA on some of the most discriminating variables (*trans* and *cis* furan and *trans* pyran linalool oxides, α-terpineol, geraniol, ho-diendiol I and II, *trans* and *cis* 8-hydroxylinalool, p-menth-1-ene-7,8-diol and benzaldehyde); the linalool was excluded because referred to a too small residue of its original content as bound form and therefore not representative of it.

The projection on the plane of eigenvectors 1 and 2 (50.3 and 27.8 % of the total variance, respectively) shows a very good separation among the groups as well as a good homogeneity and varietal correspondence of the wines (Fig. 2). In particular, eigenvector 1 is similarly charged by all the variables, but with opposite sign for *cis* furan linalool oxide and benzaldehyde, while eigenvector 2 mostly by *cis* furan and *trans* pyran linalool oxide, geraniol and *cis* 8-hydroxylinalool and, with opposite sign, by α-terpineol, ho-diendiol II and p-menth-1-ene-7,8-diol.

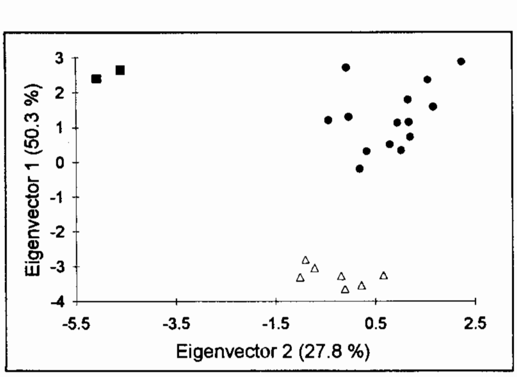

Fig. 2: PCA on 11 bound compounds (see the text). Data set wines: scores on eigenvectors 1 and 2. (●) Albariño, (Δ) Godello, (■) Loureira.

Finally, it must be remarked that, differently from what evidenced for the free forms, the ratio of bound *trans* and *cis* 3-hexen-1-ol is similar for all the varieties and always with a remarkable prevalence of the *cis* isomer. The *trans* 2-hexen-1-ol, at a level similar to that of *cis* 3-hexen-1-ol, is also present under the bound forms, as already observed by BAUMES *et al.* (1989).

Conclusions

A deep analysis of varietal and prefermentative compounds in wines has given us further indications about the possible aroma contributors for the considered Galician products and, at the same time, very useful elements to evidence singularities and analogies with respect to other already studied cultivars, as well as to check the varietal correspondence and homogeneity of the wines on the market, which have been widely verified. We would like to recall the strict analogies, as for the free monoterpenols, of the Albariño and Loureira wines with the Rhine Riesling types. There are, on the contrary, some important differ-ences as regard the bound forms. The remarkable presence of bound benzaldehyde is the very singular peculiarity of Godello products, which are the poorest in monoterpenols under both forms.

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References

BAUMES, R.; BAYONOVE, C.; BARILLÈRE, J. M.; ESCUDIER, J. L.; CORDONNIER, R.; 1988: La macération pelliculaire dans la vinification en blanc. Incidence sur la composante volatile des moûts. Conn. Vigne Vin **22**, 209-223.

--; --; CORDONNIER, R.; TORRES, P.; SEGUIN, A.; 1989: Influence de la macération pelliculaire sur la composante aromatique des vins doux naturels de Muscat. Rev. Franç. Oenol. **29** (116), 6-11.

DELFINI, C.; GAIA, P.; BARDI, L.; MARISCALCO, G.; CONTIERO, M.; PAGLIARA, A.; 1991: Production of benzaldehyde, benzyl alcohol and benzoic acid by yeasts and *Botrytis cinerea* isolated from grape musts and wines. Vitis **30**, 253-263.

DRAWERT, F.; RAPP, A.; 1968: Gas chromatographic analysis of plant aromas. Enrichment, separation and identification of volatile aroma substances in grape, musts and wines. Chromatographia **1**, 446-457.

GABRI, G.; SALVAGIOTTO, R.; 1980: Dosamento gas-cromatografico simultaneo della acetaldeide, del metanolo, dell'acetato e del lattato di etile, e degli alcoli superiori nei distillati alcolici. Vini d'Italia, **22**, 37-43.

GARCIA JARES, C. M.; CARRO MARINO, N.; GARCIA MARTIN, M.S.; CEALA TORRIJOS, R.; 1993: Study of the terpenic profile of monovarietal Albarino wines from Galicia (Spain). In: SANDRA, P. (Ed.): Proc. 15th Intern. Symp. Capillary Chromatography,1302-1306. Dr. A. Hüthig, Heidelberg.

GOETGHEBEUR, M; NICOLAS, M.; BLAISE, A.; GALZY, P.; BRUN, S.; 1992: Etude sur le rôle et l'origine de la benzyl alcool oxydase responsable du goût d'amande amère des vins. Bull. O.I.V. **65**, 345-360.

GUEDES DE PINHO, M. P.; 1993: La discrimination des cépages. In: DONÈCHE, B. (Ed.): Les Acquisitions Récentes en Chromatographie du Vin. Applications à L'analyse Sensorielle des Vins, 221-240. TEC & DOC, Paris.

GUNATA, Y. Z.; BAYONOVE, C.; BAUMES, R.; CORDONNIER, R.; 1985: The aroma of grapes. I. Extraction and determination of free and glicosidally bound fractions of some grape aroma components. J. Chromatogr. **331**, 83-90.

--; --; --; --; 1986. Stability of free and bound fractions of some aroma components of grapes cv. Muscat during the wine processing. Preliminary results. Amer. J. Enol. Viticult. **37**, 112-114.

MEILGAARD, M.C.; 1975: Aroma volatiles in beer: purification, flavour, threshold and interaction. In: DRAWERT, F. (Ed.): Geruch- und Geschmackstoffe, 211-254. H. Carl, Nürnberg, 1975.

MORET, I.; SCARPONI, G.; CESCON, P.; 1984: Aroma components as discriminant parameters in the chemometrics classification of Venetian white wines. J. Sci. Food Agricult. **35**, 1004-1011.

ORRIOLS, I.; ALVAREZ, V.; PEREZ, J.; REGA, J.; 1993: Les cépages blancs de Galice - Albariño, Loreira, Godello, Treixadura - et leurs composés volatils. In: BAYONOVE, C.; CROUZET, J.; FLANZY, C.; MARTIN, J. C.; SAPIS, J. C. (Eds.): Proc. Intern. Symp. "Connaissance Aromatique des Cépages et Qualité des Vins". Montpellier-Le Corum, February 9-10, 1993, 166-171.

--; MORENO CAMACHO, F. M.; 1991: Influencia de las levaduras en la formación de substancias volatiles en la vinificación de la variedad Albariño. Vitivinicultura **2** (6), 21-24.

--; --; 1992: Elaboración de vino Albariño. Incidencia de la maceracion pelicular. Experiencias de 1989 y 1990. Vitivinicultura **3** (1), 41-45.

ORTEGA HERNANDEZ-AGERO, A. P.; LOPERENA DESAA, C.; TIENDA PRIEGO, P.; HIDALGO TOGORES, J.; 1991: Estudio de los aromas varietales de las viniferas Albariño y Loureira. Influencia del sistema de elaboración. Vitivinicultura **2** (6), 38-41.

PEREZ FERNANDEZ, J. E.; REGA PINEIRO, J.; ORRIOLS FERNANDEZ, I.; 1992: "Variedad auctoctonas de cepas gallegas para vinos blancos", JCI-Zeltia Ed., 37-44.

RAPP, A.; KNIPSER, W.; ENGEL, L.; HASTRICH, H.; 1981: Neuere Ergebnisse über die Aromastoffe verschiedener Weine. In: LEMPERLE, E. (Ed.): Proc. 6th Intern. Oenol. Symp., April 28-30, Mainz, 137-147. Intern. Assoc. Winery, Technol. Management, Breisach.

--; GÜNTERT, M.; RIETH, W.; 1985. Einfluß der Maischestandzeit auf die Aromastoffzusammensetzung des Traubenmostes und Weines. Dt. Lebensm. Rundsch. **81**, 69-72.

SIMPSON, R.F.; 1979. Some important aroma components of white wines. Food Technol. Austral. **31**, 516-522.

TERRIER, A.; BOIDRON, J. N.; RIBÉREAU-GAYON, P.; 1972. Teneur en composés terpéniques des raisins de *Vitis vinifera*. C. R. Acad. Sc. Paris Sér. D **275**, 941-944.

VERSINI, G.; DALLA SERRA, A.; DELL'EVA, M.; SCIENZA, A.; RAPP, A.; 1988: Evidence of some glicosidically bound new monoterpenes and norisoprenoids in grapes. In: SCHREIER, P. (Ed.): Bioflavour '87, 161-170. De Gruyter, Berlin.

--; --; MONETTI, F.; DE MICHELI, L.; MATTIVI, F.; 1993 a: Free and bound grape aroma profile variability within the family of Muscat-called varieties. In: BAYONOVE, C.; CROUZET, J.; FLANZY, C.; MARTIN, J. C.; SAPIS, J. C. (Eds.): Proc. Intern. Symp. "Connaissance Aromatique des Cépages et Qualité des Vins". Montpellier-Le Corum, February 9-10, 1993, 12-21.

--; --; SCIENZA, A.; BARCHETTI, P.; 1990: Particolarità compositive dell'uva e del vino Traminer aromatico. Confronto fra cultivar e variazioni a livello terpenico in fermentazione e nell'invecchiamento. In: Proc.. Intern. Symp. Gewürztraminer, 59-71. C.C.I.A.A., Bolzano.

--; NICOLINI, G.; DALLA SERRA, A.; ADAMI, E.; 1994. Peculiarities in aroma profile of Müller Thurgau wines of Trentino (in prep.).

--; RAPP, A.; DALLA SERRA, A.; 1993 b: Consideration about the presence of free and bound p-menth-1-enediols in grape products. In: SCHREIER, P.; WINTERHALTER, P. (Eds.): Progress in Flavour Precursor Studies. Analysis, Generation and Biotechnology, 243-249. Allured Publish. Co., Carol Stream.

VOLKMANN, C.; 1989: Untersuchungen flüchtiger Inhaltsstoffe des Traubenmost- und Weinaromas: Beitrag zur Sortencharakterisierung von Neuzüchtungen mit rieslingähnlicher Aromanote mittels Gaschromatographie/Massenspektrometrie. Diss. Univ. Karlsruhe.

WILLIAMS, P. J.; STRAUSS, C. R.; WILSON, B.; 1980: Hydroxylated linalool derivatives as precursors of volatile monoterpenes of Muscat grapes. J. Agricult. Food Chem. **28**, 766-771.

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