INFLUENCE OF DIFFERENT WOOD CHIPS SPECIES (OAK, ACACIA AND CHERRY) USED IN A SHORT PERIOD OF AGING ON THE QUALITY OF 'ENCRUZADO' WHITE WINES

LORENZO DELIA [1], ANTÓNIO M. JORDÃO [2] AND JORGE M. RICARDO-DA-SILVA [1]

[1] LEAF Linking Landscape, Environment, Agriculture and Food, Laboratório Ferreira Lapa (Sector Enologia), Instituto Superior de Agronomia, Universidade de Lisboa
PT-1349-017 Lisboa, Tapada da Ajuda

[2] Instituto Politécnico de Viseu (CI & DETS), Escola Superior Agrária
PT-3500-606 Viseu, Estrada de Nelas, Quinta da Alagoa, Ranhados
E-Mail: antoniojordao@esav.ipv.pt

The total phenolic composition and the sensory profile of an 'Encruzado' white wine aged in contact with chips from different wood species (cherry - *Prunus avium*, acacia - *Robinia pseudoacacia*, and two oak species - *Quercus petraea* and *Quercus alba*) were investigated over 28 aging days.
During the short aging period studied, the use of wood chips, in particular from acacia wood, induced a tendency for increases of total phenols, non-flavonoid and flavonoid compounds and color intensity of white wines. In this sense, after 28 aging days white wine aged with acacia wood chips also showed significant color differences in relation to the control wine. The results also showed that white wines aged in contact with cherry and acacia wood chips maintained high browning potential values during the aging time investigated. From the sensory point of view, in general the white wines showed similar sensory profiles. However, concerning the overall appreciation the panel test preferred the white wine aged in contact with acacia chips, while the wine aged in contact with cherry chips showed similar overall appreciation scores to those obtained for the wines aged with oak wood chips. This work advances our understanding of the potential impact of other than oak woods, such as cherry and acacia on white wine quality.
Keywords: acacia, cherry, phenolic composition, white wine, wood chips, sensory profile.

Einfluss von Holzchips unterschiedlicher Baumarten (Eiche, Akazie und Kirsche) auf die Qualität von Weißweinen der Sorte 'Encruzado' bei Einsatz über eine kurze Periode des Weinausbaus. Die Gesamtphenole und das sensorische Profil eines Weißweins der Sorte 'Encruzado', der in Kontakt mit Holzchips verschiedener Baumarten ausgebaut wurde (Kirsche *Prunus avium*, Akazie *Robinia pseudoacacia* und zwei Eichenarten *Quercus petraea* und *Quercus alba*), wurden über 28 Tage des Ausbaus untersucht. Während dieser kurzen Ausbauperiode bewirkte der Einsatz verschiedener Holzchips, speziell von Akazie, eine Tendenz zur Erhöhung des Gesamtphenolgehalts, der nicht-flavonoiden und flavonoiden Verbindungen und der Farbintensität des Weißweins. Somit wies der Wein, welcher über 28 Tagen mit Akazienchips ausgebaut wurde, signifikante Farbunterschiede im Vergleich zum Kontrollwein auf. Die Ergebnisse zeigten auch, dass die mit Kirschholz- und Akazienchips ausgebauten Weine ein höheres Bräunungspotenzial während der beobachteten Ausbauperiode aufwiesen. Generell zeigte sich das sensorische Profil der Weißweine ziemlich ähnlich. Hinsichtlich des Gesamteindrucks wurden jedoch die mit Akazienchips ausgebauten Weine bevorzugt, während die mit Kirschholzchips bezüglich ihres Gesamteindrucks ähnlich bewertet wurden wie die Weine, die mit Eichenchips ausgebaut wurden. Diese Arbeit erweiterte unser Verständnis bezüglich des potenziellen Einflusses von Chips anderer Holzarten als Eiche, wie zum Beispiel Kirsche und Akazie, auf die Qualität von Weißwein.
Schlagwörter: Akazie, Kirsche, phenolische Zusammensetzung, Weißwein, Holzchips, sensorisches Profil

Recently several works have reported the influence of diverse winemaking technologies on white wine characteristics, such as, fermentation and aging in barrels from different oak wood species (Herjavec et al., 2007; Liberator et al., 2010; Kozlovic et al., 2010; Bavčar et al., 2011). This topic is particularly interesting, since the option for aging white wines in oak barrels is increasingly and widely chosen by winemakers.

Wine aging with alternative systems consists of adding wood to wine so that it acquires certain properties reminiscent of wine that has been aged in barrels. Pieces of wood from different types (concerning, wood origin, size, toasting level, etc.), are usually used to simulate the aging process in barrels (Gallego et al., 2012; Navojska et al., 2012; Jordão et al., 2012; Oberholster et al., 2015). It is also important to note that the increased use of these alternatives is mainly related to low investments, similar sensory results obtained in a shorter time and simplicity of use (Fernández de Simón et al., 2009). In Europe, alternative products could not be used until 2006, and only some experimental practices were allowed (EEC 822/87). The EEC regulation No. 606/2009 of July, 10^{th}, 2009 (appendix 9) modified previous rules by regulating the use of pieces of oak for winemaking and the description and presentation of wine undergoing this treatment . It states that the pieces of oak wood must exclusively come from the *Quercus* genus and with different toasting levels or also without toasting.

In fact, aging in oak barrels and related oak products is a traditional winemaking practice for improving wine quality. However, it is important to note that the increasing demand of oak wood caused a remarkable potential increase in costs due to the limited availability of materials. In addition, the high demand of oak wood products has also an ecological impact of harvesting oak trees in forests, where the replacement of trees is not guaranteed. Thus, the use of alternative woods, such as acacia (*Robinia pseudoacacia*) and cherry (*Prunus avium*), may be an interesting option for the wine aging process. In the last years several papers have been published relating to the use of woods other than oak, especially acacia and cherry woods (Kozlovic et al., 2010; Sanz et al., 2012; Chinnici et al., 2011 and 2015; Fernández de Simon et al., 2014). However, these scientific works focused on the impact of alternative wood species exclusively on the quality of red wines and not of white wines.

Thus, there is a restricted knowledge about the potential impact of the use of alternative products from acacia and cherry on white wine quality during the aging process. In this context, the main goal of our study was to evaluate the impact of the use of wood chips from acacia and cherry species during a short aging period on the general phenolic composition and the sensory profile of a white wine from 'Encruzado' grape variety. In addition, a comparative analysis between the use of these wood species and oak wood species (*Quercus alba* and *Quercus petraea*) was also an aim of this study. 'Encruzado' is a traditional Portuguese white grape variety cultivated traditionally in the northeast of Portugal and has been commercially very successful in national and international markets over the last years. Thus, to the best of our knowledge, this is also the first report concerning the potential influence of the use of different alternative wood chips on 'Encruzado' wine.

MATERIAL AND METHODS

WHITE WINE

The wine used in this experiment was a white wine made entirely from the *Vitis vinifera* grape variety 'Encruzado', harvested during the vintage 2014 and vinified by the winery at the Instituto Superior de Agronomia in Lisbon, following the classical procedure for white wine. The sulphitation of the grapes (50 mg/kg of $K_2S_2O_5$) was followed by a natural clarification process for 24 hours at 12 °C. The must was fermented in a stainless steel tanks using a standard *Saccharomyces cerevisiae* yeast strain (Fermol Arôme Plus; AEB Group, Bréscia, Italy) and inoculated at 20 g/hl. The alcoholic fermentation process was completed in two weeks keeping the temperature below 20 °C. After the alcoholic fermentation the wine was racked and removed from contact with the lees. The general physico-chemical and phenolic compositions of the 'Encruzado' white wine at the beginning of the experimental work are shown in Table 1.

Table 1: General physico-chemical and phenolic composition of 'Encruzado' white wine used in the study

Parameters	Values*
Volatile acidity (g/l acetic acid)	0.23
Total SO_2 (mg/l)	115
Free SO_2 (mg/l)	36
pH	3.33
Total acidity (g/l tartaric acid)	6.7
Alcohol degree (%vol., 20 °C)	12.9
Sugars (g/l)	0.7
Total phenols (mg/l gallic acid eq.)	317.0
Non-flavonoid phenols (mg/l gallic acid eq.)	114.8
Flavonoid phenols (mg/l gallic acid eq.)	202.3
Color intensity (abs. units at 420 nm)	0.086
Browning potential index**	0.031

* Average values of three replicates
** Difference between with and without nitrogen

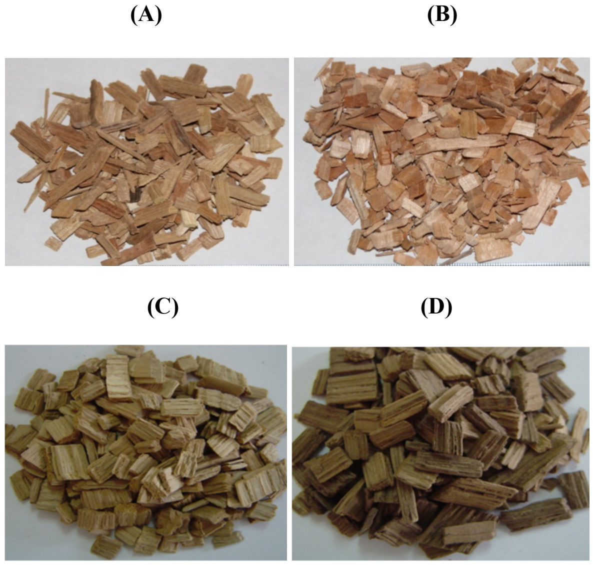

Fig. 1: Visual appearance of the different wood chips species used in the study
(A) - Acacia (*Robinia Pseudoacacia*); (B) - Cherry (*Prunus avium*); (C) - American oak (*Quercus alba* L.); (D) - French oak (*Quercus petraea* L.)

EXPERIMENTAL CONDITIONS

A total of four different wood chips species were used: acacia (*Robinia pseudoacacia*) purchased from SAI company (Paredes, Portugal), and cherry (*Prunus avium*), American (*Quercus alba*) and French (*Quercus petraea*) oak wood chips purchased from AEB Bioquímica company (Viseu, Portugal). All the wood chips presented a medium toasting level and a particle dimension of 8 mm (average size). Figure 1 shows the visual appearance of the different wood chips samples used in this study.

The white wine samples (10 litres each) were aged in contact with different wood chips species (concentration of 0.5 g/l) during a short aging time (28 days) at a cellar temperature (between 15 to 18 °C) and stirred twice a week. A control white wine (without wood chips addition) was also considered in our study. The wine samples were filtered before analysis.

GENERAL PHYSICO-CHEMICAL CHARACTERIZATION

The general physico-chemical characterization (pH, total and volatile acidity, reducing sugars, alcohol level, total and free sulfur dioxide) was made following the analytical methods recommended by OIV (2012).

GENERAL PHENOLIC COMPOSITION AND CHROMATIC CHARACTERISTICS

Total polyphenolic content was determined according to Ribéreau-Gayon et al. (2006), while non-flavonoid and flavonoid phenols were determined using the methodology described by Kramling and Singleton (1969). For these parameters the results were expressed as gallic acid equivalents by means of calibration curves with standard gallic acid from Extra-Synthese (Genay, France). Color intensity at 420 nm was also evaluated following the methodology described by OIV (2012).

Browning potential index was evaluated following the methodology proposed by Singleton and Kramling (1976). Thus briefly: Test tubes were filled with 20 ml of the wine to be tested. Control and test samples were sparged thoroughly with nitrogen and oxygen, respectively. All tubes were sealed hermetically and kept at 55 °C for 5 days. The test was conducted with treated and untreated wine, and the browning value difference was calculated by measuring the increase in absorbance at 420 nm.

Tannicity was quantified following the methodology developed by De Freitas and Mateus (2001). This method includes a dilution 1:50 with a hydroalcoholic solution (12 %vol., pH = 3.2 and T = 20 °C), followed by the reading at the turbidimeter (d0). Then, 8 ml of the previous dilution and 300 µl of BSA (Bovine Serum Albumin) are put in a tube and after an agitation and 45 minutes in darkness, a second reading is carried out at the turbidimeter (d1). The final value (NTU/ml) was calculated from: Tannicity = (d1 - d0)/0.08.

Finally, using the CIELab method, chromatic characteristics (scanned from a range of 380 to 770 nm) was also determined by the calculation of several chromatic parameters: L* (%) (lightness), a* (redness), b* (yellowness), hue-angle [ho = tg-1 (b*/a*)] and chroma [C* = $[(a^*)^2 + (b^*)^2]^{1/2}$] according to OIV (2012) method. In order to distinguish the color more accurately, the color difference was also calculated using the following formula: ($\Delta E=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$). All analyses were done in triplicate.

SENSORY EVALUATION

Each white wine sample was stored for 24 hours at room temperature before sensory analysis, which was performed at 20 to 22 °C in a tasting room with individual booths for each expert and according to standardized procedures (ISO 3591, 1977). All evaluations were conducted in the morning from 10:00 to 12:00 o'clock. Eight expert judges with wine tasting experience evaluated the white wine samples after 28 days of aging. Samples were presented to the panel in tasting glasses marked with three digit numbers and in a randomized order.
The wines were evaluated using different descriptors for appearance (color and clarity) aroma (fruity, floral, vegetal, spicy, almond, oxidation, woody; intensity and quality), taste (acidity, body, astringency, equilibrium, persistency and quality) and overall appreciation. The experts rated each sensory attribute, except for overall appreciation, on a 1 to 5 point scale (1 = absence; 2 = little intensity; 3 = moderate intensity; 4 = intense; 5 = high intensity) for each characteristic according to their sensory knowledge, training and experience; the overall appreciation was scored on a 0 to 20 point scale (0 to 4 = bad; 5 to 9 = mediocre; 10 to 13 = pleasant; 14 to 17 = good; 18 to 20 = very good).

STATISTICAL ANALYSIS

The data are presented as mean ± standard deviation. Phenolic and sensory data were statistically tested by analysis of variance (ANOVA, one-way). Tukey test ($p < 0.05$) was applied to the data to determine significant differences between wines. All analyses were performed using SPSS Software (version 23).

RESULTS AND DISCUSSION

GENERAL PHENOLIC COMPOSITION AND CHROMATIC CHARACTERISTICS

The results obtained for total phenols, flavonoid and non-flavonoid compounds, color intensity and tannicity of 'Encruzado' wines aged in contact with the different wood chips species during 28 days are shown in Figure 2. For total phenolic contents an increase in all white wines during the aging time considered was quantified (except for the wine aged with French oak wood where the values remained constant). Wines aged in contact with acacia wood chips showed the significantly highest values (333.66 and 342.94 mg/l gallic acid equivalents, respectively, after 20 and 28 aging days). After 28 aging days, total phenolic contents followed the following decrease order: wine aged with acacia chips (342.94 mg/l gallic acid equivalents), wine aged with cherry chips (328.59 mg/l gallic acid equivalents), wine aged with French oak chips (319.86 mg/l gallic acid equivalents), wine aged with American oak chips (319.32 mg/l gallic acid equivalents) and control wine (314.46 mg/l gallic acid equivalents). These results could reflect the large quantities of potentially extractable phenolic substances from wood chips especially from acacia and cherry wood species. According to several studies, during wine aging in contact with wood (chips or barrels) there is an increase in total phenol contents as a consequence of a phenols transfer from wood to wine (Jindra and Gallender, 1987; Gonçalves and Jordão, 2009; Chira et al., 2015). In addition, it was also clear that 20 aging days were sufficient for the extraction of phenolic compounds from French wood chips because the values remained constant between 20 and 28 aging days. The opposite tendency was verified for the wines aged in contact with acacia, cherry and American oak wood chips, where the values showed an increase between 20 and 28 aging days. Thus, this result predicts the possibility of longer contact times with wines and these wood chips species to increase the potential extraction of extractable phenolic compounds.

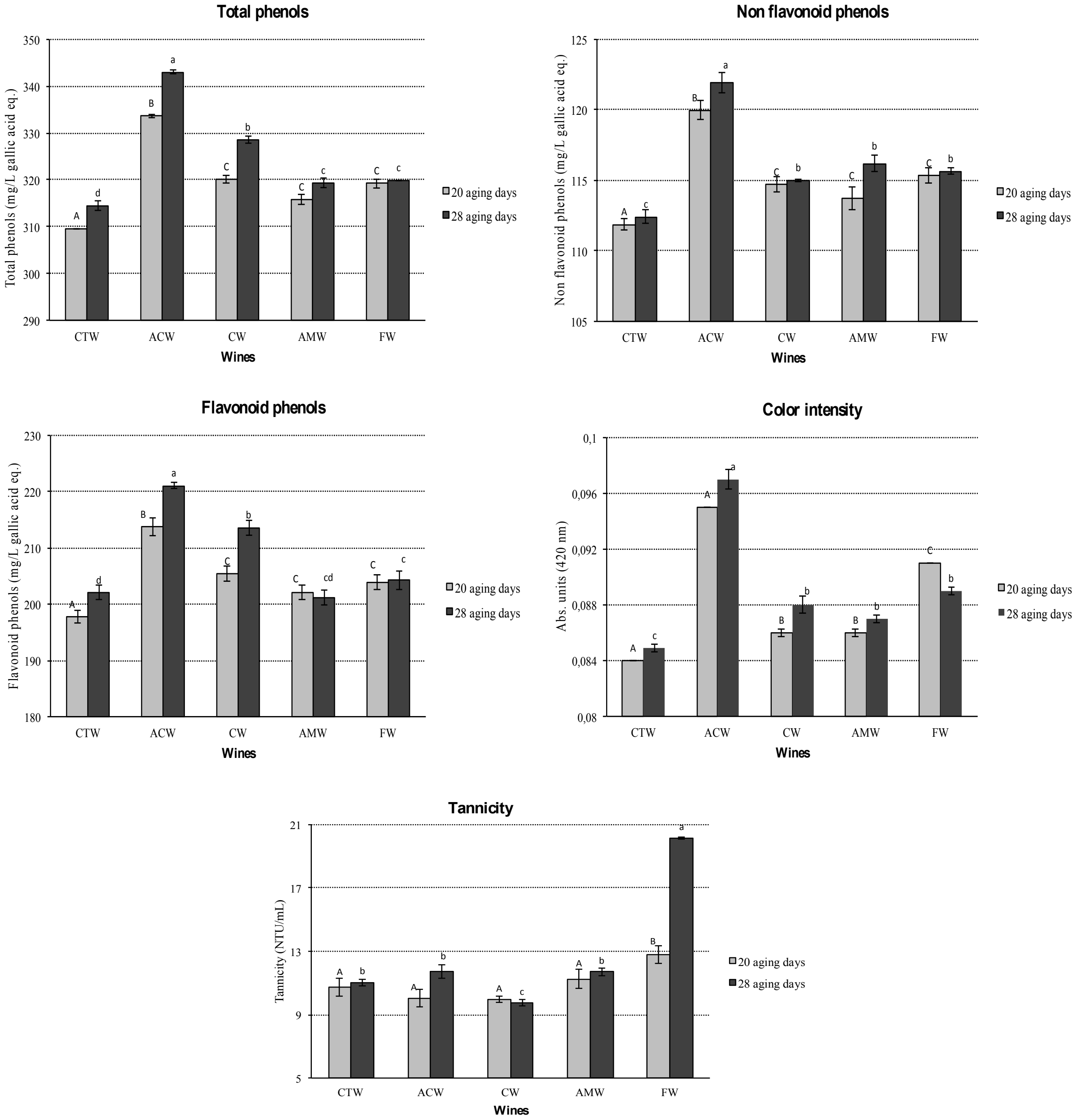

Fig. 2: General phenolic composition of 'Encruzado' white wine aged in contact with different wood chips species after 20 and 28 aging days

CTW - control wine aged without any wood chips; ACW – wine aged with acacia wood chips; CW – wine aged with cherry wood chips; AMW – wine aged with American wood chips; FW – wine aged with French wood chips.

* Values with same letters for each aging day are not significantly different (Tukey test, $p < 0.05$), capital letters for 20 aging days and small letters for 28 aging days.

Previously, Chinnici et al. (2015) analyzed the changes in the phenolic composition of red wines aged in cherry wood barrels and only detected significant changes in several phenolic compounds after four months of storage. However, between the 30th and the 45th aging day a slight increase of flavonoid compounds in wine aged in contact with chips from acacia wood compared to other wines was detected. The favorable porosity of acacia and cherry woods could be considered the reason for an easier extraction of flavonoid phenolic compounds from these wood chips. In addition, according to Fernández de Simón et al. (2010) each type of wood and piece size showed particular extraction kinetics. Thus, the extraction compounds evolution occurred more slowly or not, as a result of the slower or faster wine penetration into the wood, the concentration gradient between wine and wood, and the potential phenolic richness of each wood species.

All these tendencies verified for total phenolic compounds were also in general detected for flavonoid and non-flavonoid phenols. Thus, for non-flavonoid phenols, the wine aged in contact with acacia wood chips showed the significantly highest values (119.96 and 121.91 mg/l gallic equivalents, respectively, after 20 and 28 aging days) while for the wines aged in contact with cherry and oak wood chips similar values were quantified. In addition, for flavonoid phenols, white wines aged in contact with acacia and cherry wood chips showed the significantly highest values after 28 aging days (6.83 and 6.60 mg/l, respectively) while with wines aged in contact with French or American oak wood chips no significant differences were obtained between the two dates studied.

The high values of flavonoid and non-flavonoid compounds quantified especially in wines aged with acacia wood chips corresponds to a potential higher extraction of individual phenolic compounds, such as, for example, gallic acid, ellagitannins and ellagic acid. A similar tendency was also reported by Sanz et al. (2011), where seasoned acacia wood showed high concentrations of flavonoid compounds, and this could explain the difference found. In addition, several authors (De Rosso et al., 2009a; Sanz et al., 2011 and 2012) also described a particular richness of some phenolic compounds in acacia woods and consequently in wines aged in contact with this wood species. In this regard, Soares et al. (2012) reported high values of absorbance measures at 280 nm and also total polyphenolic contents for acacia extracts produced in model wine solutions.

Regarding color intensity, all wines showed changes throughout the aging time. White wine aged in contact with acacia wood chips showed the significantly highest values (0.095 and 0.097 abs. units, respectively, after 20 and 28 aging days) followed by the wine aged with French wood chips (0.091 and 0.089 abs. units, respectively, after 20 and 28 aging days). Wines aged with cherry and American oak wood chips showed similar lower values (between 0.086 and 0.088 abs. units, respectively, after 20 and 28 aging days). In addition, the control wine showed the lowest color intensity values at the two dates considered and very similar values (0.0840 and 0.0849 abs. units, respectively, after 20 and 28 aging days). Finally in all white wines, an increase of color intensity was detected from the beginning of the aging process until the 28th aging day except for wine aged with French oak wood where the color intensity values showed a slight decrease (from 0.091 to 0.089 abs. units, respectively, after 20 and 28 aging days).

A previous investigation detected similar changes in white wine color intensity over aging time in wood barrels (Recamales et al., 2006). In addition, Vivas et al. (2008) describe the formation of a diversity of new compounds resulting from the interaction between high concentration of several oak wood compounds and wine (+)-catechin and their effect on the initial white wine color change. According to these authors, white wines aged in oak wood barrels showed an increase in yellow color as a consequence of the new compounds obtained from these interactions. In addition, several references have described the participation of phenolic aldehydes in a variety of reactions that influence also the color wine evolution. For example, diverse condensation products have been described as resulting from the direct reaction of some individual oak wood phenolic aldehydes (namely vannilin and syringaldehyde) with wine flavanols, contributing to wine color and astringency evolution (Nonier et al., 2006; Sousa et al., 2007).

Still with regard to wine color, the results obtained with

Table 2: Chromatic characteristics of 'Encruzado' white wine aged in contact with different wood chips species after 28 aging days using CIELab coordinates

CIELAB coordinates	Wines aged with wood chips				
	CTW	ACW	CW	AMW	FW
L^*	51.68 ±0.06[a]	51.66 ±0.03[a]	51.69 ± 0.03[a]	51.70 ± 0.02[a]	51.72 ± 0.13[a]
a^*	-0.28 ±0.07[a]	-0.41 ±0.02[b]	-0.75 ± 0.05[c]	-0.76 ± 0.14[c]	-0.82 ± 0.11[c]
b^*	4.93 ±0.03[a]	7.25 ±1.31[b]	5.79 ± 0.18[b]	6.20 ± 0.20[b]	5.72 ± 0.08[c]
C^*	4.94 ±0.09[a]	6.02 ±0.54[b]	5.84 ± 0.18[b]	6.25 ± 0.18[b]	5.78 ± 0.09[b]
h^o	86.74 ± 0.05[a]	86.76 ±0.66[a]	82.62 ±0.11[b]	83.01 ± 0.17[b]	81.84 ± 0.09[b]
ΔE*	----	2.32 ±0.65[a]	0.978 ±0.41[b]	1.35 ±0.60[b]	0.955 ±0.32[b]

CTW - control wine aged without any wood chips; ACW - wine aged with acacia wood chips; CW - wine aged with cherry wood chips; AMW - wine aged with American wood chips; FW - wine aged with French wood chips; L^* (%) (lightness); a^* (from green to red); b^* (from blue to yellow); C^* (Chroma); h^o (hue-angle); ΔE^* total color difference; the values corresponding to ΔE^* were obtained taking as a reference the control wine (CTW). Values with same letters for each CIELab coordinate are not significantly different (Tukey test, $p < 0.05$); ± standard deviation; average values of three replicates

the CIELab method for the chromatic characteristics of the white wines after 28 aging days are shown in Table 2. For lightness (L*) no significant differences were detected between all wines. However, concerning a* values (redness) the control wine showed the significantly highest values (0.28 expressed by the CIELab coordinates). On the other hand, as expected for white wines, the a* values were all extremely low (all negative values) reflecting the obvious non-existence of red color in white wines and a tendency for a slightly blue color especially for the wines aged in contact with cherry and oak wood chips, where the values were significantly different and wine aged in contact with acacia wood chips. For b* values, the addition of wood chips (independently of the wood chips species used) induced a significant increase of the yellow color after 28 aging days confirming the results obtained for color intensity obtained at 420 nm (Fig. 2). Thus, after 28 aging days the b* values of the white wines showed in descending order the following sequence: wine aged in contact with acacia chips (7.25 expressed by the CIELab coordinates), wine aged in contact with American oak chips (6.20 expressed by the CIELab coordinates), wine aged in contact with cherry chips (5.79 expressed by the CIELab coordinates), wine aged with French oak wood chips (5.72 expressed by the CIELab coordinates) and control wine (4.93 expressed by the CIELab coordinates). The b* values obtained for white wine aged in contact with acacia wood chips also confirm the results already showed for color intensity determined at 420 nm. It is important to note that the extraction of several phenolic wood compounds could also induce an increase in b* values (yellowness) that was detected in wines aged in contact with wood chips. A similar tendency was also detected for c* values where wine aged with wood chips showed the significantly highest values (ranging from 5.78 to 6.25 expressed by the CIELab coordinates) while the control wine showed the lowest c* values (4.94 expressed by the CIELab coordinates) corresponding to a lower wine color intensity. The highest c* values were obtained for white wines aged in contact with American oak and acacia wood chips (6.25 and 6.02 expressed by the CIELab coordinates, respectively). Concerning to h° values the significantly highest values were obtained for the control wine and the white wine aged in contact with acacia wood chips (86.74° and 86.76°, respectively).

Despite the differences in results obtained for the different color coordinates, the values obtained for color difference (ΔE) between control wine and wines aged in contact with different wood chip species (Table 2) showed that only white wine aged with acacia wood chips showed values higher than two CIELab units, indicating that the color difference could be detected by human eyes (Spagna et al., 1996).

Finally for tannicity evolution the values are shown in Figure 2. Tannicity stands for the expression of the adstringency perception of a wine, namely, the capacity that some phenolic compounds as tannins have to interact with proteins, influencing the astringent character of the wine in taste. In general, except for the wine aged in contact with cherry wood chips, all wines showed a tendency for an increase of tannicity values. This increase was in particular significant for the wine aged in contact with French oak wood chips (from 12.79 to 20.13 NTU/ml, respectively, after 20 and 28 aging days) with respect to the other white wines. In fact, high phenolic composition, and especially the high ellagitannin content that characterize French oak heartwood (Chatonnet and Dubourdieu, 1998; Jordão et al., 2007 and 2012; Chira and Teissedre, 2015) may explain the high tannicity quantified in white wine aged in contact with French oak wood chips, especially after 28 aging days. Conversely, tannicity results for white wines aged with acacia and American oak samples were not statistically significantly different from the control wine. This result could be explained by the low concentrations of ellagitannins that characterize these wood species (Chatonnet and Dubourdieu, 1998; Cabrita et al., 2011; Sanz et al., 2012) and consequently the low level of interactions between these phenolic compounds and saliva proteins inducing low levels for wine astringency.

BROWNING POTENTIAL INDEX EVOLUTION

The results for the evolution of the browning potential index of white wines aged in contact with different wood chips over 28 aging days are shown in Figure 3. During the aging time considered, a tendency for a browning potential index decrease was evident for all wines. Thus, with increasing aging time an increase of the stability to oxidation of these wines occurred. This browning potential index decrease can be reasonably attributed to the precipitation of oxidized phenols (including also the phenolic compounds extracted from wood chips) present at the beginning of the aging process, as well as for the phenolic polymers. Barrón et al. (1997) reported that the removement of flavan-3-ol derivates induce a protection of wines from an excessive browning, and consequently the wines become more stable. In addition, the extraction of several wood components, such as ellagitannins induce an increase of the antioxidant protection of wines. In this trend Gonçalves and Jordão (2009) also reported an increase in the antioxidant activity in wines aged in contact with the oak wood chips species during the first 52 days of storage followed by a slight decrease.

However, white wines aged in contact with acacia, cherry and French oak wood chips showed the significantly highest values. This tendency was particularly evident for the white wines aged in contact with cherry wood chips, where the browning potential values maintained high values over the total aging time considered. This fact confirmed previous works that reported much more sensibility to oxidation reactions in wine aged in cherry barrels as a result of low contents of oxidizable polyphenols that characterizes cherry heartwood, leading to a higher oxidative environment than the other wood species (De Rosso et al., 2009a and 2009b; Chinnici et al., 2015). Finally, it was also clear that the wine aged in contact with American oak wood chips showed the significantly lowest values at all storage dates considered.

SENSORY EVALUATION

The sensory profile for taste and aroma descriptors of the white wines after 28 aging days in contact with different wood chips species was evaluated and is shown in Figure 4. The significant differences were related to the "persistency" and "astringency" taste descriptors. Thus, the significantly highest persistency was obtained for the white wines aged in contact with acacia and French oak wood chips in relation to the other white wines aged in contact with cherry, American oak wood chips and the control wine. In addition, significantly higher astringency scores were obtained for all white wines aged in contact with the different wood chips in relation to the control wine. These differences could be explained as a result of a high potential of extractable phenolic compounds transferred from the wood to the wines during the aging process. All of these extractable phenolic compounds will contribute to change of sensory properties of the white wines aged in contact with wood chips. According to some authors (Gallego et al., 2012; Chira and Teissedre, 2015) wood ellagitannin concentration and other extractable phenolic wood components are closely correlated with several wine sensory descriptors, namely "complexity", "persistency", "astringency" and "round tannins".

For aroma descriptors the panel test did not detect significant differences between the white wines. However,

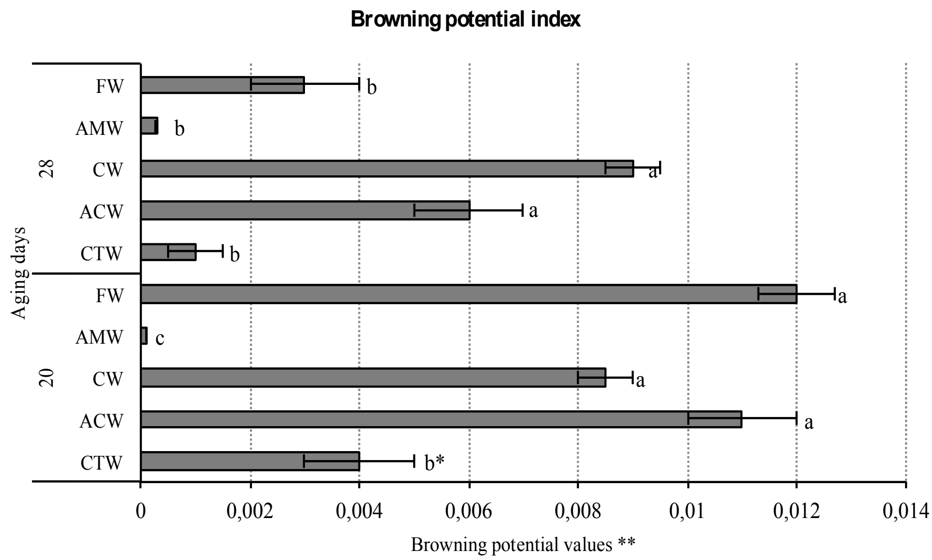

Fig. 3: Browning potential index of 'Encruzado' white wine aged in contact with different wood chips species after 20 and 28 aging days.
CTW - control wine aged without any wood chips; ACW - wine aged with acacia wood chips; CW - wine aged with cherry wood chips; AMW - wine aged with American wood chips; FW - wine aged with French wood chips
* Values with same letters for each aging day are not significantly different (Tukey test, $p < 0.05$).
** Difference between with and without nitrogen

for "woody" aroma descriptors, there was a slight differentiation (without statistical significance) between the wines aged in contact with acacia and oak wood chips in relation to the wine aged in contact with cherry wood chips and the control wine.
The results for overall appreciation scores obtained from sensory analysis (Fig. 5) pointed out significant differences between white wine aged in contact with acacia wood chips in relation to the other white wines. According to the results, white wine aged in contact with acacia wood chips showed the best overall appreciation score from the panel test. The remaining wines had similar scores for overall appreciation. Previously, Kozlovic et al. (2010) have described the contribution of oak and acacia wood barrels to white wines from the 'Malvazija' grape variety. According to these authors, white wines aged in acacia barrels were rated the best in the panel test showing more pronounced fruit, vanilla and spicy character and at the same time less pronounced oak flavor in relation to the white wines aged in oak wood barrels.

CONCLUSIONS

This study provides information on the potential impact of the use of wood chips from different species, especially for alternative wood chips from acacia and cherry, on the quality of white wines during a short aging period. For an overall point of view, it was possible to detect a clear influence of the use of acacia wood chips on the overall phenolic parameters and chromatic characteristics of white wine. In addition, the use of acacia and cherry wood chips could induce a potentially higher sensibility to oxidation reactions of white wines during the aging time. Concerning the impact of the use of different wood chips species used on sensory characteristics of white wines from 'Encruzado' white grape variety the results did not show a clear differentiation with the sensory descriptors analysed. However, white wine aged in contact with acacia wood chips showed significantly higher overall appreciation scores.

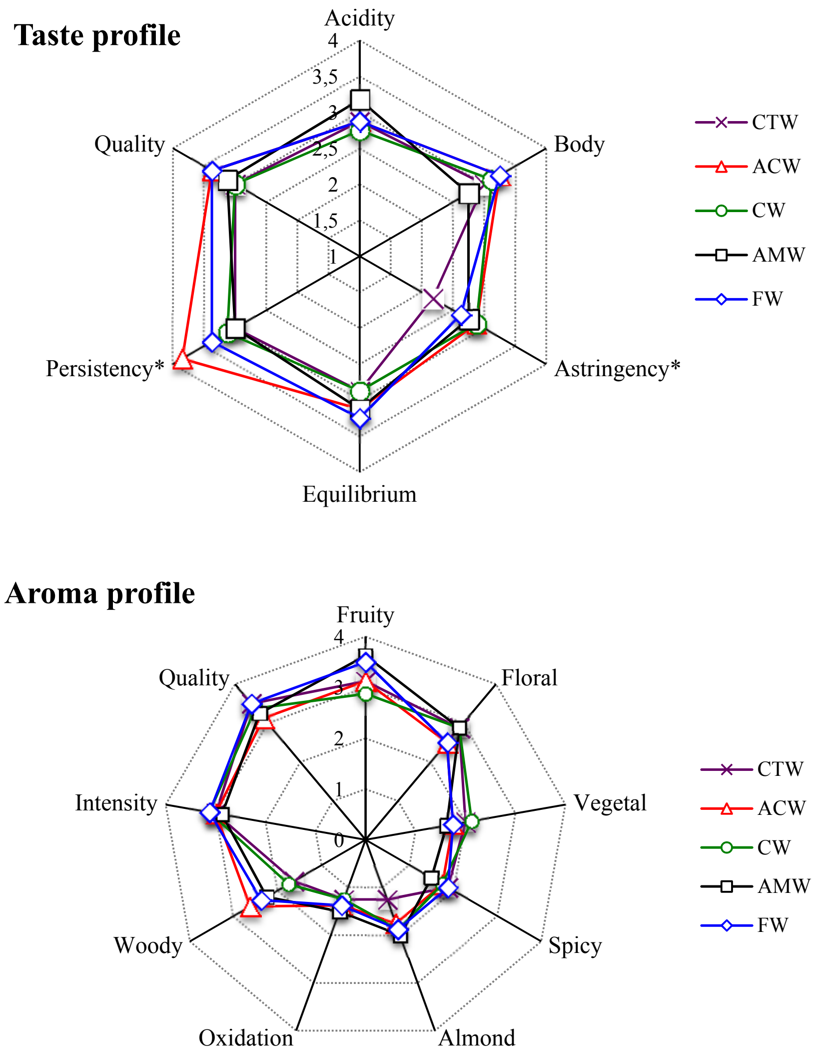

Fig. 4: Sensory profile for aroma and taste parameters of 'Encruzado' white wine aged in contact with different wood chips species after 28 aging days

CTW - control wine aged without any wood chips; ACW - wine aged with acacia wood chips; CW - wine aged with cherry wood chips; AMW - wine aged with American wood chips; FW - wine aged with French wood chips

* Values with significant differences (Tukey test, $p < 0.05$).

Further research, including more detailed chemical analyses, will be necessary to improve the knowledge about the potential impact of the use of new wood chips sources (besides the species used in this study) on white wine quality. In addition, the use of a more extended aging time, different wood chip concentrations and toasting levels will also be other points to be considered in future studies.

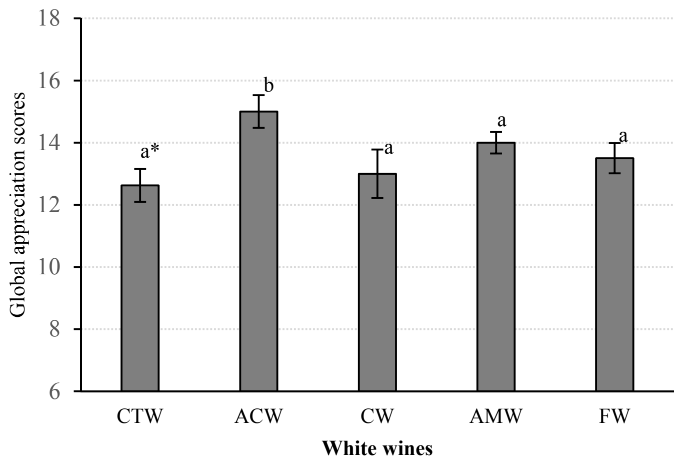

Fig. 5: Overall appreciation scores for the 'Encruzado' white wine aged in contact with different wood chips species after 28 aging days

CTW - control wine aged without any wood chips; ACW - wine aged with acacia wood chips; CW - wine aged with cherry wood chips; AMW - wine aged with American wood chips; FW - wine aged with French wood chips

* Values with same letters are not significantly different (Tukey test, $p < 0.05$).

ACKNOWLEDGEMENTS

Authors' thanks to SAI and AEB Bioquímica Portuguesa companies for supplying the wood chips samples used in this study.

REFERENCES

Barrón, R., Mayén, M., Mérida, J. and Medina, M. 1997: Changes in phenolic compounds and browning during biological aging of sherry-type wine. J. Agric. Food Chem. 45: 1682-1685.

Bavčar, D., Baša, Č.H., Čuš, F., Vanzo, A., Gašperlin, L. and Košmerl, T. 2011: Impact of alternative skin contact procedures on the aroma composition of white wine. S. Afr. J. Enol. Vitic. 32: 190-203.

Cabrita, M.J., Barrocas Dias, C. and Costa Freitas, A.M. 2011: Phenolic acids, phenolic aldehydes and furanic derivatives in oak chips: American vs. French oaks. S. Afr. J. Enol. Vitic. 32: 204-210.

Chatonnet, P. and Dubourdieu, D. 1998: Comparative study of the characteristics of American white oak (*Quercus alba*) and European oak (*Quercus petraea* and *Q. robur*) for production of barrels used in barrel aging of wines. Am. J. Enol. Vitic. 49: 79-85.

Chinnici, F., Natali, N., Sonni, F., Bellachioma, A. and Riponi, C. 2011: Comparative changes in color features and pigment composition of red wines aged in oak and cherry wood casks. J. Agric. Food Chem. 59: 6575-6582.

Chinnici, F., Natali, N., Bellachioma, A., Versari, A. and Riponi, C. 2015: Changes in phenolic composition of red wines aged in cherry wood. LWT - Food Sci. Technol. 60: 977-984.

Chira, K. and Teissedre, P.-L. 2015: Chemical and sensory evaluation of wine matured in oak barrel: effect of oak species involved and toasting process. Eur. Food Res. Technol. 240: 533-547.

De Rosso, M., Cancian, D., Panighel, A., Dalla Vedova, A. and Flamini, R. 2009a: Chemical compounds released from five different woods used to make barrels for aging wines and spirits: volatile compounds and polyphenols. Wood Sci. Technol. 43: 375-385.

De Rosso, M., Panighel, A., Dalla Vedova, A., Stella, L. and Flamini, R. 2009b: Changes in chemical composition of a red wine aged in acacia, cherry, chestnut, mulberry, and oak wood barrels. J. Agric. Food Chem. 57: 1915-1920.

De Freitas, V. and Mateus, N. 2001: Structural features of procyanidin interactions with salivary proteins. J. Agric. Food Chem. 49: 940-945.

Fernández de Simón, B., Cadahía, E., Del Álamo, M. and Nevares, I. 2009: Volatile compounds in acacia, chestnut, cherry ash and oak woods, with a view to their use in cooperage. J. Agric. Food Chem. 57: 3217-3227.

Fernández de Simón, B., Cadahía, E., Muiño, I., Del Álamo, M. and Nevares, I. 2010: Volatile composition of toasted oak chips and staves and of red wine aged with them. Am. J. Enol. Vitic. 61: 157-165.

Fernández de Simón, B., Martínez, J., Sanz, M., Cadahía, E., Esteruelas, E., and Muñoz, A.M. 2014: Volatile compounds and sensorial characterization of red wine aged in cherry, chestnut, false acacia, ash and oak wood barrels. Food Chem. 147: 346-356.

Gallego, L., Del Álamo, M., Nevares, I., Fernández, J.A., Fernández de Simón, B. and Cadahía, E. 2012: Phenolic compounds and sensorial characterization of wines aged with alternative to barrel products made of Spanish oak wood (*Quercus pyrenaica* Willd.). Food Sci. Technol. Int. 18: 151-165.

Gonçalves, F.J. and Jordão, A.M. 2009: Changes in antioxidant activity and proanthocyanidin fraction of red wine aged in contact with Portuguese (*Quercus pyrenaica* Willd.) and American (*Quercus alba* L.) oak wood chips. Ital. J. Food Sci. 21: 51-64.

Herjavec, S., Jeramol, A., Da Silva, A., Orlic, S. and Redzepovic, S. 2007: The quality of white wines fermented in Croatian oak barrels. Food Chem. 100: 124-128.

ISO-3591 1977: Sensory analysis - apparatus - wine - tasting glass. From<http://www.iso.org/iso/rss.xlm?csnumber=9002&rss=detail>. Retrieved 20.11.2008.

Jindra, J.A. and Gallender, J.F. 1987: Effect of American and French oak barrels on the phenolic composition and sensory quality of Seyval blanc wine. Am. J. Enol. Vitic. 38: 133-138.

Jordão, A.M., Ricardo-da-Silva, J.M. and Laureano, O. 2007: Ellagitannins from Portuguese oak wood (*Quercus pyrenaica* Willd.) used in cooperage: Influence of geographical origin, coarseness of the grain and toasting level. Hollforschung 61: 155-160.

Jordão, A.M., Correia, A.C., DelCampo, R. and González-SanJosé, M.L. 2012: Antioxidant capacity, scavenger activity and ellagitannins content from commercial oak pieces used in winemaking. Eur. Food Res. Technol. 235: 817-825.

Kozlovic, G., Jeromel, A., Maslov, L., Pollnitz, A. and Orlić, S. 2010: Use of acacia barrique barrels - Influence on the quality of Malvazija from Istria wines. Food Chem. 120: 698-702.

Kramling, T.E. and Singleton, V.L. 1969: An estimate of the non flavonoid phenols in wines. Am. J. Enol. Vitic. 20: 86-92.

Liberator, M.T., Pati, S., Del Nobile, M.A. and La Notte, E. 2010: Aroma quality improvement of Chardonnay white wine by fermentation and ageing in barrique on lees. Food Res. Int. 43: 996-1002.

Navojska, J., Brandes, W., Nauer, S., Eder, R. and Francakova, H. 2012: Influence of different oak chips on aroma compounds in wine. J. Microbiol. Biotechnol. Food Sci. 1: 957-971.

Nonier, M.F., Pianet, I., Laguerre, M., Vivas, N. and De Gaulejac, N.V. 2006: Condensation products derived from flavan-3-ol oak wood aldehydes reaction-1. Structural investigation. Anal. Chim. Acta 563: 76-83.

Oberholster, A., Elmendorf, B.L., Lerno, L.A., King, E.S., Heymann, H., Brenneman, C.E. and Boulton, R.B. 2015: Barrel maturation, oak alternatives and micro-oxygenation: influence on red wine aging and quality. Food Chem. 173: 1250-1258.

OIV (Organisation International de la Vigne et du Vin) 2012 : International Oenological Codex. Edition Officielle, Paris.

Recamales, Á.F., Sayago, A., González-Miret, M.L. and Hermanz, D. 2006: The effect of time and storage conditions on the phenolic composition and color of white wine. Food Res. Int. 39: 220-229.

Ribéreau-Gayon, P., Glories, Y., Maujean, A. and Dubourdieu, D. 2006: Handbook of Enology. The Chemistry of Wine Stabilization and Treatments. (2nd ed.). (Vol. 2). France: Bordeaux. Wiley & Sons Ltd., Chichester: England, 2006.

Sanz, M., Fernández de Simón, B., Esteruelas, E., Muñoz, A.M. and Cadahía, E. 2011: Effect of toasting intensity at cooperage on phenolic compounds in acacia (*Robinia pseudoacaci*a) heartwood. J. Agric. Food Chem. 59: 3135-3145.

Sanz, M., Fernández de Simón, B., Esteruelas, E., Muñoz, A. M., Cadahía, E., Hernández, T., Estrella, I. and Martinez, J. 2012: Polyphenols in red wine aged in acacia (*Robinia pseudoacacia*) and oak (*Quercus petraea*) wood barrels. Anal. Chim. Acta 732: 83-90.

Spagna, G., Pifferi, P.G., Rangoni, C., Mattivi, F., Nicolini, G. and Palmonari, R. 1996: The stabilization of white wines by adsorption of phenolic compounds on chitin and chitosan. Food Res. Int. 29: 241-248.

Singleton, V.L. and Kramling, T.E. 1976: Browning of white wines and an accelerated test for browning capacity. Am. J. Enol. Vitic. 27: 157-160.

Soares, B., Garcia, R., Freitas, A.M.C. and Cabrita, M.J. 2012: Phenolic compounds released from oak, cherry, chestnut and robinia chips into a sybtethic wine: influence of toasting level. Ciência Téc. Vitiv. 27: 17-26.

Sousa, C., Mateus, N., Silva, A.M.S., González-Paramás, A.M., Santos-Buelga, C. and De Freitas, V. 2007: Structural and chromatic characterization of a new malvidin-3-glucoside-vanillyl-catechin pigment. Food Chem. 102: 1344-1351.

Vivas, N., Bourden Nonier, M.F., Absalon, C., Abad, V. L., Jamet, F., Vivas de Gaulejac, N., Vitry, C. and Fouquet, É. 2008: Formation of flavanol-aldehyde adducts in barrel-aged white wine - possible contribution of these products to colour. S. Afr. J. Enol. Vitic. 29: 98-108.

Received December, 29th, 2016