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Influence of oak woods of different geographical origins on quality of wines aged in barriques and using oak chips

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Abstract

Wine ageing in wood barrels is a traditional practice in quality wine-making areas. It is generally believed that the organoleptic characteristics of wines aged in barrels are deeply influenced by wood geographical origin, as well as by age of barrels (new or used).

The main purpose of this work was to investigate the variation of some qualitative characteristics of a local red wine aged in medium-toasted barrels made of oak wood from four different French forests: Allier, Never, Tronçais and Limousin. A second target was the evaluation of the persistence of the influence of the wood geographical origin on wine characteristics with the use of old barrels and wood-shaving chips. Therefore, we chose the mostly appreciated wood typologies in the wine barrel making industry.

Keywords: Wine; Polyphenols; Volatile compounds; French oak; Oak chips

1. Introduction

In the past few years, productive wine strategy has been focussed on the improvement of quality, by protocols directed to the expectations of the market.

The issue has been increasingly oriented toward red wines, especially toward very structured ones and these aged in wood (Dennison, 1999). Ageing in wood oak barrels gives to wine structure, complexity and persistence of scents; however, it does not constitute a treatment able to transform a not-so-good wine to an excellent product; it rather exalts the quality of the product, especially if it is highly controlled and rationally used.

It is known that the organoleptic characteristics of wines aged in wood are profoundly influenced by the geographical origin of wood used. (Feuillat, Keller, & Huber, 1998). The choice is generally oriented toward French wood from various regions or forests, namely Allier (forest of the Tronçais), Limousin, Cher (forest of S. Palais), Nievre (forest of Never and Bertange), Borgogna (forest of Citeaux), Vosges (forest of Darney) and Argonne.

The type of wood barrels used was mainly based on the empirical choice of producers and it was also influenced by economic factors (Garde Cerdán, Rodríguez Mozaz, & Ancín Azpilicueta, 2002).

The ever-growing need for wood barrels, and the consequent increase of costs due to the limited availability of materials, has led some producers, especially those in the emergent countries, to use wood-shaving chips instead of oak wood.

Today the addition of wood-shaving chips in the EU countries is forbidden; but it is allowed in other countries, such as Hungary, Slovenia, Switzerland, Chile and Argentine (Spillman, 1999).

From an economic point of view, the two practices involve widely different costs; it is clear that the exclusive use of new barriques markedly affects the final price of a wine (Morris, 1992), while multi-year use can reduce the costs of containers (Spillman, 1999).

The aim of this work was to monitor the variation of some qualitative characteristics of a red wine aged in medium-toasted barrels made of oak wood of four different

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French forests: Allier, Never, Tronçais and Limousin. Moreover, we wanted to verify the persistence of the influence of the various wood geographic origins on wine characteristics with the use of old barrels and wood-shaving chips. We chose these types as they are mostly appreciated in the wine barrel-making industry.

Most investigations in this field have studied the contribution that new barrels make to wine. However, in many regions, the barrels are used at the discretion of the winemaker and the number of uses usually depends on economic factors. For this reason, the aim of this work was to compare the different contribution of new, used barrels and wood-shaving chips on qualitative wine characteristics.

2. Materials and methods

2.1. Reagents and samples

All reagents were of analytical grade unless other wise stated. Ethanol (96% v/v), HPLC-grade methanol, Folin Ciocalteau reagent, formic acid and 37% hydrochloric acid were supplied by Carlo Erba (Rodano, Milan, Italy). Milli-Q Water (Millipore, Molsheim, France) was used. Gallic acid, HMF, furfural, vanillic acid, caffeic acid, vanillin, syringic acid, syringaldehyde, ferulic acid, ellagic acid, *cis*-β-methyl-γ-octalactone, 4-methylguaiacol, *trans*-β-methyl-γ-octalactone, 4-ethylguaiacol and eugenol were supplied by Sigma–Aldrich S.r.l. (Milan, Italy). Sep-Pak C_{18} cartridges were provided by Waters (Milan, Italy) and 0.45 μm filters by Millipore (Rome, Italy).

2.2. Vinification and sample collection

Merlot grapes, produced in the hills surrounding Bolsena Lake at Montefiascone (VT, Italy), were made into wine by the local Falesco winery. In the experimental design, there were two barrels for each source.

The study was carried out for 3 years by storing the young wine in four couples of 225 l medium-toasted oak barrels (barriques), from four different French forests: Allier (A), Never (N), Tronçais (T) and Limousin (L), provided by the "Tonnellerie Remond" coopers. The wine of vintage 2000 (W00) was kept in new barrels for 7 months. The 2001 vintage wine (W01) was aged in 1-year-old barriques for 7 months. The 2002 vintage wine (W02) was stored in 2-year-old wood barrels, by now exhausted, for 2 months. Those barrels are generally regarded as exhausted so W02 wine was integrated with 5 g/l of wood-shaving chips of the same oak types as studied before. Wines were not stored in a non-oak container as our purpose was to compare the contribution of different woods to wine characteristics.

Each sample was analysed in accordance with the Official Methods (MAF, 1986) of analysis. Alcoholic strength, pH, total and volatile acidity, solid residue, colour (François, 1991), total anthocianins (Di Stefano et al., 1989), total polyphenols (Di Stefano, Cravero, & Gentilizi, 1989), aromatic compounds (Rocha, Ramalheira, Barros, Delgadillo, & Coimbra, 2001), phenolic compounds, furans (Moutounet, Rabier, Puech, Verette, & Barillere, 1989) and ellagitannins (Poiana & Mincione, 1994; Quinn & Singleton, 1985) had been defined. Each sample was finally submitted to sensory analysis (expert official taste). All analyses were carried out in triplicate and the results were averaged.

2.3. Identification and quantification of phenolic compounds by HPLC

The method by Moutounet et al. (1989), appropriately modified, was used to quantify phenolic compounds. Once filtered on 0.45 μm filters (Millipore, USA), a 20 μl sample was directly injected into an HPLC apparatus, Waters 600 E, equipped with a UV detector Perkin–Elmer Lc-95 UV/vis, an integrator Data Jet (Thermo Separation Products) and a 4 μm Nova Pak® C_{18} (∅ 300 mm × 3.9) column (Waters). The eluent was fed at 0.8 ml/min and consisited of solvent A (water–formic acid (98:2)) and solvent B (700 ml of methanol containing 2% formic acid with 300 ml of solvent A) with the following gradient elution programme: 3 min at 0% B, to 10% B in 7 min, to 40% B in 50 min, to 60% B in 20 min, to 100% B in 20 min, 10 min at 100% B.

The ellagic tannins index (expressed as mg/l of ellagic acid) was defined through acid hydrolysis (Poiana & Mincione, 1994) followed by HPLC (Quinn & Singleton, 1985). All compounds were detected at 280 nm and were identified by comparing their retention times with those of several standards.

A parametric statistical analysis of phenolic compounds, furans and ellagitannins data was carried out. An ANOVA two way test was used. Variance homogeneity was then analysed with the Levene, Dunnet (T3) and Student Neman Keuls test (S–N–K) (Underwood, 1997).

2.4. Volatile compounds by SPME/GC

To fast screen wine bouquet components, headspace solid phase microextraction (HS-SPME) was used, according to the following protocol (Rocha et al., 2001): 5 ml of wine were placed in a 25 ml vial capped with a silicon septum, containing a small magnetic stirrer. A 100 μm diameter polydimethylsiloxane (PDMS) coated SPME fibre, was manually inserted through the vial septum and exposed to the headspace at 20 °C for 30 min under stirring (140 rpm). Afterwards, the fibre was removed from the vial and inserted into the GC injector, and held at 250 °C for 7 min, in splitless mode, for thermal desorption of the aromatic compounds, which were then analysed by GC.

Chromatographic analyses were carried out through a Trace gas chromatograph (Thermo-Finnigan, Rodano, Mi, Italy), equipped with a FID detector, a DB - WAX (J & W Scientific Inc., Folson, CA, USA), 60 m × 0.25 mm × 0.25 μm capillary column, with helium as carrier gas at a flow-rate of 0.9 ml/min. The oven temperature was kept at 40 °C for 7 min, then was increased to 230 °C at a rate of 3 °C/min.

The identification of the peaks was performed by comparing the corresponding retention times to those of several standards.

2.5. Sensory analysis

Sensory analysis was carried out by an expert commission of official tasters from the Rome section of the Associazione Italiana Sommeliers (A.I.S). Standard environment (room, sample, taster) was: odour-free, quiet, well-lit, temperature 21 °C, 45–55% humidity, samples anonymous and uniformly poured and covered, tasting at the same time. A volume of 30 ml of wine was evaluated in tulip-shaped ISO (International Standardization Organization) tasting glasses at 20 °C. The commission used the A.I.S. Analytical descriptive Form (Fig. 1), which takes into consideration the different aspects of a wine: visual, olfactory and gustative. With this form, therefore, it is possible to evaluate its harmony and its evolution stage.

3. Results and discussion

For each of the three samples tested, the measured levels of alcoholic strength, pH, total and volatile acidity, solid residue and colour were typical for red wines destined to be aged in casks, but they gave no useful information on the effect of wood geographical origin.

As for sample W00 (Fig. 2), the evolutions of the content of total polyphenols in the samples stored in the four barrels used were different. Despite a first increase in wines aged in A and T barrels (S–N–K test $p < 0.05$) or a reduction in those stored in N and L barriques (S–N–K test $p < 0.05$), a completely different result was obtained after a 7-month aging. Wines mellowed in L barriques exhibited the highest total polyphenols level, while those in A casks showed the lowest (T3 test $p < 0.05$). Such behaviour may be due to different effects on these compounds by the wood: immediate in A and T barriques, slow but continuous in L and N ones.

In sample W01 (Fig. 2), the initial high content of total polyphenols showed different trends in the barrels used. In wines kept in T and N barriques, after a rapid increase, particularly evident in T ones (S–N–K test $p < 0.05$), there was a progressive decrease in total polyphenols, but the final values were slightly greater than the initial ones (S–N–K n.s. test). No substantial changes in wines kept in L casks were detected (S–N–K n.s. test), while samples in A barrels evidenced a low reduction (S–N–K test $p < 0.05$).

In samples W02 (Fig. 2), total polyphenols content, after a quick accumulation, showed a certain decrease which was greater in the samples kept in A and N barriques (S–N–K test $p < 0.05$). On the other hand, wines aged in T and L barrels showed a small increase in polyphenols content (S–N–K test $p < 0.05$).

Such different behaviour are difficult to explain because of the interactions between the absorption and precipitation phenomena, oxidation reactions that involve these

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ANALYTICAL DESCRIPTIVE FORM

VISUAL ANALYSIS
Limpidity: *veiled - quite limpid – limpid - crystal clear - brilliant*
Colour red wine: *purple red – ruby – garnet – orange red*
Fluidity: *watery – fluid – quite thick – thick/oily*

OLFACTORY ANALYSIS
Intensity: *weak – scarcely intense – quite intense – intense – very intense*
Persistence: *short – shortly persistent – quite persistent – persistent – long persistent*
Quality: *coarse – scarcely fine – quite fine – fine - excellent*
Description: *aromatic – flowery – fruity – fragrant –herbaceous - spicy - ethereal*

GUSTATIVE ANALYSIS:
Sugars: *dry – medium dry – medium sweet – sweet – excessively sweet*
Alcohols: *light - lightly warm – medium warm – warm - alcoholic*
Poly-alcohols: *sharp – scarcely soft – quite soft – soft - velvety*
Acids: *flat – scarcely fresh – quite fresh – fresh - acidulous*
Tannins: *scarcely tannic – quite tannic – tannic - astringent*
Mineral salts: *scarcely tasty – quite tasty – tasty – salty -*
Balance: *unbalanced – quite balanced - balanced*
Intensity: *scarcely intense – quite intense – intense – very intense*
Persistence: *scarcely persistent – quite persistent – persistent – very persistent*
Quality: : *scarcely fine – quite fine – fine – excellent*

FINAL CONSIDERATIONS:
Harmony: *disharmonious – quite harmonious - harmonious*
Evolution: *immature – young – ready – mature - old*

Fig. 1. A.I.S. Analytical descriptive form for sensorial analysis of wine.

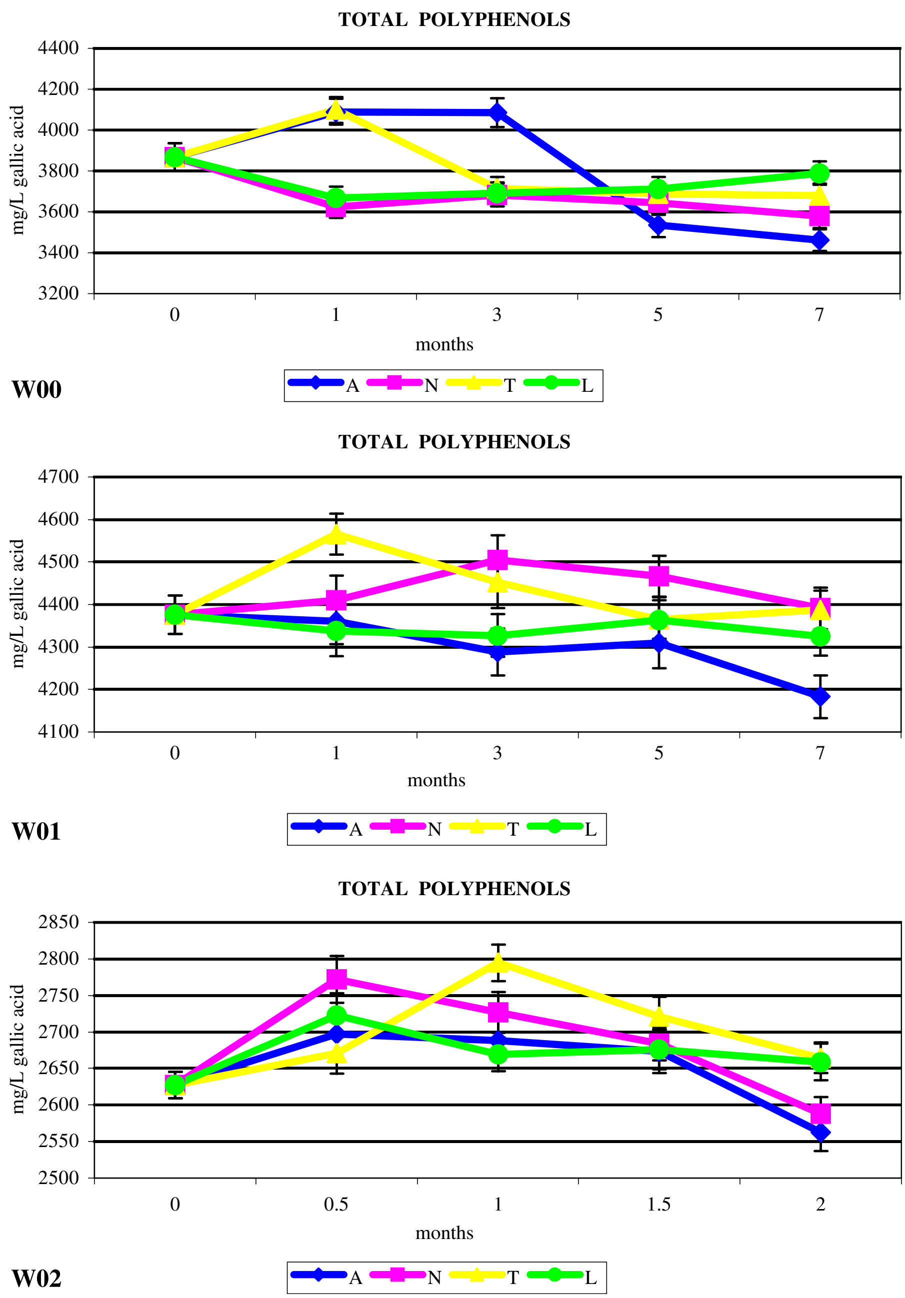

Fig. 2. Evolution of total polyphenols content in the samples stored in new barriques (W00), old barriques (W01) and oak chips (W02).

compounds (Masson, Puech, & Moutounnet, 1996) and the effect on phenols by the wood. However, we can suppose a more gradual but prolonged effect on phenolic compounds for Limousin wood in all three cases. At the same time, the high surface of wood–wine contact, which characterizes the use of chips and allows a more rapid release of wood compounds can explain the standardization in the behaviour observed in W02 among the four types of wood.

To better appreciate the influence of oak woods from different geographical areas on wine characteristics and the effect of the use of new or old barrels and chips addition, the percentage increases in several analysed parameters, as referred to the young wine, were determined.

Ellagic tannins tended to increase as a consequence of the contact with wood in all three samples (Fig. 3; Table 1). As we expected, this increase was higher in wines treated with chips (W02) and lower in those aged in old barrels (W01). Moreover, in W00 and W01 samples, ellagic tannins showed a greater increase in wines aged in A and L barrels while, in W02, the increase was higher in wines contacting A chips.

The significant post hoc comparisons are shown in Fig. 3.

Bibliographical data report a high presence of ellagic tannins in Limousin wood (Mosedale, Charrier, Crouch, Janin, & Savill, 1996; Chatonnet & Dubourdieu, 1998;

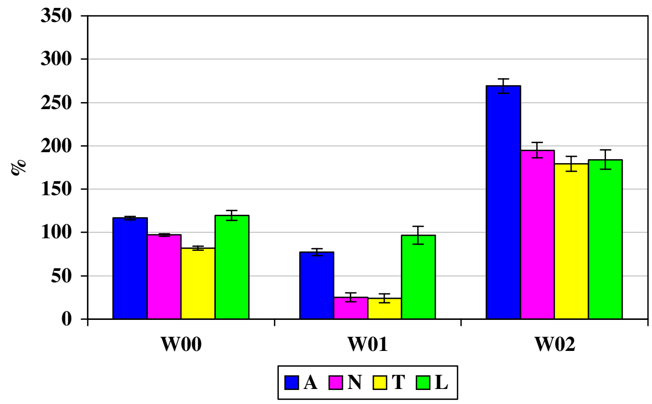

Fig. 3. Percentage increase in ellagic tannins of wines aged in Allier, Never, Tronçais and Limousin barriques in W00, W01, W02 samples. On each bar the names of woods with significant comparisons ($p < 0.05$) are shown.

Hooper & Marks, 1992) but not in the Allier one. This may be due to the different concentration in the heart-wood which changes according to species (Masson, Moutounet, & Puech, 1995), the different geographical origin (Marco, Artajona, Larrechi, & Rius, 1994), but also among clones (Feuillat & Keller, 1997), and age and section of the tree used for barrel production.

Seasoning (Fernández de Simón, Cadahía, Conde, & García–Vallejo, 1999; Hale, McCatterty, Larmie, Newton, & Swan, 1999; Chatonnet, Boidron, Dubourdieu, & Pons, 1994; Swan, Reid, Howie, & Howlet, 1993; Masson, Baumes, Moutounet, & Puech, 2000; Cavahìa, Varea, Munoz, Fernandez de Simòn, & Garcia–Vallejo, 2001) and toasting (Matricardi & Waterhous, 1999), which profoundly influence the amount of ellagitannins in wine, should be not involved among the causes of variability in our study.

In wines treated with chips, the way of production should explain such different behaviours. Among several factors of variability, the absence of standardization in the production of chips may lead to very different results in the use of chips and barriques for aging wine (Ducournau, Chassin, & Lemaire, 1999).

Evolution of furfural, 5-hydroxymethyl-2-furaldehyde (HMF), vanillin, syringaldehyde, ellagic acid, 4-ethylguaiacol, eugenol, 4-methylguaiacol, *cis*- and *trans*-β-methyl-γ-octalactone in cask wines allowed the influence of wood geographical origin to be assessed.

In samples W00 (Fig. 4, Tables 2 and 3), there was a greater increase in HMF and furfural for the wines aged in A (S–N–K $p < 0.05$) and T (S–N–K $p < 0.05$) barrels, in vanillin for wines matured in A (S–N–K $p < 0.05$) and L (S–N–K $p < 0.05$) barriques, in syringaldehyde (S–N–K $p < 0.05$), *trans*-β-methyl-γ-octalactone and 4-ethylguaiacol for wines matured in L barriques, and in eugenol for wines aged in L barrels, in ellagic acid for wines kept in N casks.

Table 1
Average and percentage increase in ellagic tannins (mg/l ellagic acid) of wines aged in Allier (A), Never (N), Tronçais (T), Limousin (L) barriques for the three samples tested: new barriques (W00); old barriques (W01); oak chips (W02)

Compound	V	A		N		T		L	
	mg/l average	mg/l average	% increase	mg/l average	% increase	mg/l average	% increase	mg/l average	% increase
Ellagic tannins (W00)	17.7	38.3	117	34.8	97.3	32.1	81.8	38.8	120
Ellagic tannins (W01)	18.2	32.3	77.4	22.8	25.4	22.6	24.0	35.8	96.7
Ellagic tannins (W02)	10	36.9	269	29.5	195	27.9	179	28.4	184

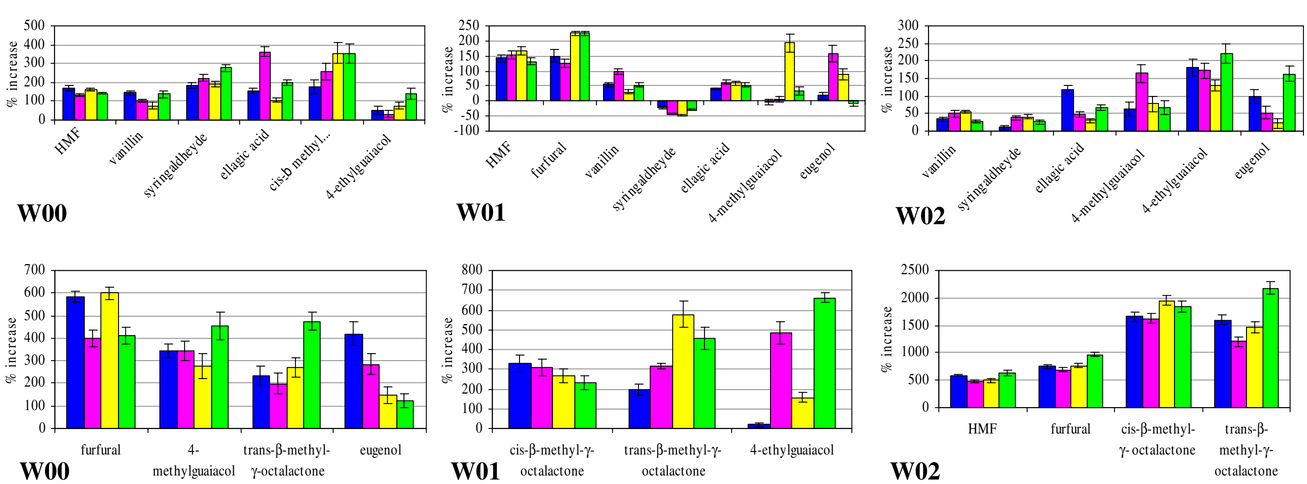

Fig. 4. Percentage increase in some phenolic and aromatic compounds of wines aged in Allier (■), Never (■), Tronçais (■), Limousin (■) barriques for the three samples tested: new barriques (W00); old barriques (W01); oak chips (W02).

Table 2
Average (mg/l) and percentage increase in some phenolic compounds of wines aged in Allier (A), Never (N), Tronçais (T), Limousin (L) barriques for the three samples tested: new barriques (W00); old barriques (W01); oak chips (W02)

Compound	V	A		N		T		L	
	mg/l average	mg/l average	% increase	mg/l average	% increase	mg/l average	% increase	mg/l average	% increase
New barriques (W00)									
HMF	1.52	4.08	168	3.53	132	3.93	158	3.67	141
Furfural	0.16	1.09	581	0.80	400	1.12	600	0.82	412
Vanillin	4.11	10.1	145	8.28	101	7.21	75	9.72	136
Syringaldheyde	4.03	11.5	185	13.1	224	11.8	192	15.2	277
Ellagic acid	1.86	4.74	155	8.60	363	3.79	104	5.55	198
Old barriques (W01)									
HMF	0.69	1.67	142	1.75	154	1.83	165	1.6	132
Furfural	0.04	0.1	150	0.09	125	0.13	225	0.13	225
Vanillin	7.57	11.7	55	14.9	97	9.86	30	11.7	54
Syringaldheyde	10.8	8.39	−22	6.13	−43	5.53	−49	7.65	−29
Ellagic acid	6.29	8.91	42	10.3	63	10.0	59	9.65	53
Oak chips (W02)									
HMF	1.03	7.04	583	5.91	474	6.14	496	7.48	626
Furfural	0.11	0.93	745	0.87	691	0.95	764	1.17	964
Vanillin	9.87	13.3	34	14.9	51	15.3	55	12.6	27
Syringaldheyde	9.57	10.53	10	13.2	38	13.3	41	12.0	26
Ellagic acid	3.95	8.6	118	5.81	47	5.19	31	6.61	67

Sensory analysis showed that, in wines kept in A casks, the aromas of red fruit and black berry, characteristics of young wines, were completely crushed by the classic scents of the barrels (vanillin, cocoa and liquorice). In wines matured in N wood, the barrique flavours clearly surpassed the typical characteristics of the Merlot wine. On the, wines aged in T casks maintained their typical characteristics which amalgamated very well with those of the wood. As regards wines in L barrels, the fruit fragrance, typical of the wine, was enriched by the vanilla and spice aroma of the barrel, even if a strong tannic character was perceived.

In samples W01 (Fig. 4), just as expected, there was a smaller transfer of aforementioned compounds, except for HMF. This phenomenon was quite similar to that observed in sample W00 (N.S. T3 test). In particular, there was a greater increases in furfural and *trans*-β-methyl-γ-octalactone for wines aged in L and T barriques (S–N–K $p < 0.05$), and in 4-methylguaiacol for those kept in T casks, in vanillin (S–N–K $p < 0.05$) and eugenol for those aged in N barrels, and in 4-ethylguaiacol for those aged in L ones. Syringaldehyde tended to decrease in all samples (S–N–K $p < 0.05$), with a minimum value in wines in N and T barrels (S–N–K $p < 0.05$).

According to sensory analyses, the wine aged in the A casks showed a good olfactory intensity, with clear features of ripe and vanilla fruit, an elegant tannin and a nice balsamic note at the end. The Merlot wine in N barrels was less refined in odour, with nice sweet notes at the end. The samples in T barriques presented a very good olfactory intensity, a strong and continuous aroma and a very long taste persistence. Wines in L barrels evidenced a deep aroma and a very good refinement even if the wood toasted features were not yet well amalgamated with those of red fruits typical of Merlot wine.

In samples W02 (Fig. 4), HMF and furfural levels showed large increases (S–N–K $p < 0.05$), as well as *cis*- and *trans*-β-methyl-γ-octalactone. In particular, the highest percentage increase in vanillin and syringaldehyde were in wines matured in the presence of N (S–N–K $p < 0.05$) and T (S–N–K $p < 0.05$) wood chips, and in ellagic acid for those contracting A chips (S–N–K $p < 0.05$), in HMF for those integrated with L (S–N–K $p < 0.05$) and A ones (S–N–K $p < 0.05$), in furfural (S–N–K $p < 0.05$), *trans*-β-methyl-γ-octalactone and eugenol for wines aged with L chips, in 4-methylguaiacol for those kept in the presence of N chips.

As regards sensory analysis, wines integrated with the A wood chips appeared full-bodied and with a long persistence; those with N chips presented marked wood sensations. T chips-treated wines resulted in a marked tannin and a very good structure, while the L chips-treated ones yielded a strong and a powdery tannin.

Except for gallic acid, all the effects studied by two way variance analysis were highly significant (Table 4).

As regards the difference among the samples, we generally observed a higher release of wood compounds in wines aged in new barrels while HMF, furfural, and *cis*- and *trans*-β-methyl-γ-octalactone showed greater increases in wines treated with chips. Old barriques showed the minor release of those compounds, except for HMF, and *cis*- and *trans*-β-methyl-γ-octalactone which showed high amounts. We can explain the differences observed for these compounds between wines aged in new and old barrels, because they are present in the wood in limited amounts (Rous & Alderson, 1983); on the other hand, it is difficult to explain their low increases observed in wines treated with chips. Even though some works (Rowe, 1999) have found a greater increase in vanillin and syringaldehyde in

Table 3
Average peak area and percentage increase in some aromatic compounds of wines aged in Allier (A), Never (N), Tronçais (T), Limousin (L) barriques for the three samples tested: new barriques (W00); old barriques (W01); oak chips (W02)

Compound	V	A		N		T		L	
	Average peak area	Average peak area	% increase	Average peak area	% increase	Average peak area	% increase	Average peak area	% increase
New barriques (W00)									
Cis-β-methyl-γ-octalactone	1078	2964	175	3857	258	4920	356	4903	355
4-Methylguaiacol	638	2817	341	2819	342	2403	277	3534	454
Trans-β-methyl-γ-octalactone	500	1663	233	1497	199	1854	271	2866	473
4-Ethylguaiacol	2480	3802	53	3284	32	4360	76	5970	141
Eugenol	2504	12,990	419	9643	285	6204	148	5584	123
Old barriques (W01)									
Cis-β-methyl-γ-octalactone	506	2169	329	2069	309	1856	267	1687	233
4-Methylguaiacol	1300	1271	−2	1366	5	3808	193	1756	35
Trans-β-methyl-γ-octalactone	154	454	195	640	315	1045	578	856	456
4-Ethylguaiacol	5300	5335	0.7	30,992	485	13,526	155	40,325	661
Eugenol	3051	3640	19	7874	159	5692	86	2829	−7
Oak chips (W02)									
Cis-β-methyl-γ-octalactone	531	9346	1660	9178	1628	10916	1956	10321	1844
4-Methylguaiacol	18,511	30,111	63	48,933	164	32,887	78	30,915	67
Trans-β-methyl-γ-octalactone	125	2128	1602	1628	1202	1943	1454	2845	2176
4-Ethylguaiacol	28,511	80,222	181	77,866	173	65,774	131	91,830	222
Eugenol	510,393	1,012,887	98	781,300	53	621,895	22	1,344,508	163

Table 4
Analysis of variance: two way test

Parameter Y	Model $Y = A + B + (A \times B) + \varepsilon$	Barrique effect (A)	Year effect (B)	Barrique × year effect (A × B)
Ellagic acid	$F(12.24) = 214.24.1$ $p < 0.001$	$F(3.24) = 46.6$ $p < 0.001$	$F(2.24) = 302.2$ $p < 0.001$	$F(6.24) = 52.2$ $p < 0.001$
Ferulic acid	$F(12.24) = 752.89$ $p < 0.001$	$F(3.24) = 138.2$ $p < 0.001$	$F(2.24) = 271.8$ $p < 0.001$	$F(6.24) = 76.8$ $p < 0.001$
Caffeic acid	$F(12.24) = 51.29$ $p < 0.001$	$F(3.24) = 11.47$ $p < 0.001$	$F(2.24) = 29.18$ $p < 0.001$	$F(6.24) = 11.08$ $p < 0.001$
Gallic acid	$F(12.24) = 8.39$ $p < 0.001$	$F(3.24) = 2.48$ $p = 0.085$	$F(2.\ 2.24) = 2.53$ $p = 0.1$	$F(6.24) = 13.98$ $p < 0.001$
Vanillic acid	$F(12.24) = 20.76$ $p < 0.001$	$F(3.24) = 19.5$ $p < 0.001$	$F(2.24) = 38.45$ $p < 0.001$	$F(6.24) = 12.74$ $p < 0.001$
Furfural	$F(12.24) = 651.4$ $p < 0.001$	$F(3.24) = 21.38$ $p < 0.001$	$F(2.24) = 759.3$ $p < 0.001$	$F(6.24) = 18.35$ $p < 0.001$
HMF	$F(12.24) = 423.8$ $p < 0.001$	$F(3.24) = 5.48$ $p = 0.005$	$F(2.24) = 769.5$ $p < 0.001$	$F(6.24) = 7.72$ $p < 0.001$
Syringaldehyde	$F(12.24) = 260.8$ $p < 0.001$	$F(3.24) = 10.36$ $p < 0.001$	$F(2.24) = 1060.8$ $p < 0.001$	$F(6.24) = 10.7$ $p < 0.001$
Syringic acid	$F(12.24) = 89.4$ $p < 0.001$	$F(3.24) = 11.73$ $p < 0.001$	$F(2.24) = 67.87$ $p < 0.001$	$F(6.24) = 8.13$ $p < 0.001$
Vanillin	$F(12.24) = 102.7$ $p < 0.001$	$F(3.24) = 7.69$ $p < 0.001$	$F(2.24) = 88.82$ $p < 0.001$	$F(6.24) = 11.51$ $p < 0.001$
Ellagic tannins	$F(12.24) = 300.24$ $p < 0.001$	$F(3.24) = 32.65$ $p < 0.001$	$F(2.24) = 362.5$ $p < 0.001$	$F(6.24) = 9.58$ $p < 0.001$
Total polyphenols (W00)	$F(20.40) = 34.7$ $p < 0.001$	$F(3.40) = 15.8$ $p < 0.001$	$F(4.40) = 45.7$ $p < 0.001$	$F(12.40) = 23.1$ $p < 0.001$
Total polyphenols (W01)	$F(20.40) = 6.38$ $p < 0.001$	$F(3.40) = 20.3$ $p < 0.001$	$F(4.40) = 5.18$ $p = 0.002$	$F(12.40) = 3.8$ $p = 0.001$
Total polyphenols (W02)	$F(20.40) = 14.9$ $p < 0.001$	$F(3.40) = 5.24$ $p = 0.004$	$F(4.40) = 27.05$ $p < 0.001$	$F(12.40) = 4.38$ $p < 0.001$

wines treated with chips than with new barriques, we did not observe such an increase for the above-mentioned compounds. This may be due to the absence of standardization in the production of chips (Ducournau et al., 1999).

As regards the influence of different oak wood geographical origin we observed different results in the three samples. This may be explained with the different manners of release of wood compounds by the woods of different geographical origins (Allier, Never, Tronçais and Limousin).

Moreover, the influence of the different wood geographical origins on wine characteristics was particularly evident with the use of new barrels.

4. Conclusions

Total polyphenols, ellagic tannins, qualitative composition of furanic aldehydes, phenolic and volatile compounds were the analytical determinations that, together with sensorial analysis, allowed us to evaluate the influence of the different geographical origin of wood on the quality of wine, both when using new or old barriques and adding chips.

As regards the difference among the samples, we generally observed a greater release of wood compounds in wines aged in new barrels while HMF, furfural, and *cis*- and *trans*-β-methyl-γ-octalactone showed a greater increase in wines treated with chips.

The influences of the four woods, Allier, Never, Tronçais and Limousin, on the quality of wine were different among the samples, as a consequence of a varied release of wood compounds among new and old barrels and chips.

Analytical results and sensorial analysis showed that wines matured in Tronçais barriques presented quite high values of phenolic and aromatic compounds, with a pleasant taste of vanilla, spices and toasted almonds, perfectly combined with the aroma of red fruits, typical of Merlot wine and a good content of total polyphenols, which ensure a good preservation from oxidative processes and a long life. On the other hand, wines mellowed in Allier, Never and Limousin oak wood barrels exhibited a rich phenolic and aromatic profile, with a clear vanillin note and too strong scents of wood, which were dominant over the typical characteristics of the wine.

So, clearly the best results were with barrels made of oak wood from the Tronçais forest in which wines combined the best union of between their typical components and those given by oak wood.

Moreover, the influence of the different wood geographical origin on wine characteristics was particularly evident with the use of new barrels, while the use of chips resulted in to standard wines.

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