Analytical Methods

Influence of toasting of oak chips on red wine maturation from sensory and gas chromatographic headspace analysis


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Afonso, 2003; Perez-Coello et al., 2000).

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accelerate wood maturation by extraction of chips maximising sur-

Sauvageot & Feuillat 1999). Currently wine producers seek to

Lopez-Roca, Fernandez-Fernandez, & Gomez-Plaza, 2003a, 2003b;

and age: all influence final wine character (Pérez-Prieto, Hera-Orts,

Maturation factors include oak geographic origin and species, for-

Red wine from the Greek grape cultivar Aghiorghitiko, was aged in stainless steel with and without wood chips toasted to different degrees (heavily, medium, lightly) and in a 225L American standard oak barrel for 32 days. Headspace concentrations of four wood-derived congeners (furfural, guaiacol, cis and trans

Oak lactones) were determined over this period after which the wines were bottled, stored and subjected to sensory descriptive analyses. Of the 36 attributes for appearance, aroma and oral characters, 14 were significant in univariate analyses and differentiated wines in a multivariate (principal component analysis) product space explaining 72% variance in two factors. Wines from medium toast wood chips scored highest for woody, vegetative and smoky aromas and flavours but also for bitter taste and astringent mouthfeel and after 14 days had the highest headspace concentrations of furfural and cis oak lactone. Wood-related notes were ranked from heavily and lightly toasted chips, barrel and steel control.

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1. Introduction

Traditionally quality red wines are wood-matured in oak casks and barrels which evoke changes in wine flavour (Diaz-Plaza, Reyero, Pardo, Alonso, & Salinas, 2002; Escalona, Birkmyre, Piggott, & Paterson, 2002; Garde-Cerdan & Ancin-Azpilicueta, 2006; Singleton, 1995). Cask maturations produce distinctive flavours but are slow processes- taking from a few months to several years (Arapit-

Reports on wood maturation of wines concentrate on composi-

tional changes with few examples, in the literature, on sensory

character (Boidron, Chatonnet, & Pons, 1988) and liquid matrix effects of less volatile components influence headspace partitioning of aroma-active volatile congeners and thus orthonasal and retronasal perceptions contributing to the character.

Wood maturations proceed by depolymerisation and extraction of lignin and hemicellulose components yielding low molecular weight products including: phenolic aldehydes (vanillin, syringaldehyde, and coniferaldehyde), phenolic alcohols and ethylphenols (guaiacol, 4-methylguaiacol, 4-ethylguaiacol, 4-propyl-
guaiacol, and eugenol), oak lactones (trans and cis β-methyl-γ-octalactone) and furanic compounds (furfural, 5-hydroxymethyl furfural, 5-methyl furfural) (Diaz-Maroto, Sanchez-Palomo, & Perez-Coello, 2004; Garde-Cerdan & Ancin-Azpilicueta, 2006; Perez-Coello et al., 2000). Quantitative variations are observed in wines and wood extracts (Cerdán, Gom-i, & Azpilicueta, 2004; Chatonnet, 1999; Chatonnet, Cutzach, Pons, & Dubourdieu, 1999; Pollinitz, Jones, & Sefton, 1999). Oxygen passage through staves plays a role in these processes. Derived compounds vary in sensory impact (Boidron, Chatonnet, & Pons, 1988) and liquid matrix effects of less volatile components influence headspace partitioning of aroma-active volatile congeners and thus orthonasal and retronasal perceptions contributing to the character.

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A R T I C L E  I N F O

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Oak lactones) were determined over this period after which the wines were bottled, stored and subjected to sensory descriptive analyses. Of the 36 attributes for appearance, aroma and oral characters, 14 were significant in univariate analyses and differentiated wines in a multivariate (principal component analysis) product space explaining 72% variance in two factors. Wines from medium toast wood chips scored highest for woody, vegetative and smoky aromas and flavours but also for bitter taste and astringent mouthfeel and after 14 days had the highest headspace concentrations of furfural and cis oak lactone. Wood-related notes were ranked from heavily and lightly toasted chips, barrel and steel control.

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1. Introduction

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tional changes with few examples, in the literature, on sensory

character (Guchu, Diaz-Maroto, Perez-Coello, Gonzalez-Vinas, & Cabezudo Ibanez, 2006; Gutierrez Afonso, 2002; Gutierrez Afonso, 2003; Perez-Coello, 2004; Garde-Cerdan & Ancin-Azpilicueta, 2006; Perez-Coello et al., 2000). Quantitative variations are observed in wines and wood extracts (Cerdán, Gom-i, & Azpilicueta, 2004; Chatonnet, 1999; Chatonnet, Cutzach, Pons, & Dubourdieu, 1999; Pollinitz, Jones, & Sefton, 1999). Oxygen passage through staves plays a role in these processes. Derived compounds vary in sensory impact (Boidron, Chatonnet, & Pons, 1988) and liquid matrix effects of less volatile components influence headspace partitioning of aroma-active volatile congeners and thus orthonasal and retronasal perceptions contributing to the character.

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tional changes with few examples, in the literature, on sensory

character (Guchu, Diaz-Maroto, Perez-Coello, Gonzalez-Vinas, & Cabezudo Ibanez, 2006; Gutierrez Afonso, 2002; Gutierrez Afonso, 2003; Perez-Coello et al., 2000; Perez-Coello et al., 2003a, 2003b), Perez-Prieto and co-workers (2003a, 2003b) explored effects of specific cask characteristics on the sensory properties of matured wines. Fermentations in the presence of oak chips were compared with cask maturations in another three studies (Gutierrez Afonso, 2002; Gutierrez Afonso, 2003; Perez-Coello et al., 2000), establishing compositional and sensory differences. Guchu and co-workers (2006) compared sensory characters of Chardonnay wines treated with American and Hungarian oak chips.
In this present study, red wine from an experimental winery and the indigenous Greek variety Aghiorghitiko, was aged in stainless steel without wood or with oak chips varying in toast level then compared with that aged of an American oak barrel, where oxygen is passed through staves. Sensory characters of wines were established by descriptive profiling and related to headspace quantitations of four key wood-derived congeners: furfural, guaiacol, and cis and trans oak lactones. The aim was to compare the maturation effects.

2. Materials and methods

2.1. Wines and wood maturations

Wine was vintage 2004 from the Greek variety: ‘Aghiorghitiko’ (Koussissi, Paterson, & Paraskevopoulos, 2008; Koussissi, Paterson, & Piggott; 2003; Koussissi, Paterson, & Piggott, 2007; Manessis, 2000) from Nemea (Peloponnese). During the crushing stage of vinification, untoasted American wood powder was added (2 kg per tonne grapes). Oenological parameters of resulting wines were: ethanol – 11.8% (v/v); total acidity: 4.5 g/l expressed as tartaric acid, volatile acidity: 0.23 g/l expressed as acetic acid; pH: 3.86; 21.8 and 24.3 ppm of free and bound sulphur dioxide, respectively.

An American standard barrel (ASB: 225 l) of white American oak (Quercus alba), was purchased from ‘Tonnellerie Du Monde World Cooperage’ as an extra fine grain. Staves were of 24 years-old wood, heat bent with a medium toasting. Three wooden staves (heavy, medium and light toast) were purchased from the same company, as they were of similar wood and age, and chipped into 1 × 1 × 2.5 cm pieces, oven dried at 170 °C for 2 h and immersed in wine.

Five experimental conditions were created: a 32-day barrel maturation (ASB) and control in stainless steel, and stainless steel with chips from lightly, medium and heavily toasted chips. Containers with wood chips were opened and stirred manually for each of the first 14 days and matured at an average 15 °C. After 32 days wines were bottled and stored for 82 days before descriptive sensory analysis. For ASB samples wine was taken directly from the barrel for sensory analysis after 113 days in wood.

2.2. Sensory analyses

Fifteen (15) assessors (eight males and seven females, from 21 to 28 years old), were self-selected oenology students of Technological Educational Institute of Athens. All had completed a class in wine sensory evaluation and 10 were regular wine consumers (at least once per week).

Assessor training and vocabulary development (5 days) was as follows: 2 days with 23 labelled aroma standards derived from previous red wine sensory studies (Aiken & Noble, 1984; Koussissi et al., 2002; Koussissi et al., 2003) (Table 1); and a further 2 days for basic tastes: sweet (1, 2, 3, 4 g/l sucrose), bitter (0%, 50% and 100% tonic water), sour (0.5, 1, 2, 3 g/l tartaric acid) and astringent mouthfeel (1, 2, 4 g/l oenological tannins). The training procedure used ranking in stimulus intensity (Koussissi et al., 2003). A final profiling vocabulary was achieved by giving each assessor all wine samples and asking for a lexicon of attributes. The consensus was: 5 attributes for appearance: clarity, red, purple, brown, and blue; 14 for aroma: floral, fruity (berries), fruity (other), vegetative (fresh), vegetative (dried), smoky, caramelised, nutty, coconut, woody, spicy, green/black olive, earthy and chemical; 3 primary tastes: sweet, bitter and sour; 11 for flavour by mouth: fruity (berries), fruity (other), caramelized, vegetative, smoky, nutty, coconut, woody, spicy, olive and earthy; 2 for mouthfeel: astringent and body and aftertaste intensity (irrespective of character).

<table>
<thead>
<tr>
<th>Attribute Reference</th>
<th>Aroma training standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floral</td>
<td>1a (Rose) 1 mg l⁻¹ aqueous solution of 2-phenyl ethanol</td>
</tr>
<tr>
<td></td>
<td>1b (Violet) Standard a</td>
</tr>
<tr>
<td>Fruity (berries)</td>
<td>2a (Strawberry) Crushed strawberries</td>
</tr>
<tr>
<td></td>
<td>2b (Raspberry) Crushed raspberries</td>
</tr>
<tr>
<td></td>
<td>2c (Blackberries) Crushed blackberries</td>
</tr>
<tr>
<td>Vegetative (fresh)</td>
<td>3a (Bell Pepper) Standard</td>
</tr>
<tr>
<td></td>
<td>3b (Grassy) Fresh cut green grass</td>
</tr>
<tr>
<td>Vegetative (dried)</td>
<td>4a (Tobacco) Standard a</td>
</tr>
<tr>
<td></td>
<td>4b (Pipe tobacco) Fresh tobacco for pipe</td>
</tr>
<tr>
<td></td>
<td>4c (Tea) Standard a</td>
</tr>
<tr>
<td>Caramelised</td>
<td>5a (Caramel) Standard a</td>
</tr>
<tr>
<td></td>
<td>5b (Honey) Honey</td>
</tr>
<tr>
<td></td>
<td>5c (Chocolate) Chocolate powder</td>
</tr>
<tr>
<td>Nutty</td>
<td>6a (Almond) Crushed almonds</td>
</tr>
<tr>
<td></td>
<td>6b (Hazelnut) Crushed hazelnuts</td>
</tr>
<tr>
<td>Woody</td>
<td>7a (Oak extract) Oak wood chips in 10% ethanol-water solution</td>
</tr>
<tr>
<td></td>
<td>7b (Vanilla) Commercial cooking vanilla powder</td>
</tr>
<tr>
<td>Spicy</td>
<td>8a (Pepper) Black pepper</td>
</tr>
<tr>
<td></td>
<td>8b (Cinnamon) Cinnamon</td>
</tr>
<tr>
<td></td>
<td>8c (Clove) Cloves in powder</td>
</tr>
<tr>
<td></td>
<td>8d (Nutmeg) Nutmeg powder</td>
</tr>
<tr>
<td>Green/black olive</td>
<td>9 (Black olives) Black olive paste</td>
</tr>
<tr>
<td>Earthy</td>
<td>10 (Mushroom) Standard a</td>
</tr>
</tbody>
</table>


Wines were assessed simultaneously for all attributes in duplicate (two sessions of five products) using a Latin square presentation design (Macfie, Bratchell, Greenhoff, & Vallis, 1989), with 30 ml aliquots in standard wine glasses (ISO 3591: 1977) in booths with white lighting. Assessors scoring began with appearance then proceeded to evaluate aroma, taste, flavour by mouth, mouthfeel and finally aftertaste by using an 11-point scale from 0 (attribute absent) to 10 (attribute at maximum intensity), on ballots.

2.3. Headspace quantitation of congeners by Solid-phase micro extraction GC

Headspace solid-phase micro extraction capillary gas chromatography (HS-SPME-GC) was performed on aliquots (13 ml) of wine, supplemented with 2 g NaCl, in 25 ml conical Supelco vials, containing a (20 mm) magnetic stirrer bar. Vials were sealed with PTFE lined silicone septa in plastic screw caps, and headspaces were equilibrated for 30 min at 30 °C stirred at 300 rpm, and a 50/30 μm Stableflex Divinylbenzene/Carboxen/Polydimethylsiloxane (DVB/CAR/PDMS) fibre in a Supelco fibre holder was inserted into the headspace. Volatile congeners were adsorbed for 30 min then the fibre phase was immediately desorbed at 230 °C for 5 min in a splitless injector (equipped with a SPME liner) of a Hewlett Packard, HP 6890 Series GC system equipped with a FID. Congeners were separated in a DB-WAX coated capillary column (30 m length × 0.251 mm i.d. × 0.25 μm film thickness; J&W Scientific, USA) with injector and detector at 230 and 250 °C, respectively. A temperature programme was used: 54 °C (4 min); to 195 °C at 6 °C min⁻¹; held for 3 min; to 230 °C at 2 °C min⁻¹, held for 10 min (total run time 58 min). Carrier gas was Nitrogen at 1.5 ml min⁻¹. Chromatographic data were recorded on HP Gas Chromatography Chemstation Rev.06.03 software. Vials were used once without introduction of an internal standard and each wine sample was analysed in duplicate.

Quantification of four compounds (furfural, guaiacol, cis and trans isomers of β-methyl-γ-octalactone) was achieved using
calibration curves for each sample over the range 40–500 μg/l. in 10% v/v aqueous ethanol.

2.4. Statistical analyses

Sensory data were initially analysed with one-way analysis of variance (ANOVA: Minitab v 13) to determine significance of attributes in product differentiations, and of individual assessor data (Koussissi et al., 2003). Data were subsequently averaged across the panel for: (a) all 15 assessors (b) the residual (10 assessor) panel after data of five non-discriminative assessors were removed. Principal component analysis (PCA; Unscrambler v 7.6) was effected on averaged data from both initial and residual panels with:

- Principal component analysis (PCA; Unscrambler v 7.6) was effect

Principal component analysis revealed 10 out of the 36 attributes were significant at 0.05 < P < 0.09 – fruity (berries) aroma, and vegetative and smoky flavours (Tables 2 and 3). Averaging data across the panel gave 12 significant attributes (clarity, purple and brown from appearance, vegetative (dried), caramelised, woody, spicy and chemical aromas, sweet and bitter tastes woody and earthy flavours) and 2 (natty aroma and vegetative flavour) at 0.05 < P < 0.09. From ANOVA five assessors used only 2 or less attributes significantly in discriminations and data from these assessors were removed from the matrix. The residual (10 member) panel data were again subject to ANOVA yielding 11 attributes significant (P < 0.05) in wine discrimination – clarity, red, purple from appearance, fruity (berries), vegetative (dried), woody, and chemical aromas, smoky, woody and earthy flavours by mouth and astringent mouthfeel. A further three attributes – aroma: fruity (other), sweet and bitter tastes – were significant at 0.05 < P < 0.09. Finally, when data were averaged across the residual (10) panel 14 attributes were significant at P < 0.05: clarity, purple, brown from appearance; floral, vegetative (dried), smoky, and chemical aromas; sweet and bitter tastes; fruity (berries), vegetative, smoky, woody and earthy flavours by mouth. A further 3 attributes showed 0.05 < P < 0.09: nutty, woody and spicy aromas (Tables 2 and 3).

In a previous study (Koussissi et al., 2002) of 41 attributes for appearance, aroma and oral attributes in single session, only nine were significant in wine discriminations. Guchu and co-workers (2006) used 23 flavour attributes to describe sensory character in Chardonnay wines treated with American and Hungarian oak chips but did not report the levels of significance in product differentiation. In other studies on sensory profiles of wines treated with oak (Gutierrez Afonso, 2002; Gutierrez Afonso, 2003; Perez-Coello et al., 2000; Perez-Prieto et al., 2003a, 2003b), significance was observed with restricted vocabularies (less than eight terms including aroma and oral attributes), thus a potential (Carlucci & Monteleone, 2001; Lawless, 1999) discrimination difficulty due to extended vocabularies was not a problem.

3.2. The product space of sensory data

Principal component analysis of data from all assessors and all 36 attributes, followed by ANOVA, firstly gave a highly significant component (PC1, P = 0.001) and a second component (PC2) with P = 0.055 explaining 56% variance. Scores in the product space (Fig. 1) showed good replication and clear differentiation of the five

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**Table 2** Summary of one-way ANOVA analyses of aroma sensory data.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Initial data</th>
<th>Data averaged across initial panel</th>
<th>Data of residual panel</th>
<th>Data averaged across residual panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floral</td>
<td>0.284</td>
<td>0.129</td>
<td>0.178</td>
<td>0.025**</td>
</tr>
<tr>
<td>Fruity (berries)</td>
<td>0.066</td>
<td>0.116</td>
<td>0.027**</td>
<td>0.128</td>
</tr>
<tr>
<td>Fruity (other)</td>
<td>0.199</td>
<td>0.285</td>
<td>0.078</td>
<td>0.171</td>
</tr>
<tr>
<td>Vegetative (fresh)</td>
<td>0.720</td>
<td>0.703</td>
<td>0.697</td>
<td>0.723</td>
</tr>
<tr>
<td>Vegetative (dried)</td>
<td>0.002***</td>
<td>0.003***</td>
<td>0.001***</td>
<td>0.001***</td>
</tr>
<tr>
<td>Smoky</td>
<td>0.472</td>
<td>0.116</td>
<td>0.150</td>
<td>0.047***</td>
</tr>
<tr>
<td>Caramelised</td>
<td>0.355</td>
<td>0.029**</td>
<td>0.562</td>
<td>0.351</td>
</tr>
<tr>
<td>Nutty</td>
<td>0.081</td>
<td>0.056</td>
<td>0.509</td>
<td>0.060</td>
</tr>
<tr>
<td>Coconut</td>
<td>0.296</td>
<td>0.311</td>
<td>0.401</td>
<td>0.282</td>
</tr>
<tr>
<td>Woody</td>
<td>0.003***</td>
<td>0.023**</td>
<td>0.001***</td>
<td>0.055</td>
</tr>
<tr>
<td>Spicy</td>
<td>0.208</td>
<td>0.020**</td>
<td>0.146</td>
<td>0.093</td>
</tr>
<tr>
<td>Green/black olive</td>
<td>0.989</td>
<td>0.968</td>
<td>0.677</td>
<td>0.699</td>
</tr>
<tr>
<td>Earthy</td>
<td>0.642</td>
<td>0.613</td>
<td>0.775</td>
<td>0.812</td>
</tr>
<tr>
<td>Chemical</td>
<td>0.000</td>
<td>0.021**</td>
<td>0.000***</td>
<td>0.029***</td>
</tr>
</tbody>
</table>

* P < 0.05; ** P < 0.01; *** P < 0.001.
experimental wines. In PC1 (43% of variance), wines are clearly differentiated into two groups: (a) medium and heavily toasted chips and (b) barrel and unoaked (stainless steel). Wines from appreciably (medium, high) toasted chips were clustered with high scores on PC1, related to earthy, nutty, vegetative (fresh), vegetative (dried), chemical, smoky, spicy, and woody aromas; earthy, vegetative, spicy, smoky and woody flavours; bitter taste; high astringency and body as mouthfeel; brown hues and strong aftertaste. Wines aged in barrels and unoaked in steel were also clustered with negative PC1 scores and related to: clarity and red appearance, floral, fruity (berries), fruity (other), and caramelised aromas; fruity (berries), fruity (other), caramelised and green/black olive flavours; and sweet taste. Wine from lightly toasted chips was scored between the two clusters on PC1 (Fig. 1).

In PC2 wine from lightly toasted chips was clearly differentiated from all other wines, with negative scores and a close relationship to coconut aroma, sweet taste, and blue and purple hues in appearance. Stainless steel and barrel conditions were also resolved on PC2 with the former having a higher correlation with loadings for red hues and clarity and also for green/black olive flavour, the latter being more related to fruity aromas and flavours. Finally, wines from toasted chips were also differentiated in PC2 with medium toasting yielding higher correlations with: brown colour, spicy, woody and smoky aromas and flavours, vegetative (dried) aroma, body in mouthfeel and higher scores in aftertaste. In contrast, wines of heavy toasted chips were related to: earthy, nutty and vegetative (fresh) in aromas, earthy and vegetative in favour and bitter in taste (Fig. 1).

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**Fig. 1.** Principal component analyses (PC1 versus PC2) for sensory data on five different maturation conditions: CO: control; BA: barrel maturation; LT: light toasted chips; MT: medium toasted chips; HT: heavy toasted chips. Data from all assessors and attributes.

**Fig. 2.** Principal component analyses (PC1 versus PC2) for sensory data on five different maturation conditions: CO: control; BA: barrel maturation; LT: light toasted chips; MT: medium toasted chips; HT: heavy toasted chips. Data from residual panel, and significant in differentiation attributes.
In order to enhance the information obtained from the product space (improve principal component significance and variance explained), the PCA of the data was repeated with the data from the discriminating 10 assessors, after removal of 14 non-significant attributes (appearance: blue; aroma: vegetative (fresh), coconut, green/black olive, earthy; taste: sour; flavour: fruity (other), caramelised, nutty, coconut, spicy, green/black olive; mouthfeel: body, and overall aftertaste (Tables 2 and 3). Improvements were observed in the significance of the first two PCs explaining the 72% variance (PC1: 59%, $P < 0.001$; PC2: 13%, $P = 0.005$) (Fig. 2). In previous reports of sensory descriptive profiling of wines treated with oak, data was reported from ANOVA as mean ratings or average attribute scores (Guchu et al., 2006; Gutierrez Afonso, 2002; Gutierrez Afonso, 2003; Perez-Coello et al., 2000; Pérez-Prieto et al., 2003a, 2003b). In this study PCA was employed with many (36) attributes and variance described above compared well with those of other wine sensory studies (Koussissi et al., 2002, 2003; Lee & Noble, 2003). Lee and Noble (2003) in profiling Chardonnay wines achieved a two-component PCA space, explaining an 80.5% variance using only eight aroma attributes. As noise increases in parallel with the number of variables (Wold, 1989), a 72% variance shown with 22 attributes was considered optimal.

In this final product space replicates were scored similarly (data not shown) and the experimental wines were differentiated as follows: In PC1 (59% variance explained) the main separation was between wines treated with medium and heavily toasted chips and the ones from the stainless steel and the barrel conditions. Wines from medium and heavily toasted wood chips were clustered with high scores on PC1 and related to: brown colour, woody, smoky and vegetative aromas and flavours in the mouth, but also spicy, nutty and chemical aromas, earthy flavour in the mouth, bitter taste and astringent mouthfeel. On the contrary, stainless steel and barrel aged products were negatively scored on PC1, linked to loadings for clarity and red appearance, floral, fruity (berries), fruity (other), caramelised aromas and fruity (berries) flavour. Wines treated with lightly toasted chips were in the middle of the two clusters on PC1.
but closer to the control and barrel wines (Fig. 2). In PC2, wines from the light toasted chips were clearly separated from all the rest, linked to loadings for purple colour and sweet taste. In that component a separation between the wines from the medium and the heavily toasted chips conditions was achieved: with the latter being higher in nutty aromas and earthy flavours in the mouth and the former being more smoky, woody, vegetative (dried) and spicy (Fig. 2).

The control (stainless steel) wines, were linked to attributes typical of the variety Aghiorghitiko (Koussissi et al., 2002, 2003, 2007, 2008), despite addition of wood powder during the initial step of vinification. Barrel wine maturation can take up to several years (Garde-Cerdan & Ancin-Azpilicueta, 2006; Singleton, 1995). In a study of wine volatile compounds during ageing in oak, differences in extracting capacity were found primarily after four months in the barrel (Ortega-Heras, Gonzalez-Huerta, Herrera, & Gonzalez-Sanjose, 2004). In this study descriptive profiling was affected before this point thus similarity of stainless steel and barrel aged wines could be explained by limited contact time between wine and barrel. Contact of wine to medium toasted wood chips led to an increase correlations with brown colour, spicy, vegetative (dry), woody, smoky and chemical aromas, vegetative, woody and smoky flavours, bitter taste and astringent mouthfeel, but when toasting of chips increased further, correlation with those loadings was slightly reduced and linkage was enhanced to nutty aroma and earthy flavour. This is in agreement with Perez-Coello et al. (2000) and Guchu et al. (2006). Thermal treatment of oak used in wine maturations has proven a key factor influencing the quantity of volatile phenols and furanic compounds transferred to wines (Chatonnet, 1998; Chatonnet, 1999; Chatonnet et al., 1999) responsible for smoky, spicy and toasty aroma notes. Chatonnet (1998) reported higher toasty and vanilla aromas on contact with medium toast.

The above is in accordance with the findings of this study, in which the medium toasted chip wines scored highest for bitter taste and astringent mouthfeel, possibly due to increased ellagitanins extracted at this toast intensity.

### 3.3. Extraction of oak-derived congeners

Furfural, guaiacol, cis and trans oak lactones in wine headspaces, were quantified by GC in each of the initial 14 days and days 21, 29 and 32 (day before removal of the oak chips) and on the initial day of sensory profiling (day 114). Headspace concentration of each increased to a maximum at day 14 as in other studies (Arapitsas et al., 2003) and showed a decrease in concentration on days 21 and 29, then maintained until 32nd day (Fig. 3). As reported by Chatonnet et al. (1999), furfural and cis oak lactone were at highest headspace concentration with medium followed by heavily then lightly toasted chips and lowest with the barrel aged wine (Fig. 3). The highest concentration of those compounds in the medium toasted condition could be possibly related to the high scores of this condition in smoky and woody attributes. Light toasting was related to high score for coconut aroma (Fig. 1) and showed highest initial extraction rate for the trans isomer of oak lactone (data not shown). A coconut note in wines has previously been correlated with cis and trans oak lactone contents (Gutierrez Afonso, 2002). Furfural and cis oak lactone in wine aged in stainless steel can be related to the vinification addition of wood powder with residual extraction from particulate matter. Headspace concentration of furfural increased until day 14 in the control (steel-aged) wine (Fig. 3).

### 4. Conclusions

In this study, the effect of different technologies/conditions on red wine maturation was investigated using the tools of sensory analyses coupled by quantitative measurement of certain head-space volatiles known to originate from the contact of wine with wood. Sensory characters of the resulting wines were well distinguished and specified for all examined conditions. Of those, the ones of medium and heavily toasted chips had the most significant sensory effect, making wines more woody, vegetative and smoky but also more bitter and astringent. Wines aged with medium toast chips also showed highest headspace concentrations of furfural and cis oak lactone followed by those aged with heavily and lightly toasted chips, in the barrel and in stainless steel (ranked). Wines from heavily toasted chips scored highest in nutty aromas and earthy flavours and those of lightly toasted highest in sweet taste. These results indicate that the use of oak chips is not only an effective alternative to barrel use in red wine maturation, but also –through toasting control– a tool to affect specific sensory characters of the resulting wines.

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### References


