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ORIGINAL PAPER

Effect of different ageing techniques on the polysaccharide and phenolic composition and sensorial characteristics of Chardonnay white wines fermented with different selected *Saccharomyces Cerevisiae* yeast strains

Rubén del Barrio-Galán[1] · Marcela Medel-Marabolí[1] · Álvaro Peña-Neira[1]

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Abstract Polysaccharides, mainly mannoproteins, play an important role on technological and sensory quality of wines. These compounds are released to the wine during alcoholic fermentation and, thereafter, during yeast autolysis in the ageing process. The effect of the ageing on lees and other alternative ageing techniques were studied in Chardonnay Chilean white wines previously fermented with different *Saccharomyces cerevisiae* yeast strains (Zymaflore VL2 and Lalvin CY3079). The Lalvin CY3079 released higher amounts during alcoholic fermentation and during the first stages of the ageing than the Zymaflore VL2, which could produce a positive effect on the colour intensity of wines. Some statistically significant differences on phenolic families and sensory attributes were observed after alcoholic fermentation, during the ageing period and bottle storage, but this depended on the yeast strain used, the ageing technique applied and the period of ageing and bottle storage analysed.

Keywords Polysaccharides · Phenolic compounds · White wines · *Saccharomyces cerevisiae* yeast strains · TDS sensory analysis

Introduction

Over the years, the wine industry has made several efforts in order to continue improving the quality of white wines adapting, on one hand, to the consumers' demand, who demand more complex wines with more fruity, varietals and fresh aromas in nose and balanced in mouth and, on the other hand, extending the range of quality wines [1].

In last few years, several scientific studies have postulated that yeast polysaccharides (mainly mannoproteins) play an important role in the technological and sensorial characteristics of wines. They can improve the tartaric [2] and protein stability [3, 4], reduce wine astringency and bitterness [5–8], enhance the mouthfeel [5, 7, 9] and improve the aromatic complexity and persistence [9–11]. In addition, they can adsorb phenolic compounds [12, 13], preventing the oxidation and, therefore, the formation of browning compounds of white wines [5, 14, 15]. Mannoproteins are released in the wine during alcoholic fermentation [16] and, thereafter, during yeast autolysis [3, 17]. They are synthesised in the cytoplasm of yeasts, but they are not entirely used in the cell wall synthesis [18], and the excess could be released into the must during the alcoholic fermentation [19]. This liberation occurs during the active growth phase of the yeasts, and their final content after alcoholic fermentation depended on the initial concentration of colloids in the must [20]. On the other hand, winemakers have used the ageing of white wines on lees after alcoholic fermentation since several years ago in order to release into the wine higher amounts of polysaccharides (mainly mannoproteins) by the autolytic processes and, thereby, obtaining higher-quality wines. This technique is performed, in most of the cases, in oak barrels increasing the complexity of wines as the oak wood can provide other polysaccharides (different to the yeast polysaccharides) that can improve the sensorial characteristics of the wines [5]. However, this technique also entails a cost that, in some cases and given the current global wine market, nowadays cannot be maintained [21]. This fact forced winemakers to

✉ Rubén del Barrio-Galán
rdelbarriogalan@gmail.com

[1] Department of Agro-Industry and Enology, Faculty of Agronomical Sciences, University of Chile, Post Office Box 1004, Santiago, Chile

search alternative techniques, such as the use of oak wood chips with or without toasting, in order to obtain wines with similar characteristics to those produced in oak barrels but reducing costs. The use of oak wood chips with different toasting levels can provide volatile compounds which can modify the aromatic characteristics of wine and increase the complexity.

However, despite the positive effects referred to above, the liberation of the polysaccharides during the ageing of wines on lees is too slow, because the temperature and pH conditions are not the most suitable for this process [22]. In addition, these techniques can also involve many disadvantages, such as greater demands on winery resources, namely more staff to perform the 'batonnage' and longer wine storage times, which increase the price of the final product, as well as the appearance of reduction notes [23]. The ageing of wines on lees, with or without oak wood chips, may involve some microbiological alterations due to the development of spoilage microorganisms such as *Brettanomyces* [23, 24]. Therefore, commercial yeast derivative products from *Saccharomyces cerevisiae*, such as inactive dry yeasts, are being marketed in order to provide similar benefits as the yeast lees but in a shorter period of time and by reducing their disadvantages [9]. Thus, the wineries can put the wine in the market in a shorter period of time. Inactivated dry yeast belongs to a wide group of yeast derivative products, which presented different structure and chemical composition due to their different inactivation (thermal or enzymatic), extraction and purification processes [25]. Today, we still do not have a complete description of the mechanism of action of yeast derivatives on the composition and quality of wine, but there are recent studies that establish an important basis on their action mode and their effect on the quality of wines [12, 13]. These studies explain the potential implications of the use of some yeast derivatives on winemaking due to their capacity to interact with phenolic compounds.

As mentioned above, yeast cells can release polysaccharides during the wine fermentation which can contribute to the wine quality. Some studies have been carried out in last years in order to isolate and develop yeast strains that secrete higher amounts of mannoproteins using different genetic methods [3, 26]. For this reason, the use of some of these selected yeast strains have gained interest in the wine industry because they are capable of releasing mannoproteins more rapidly into the wine, minimizing production costs as well as the technological and microbiological disadvantages involved in the ageing on lees.

No studies have been found relating to the effect of these techniques on the quality of Chilean white wines. For this reason, the objective of this work was to study the effect of the ageing on lees, with or without oak wood chips, with a commercial inactive dry yeast and previously fermented with different *Saccharomyces cerevisiae* yeast strains, which exhibit different capabilities for polysaccharide release, on the quality of Chardonnay Chilean white wines.

Materials and methods

Winemaking and treatments

All fermentation process was carried out in Santa Carolina Winery. Approximately 100 tons of Chardonnay grapes variety were used and supplied by the winery. The grapes were harvested with 22.6 ± 0.2 °Brix, and the total acidity value was 4.45 ± 0.01 (g L^{-1} of H_2SO_4) and the traditional winemaking process in white wines was followed. The alcoholic fermentation was carried out in two different 40,000-L stainless steel tanks which were inoculated with different *Saccharomyces cerevisiae* yeast strains. One tank, was inoculated with Zymaflore VL2 (Laffort, Bordeaux, France) **(VL2)** and the other with Lalvin CY 3079 (Lallemand-South America, Santiago, Chile) **(CY)** (Fig. 1). Both yeast strains were used in a dose of 30 g HL^{-1}.

Alcoholic fermentation was carried out at a controlled temperature of 16 (±2) °C, and once it was completed, we followed the methodology described by Del Barrio-Galán et al. [21]. Briefly, the wines were racked off to other tanks for 5 days to permit the sedimentation of gross lees, and they were then racked off again. Then, 500 L of each type of fermented wine was transported to the pilot plant of the Department of Agro-industry and Enology of Agronomical Sciences Faculty of Chile University, and the free SO_2 was adjusted to 35 mg L^{-1}. Each type of wine was divided in different 25-L food-grade plastic tanks and stored for 5 days to favour the sedimentation of fine lees. Then, the wines were racked again, and the fine lees were collected. Different treatments were performed in triplicate (Fig. 1) and lasted 6 months: control wines (fermented wines without any treatment) **(C)**; wines treated with fine lees (3 % v/v) **(L)**; wines treated with fine lees (3 % v/v) and French (*Quercus petraea*) oak wood chips (3 g L^{-1} medium-toasted degree of Noble Sweet, l'oenologie du bois (Laffort, France) **(L + CH)**; which have a length between 7 and 20 mm; and wines with commercial inactive dry yeast added (30 g HL^{-1} of OPTILEES supplied by Lallemand-South America, Santiago, Chile) **(CIDY)** that were rich in low molecular weight polysaccharides, mainly mannoproteins (according to the supplier specifications). All the wines were homogenized with lees, chips and commercial inactive dry yeast through two batonnages per week during the first two months. Over the next four months, only one batonnage per week was performed in order to prevent wine oxidation and microbiological alteration. After the

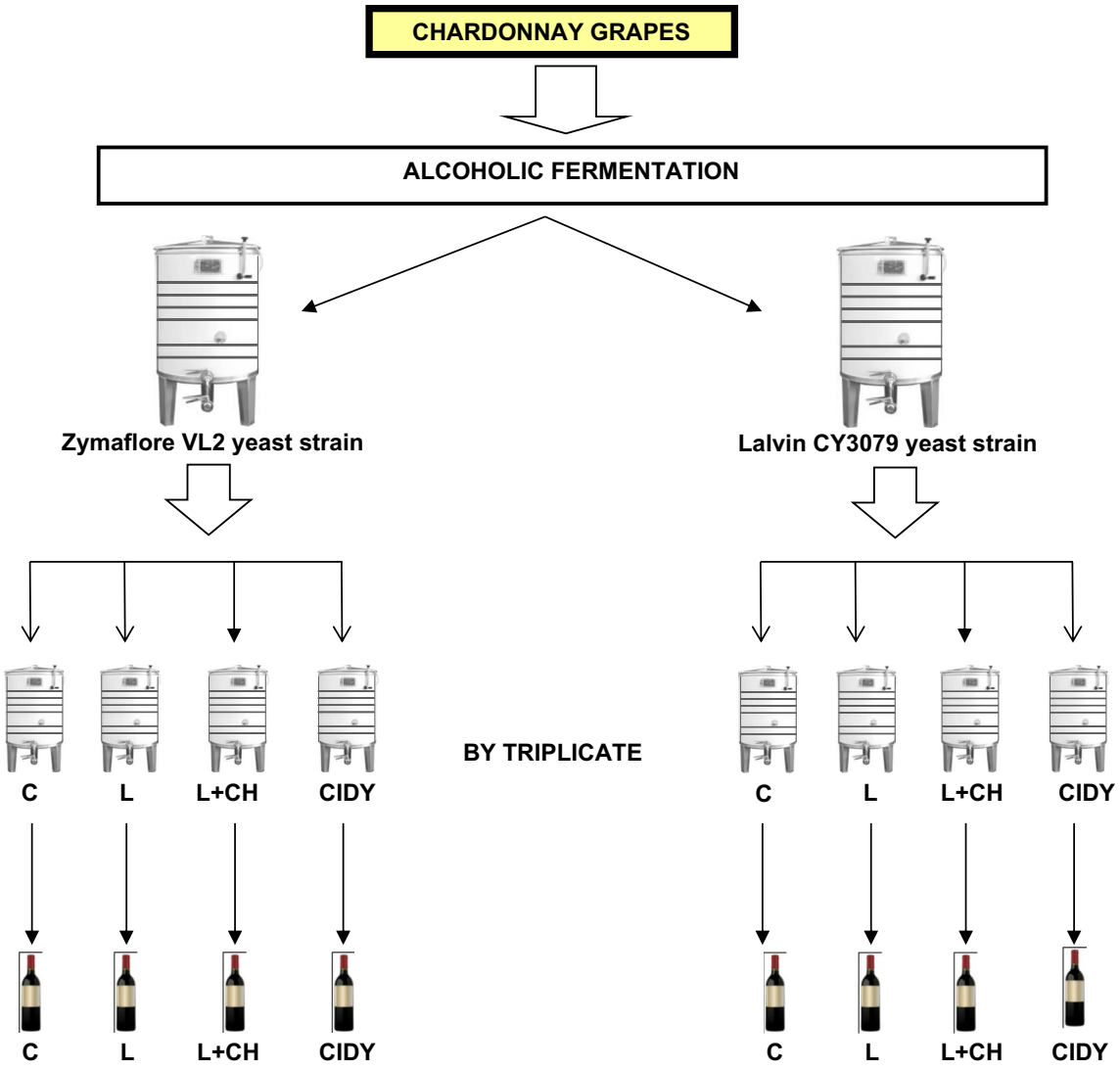

Fig. 1 Scheme of the experiences carried out

ageing period, the wines were filtered and bottled and were stored for 6 months.

Chemical reagents

The standards of gallic, protocatechuic, caffeic, syringic, *p*-coumaric, ferulic, ellagic and caftaric acids, tyrosol, thyptophol, quercetin, myricetin, astilbin, (+)-catechin and (−)-epicatechin, dextrans and pectines were purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO, USA). Polyethylene membranes of 0.45- and 0.22-μm pore size were acquired from EMD Millipore (Billerica, MA, USA). Sodium sulphate (anhydrous), potassium metabisulfite, vanillin (99 %), ethyl acetate, diethyl ether, sodium hydroxide, acetic acid, formic acid, sulphuric acid, ethanol, hydrochloric acid and high-performance liquid chromatography (HPLC)-grade acetonitrile, methanol and ammonium formiate were purchased from Merck (Darmstadt, Germany). All the reagents were of analytical grade or higher.

Analytical methods

Classic oenological parameters were evaluated following official analyses methods [27]. The total (TA) and volatile (VA) acidity, pH (Mettler-Toledo SevenCompact pH/ion S220, Santiago, Chile), SO_2F (sulphur dioxide free) and SO_2T (sulphur dioxide total) and alcoholic degree (A°) were evaluated following the OIV official analytical methods.

The content of total polyphenols [28] and total tannins [29] was expressed as mg L^{-1} of gallic acid and g $L^{-1}$of (+)-catechin, respectively. The colour intensity (CI) was

evaluated by the absorbance at 280 nm using the method described by OIV 2012 [27]. These measurements were performed using a UV/Vis 1700 Pharmaspec spectrophotometer (Shimadzu, Kyoto, Japan).

The polysaccharides were analysed using the methodology described by Ayestarán et al., 2004 [30]. Twenty-five mL of white wine was centrifuged 3500 rpm during 30 min. Then, 10 mL of supernatant was concentrated until 2 mL in a vacuum rotavapour at 35 °C. After that, 10 mL of acid ethanol solution 0.3 M was added to the aliquot of 2 mL of wine in a centrifuge tube and maintained in refrigeration at 4 °C during 24 h to favour the precipitation of polysaccharides. Then, the sample was centrifuged at 3500 rpm during 20 min, and de-supernatant was discarded. The precipitated fraction was washed three times with 0.35 mL refrigerated ethanol and dried at 50 °C. Finally, it was reconstituted with 1 mL of ammonium formiate and filtrated with 0.22-µL membrane in a HPLC vial. HPSEC-RID was performed using an Agilent 1260 Infinity Series liquid chromatograph (Agilent Technologies, Santa Clara, CA, USA) equipped with a G1362A refractive index detector (RID), a G1311B quaternary pump, a G1316A column oven with two Shodex columns, an OHpak SB-803 HQ and a SB-804 HQ (Showa Denko, Tokio, Japan) connected in series (300 mm × 8 mm I.D.), and a G1329A autosampler. The polysaccharides fractions were quantified using dextrans and pectines (*Leuconostoc mesesteroides*) to prepare the calibration curves. The molecular weight distribution of the different polysaccharide fractions was determined by the columns calibration with dextran standards.

Low molecular weight phenolic compounds (non-flavonoids and flavonoids) were analysed using the methodology described in Peña-Neira et al. [31]. 50 mL aliquot of white wine was extracted with diethyl ether (3 × 20 mL) and ethyl acetate (3 × 20 mL) to concentrate the phenolic compounds. The organics fraction were combined, dehydrated with 2.5 g of anhydrous sodium sulphate and evaporated to dryness under a vacuum at 30ºC. The solid residue was dissolved in 2 mL of a methanol/water (1:1, v/v) solution and filtered through a 0.22-µm pore size membrane. Aliquots (25 µL) of the final solution were subjected to reverse-phase chromatographic separation. These compounds were analysed with a HPLC 1100 Series system (Agilent Technologies, Santa Clara, CA, USA) consisting of a G1315B photodiode array detector (DAD), a QuatPump G1311A quaternary pump, a G1379A degasser and a G1329A autosampler. A reverse-phase Nova-Pak C18 column (4 µm, 3.9 mm i.d. × 300 mm; Waters, Milford, MA, USA) was used for HPLC–DAD analysis of individual phenolic compounds at 20ºC. Each major peak in the HPLC chromatograms of the extracts was characterized by retention time, the absorption and the spectrum form (from 210 to 360 nm). The acquisition time was 1 s. The calibration curves at 280 nm were produced by injecting the standard solutions before an extraction under the same conditions as the samples analysed over the range of concentrations observed ($r^2 \geq 0.93$). The quercetin glycosides, dimmeric procyanidins, gallates and stilbenes glucosides, for which no standards are available, were quantified using standard curves for quercetin, (+)-catechin, gallic acid and *trans*-resveratrol, respectively.

Sensory analysis

The analysis of the wines was performed by a trained sensory panel of 10 people who were all workers and students at the Department of Agro-Industry and Enology of Agronomical Sciences Faculty of Chile University. The wines were evaluated in individual temperature-controlled tasting booths using a completely randomized order. 20 mL of each wine were served at 18–19 °C in dark wine-tasting glasses (RCristal, Mendoza, Argentina) labelled with a three-digit code. The dark wine-tasting glasses were used to prevent the interference of visual sensations and to focus the attention of the panellists on gustative sensations. Between each sample, the panellists have a break for 1 min to chew on a cracker and then rinsed their mouths with water. The FIZZ software (Biosystems, France) was used. This is a visual tool for delivery of the methodology, automation and data collection [32]. The methodology used was the Temporal Dominance of Sensations (TDS), which allows to observe the progression of the dominance of each attribute studied over time [33]. The attributes evaluated were: sweet, bitter, acid, alcohol and preserved fruits. A gustative protocol was used: the tasters used one hand to bring the sample to their mouth, while using the other to click the "Start" button activating the stopwatch, and checking the dominant attribute throughout. After 12 s the sample was spit out. Sample evaluation was over when the taster could no longer perceive any attribute, or after a maximum of 100 s [34].

All the analyses were performed after alcoholic fermentation (AAF) and after 2, 4 and 6 months of ageing treatment (2MT, 4MT and 6MT, respectively) and after 3 and 6 months of bottle storage (3 and 6 MB, respectively).

Statistical analysis

All the data were treated using the analysis of variance (ANOVA). The Tukey's honestly significant difference (HSD) was used in order to determine statistically significant differences between the means, with a significance level of 95 % ($p < 0.05$). All the statistical analyses were conducted using Statgraphics Centurion version 15.2 (StatPoint Technologies, Inc., Warrenton, VA, USA) and Excel 2007 version 12.0 (Microsoft Corp., Redmond, WA, USA).

For the sensory analysis with TDS, two different lines are represented in the graphs: the "chance level" indicates that if the dominance rate of a descriptor is below this line, the attribute is considered to have been quoted by chance. The "significance level" ($p < 0.05$) indicates that if the dominance rate exceeds this curve, the attribute is considered to be significantly dominant. When the attribute curves are between these two lines, the descriptor is dominant but not significantly.

Results and discussion

Effect on the classic oenological parameters

The data ranges of these parameters were: alcoholic degree between 12.5 and 13.6 (% of ethanol); pH between 3.53 and 3.75; SO_2F between 35.2 and 12.8; SO_2T between 96.0 and 148; volatile acidity between 0.30 and 0.60 (g L^{-1} acetic acid); and total acidity between 2.85 and 3.43 (g L^{-1} of sulphuric acid). No statistically significant differences were found between the wines fermented with both VL2 and CY yeast strains. Same results were found between the different ageing treatments applied. Other studies carried out in white and red wines postulated that similar techniques did not produce differences in these parameters [5, 9, 21].

Effect on the different polysaccharide fractions and total content

Three different polysaccharide fractions (H, M and L) were obtained and classified according to their molecular weight. H corresponded with the highest molecular weight polysaccharides (320–370 kDa), M with the medium molecular weight (40–65 kDa) and L with the lowest molecular weight (≥10 kDa). The total polysaccharide content corresponded to the summary of H, M and L fractions (Fig. 2). Fraction M presented the highest content in VL2 and CY wines (52.1 and 47.1 mg/L, respectively) after the alcoholic fermentation period (AAF), but no statistically significant differences were found. However, the CY wines showed a significantly higher content of H and L fractions than VL2 wines, which resulted in a significantly higher concentration of total polysaccharides (18.1 % higher). As occurred in a similar study carried out by our group on red wines but used other yeast strains [21, 35], these differences between both yeast strains were maintained after 2MT period, but after 4MT period were lower. The content of total polysaccharides increased using the L, L + CH and CIDY ageing techniques. This content also increased in the control wines, most likely due to a small portion of the fine lees which could pass to the control wine in the racking process during the winemaking, releasing some polysaccharides. However, as expected, this increase was more statistically significant in the wines treated with the different ageing techniques than in the control wines throughout the entire ageing process, being higher after the 2MT period. These differences were maintained during the bottle storage. Similar results were found by other authors using similar ageing techniques in white wines [9, 11]. Del Barrio-Galán et al. [11] studied the effect of six commercial yeast derivatives with different content on polysaccharides on the quality of Verdejo white wines. It reported that all of these products presented higher content than the control wines after 2 months of ageing. On the other hand, Del Barrio-Galán et al. (2011) [9] also study the effect of the ageing on lees and three different commercial yeast derivatives rich in polysaccharides lasting 2 months, and then the 6-month bottle storage on the quality of Verdejo white wines. They reported that all of the treated wines presented higher content of polysaccharides than the control wines after the ageing period. However, after 6 months in bottles, only two of these commercial yeast derivatives released higher content compared with the control wines.

Analyses of phenolic compounds

Figure 3 shows the trend of the total polyphenols (TP) and total tannins (TT). In general terms, the wines fermented with the CY yeast strain contained a lower content of TP than those fermented with the VL2 yeast strain after the AAF period, throughout the ageing period and bottle storage, with the exception of the wines treated with L + CH. These results could be explained by the adsorption or retention phenomena produced by the higher content of polysaccharides released from CY yeast strain [1, 6, 9, 11, 36–38]. The wines assayed with the different ageing techniques presented similar or higher content of these compounds than the control wines throughout the ageing period and the bottle storage. As expected, the higher content was observed in the wines treated with L + CH in both CY and VL2 wines because some of these compounds (mainly ellagic and gallic acids) can be extracted from oak wood [39]. The content of TT was higher in the CY wines than in the VL2 wines after AAF period. All the CY-treated wines showed lower content of these compounds than the VL2-treated wines after the ageing period and bottle storage, with the exception of those treated with L + CH which were higher in CY wines. Some differences were also found between the different ageing techniques assayed. After 2MT period, all the VL2-treated wines and the CY wines treated with CIDY contained lower TT than the control wines, being these wines which presented the lowest values in both types of fermented wines. After the ageing and 3 MB periods, only the VL2 and CY wines treated with CIDY showed lower concentration than the control wines. Finally, at 6 MB

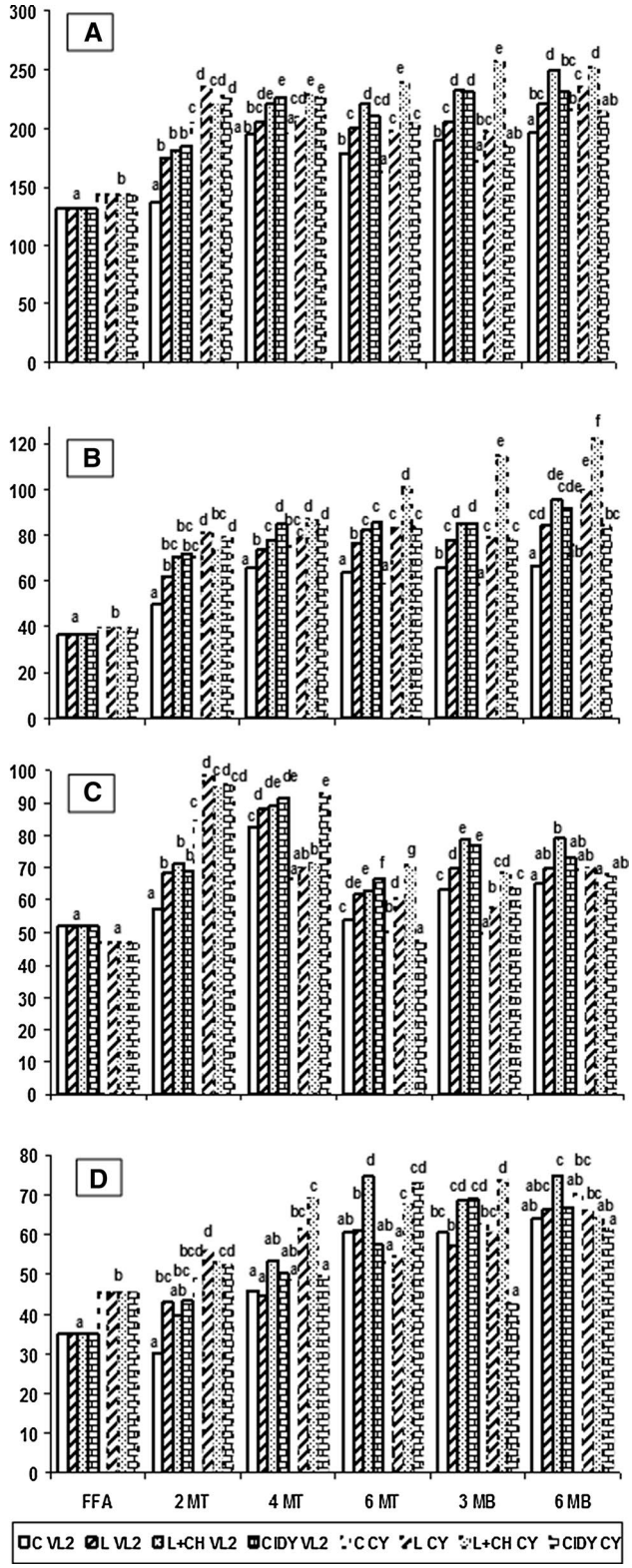

Fig. 2 Total polysaccharide (**A**) and different polysaccharide fractions concentration (**B**: fraction H; **C**: fraction M and **D**: fraction L) (mg L^{-1}) of wines. *AAF* after alcoholic fermentation, *2MT* 2 months of treatment and *4MT* 4 months of treatment, *6MT* 6 months of treatment, *3 MB* 3 months of bottle storage and *6 MB* 6 months of bottle storage. Values with *different letters* indicate statistically significant differences for $p < 0.05$

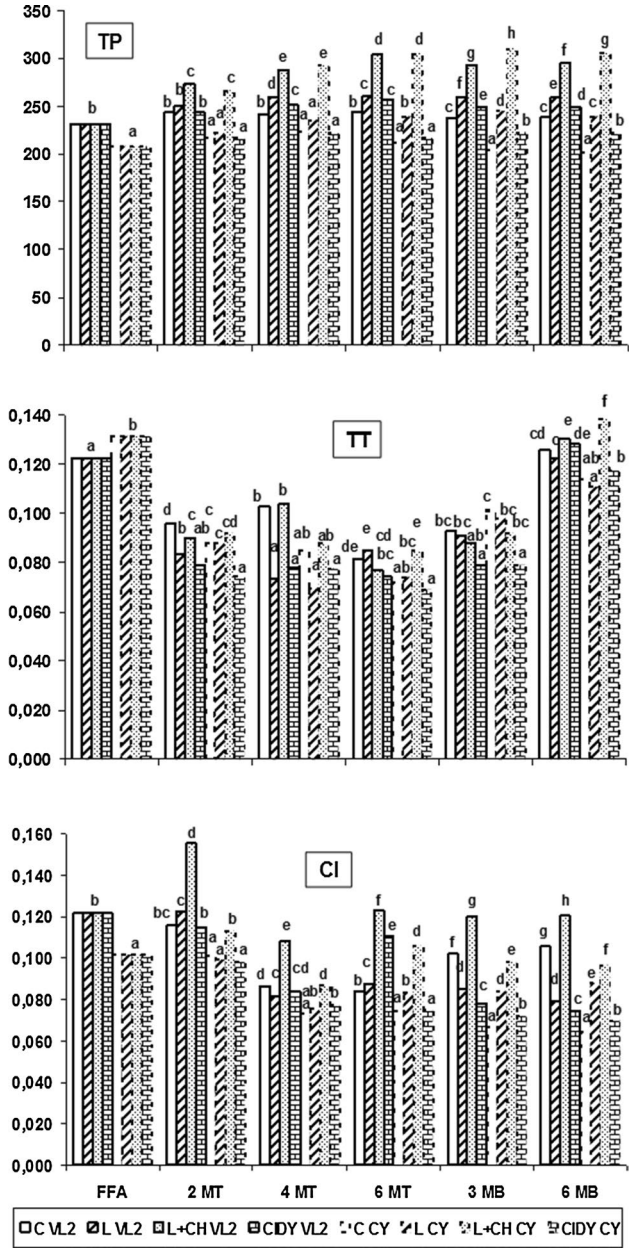

Fig. 3 Total polyphenol (TP) (mg L^{-1}) and total tannins (g L^{-1}) concentration, and colour intensity (units of absorbance) of wines. Values with *different letters* indicate statistically significant differences for $p < 0.05$

period, all the treated wines presented similar or higher content than the controls.

Tables 1, 2 and 3 show the different low molecular weight phenolic compounds identified and quantified. Tyrosol, astilbin, *trans*-caffeic acid and protocatechuic acid were the compounds with the highest concentrations after the AAF period, ageing period and bottle storage. The content of hydroxycinnamic acids (HCA), flavanol monomers, procyanidins and flavonols was lower in CY wines than

Table 1 Low molecular weight phenolic compounds quantified (mg L^{-1}) after alcoholic fermentation (AAF) and after 2 months of treatment in wines

	AAF[a]		2MT[a]							
	VL2	CY	VL2				CY			
	C	C	C	L	L + CH	CIDY	C	L	L + CH	CIDY
Non-flavonoids phenolic compounds										
Gallic acid	0.353a	0.372a	0.334a	0.340a	0.597b	0.318a	0.359a	0.373a	0.603b	0.374a
Protocatechuic acid	1.22a	1.32a	1.51ab	1.79abc	1.88c	1.45a	1.48ab	1.66abc	1.83bc	1.65abc
Vanillic acid	n.d	n.d	n.d	n.d	0.447a	n.d	n.d	n.d	0.434a	n.d
Syringic acid	0.129b	0.104a	0.177c	0.161bc	0.395d	0.136ab	0.155bc	0.104a	0.376d	0.129ab
Ethyl gallate	0.233a	0.238a	0.236a	0.216a	0.272ab	0.223a	n.d	n.d	0.299b	0.234a
Ellagic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Total HBA[a]	1.95a	2.06a	2.26ab	2.51b	3.59c	2.13ab	2.00a	2.14ab	3.54c	2.39ab
C-caffeic acid	0.115a	0.174b	0.168def	0.123abc	0.071a	0.082ab	0.179ef	0.189f	0.094abc	0.140cde
T-caffeic acid	2.17b	1.52a	2.27d	2.36d	2.12cd	1.94bc	1.67ab	1.62a	1.48a	1.60a
T-*p*-coumaric acid	0.286b	0.122a	0.369b	0.363b	0.332b	0.323b	0.211a	0.209a	0.188a	0.214a
C-*p*-coumaric acid	0.335a	0.296a	0.348c	0.348bc	0.334abc	0.288a	0.325abc	0.315abc	0.300ab	0.304abc
T-ferulic acid	0.202b	0.129a	0.269bc	0.281c	0.301c	0.229b	0.134a	0.134a	0.168a	0.149a
Total HCA[a]	3.10b	2.24a	3.43d	3.47d	3.16cd	2.86bc	2.52ab	2.47ab	2.23a	2.40a
T-caftaric acid	0.188a	0.180a	0.134a	0.152ab	0.143a	0.128a	0.179bc	0.184c	0.149ab	0.186c
C-coutaric acid	0.554a	0.597a	0.353a	0.344a	0.467a	0.268a	0.550a	0.331a	0.408a	0.434a
T-coutaric acid	0.043a	0.056a	0.040a	0.037a	0.044a	0.036a	n.d	0.023a	0.044a	0.045a
T-fertaric acid	0.023a	0.035b	0.005a	0.031ab	0.022ab	0.005a	0.080d	0.061cd	0.035bc	0.058cd
Total HCATE[a]	0.807a	0.868a	0.532ab	0.607abc	0.767cb	0.436a	0.858d	0.599abc	0.695cd	0.723bcd
C-resveratrol-3-glucoside	n.d	n.d	0.072a	0.076ab	0.080abc	0.072a	0.090cd	0.098d	0.081abc	0.089bcd
T-resveratrol	0.059a	0.055a	0.063b	0.058ab	0.058ab	0.056ab	0.065b	0.063b	0.051a	0.059ab
C-resveratrol	0.091a	0.086a	0.083a	0.084a	0.081a	0.069a	0.085a	0.088a	0.065a	0.085a
Total stilbenes	0.151a	0.142a	0.218ab	0.219ab	0.219ab	0.197a	0.241b	0.250b	0.196a	0.234ab
Tyrosol	8.92a	8.51a	5.31a	5.87a	6.07ab	6.23ab	9.32c	8.10bc	8.45c	9.59c
Tryptophol	0.158a	0.408b	0.112a	0.151a	0.100a	0.073a	0.236ab	0.376ab	0.579b	0.364ab
Total phenolic alcohols	9.08a	8.91a	5.42a	6.02a	6.17a	6.30a	9.56b	8.48b	9.03b	9.95b
Flavonoids phenolic compounds										
Catechin	0.831b	0.687a	0.956b	0.806ab	0.821ab	0.640a	0.710ab	0.707ab	0.852ab	0.697ab
Epicatechin	0.503a	0.481a	0.464a	0.381a	0.313a	0.335a	0.505a	0.322a	0.406a	0.351a
Total flavanol monomers	1.33b	1.17a	1.42b	1.19ab	1.13ab	0.975a	1.22ab	1.03ab	1.26ab	1.05ab
Procyanidin B3	0.736a	0.608a	0.761a	0.867a	1.36b	0.747a	0.760a	0.916a	1.41b	0.750a
Procyanidin B4	0.241a	0.220a	0.274c	0.216abc	0.163ab	0.148a	0.195abc	0.197abc	0.253bc	0.193abc
Procyanidin B2	0.304a	0.250a	0.330b	0.259ab	0.175a	0.231ab	0.251ab	0.204a	0.246ab	0.221ab
Total Procyanidins	1.28b	1.08a	1.37a	1.34a	1.70b	1.13a	1.21a	1.32a	1.91b	1.16a
Quercetin-3-galactoside	0.147b	0.084a	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Quercetin-3-glucuronide	0.125b	0.055a	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Quercetin-3-glucoside	0.162b	0.081a	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Astilbin	0.549b	0.427a	2.28a	2.40a	2.36a	2.00a	1.96a	1.86a	2.04a	1.82a
Astilbin derivatives	3.22	2.61	1.38a	1.40a	1.47a	1.28a	1.28a	1.24a	1.26a	1.30a
Total flavonols	4.20b	3.26a	3.66a	3.80a	3.83a	3.28a	3.24a	3.11a	3.29a	3.12a

Values with different letter indicate statistically significant differences ($p < 0.05$)

n.d. Not detected compound

[a] *HBA* hydroxybenzoic acids, *HCA* hydroxycinnamic acids, *HCATE* hydroxycinnamic acids tartaric esters

Table 2 Low molecular weight phenolic compounds quantified (mg L^{-1}) after 4 and 6 months of treatment (4MT and 6MT) in wines

	4MT[a]							
	VL2				CY			
	C	L	L + CH	CIDY	C	L	L + CH	CIDY
Non-flavonoids phenolic compounds								
Gallic acid	0.257a	0.248a	0.464d	0.254a	0.292b	0.336c	0.561e	0.302b
Protocatechuic acid	1.39a	1.71cd	1.97e	1.60bc	1.36a	1.79d	2.07e	1.50ab
Vanillic acid	n.d	n.d	0.466a	n.d	n.d	n.d	0.543b	n.d
Syringic acid	0.113a	0.111a	0.424b	0.116a	0.100a	0.108a	0.415b	0.110a
Ethyl gallate	0.201ab	0.198ab	0.205ab	0.194a	0.199ab	0.216ab	0.240b	0.181a
Ellagic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Total HBA[a]	1.96a	2.27bc	3.53d	2.16ab	1.95a	2.45c	3.82e	2.10ab
C-caffeic acid	0.135b	n.d	n.d	n.d	0.171c	0.176c	0.057a	0.138b
T-caffeic acid	2.28c	2.24c	2.16c	2.20c	1.47a	1.74b	1.57ab	1.58ab
T-*p*-coumaric acid	0.450bc	0.485c	0.426b	0.495c	0.307a	0.333a	0.324a	0.281a
C-*p*-coumaric acid	0.297c	0.283bc	0.295c	0.286bc	0.232a	0.263b	0.265b	0.273bc
T-ferulic acid	0.274c	0.265c	0.293c	0.269c	0.104a	0.101a	0.163b	0.104a
Total HCA[a]	3.44d	3.27cd	3.17c	3.25cd	2.29a	2.61b	2.38ab	2.38ab
T-caftaric acid	0.095ab	0.095ab	0.079a	0.094ab	0.110b	0.113b	0.099ab	0.113b
C-coutaric acid	0.365a	0.282a	0.264a	0.312a	0.532c	0.505bc	0.591c	0.379ab
T-coutaric acid	0.014abc	0.008a	0.013abc	0.010abc	0.007a	0.016c	0.014bc	n.d
T-fertaric acid	0.033a	0.085b	0.020a	0.079b	0.015a	0.026a	0.052ab	0.023a
Total HCATE[a]	0.507a	0.469a	0.376a	0.496a	0.666b	0.659b	0.756b	0.515a
C-resveratrol-3-glucoside	0.061a	0.061a	0.061a	0.064a	0.080ab	0.082ab	0.093ab	0.102b
T-resveratrol	0.052a	0.055ab	0.050a	0.059ab	0.066ab	0.060ab	0.053a	0.072b
C-resveratrol	0.073a	0.075ab	0.075ab	0.073a	0.078abc	0.089c	0.087bc	0.087bc
Total stilbenes	0.187a	0.192a	0.186a	0.195ab	0.224bc	0.231cd	0.233cd	0.262d
Tyrosol	6.20a	4.77a	4.47a	5.29a	9.05c	8.59bc	10.06c	6.44ab
Tryptophol	0.200ab	0.150a	0.226bc	0.183ab	0.265c	0.391d	0.347d	0.281c
Total phenolic alcohols	6.40a	4.92a	4.69a	5.48a	9.32b	8.98b	10.40b	6.73a
Catechin	0.584cd	0.647d	0.632d	0.583cd	0.394abc	0.536bcd	0.365ab	0.333a
Epicatechin	0.434bc	0.256ab	0.516c	0.252ab	0.350bc	0.318b	0.419bc	0.120a
Total flavanol monomers	1.02bc	0.902bc	1.15c	0.834b	0.744b	0.855b	0.784b	0.454a
Procyanidin B3	0.625ab	0.608ab	0.835b	0.645ab	0.468a	0.611ab	1.20b	0.561a
Procyanidin B4	0.096ab	0.061a	0.095ab	0.074	0.057a	0.110b	0.098ab	n.d
Procyanidin B2	0.155b	0.105a	0.199bc	0.101a	n.d	n.d	0.211c	0.089a
Total Procyanidins	0.875bc	0.774ab	1.13c	0.819ab	0.525a	0.721ab	1.51d	0.650ab
Astilbin	1.90abc	2.12bc	2.28c	2.11bc	1.73ab	1.75ab	1.83abc	1.39a
Astilbin derivatives	1.14b	1.19b	1.25b	1.25b	1.40b	1.59b	1.74b	0.70a
Total flavonols	3.04b	3.31b	3.53b	3.36b	3.13b	3.35b	3.57b	2.10a
	6MT[a]							
	VL2				CY			
	C	L	L + CH	CIDY	C	L	L + CH	CIDY
Non-flavonoids phenolic compounds								
Gallic acid	0.302a	0.288a	0.562c	0.305ab	0.312ab	0.296a	0.581c	0.345b
Protocatechuic acid	1.46a	1.59ab	1.74b	1.62ab	1.39a	1.62ab	1.64ab	1.55ab
Vanillic acid	n.d	0.397ab	0.474b	0.377ab	0.366ab	0.371ab	0.469b	0.248a
Syringic acid	0.072a	0.083a	0.316b	0.090a	0.092a	0.085a	0.086a	0.097a
Ethyl gallate	0.267b	0.244ab	0.273b	0.238ab	0.237ab	0.222a	0.224a	0.241ab

Table 2 continued

	6MT[a]							
	VL2				CY			
	C	L	L + CH	CIDY	C	L	L + CH	CIDY
Ellagic acid	0.531ab	0.466ab	1.328b	0.384ab	0.353a	n.d	1.273b	0.485ab
Total HBA[a]	2.64a	3.07a	4.70b	3.02a	2.75a	2.60a	4.27b	2.96a
C-caffeic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
T-caffeic acid	2.85cd	3.21d	2.60bc	2.68cd	2.08ab	2.00a	1.99a	1.96a
T-*p*-coumaric acid	0.731c	0.717c	0.705c	0.561b	0.426a	0.404a	0.404a	0.449a
C-*p*-coumaric acid	0.272ab	0.304ab	0.485c	0.319b	0.228a	0.275ab	0.272ab	0.255ab
T-ferulic acid	0.339b	0.330b	0.383b	0.286b	0.134a	0.143a	0.141a	0.143a
Total HCA[a]	4.19bc	4.57c	4.17bc	3.85b	2.87a	2.82a	2.81a	2.80a
T-caftaric acid	0.119ab	0.098a	0.091a	0.097a	0.139b	0.116ab	0.115ab	0.134b
C-coutaric acid	0.243a	0.334b	0.300ab	0.309ab	0.296ab	0.302ab	0.299ab	0.287ab
T-coutaric acid	0.028a	0.036ab	0.037ab	0.034ab	0.032ab	0.031ab	0.031ab	0.046b
T-fertaric acid	0.114a	0.079a	0.126a	0.096a	0.091a	0.083a	0.081a	0.094a
Total HCATE[a]	0.504a	0.547a	0.554a	0.536a	0.558a	0.532a	0.526a	0.561a
C-resveratrol-3-glucoside	0.073a	0.069a	0.111b	0.082a	0.091ab	0.071a	0.072a	0.084a
T-resveratrol	0.094b	0.079ab	0.088b	0.081ab	0.086b	0.067a	0.068a	0.080abb
C-resveratrol	0.074a	0.086abc	0.096bc	0.086abc	0.082ab	0.100c	0.098bc	0.089abc
Total stilbenes	0.241a	0.234a	0.295b	0.250ab	0.259ab	0.238a	0.238a	0.253ab
Tyrosol	7.03a	7.40ab	7.74abcd	7.87abcd	7.63abc	8.92d	8.75cd	8.33bcd
Tryptophol	0.189a	0.159a	0.245a	0.180a	0.172a	0.304a	0.294a	0.555a
Total phenolic alcohols	7.22a	7.56ab	7.98abcd	8.05abcd	7.80abc	9.22d	9.04cd	8.63bcd
Catechin	0.727d	0.616cd	0.560bc	0.432a	0.514abc	0.469ab	0.451ab	0.471ab
Epicatechin	0.512b	0.489ab	0.462ab	0.401ab	0.444ab	0.438ab	0.423ab	0.322a
Total flavanol monomers	1.24d	1.11cd	1.02bc	0.833ab	0.958abc	0.907abc	0.875ab	0.838a
Procyanidin B3	0.816cd	0.763bcd	0.783bcd	0.854d	0.684bc	0.518a	0.768bcd	0.662ab
Procyanidin B4	0.079a	0.122b	0.126b	0.070a	n.d	n.d	0.129b	n.d
Procyanidin B2	0.163a	0.155a	0.782b	0.077a	0.108a	0.093a	0.773b	0.151a
Total Procyanidins	1.06c	1.04c	1.69d	1.00bc	0.79ab	0.61a	1.67d	0.81ab
Astilbin	2.17ab	2.19ab	2.28b	2.24b	1.90ab	1.91ab	1.82ab	1.37a
Astilbin derivatives	1.61	1.63	2.13	1.49	1.53	1.61	1.58	1.99
Total flavonols	3.78a	3.82a	4.41b	3.73a	3.43a	3.52a	3.39a	3.36a

Values with different letter indicate statistically significant differences ($p < 0.05$)

n.d. Not detected compound

[a] *HBA* hydroxybenzoic acids, *HCA* hydroxycinnamic acids, *HCATE* hydroxycinnamic acids tartaric esters

in VL2 wines after the AAF period. As occurred with TP, there was an important retention/adsorption effect on these compounds by CY yeast strain. In general, this effect was maintained during the ageing period and bottle storage for HCA (mainly due to the effect on the *trans*-caffeic acid) and flavonol compounds, while for the flavanol monomers and procyanidins, it was only maintained during the ageing period. In the case of the phenolic alcohols, both CY- and VL2-fermented wines presented similar concentrations after AAF period, but the CY wines had a higher content during the ageing period and bottle storage, mainly due to a higher content in the tyrosol. These compounds are formed by deamination and decarboxylation reactions of tyrosine and tryptophan amino acids, respectively, during yeast fermentation [40].

Regarding the ageing treatments, the wines treated with L + CH showed significantly higher content of hydroxybenzoic acids (HBA) than the rest of treated and control wines throughout the study. As occured with TP, this fact was mainly due to the release of several of these compounds by the oak wood as gallic, ellagic and protocatechuic acids [9, 35, 41]. No clear differences were found between ageing treatments with lees and control wines. For hydroxycinnamic tartaric ester acids (HCTEA), the most significant

differences were found in CY wines, observing that all the treated wines had lower content than the controls after 2MT period and 6 MB. Some authors have postulated that, in white wines, this fact implies a lower oxidation risk by reducing the content of easily oxidizable compounds such as these tartaric esters [9, 11]. However, this effect was not found in the VL2-treated wines at the time of the study.

In the case of flavanol monomers and procyanidins, only some differences were found at the end of the ageing period. Thus, the VL2 wines treated with CIDY presented lower content of flavanol monomers than the control wines, but both VL2 and CY wines treated with L + CH presented higher content of procyanidins. During bottle storage only the procyanidin B3 was detected, and no statistically significant differences were found.

As mentioned above, astilbin was the most important flavonol detected, and several astilbins derivatives were also found. Quercetin-3-galactoside, quercetin-3-glucuronide, quercetin-3-glucoside were only detected after the AAF period. The most important differences between the treatments applied were found after 3 MB period, observing that wines treated with L + CH showed higher content than the control wines. No clear effects were found in the content of total stilbenes. Few differences were also found between the ageing treatments applied in the phenolic alcohols content during the ageing period. After bottle storage, the VL2 wines treated with L and CIDY as well as the CY wines treated with L showed lower content of these compounds than the control wines. However, the CY wines treated with CIDY presented higher content than the control wines. For this reason, it is difficult to establish a correlation between the different ageing treatments and evolution of these compounds during bottle storage. In a study carried out by Del Barrio-Galán et al. [9] using similar techniques, no statistically significant differences were found during the same bottle storage in Verdejo white wines.

Recent studies about the interaction/adsorption of polyphenols by yeast, inactive yeast and yeast cell walls hypothesized that not only do the mannoproteins of yeast and yeast derivatives interact with phenolic compounds in solutions, but also some polyphenols can be adsorbed and interact directly with the cytoplasmic membrane lipids of the yeasts. This could be a protective effect on the oxidation of white wines [12, 13]. Moreover, in vitro experiments proved that yeast membrane sterols could be likely involved in the yeast's ability to adsorb polyphenolic compounds and mainly the colourless intermediate compounds of the browning reactions [42].

Colour intensity

The colour intensity (CI) parameter is a good indicator of the oxidation degree of white wines, which tend to change colour to brown tones due to the oxidation of their phenolic compounds increasing their CI value. As shown in Fig. 3, the wines fermented with CY yeast strain showed statistically significant lower values of CI than those fermented with VL2 after AAF period. This result was maintained throughout the ageing and the bottle storage periods. The result could indicate an important yeast strain effect on the prevention or reduction of the browning of white wines. However, the different ageing treatments assayed did not produce this effect during the ageing period in both types of fermented wines. Only during bottle storage some statistically significant differences were found. Thus, VL2 wines treated with L and CIDY presented lower values of CI than control wines throughout all the bottle storage. This result is well correlated with the higher amounts of polysaccharides released during the ageing period. Similar results were found by some authors using the same ageing on lees technique and other yeast derivatives products in white wines after 3 months of bottle storage [1, 9]. They proposed to use these techniques as fining agents to prevent the browning of white wines [9]. However, this result was not found in the CY-treated wines. Finally, both VL2 and CY wines treated with L + CH presented higher CI values than the control wines throughout the ageing period and bottle storage. This result could be explained due to the higher release of TP of oak wood chips which were probably oxidized producing a higher browning of the wines. The objective of combining lees and chips was to prevent this oxidation process through a higher release of polysaccharides from the autolysis of lees; however, this effect was not found.

Sensory analysis

Figures 4, 5 and 6 show the results obtained with TDS sensory analysis for the different attributes evaluated. In general, it was observed that, in all the wines evaluated, the panel tasters detected the attribute of sweet in first place when they put the wines in their mouth. It is important to note that, according to the supplier specifications, the use of oak wood chips with a medium-toasted degree could produce a sweetness sensation (compared to other treatments), but this sensation was not found by the tasters. Then, when they spat out the wine (at 12 s), they detected mainly the acid, alcohol and bitter attributes. These three attributes were dominant, but their dominance was different in function of the yeast used, the treatment performed and the ageing and bottle storage periods studied. Thus, the most significant differences were found after 2MT, 6MT and 6 MB periods. In this way, after 2MT period, the alcohol attribute was significantly more dominant than the rest attributes in the VL2 control wines, and it was higher than the CY control wines. However, the CY wines treated

Table 3 Low molecular weight phenolic compounds quantified (mg L^{-1}) after 3 and 6 months of bottle storage (3 and 6 MB) in wines

	3MB[a]							
	VL2				CY			
	C	L	L + CH	CIDY	C	L	L + CH	CIDY
Non-flavonoids phenolic compounds								
Gallic acid	0.343a	0.347a	0.640b	0.343a	0.380a	0.363a	0.587b	0.353a
Protocatechuic acid	1.40a	1.81b	1.85b	1.83b	1.70ab	1.56ab	1.78b	1.63ab
Vanillic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Syringic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Ethyl gallate	n.d	0.200a	0.250c	0.210b	n.d	n.d	n.d	n.d
Ellagic acid	0.337a	0.336a	0.444a	n.d	n.d	0.350a	0.446a	0.361a
Total HBA[a]	2.08a	2.70b	3.18c	2.38a	2.08a	2.27a	2.81b	2.35a
C-caffeic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
T-caffeic acid	2.21cd	2.36d	2.39d	2.25d	1.64a	1.78ab	1.97bc	1.76ab
T-*p*-coumaric acid	0.770d	1.14e	0.837d	1.15e	0.753cd	0.587a	0.677bc	0.657ab
C-*p*-coumaric acid	0.487d	0.403cd	0.253a	0.367bc	0.300ab	0.413cd	0.240a	0.327abc
T-ferulic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Total HCA[a]	3.46b	3.90c	3.48b	3.77bc	2.69a	2.78a	2.89a	2.75a
T-caftaric acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
C-coutaric acid	0.460a	0.490a	0.497a	0.510a	0.520a	0.483a	0.493a	0.520a
T-coutaric acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
T-fertaric acid	n.d	0.017a	0.023a	0.027a	0.083c	0.033ab	0.037ab	0.047ab
Total HCATE[a]	0.460a	0.490a	0.497a	0.510a	0.520a	0.483a	0.493a	0.520a
C-resveratrol-3-glucoside	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
T-resveratrol	0.070ab	0.100c	0.063a	0.093bc	0.100c	0.077abc	0.090abc	0.093bc
C-resveratrol	0.127b	0.123b	0.133b	0.100a	0.100a	0.133b	0.140b	0.120ab
Total stilbenes	0.193a	0.220a	0.200a	0.197a	0.200a	0.213a	0.230a	0.207a
Tyrosol	6.56a	6.19a	7.00a	6.88a	9.67b	8.57b	9.46b	8.77b
Tryptophol	0.130abc	0.087ab	0.310e	0.070a	0.160bcd	0.203cd	0.207d	0.193cd
Total phenolic alcohols	6.69a	6.28a	7.31ab	6.95a	9.83c	8.77bc	9.66c	8.96c
Catechin	0.787a	0.990ab	1.09bc	0.933ab	1.67d	0.923ab	1.20ab	0.890ab
Epicatechin	0.530b	0.220a	1.04c	0.277a	0.367ab	0.363ab	1.43d	0.410ab
Total flavanol monomers	1.32a	1.21a	2.13b	1.21a	2.04b	1.29a	2.63c	1.31a
Procyanidin B3	1.36ab	1.55ab	1.72b	1.45ab	1.68b	1.28a	1.70b	1.30a
Astilbin	2.98bc	3.56d	3.48cd	3.02bcd	2.19a	3.25cd	3.02bcd	2.60ab
Astilbin derivatives	2.72c	2.71c	3.58bc	2.47ab	2.72c	2.42a	3.48ab	2.32a
Total flavonols	5.70ab	6.27bc	7.06c	5.48ab	4.91a	5.67ab	6.50bc	4.92a
	6MB[a]							
	VL2				CY			
	C	L	L + CH	CIDY	C	L	L + CH	CIDY
Non-flavonoids phenolic compounds								
Gallic acid	0.283ab	0.270a	0.560d	0.270a	0.280a	0.323c	0.570d	0.300b
Protocatechuic acid	1.09ab	1.25bc	1.48d	1.27c	1.06a	1.48d	1.73e	1.24bc
Vanillic acid	0.397a	0.400a	0.547b	0.410a	0.397a	0.403a	0.563b	0.400a
Syringic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Ethyl gallate	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Ellagic acid	0.453b	0.390a	1.120e	0.370a	0.470b	0.630c	0.727d	0.493b
Total HBA[a]	2.49a	2.56a	4.30d	2.55a	2.44a	3.07b	3.90c	2.65a
C-caffeic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d

Table 3 continued

	6MB[a]							
	VL2				CY			
	C	L	L + CH	CIDY	C	L	L + CH	CIDY
T-caffeic acid	2.18c	2.17c	2.26c	2.20c	1.48a	1.68b	1.66b	1.60ab
T-*p*-coumaric acid	1.35c	1.53d	1.37c	1.60b	1.10a	1.12ab	1.21b	1.17ab
C-*p*-coumaric acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
T-ferulic acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Total HCA[a]	3.53c	3.70c	3.63c	3.80c	2.58a	2.81ab	2.87b	2.78ab
T-caftaric acid	n.d	0.103ab	0.080a	0.117bc	0.190e	0.130c	0.140cd	0.160d
C-coutaric acid	0.250bcd	0.193bc	0.277d	0.183b	0.213bcd	0.200bc	0.260 cd	0.100a
T-coutaric acid	0.020a	0.050bc	0.043abc	0.050bc	0.063c	0.023ab	0.060c	0.060c
T-fertaric acid	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Total HCATE[a]	0.277a	0.367ab	0.423bc	0.380b	0.557d	0.387b	0.497cd	0.367ab
C-resveratrol-3-glucoside	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
T-resveratrol	0.070b	0.100c	0.053a	0.093c	0.100c	0.077b	0.090c	0.093c
C-resveratrol	0.113bc	0.083a	0.127cde	0.080a	0.097ab	0.133de	0.137e	0.117
Total stilbenes	0.183ab	0.183ab	0.180ab	0.173a	0.197bc	0.210cd	0.223d	0.210cd
Tyrosol	6.19b	4.46a	5.52ab	4.29a	9.18de	7.06bc	7.98cd	10.0e
Tryptophol	0.277c	0.220bc	0.220bc	0.160ab	0.087a	0.443de	0.527e	0.370d
Total phenolic alcohols	6.46bc	4.68a	5.74ab	4.45a	9.27ef	7.51cd	8.51de	10.4 g
Catechin	0.303a	0.607b	0.277a	0.667b	0.567b	0.567b	0.623b	0.560b
Epicatechin	0.553d	0.483cd	0.387bc	0.223a	0.340ab	0.360abc	0.300ab	0.320ab
Total flavanol monomers	0.860ab	1.09b	0.667a	0.890ab	0.910ab	0.927ab	0.930ab	0.873ab
Procyanidin B3	1.10a	1.13a	1.12a	1.15a	0.99a	1.15a	0.99a	1.17a
Astilbin	2.83b	2.85b	2.86b	2.90b	2.41a	2.59a	2.52a	2.49a
Astilbin derivatives	1.99c	2.08d	1.83bc	1.75bc	1.46a	1.71b	1.59ab	1.63ab
Total flavonols	4.82d	4.93d	4.69cd	4.65cd	3.87a	4.30bc	4.10ab	4.12ab

Values with different letter indicate statistically significant differences ($p < 0.05$)

n.d. not detected compound

[a] *4MT* 4 months of treatment, *6MT* 6 months of treatment, *HBA* hydroxybenzoic acids, *HCA* hydroxycinnamic acids, *HCATE* hydroxycinnamic acids tartaric esters

with L and L + CH showed higher values of alcohol than the same treatments in VL2 wines. The higher differences were found in the treatments with CIDY. Thus, the VL2 wines had a higher percentage of dominance rate of bitter, alcohol and acid than the CY wines. Furthermore, it was observed that following the trend curves for each attribute, the CY wines treated with CIDY were more balanced than VL2 wines because their attribute trend curves were found in a more similar dominance range. After 6MT period, the tasters note that the VL2 control wines had a higher dominance rate of the sweet and bitter attributes than the CY control wines, but they had a higher acidity and preserved fruits than the VL2 control wines. The most important differences were found in the wines treated with L and CIDY. Thus, VL2 L and CIDY wines showed higher dominance of bitter (around 70 and 55 %, respectively) than the CY L and CIDY wines (around 44 %). Conversely, CY CIDY wines had higher notes of preserved fruit than the VL2 CIDY wines. The VL2 L + CH wines presented a higher dominance rate of acid than the CY L + CH wines. In view of this data, it can be said that the CY wines were, in general terms, more balanced in the mouth than VL2 wines because the trend curves of the attributes evaluated were in a more similar dominance range. The differences found between CY and VL2 wines after 6 MB period were lower. The CY control wines had higher dominance rate of bitter than VL2 control wines, and this attribute was more prolonged over time. In addition, these wines had higher dominance rate of alcohol attribute. Similar results were found in wines treated with CIDY but only for the alcohol attribute, showing both types of fermented wine similar dominance for the bitter. Comparing the different ageing treatments assayed in both VL2 and CY wines with the controls, an improvement in the sensory quality

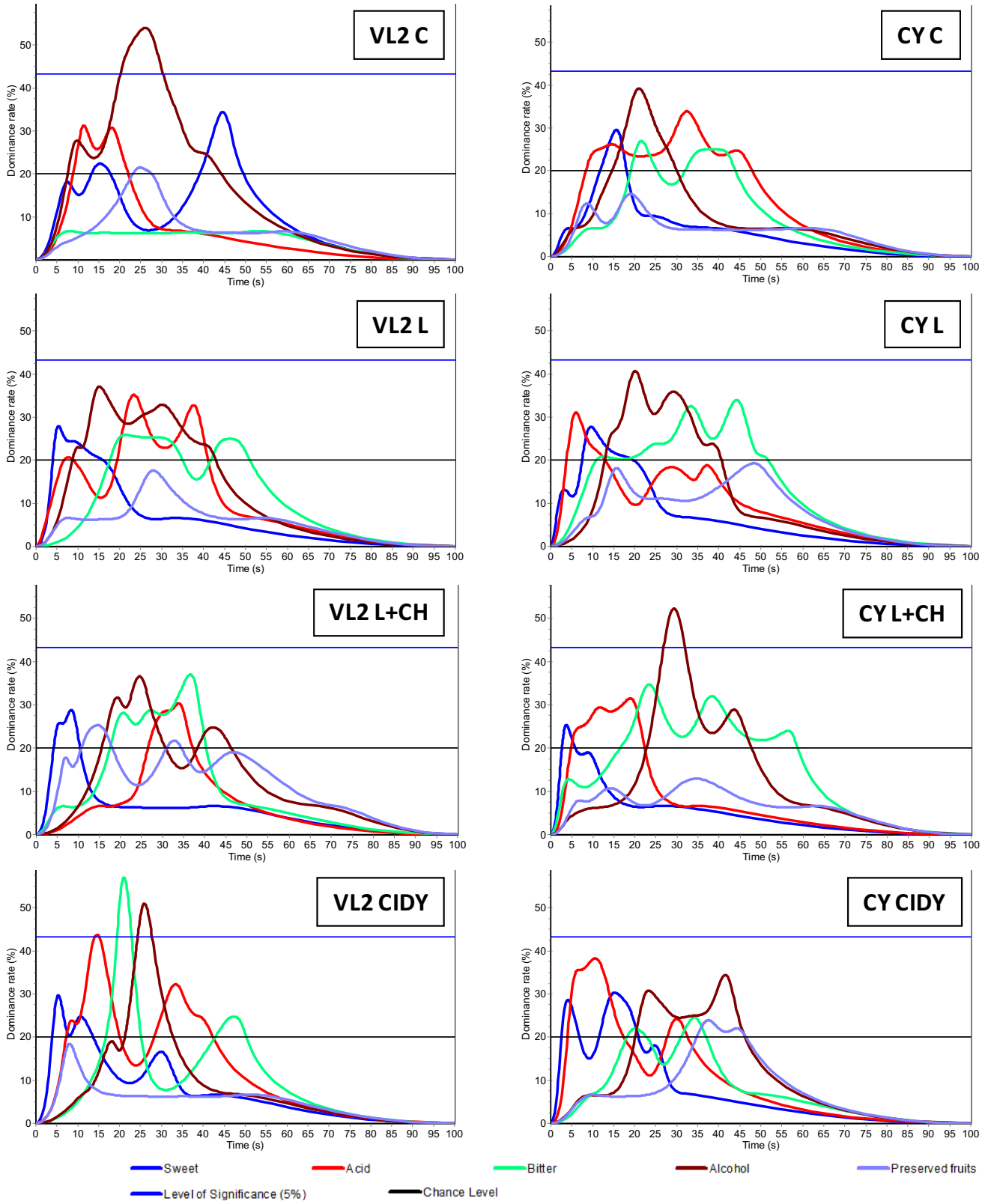

Fig. 4 Sensory analysis graphics of the different wines after 2 months of treatment (2MT)

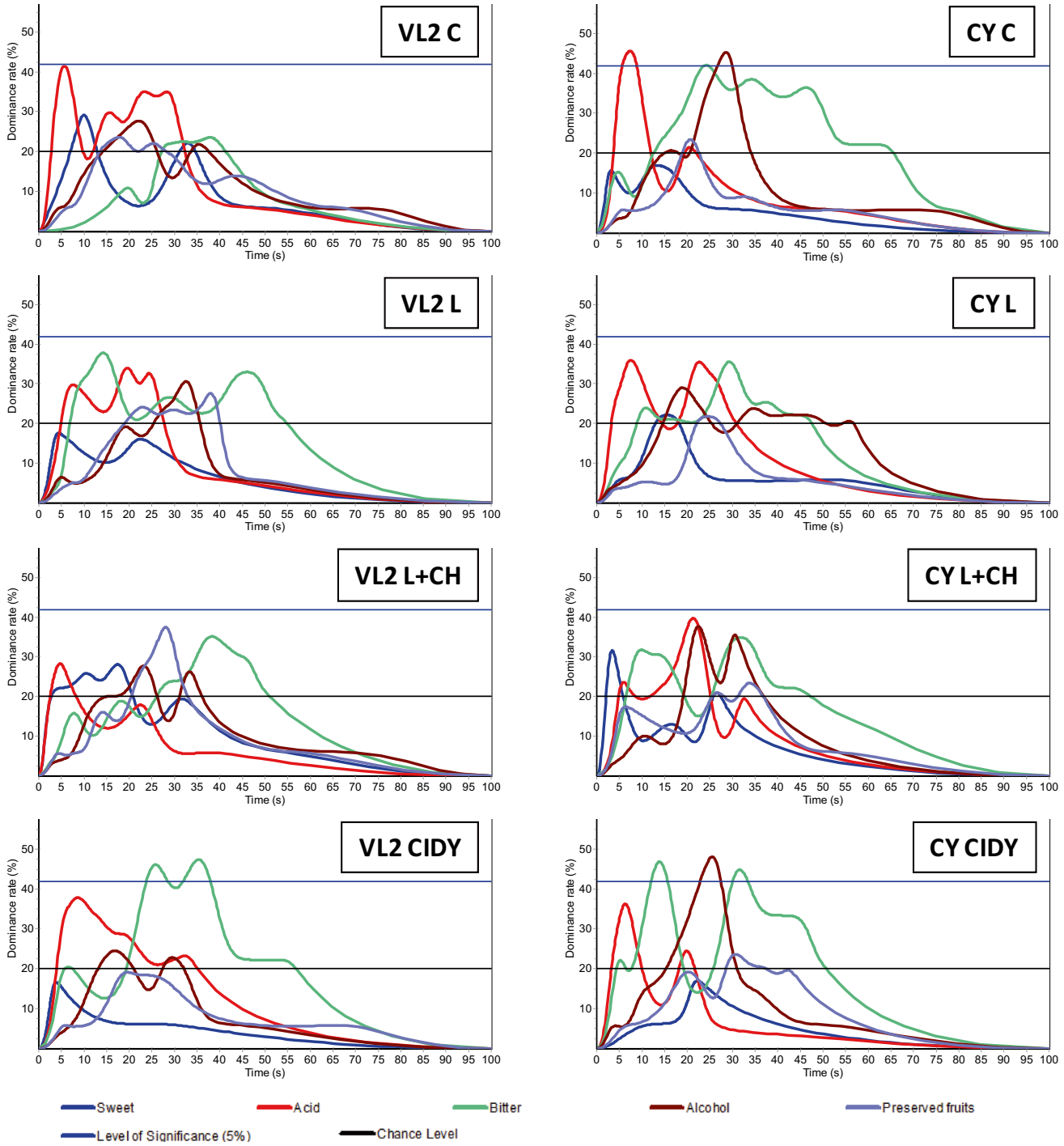

Fig. 5 Sensory analysis graphics of the different wines after 6 months of treatment (6MT)

was only seen in a few cases. Thus, after 2MT period, the tasters observed that the VL2 control wines presented a higher alcoholic character than different treated wines with the exception of VL2 CIDY. In addition, these wines presented higher bitter character. In the case of the CY wines, L + CH wines had higher alcoholic character than the control and the rest of treated wines. After 6MT period, the dominance rate of bitter was higher in the VL2 L and CIDY wines than in the rest, mainly in L wines. Finally, the wines treated with L + CH presented higher acid character respect to the rest of wines. In the case of CY wines, the control and CIDY wines presented higher

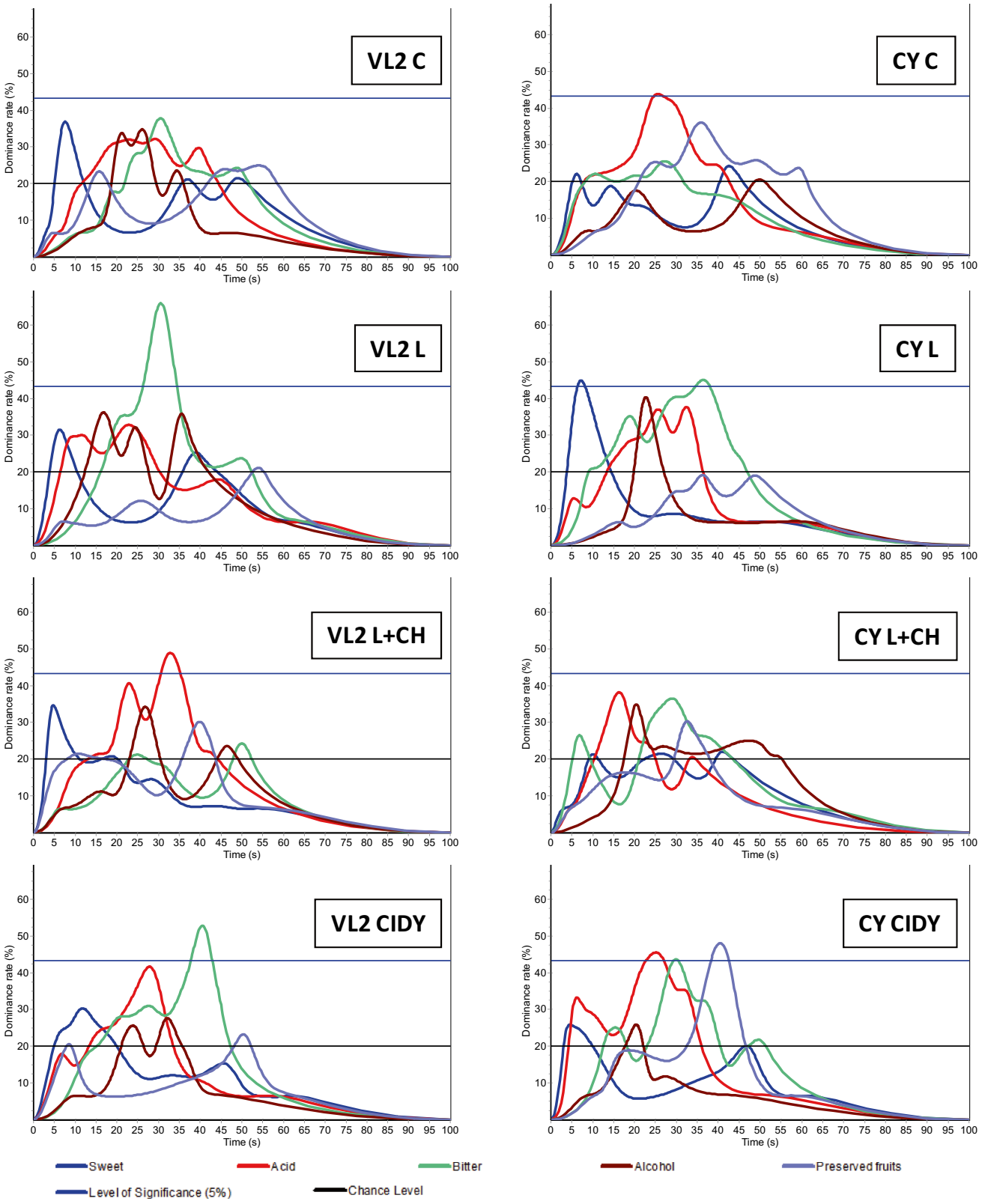

Fig. 6 Sensory analysis graphics of the different wines after 6 months of bottle storage (6 MB)

dominance of acid and preserved fruit attributes than the L. After 6 MB period, the VL2 control wines presented an important acid character respect to the treated wines which it was manifested during the first seconds of the tasting. Contrary that we expected find, all the treated wines had higher bitterness than the controls, and it was more persistent in the time. On the other hand, the control CY wines had higher bitter and alcohol dominance than the treated wines, with the exception of those treated with CIDY. Besides, the bitter attribute persistence was higher in the control wines than in the treated wines.

Conclusions

CY yeast strain permitted a faster release of polysaccharides (probably mannoproteins), mainly of low molecular weight, during alcoholic fermentation. The use of its lees for the ageing treatments permitted a faster release of the yeast polysaccharides (probably due to a better autolytic capacity) during the early stages of ageing (2MT) than VL2, but this one released higher amounts during the later stages (4MT) than CY. These results suggested that VL2 lees released the polysaccharide content more slowly than CY.

It can be say that, under our study conditions, CY yeast strain had a significant adsorption/retention effect on the phenolic compounds, which could have a prevention effect of the browning of white wines.

Based on the results obtained with TDS sensory analysis, in general terms, there was an important yeast strain effect on the modulation of some attributes, mainly bitter, acid and alcohol after 2MT and 6MT periods, but it was depended of the treatment and the ageing period studied. From our knowledge, this is the first time that Chilean white wines have been evaluated with this technique, and more studies should be carried out for a better understanding of the effect of these techniques on the sensory quality of white wines.

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Compliance with ethical standards

Conflict of interest The authors of this article do not have any conflicts of interest.

Compliance with ethics requirements This article does not contain studies with human or animal subjects.

Informed consent The authors of this article give their consent.

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