Elsevier Editorial System(tm) for Food Chemistry
Manuscript Draft

Manuscript Number: FOODCHEM-D-18-04217R2

Title: Effect of the winemaking process on the volatile composition and aromatic profile of Tempranillo Blanco wines

Article Type: Research Article (max 7,500 words)

Keywords: carbonic maceration, Tempranillo Blanco wine, volatile compounds, sensory properties, PLS

Corresponding Author: Dr. Belén Ayestarán Iturbe,

Corresponding Author's Institution:

First Author: Belén Ayestarán Iturbe

Order of Authors: Belén Ayestarán Iturbe; Leticia Martínez-Lapuente; Zenaida Guadalupe; Clara Canals; Elena Adell; Mar Vilanova

Abstract: The effects of the carbonic maceration and conventional winemaking on the volatile composition and aromatic sensory characteristics of Tempranillo Blanco wines were studied for the first time, during three consecutive vintages. Relationships between instrumental (volatiles) and sensory variables were analyzed applying partial least squares regression (PLS). Carbonic macerated wines had higher contents of alcohols and carbonyl compounds, yet lower concentrations of C6 alcohols and volatile acids than wines conventionally produced. The Odor Activity Values (OAV) exhibited an increase in wines when carbonic maceration was applied. According to the geometric mean (% GM) obtained from aroma descriptors the effect of the winemaking process was significant for seed fruit, ripe fruit and floral notes. When subjected to PLS the data from the instrumental analysis yielded a satisfactory model for the prediction of aroma descriptors in this set of wines.

Effect of the winemaking process on the volatile composition and aromatic profile of Tempranillo Blanco wines

Belén Ayestarán[a]*, Leticia Martínez-Lapuente[a], Zenaida Guadalupe[a], Clara Canals[b], Elena Adell[b], Mar Vilanova[c]

[a]Instituto de Ciencias de la Vid y del Vino (Universidad de la Rioja, Gobierno de La Rioja y CSIC), Finca La Grajera, Ctra. De Burgos Km 6, 26007 Logroño (La Rioja)

[b]Bodegas Campo Viejo (Grupo Pernod Ricard Bodegas), C/ Viejo Camino de Lapuebla 50, 26006 Logroño (La Rioja)

[c]Misión Biológica de Galicia (CSIC), C/ El Palacio-Salcedo, 36143 Pontevedra (Galicia)

*Corresponding author: Phone: +34-941-299725. Fax: +34-941-299721. E-mail: belen.ayestaran@unirioja.es

Abstract

The effects of the carbonic maceration and conventional winemaking on the volatile composition and aromatic sensory characteristics of Tempranillo Blanco wines were studied for the first time, during three consecutive vintages. Relationships between instrumental (volatiles) and sensory variables were analyzed applying partial least squares regression (PLS). Carbonic macerated wines had higher contents of alcohols and carbonyl compounds, yet lower concentrations of C_6 alcohols and volatile acids than wines conventionally produced. The Odor Activity Values (OAV) exhibited an increase in wines when carbonic maceration was applied. According to the geometric mean (% GM) obtained from aroma descriptors the effect of the winemaking process was significant for seed fruit, ripe fruit and floral notes. When subjected to PLS the data from the instrumental analysis yielded a satisfactory model for the prediction of aroma descriptors in this set of wines.

Keywords: carbonic maceration, Tempranillo Blanco wine, volatile compounds, sensory properties, PLS.

1. Introduction

Aromas are an important parameter of wine quality, especially in white wines. Wine aroma is produced by the combination of hundreds of different compounds belonging to very heterogeneous chemical groups such as esters, aldehydes, terpenes, alcohols, ketones, acids, etc. The type, amount, and presence of chemicals that affect a wine´s flavor also depends on many factors, such as grape origin, grape variety and ripeness, soil and climate, yeast used during fermentation along with other winemaking practices (Kotseridis & Baumes, 2000; Spranger et al., 2004).

White wines are commonly elaborated with mixtures of press fractions fermented separately. Blending of the fermented press fractions can produce a more balanced wine, wherein each fraction confers to greater overall aroma complexity in the wine. Maceration of whole crushed white grapes before must extraction by pressing has become a standard procedure in some wineries. In fact, skin contact has been shown to favor the release of aromatic compounds which are located mostly in the skins (Bayonove, Cordonnier, & Ratier, 1974). However, this practice could lead to a higher extraction of phenolic compounds; thus would produce white wines which are more bitter and astringent, with strange or undesirable colors and flavors (Olejar, Fedrizzi, & Kilmartin, 2016).

Carbonic maceration (CM) is another winemaking technique commonly used in red wine production. However, it has been only slightly studied as a white winemaking procedure (Olejar, Fedrizzi & Killmartin, 2015; Olejar et al., 2016; Ricardo-da-Silva, Cheynier, Samsom & Bourzeix, 1993). CM refers to putting the whole grapes in a tank filled with carbon dioxide (anaerobic atmosphere) during several days in order to allow some enzymatic reactions to take place without yeast participation: production of ethanol (up to 20–30 ml/L), malic acid consumption, extraction and formation of secondary metabolites, such as volatile and phenolic compounds (Etaio, Meillon, Pérez-Elortondo & Schlich, 2016; Pace, Giacosa, Torchio, Río Segade, Cagnasso & Rolle, 2014). After this phase the grapes break down due to the internal pressure and the yeast begins the fermentation process. Nowadays, the CM process is not isolated since some grapes break down when they are placed in the tank, thus permitting the beginning of fermentation by yeast; therefore, both phenomena occur simultaneously (Etaio et al., 2016).

The volatile compounds influencing the flavor of carbonic macerated grapes can be related to a concrete biochemical pathway regarding specific amino acids (Dourtoglou, Yannovits, Tychopoulos & Vamvakias, 1994). This pathway involves characteristic must aromas that remain after the fermentation of the carbonic macerated grapes. The scientific literature describes the odor of CM red wines as “distinctive” and “rich”, and sensorial attributes often used to describe their aromas are associated with fruits (Etaio et al., 2016; Tesniere & Flanzy, 2011). The combination of grape varietal aromas, volatile compounds originating in grape anaerobiosis, and fermentative aromas could increase the aromatic quality in carbonic macerated white wines in comparison with those white wines conventionally produced.

A new market strategy is emerging in the wine industry in order to diversify wine production and enhance the characteristics and particularities of different grape varieties. Tempranillo Blanco *Vitis vinifera* L. var. is a minority grape variety whose production has been recently authorized by the Regulatory Certification Council of La Rioja (D.O.Ca Rioja). This grape variety is nowadays used by some D.O.Ca Rioja certified wineries to elaborate fruity wines, particularly with intense citrus and tropical fruits characteristics (Balda & Martínez de Toda, 2017).

However, Tempranillo Blanco wines are mostly produced by traditional winemaking; thus, there are no published studies on the chemical composition and sensory attributes of Tempranillo Blanco wines produced with CM.

Therefore, presented herein is the analysis of the effect of the fermentation process: carbonic maceration (CM) or conventional winemaking (CW) on the volatile composition and sensory properties of the Tempranillo Blanco white wines. The study was conducted over three consecutive vintages (2014, 2015 and 2016) in the winery Bodegas Campo Viejo (Grupo Pernod Ricard Bodegas), in the D.O.Ca Rioja region.

2. Material and methods

2.1. Grapes and winemaking

Grapes from Tempranillo Blanco variety were collected during three consecutive vintages (2014, 2015 and 2016) from the same vineyard of Bodegas Campo Viejo (Grupo Pernod Ricard Bodegas) from the D.O.Ca Rioja. Grapes were harvested by hand at adequate grape maturity and at optimum sanitary state; they were placed in 12 kg plastic boxes, and transported to the Bodegas Campo Viejo winery. Two winemaking procedures were then applied in triplicate: (i) conventional winemaking (CW), and (ii) carbonic maceration (CM).

For conventional winemaking (CW), grapes (2500 kg) were directly pressed in a pneumatic press (BucherVaslin XPro 8, France). The free run juice was quickly clarified via nitrogen flotation at room temperature and the clear juice was then moved to fermentation tank. The fermentation took place in 125 L stainless steel deposits at 16 to 19 °C after inoculation with 20 g/hL of *S. cerevisiae* yeast (Zymaflore X16, Laffort, France). Once fermentation was completed (glucose plus fructose content lower than 0.5 g/L), the wines were settled and sulphited (3 g/hL). Samples for analysis were taken at the end of alcoholic fermentation, and were named as CW-14, CW-15 and CW-16 according to the vintage they were produced, 2014, 2015 and 2016, respectively.

In carbonic maceration (CM), whole bunches of grapes (1000 kg) where placed into stainless steel deposits of 1500 liters, which were inerted with carbon dioxide before, during and after filling. The must from the bottom of the deposit was inoculated with 20 g/hL of *Saccharomyces cerevisiae* yeast strain (Zymaflore X16, Laffort, France). The deposits were maintained at 16-19 ºC and the must was pumped over 2 times a day. After 12 days of intracellular fermentation/maceration (density 1010 g/L), the mash was pressed. Free-run and press wines were combined, collected in a tank, and stored at 18 °C to undergo extracellular fermentation. When alcoholic fermentation was finished (glucose plus fructose content lower than 0.5 g/L), the wine was sulphited (3 g/hL). Samples were taken at the end of alcoholic fermentation, and were named as CM-14, CM-15 and CM-16 according to the vintage they were produced, 2014, 2015 and 2016, respectively.

2.2. Standard enological parameters

Standard enological parameters were measured in the wines according to the official methods established by the International Organization of Vine and Wine (OIV, 2015). Malic acid and glucose plus fructose were analyzed by the autoanalyzer LISA 200 (Biocode Hyad, Le Rhem, France).

2.3. Wine volatile composition

The volatile composition was analyzed according to Oliveira, Faria, Sá, Barros & Araújo (2006) and Moreno et al. (2017). A volume of 2.4 µg of internal standard (4-nonanol) was added to 8 mL of wine and 400 µL of dichloromethane. The extraction was done by stirring the sample with a magnetic stir bar during 15 min at room temperature. After cooling during 10 min at 0 ºC, the magnetic stir bar was removed and the sample was centrifugated during 5 min (RCF=5118, 4 ºC). After centrifugation organic phase was recovered into a vial, using a Pasteur pipette. Then, the aromatic extract (200 µL) was picked up into a new vial after dried with anhydrous sodium sulphate. Extraction of volatiles were made in triplicate.

Gas chromatographic by Agilent Technologies (6890N) was used to analysis the volatile compounds. Chromatograph and an ion-trap mass spectrometer Agilent 5975C. 1 µL injection was made into a capillary column CP-Wax 52 CB (50 m × 0.25 mm i.d., 0.2 µm film thickness, Chrompack). The temperature of the injector was programmed from 20 ºC to 250 ºC, at 180 ºC min^{-1}. The oven temperature was 40 ºC, for 5 min, then programmed to rise from 40 ºC to 250 ºC, at 3 ºC min^{-1}, then held 20 min at 250 ºC and finally programmed to go from 250 ºC to 255 ºC at 1 ºC min^{-1}. The carrier gas was helium N60 at 103 kPa, which corresponds to a linear speed of 180 cm s^{-1} at 150 ºC and the split vent was set to 13 mL/min. Sample of 3 µL was injected in the splitless mode (vent time 15 s). The detector was set to electronic impact mode (70 eV), with an acquisition range from 29 to 360 m/z, and an acquisition rate of 610 ms.

Peaks identification was performed by WSearch32 free software and by comparison with mass spectra and retention times with those of pure standard compounds and confirming these by GC-MS. All of the compounds were quantified as 4-nonanol equivalents.

2.4. Odor activity value

To evaluate the contribution of a chemical compound to the aroma of a wine, the odor activity value (OAV) was determined. When OAV in higher than one a possible contribution to the wine aroma is considered. OAV was calculated as the ratio between the concentration and the perception threshold of the individual compound. The perception threshold used in this work were those found in the literature (Etiévant, 1991; Ferreira, Lopez & Cacho, 2000; Francis & Newton, 2005; Vilanova, Genisheva, Bescansa, Masa & Oliveira, 2009).

2.5. Sensory analysis

A sensory room ISO 8589 Standard (2010) was used to performed the sensory sessions. The sensory panel was formed by 19 expert tasters (11 male and 8 female between 35 and 60 years old) from the D.O.Ca Rioja. In a first time, the wine tasters defined the descriptors used in the sensory analysis. One session was performed to train with descriptors using structured numerical scales according to UNE-87-020-93 Standard (ISO 4121:1987). In a second session, wine samples were analyzed with a structured numerical scale of six points where 0 represented no intensity and 5 the highest intensity). The wines were analyzed by duplicate. The olfactory attributes and defined in the first session were: aromatic intensity, seed fruit, citrus fruit, tropical fruit, ripe fruit, floral, herbaceous, mineral, and yeasty.

The Geometric Mean (GM %) was calculated as the square root of the product between relative intensity (I%) and relative frequency (F%). The wine descriptors were classified in basis to GM, according to the International Organization for Standardisation ISO 11035 to make possible to eliminate the descriptors with low GM.

2.6.Statistical analysis

The statistical analyses were performed using XLstat-Pro (Addinsoft). One-way ANOVA analysis was made to determine the differences between treatments. Principal component analysis (PCA) was used to study the possible grouping of the wines according to the different winemaking procedures and volatile compounds. The GM (%) data obtained from the sensory analysis were submitted to a one way-ANOVA analysis. Analysis of partial least squares regression (PLS) were used to show the relationship between significant aroma sensory variables with %GM > 10 and volatile compounds considered as an aroma-contributing substance (OAV > 0.2) (Belitz, & Grosch, 1999).

3. Results and discussion

3.1. Oenological parameters

Alcohol content, sum of glucose plus fructose, pH, titratable acidity, volatile acidity and absorbance at 420 nm in wines after alcoholic fermentation are shown in Table 1. The values obtained after alcoholic fermentation for volatile acidity proved to be appropriate for winemaking without microbial alterations. All wines were fermented to dryness (combined glucose and fructose content < 0.5 g/L). The values of ethanol content, pH and titratable acidity were similar to those obtained in other mono varietal Spanish white wines (Vilanova et al., 2009). As expected, carbonic maceration produced wines with higher pH, volatile acidity and absorbance at 420 nm; and lower values of titratable acidity. The lower acidity and the higher pH and volatile acidity found in carbonic macerated wines was attributed to the partial metabolism of malic acid in the entire grape (Tesniere & Flanzy, 2011), which coincides with data reported by other authors (Etaio et al., 2016). As observed by Ricardo-da-Silva et al. (1993), carbonic macerated wines presented higher absorbance at 420 nm than wines conventionally produced, probably due to greater extraction of phenolic acids from the grape solids and higher browning susceptibility.

3.2. Effect of winemaking process on wine volatile composition

Table 2 shows the individual volatile compounds and the volatile composition by families of Tempranillo Blanco wines made with conventional winemaking (CW) and carbonic maceration (CM) during the vintages 2014, 2015 and 2016. The data have been organized into six chemical families: alcohols, represented by 2-methyl-1-propanol, 3-methyl-1-butanol, 2-phenylethanol, 3-methyl-1-pentanol, and methionol;

C6 alcohols, represented by 1-hexanol, *E*-3-hexen-1-ol, and *Z*-3-hexen-1-ol; ethyl esters and acetates, represented by ethyl butyrate, isoamyl acetate, ethyl hexanoate, hexyl acetate, ethyl octanoate, ethyl decanoate, and 2-phenylacetate; volatile acids, represented by 2+3-methylbutanoic acid, hexanoic acid, octanoic acid, decanoic acid, geranic acid, dodecanoic acid, and hexadecanoic acid; phenol volatiles, represented by 4-vinylguaiacol, and 4-vinylphenol; and carbonyl compounds, represented by acetoine. An ANOVA was applied to test the effect of the winemaking factor (W) on the average volatile composition of the three vintages by chemical family. Significant differences were detected between CW and CM wines for all volatile families except for phenol volatiles, ethyl esters and acetates. Some researchers also observed that carbonic maceration induced a modification of the wine volatile composition. Dourtoglou et al. (1994) concluded that red wines subjected to carbonic maceration were richer in volatile compounds than the controls after storage under the air. In the present study, carbonic maceration was found to affect various families of volatile compounds. Significantly higher concentrations of alcohols were produced in carbonic macerated wines than in wines traditionally elaborated; this was a reasonable finding being that other researchers came to the same conclusion (Bitteur, Tesniere, Sarris, Baumes, Bayonove & Flanzy, 1992; Tesniere, Baumes, Bayonove & Flanzy, 1989). As in the case of alcohols, CM wines also contained higher contents of carbonyl compounds, indicating that carbonic anaerobiosis induced the augmentation when compared with traditional winemaking. On the contrary, carbonic macerated wines exhibited significantly lower concentrations of C6 alcohols, as shown by Bitteur et al., (1992) and Spranger et al., (2004) along with volatile acids. Finally, carbonic maceration did not affect the total content of volatile phenols, ethyl esters, and acetates. These results contrasted other studies which found carbonic maceration of red grapes to induce a significant increase of ester compounds

(Salinas, Alonso, Navarro, Pardo, Jimeno & Huerta, 1996; Tesniere et al., 1989) and volatile phenols (Ducruet, Flanzy, Bourzeix & Chambroy, 1983; Ducruet, 1984). However, a decrease in the total ester content in white wines has also been reported in macerations wherein the grape skin was involved (Aleixandre-Tudo, Weightman, Panzeri, Nieuwoudt & du Toi, 2015).

Results of the ANOVA on the average of the 2014, 2015 and 2016 vintages showed the effect of “winemaking” type on 56 % (14 out 25 compounds) of the volatiles identified and quantified.

Alcohols were the group with the highest content of volatile components both in CW and CM wines. Higher alcohols are synthesized by decarboxylation and reduction of α-keto-acids produced as intermediates of amino acid synthesis and catabolism. Alcohols are related to herbaceous notes with strong and pungent tastes and smells. Contents of higher alcohols below 300 mg/L add desirable complexity to wine, whereas greater concentrations can be unfavorable to wine quality (Rapp & Versini, 1991). On the contrary, the alcohol 2-phenylethanol is generally a positive contributor to wine aroma, being characterized by a rose-like aroma (Francis & Newton, 2005). In the present study, the total content of higher alcohols in both winemaking procedures was below 40 mg/L (mean total = 37.24 mg/L and 22.83 mg/L in CM and CW wines, respectively). The compounds 2-methyl-1-propanol, 3-methyl-1-butanol and 2-phenylethanol were found in significantly higher concentrations when grapes were subjected to carbonic maceration. The winemaking process didn´t affect the content of 3-methyl-1-pentanol and methionol. The increase of alcohols has been also reported in anaerobic metabolism of red grapes (Bitteur et al., 1992; Tesniere et al., 1989).

The C6 compounds, hexanols and hexenols, add herbaceous and vegetal notes to grapes and wines. This group includes aldehydes and alcohols, which are derived from membrane lipids via the lipoxygenase pathway (Oliveira et al., 2006). Carbonic maceration of red wines has been related to lower levels of C6 compounds (Bitteur et al., 1992; Ducruet, 1984; Salinas et al., 1996; Spranger et al., 2004). This is not surprising since carbonic anaerobiosis limits the synthesis of these compounds by enzymatic oxidation of linolenic and linoleic acids. In the present study, 1-hexanol and *Z*-3-hexen-1-ol were affected by the winemaking process, resulting in lower concentrations in CM wines than in CW wines. No significant differences were detected in the content of *E*-3-hexen-1-ol.

Ethyl esters have a strong influence on wine flavor because they are normally found in high concentrations and have low detection thresholds; thus they play an essential role in the fruity aromas of wines. Ethyl esters content depends on different factors, such as sugar content, fermentation temperature, aeration, and yeast strain (Perestrelo, Fernandes, Albuquerque, Marques & Câmara, 2006). In the present study, CW and CM wines showed the same profile of ethyl esters of fatty acids. Ethyl hexanoate and octanoate were the major ethyl esters of fatty acids, whereas ethyl decanoate was found in the lowest concentration in both wines. Carbonic maceration induced a significant increase of ethyl butyrate, but a significant decrease in the content of ethyl hexanoate and ethyl decanoate.

The formation of acetates depends on must nutrient concentration (Gambetta, Bastian, Cozzolino & Jeffery, 2014), the content of unsaturated fatty acids available in the medium, and carbon-to-nitrogen ratio (Saerens, Delvaux, Verstrepen, Van Dijck, Thevelein & Delvaux, 2008). Volatile acetates are among the key compounds in the fruity flavor of wines (Vilanova et al., 2009). Three acetates were identified in the present study: hexyl acetate, isoamyl acetate and 2-phenylethylacetate. Only hexyl acetate, which supplies pleasant “apple” nuances to the wines (Etiévant, 1991), varied with the winemaking treatment; the highest value was produced in the conventional winemaking process.

Fatty acids are produced in the lipid metabolism of yeast; thus, have been related with fatty, cheese and rancid attributes (Rocha, Rodrigues, Coutinho, Delgadillo & Coimbra, 2004). Among the fatty acids are decanoic acid, octanoic acid and hexanoic acid which were present at high concentrations in both wines. 2+3-methylbutanoic acid, octanoic acid, decanoic acid and geranic acid concentrations were significantly lower when carbonic maceration was applied.

Among the group of vinylphenols, only 4-vinylguaiacol and 4-vinylphenol were detected. This result was logical being that vinylphenols are the main phenols in white wines, while ethylphenols are more abundant in red wines (Boidron, Chatonnet & Pons, 1988). These compounds are related with heavy pharmaceutical odors (Castro Mejías, Natera Marín, García Moreno & García Barroso, 2003). The winemaking procedure didn’t affect the content of volatile phenols in wines.

Regarding carbonyl compounds, carbonic maceration induced an increase in the acetoin concentration.

3.3. Principal component analysis (PCA) applied on wine volatile composition

Principal component analysis (PCA) was applied on Tempranillo Blanco wine volatile compounds with significant differences among winemaking treatments (Figure 2).

The first two principal components (PC1 and PC2) explained 74.76 % of the total variance (50.91 % and 23.85 %, respectively). PC1 was characterized by the major contribution of 2-methyl-1-propanol, 3-methyl-1-butanol, 2-phenylethanol and ethyl butyrate on the positive loading, and hexyl acetate, 2+3-methylbutanoic acid, octanoic acid, and decanoic acid on the negative loading. PC2 was characterized by ethyl hexanoate and ethyl decanoate in the positive side and 1-hexanol, geranic acid and Z-3-hexen-1-ol in the negative side.

PCA differentiated two groups. The first group, formed by carbonic macerated wines (CM) from 2014, 2015 and 2016 vintages, was located in the positive side of PC1. The second group, formed by wines made by conventional winemaking (CW) from 2014, 2015 and 2016 vintages, was positioned in the negative side of PC1. CM wines from 2014 and 2015 vintages were related to high contents of ethyl butyrate and 2-phenylethanol. However, CM wines from 2016 vintage were strongly associated with alcohols (2-methyl-1-propanol and 3-methyl-1-butanol). CW wines produced from the 2014 vintage were strongly related to high ethyl esters (ethyl hexanoate and decanoate) and acetate (hexyl acetate) contents. Finally, the presence of high contents of volatile acids (2+3-methylbutanoic acid, octanoic acid, decanoic acid and geranic acid) and C6 compounds (1-hexanol and Z-3-hexen-1-ol) contributed to the distinction of CM wines from 2015 and 2016 vintages.

3.4. Odor activity values of Tempranillo Blanco wines

The results in Table 3 illustrate how that 12 out of 25 quantified volatile compounds (48 % of total compounds) were found at average concentrations higher than their corresponding odor thresholds (OAV >1). These volatiles are considered to be potential contributors to the global bouquet of the wines analyzed; although their sensory impact is likely to be affected by the actual wine matrix (Pineau, Barbe, Van Leeuwen & Dubourdieu, 2007).

Tempranillo Blanco wines from carbonic maceration were the most aromatic wines, with a total OAV of 822, versus an OAV of 770 from CW wines. Four ethyl esters (fruity aroma), which contribute favorably to white wine aroma as fruity characteristics (Vilanova et al., 2009), were found in levels over the perception threshold in both the

CM and CW wines. Isoamyl acetate and ethyl octanoate, related to banana and apple aroma respectively, were the most powerful odorants in wines regardless of the vinification method. Carbonic macerated wines contained the highest OAV of isoamyl acetate (367), while ethyl octanoate was highest in wines elaborated by traditional winemaking (353). 2-phenylacetate, with floral aroma, was also detected above its odor threshold for all wines, with similar values from both winemaking procedures. Among alcohols, 3-methyl-1-butanol (alcohol and banana notes) was the only alcohol with OAV > 1, and made a major contribution in wines from carbonic maceration.

The presence of C6–C10 fatty acids, generally associated with the occurrence of negative odors, has been associated with notes described as fruity, cheese-like and rancid (Rocha et al., 2004). However, they could have a great impact on the aromatic balance of wines because they oppose the hydrolysis of the corresponding esters (Edwards, Beelman, Bartley & McConnell, 1990). In the present study, 2+3 methylbutanoic acid, hexanoic, octanoic and decanoic acids showed a high contribution to wine aroma in traditional white wines (CW), although their influence to the wine aroma was low in comparison with other compounds. Only the volatile phenol 4-vinylguaiacol, associated with clove and curry notes, presented OAV > 1 in all wines. This compound showed a maximum OAV value in wines subjected to conventional winemaking (CW). The OAV of ethyl esters and acetates illustrated an increase in fruity odors in Tempranillo Blanco wines when carbonic maceration was applied. An increase in fruity notes together with a decrease in fatty acids with rancid aromas would contribute to the improvement of the overall aroma in carbonic macerated wines.

3.5. Aromatic sensory properties

Table 4 shows the geometric mean (GM %) of the aromatic sensory descriptors of Tempranillo Blanco wines, together with the ANOVA results for the winemaking factor

(W). The aromatic sensory characterization of the Tempranillo Blanco wine was obtained by an experienced panel using a total of nine aromatic descriptors (Table 4). According to the ANOVA analysis, the effect of the winemaking procedure was significant ($p < 0.05$) for the seed fruit, ripe fruit and floral notes. Ripe fruit presented maxima GM (%) for carbonic macerated wines (CM) in all vintages studied, whereas seed fruit and floral notes exhibited the highest GM (%) for wines made with conventional winemaking (CW). This indicated that, from the nine descriptors evaluated, these three notes were useful to differentiate between Tempranillo Blanco wines. Apart from the aromatic intensity, the maxima GM (%) values for both winemaking processes were given to the seed fruit, citrus, tropical, floral and ripe fruit notes (GM >30%). All sensory attributes evaluated showed GM >10 % in both wines and therefore, could be used to define the aroma of Tempranillo Blanco wines, as defined by Vilanova, Genisheva, Masa & Oliveira (2010).

3.6. PLS modeling relationship between aromatic sensory descriptors and volatile compounds of wines

Partial least squares (PLS) regression was used to show the relationships between the sensory attributes and volatile compounds of the wines. Figure 3 contains the PLS carried out between aroma descriptors with GM > 10 % (aromatic intensity, seed fruit, citrus, tropical, ripe fruit, floral, herbaceous, mineral, and yeasty notes), and volatiles considered as an aroma-contributing substance with OAV > 0.2 (V1-V20).

The data were standardized before to PLS analysis for easier identification of the relationships between volatiles and sensory variables. The plot (explaining 62.57 % of the total variance) suggested a correlation of volatile compounds and sensory descriptors and their association with the wines analyzed. The PLS discriminated between the winemaking processes. CM wines were positioned in the positive side of

PC1 and CW wines in the negative side of the same axe. In both elaborations wines from 2015 were different than the other vintages.

Aromatic intensity and ripe fruit descriptors were highly correlated and were associated to CM-14 and CM-16 wines. According to the loading weight, these attributes were mainly predicted by 3-methyl-1-butanol (V1), 2-phenylethanol (V2), and ethyl butyrate (V6). The perception of wine fruitiness is highly dependent on some esters (Ferreira, Fernandez, Pena, Escudero & Cacho, 1995). Some authors have suggested that higher alcohols give wine a pungent aroma (Rapp & Versini, 1991) or a solvent aroma nuance (Cameleyre, Lytra, Tempere & Barbe, 2015). On the other hand, some authors suggest that 2-phenylethanol present a positive correlation with aromatic intensity in red wines (Vilanova, Campo, Escudero, Graña, Masa & Cacho, 2012).

Figure 3 showed positive correlations between floral descriptor and hexanoic (V14) and decanoic acids (V15). The citrus, tropical and seed fruit attributes were highly correlated with hexyl acetate (V9), ethyl decanoate (V11) and hexanoic acid (V14). Floral, citrus, tropical and seed fruit notes were mainly associated to CW wines from 2014 and 2016 vintages. The herbaceous attribute was highly correlated to E-3-hexen-1-ol (V4), ethyl butyrate (V6) and 2-phenylacetate (V12). CM wines had strong herbaceous notes; probably due to the presence of stems during the fermentation process. CW wines from 2015 vintage showed the highest mineral aroma. This descriptor was satisfactorily predicted by 4-vinylguaiacol (V19) and 4-vinylphenol (V20). These results were in agreement with other authors who reported volatile phenols to be related to wine aromatic minerality (Zaldivar, 2017). Finally, CM wines from 2014 and 2016 vintages presented the highest correlation with a yeasty aroma and 4-vinylphenol (V20).

4. Conclusions

The effect of the winemaking process (carbonic maceration *vs* conventional winemaking) on the volatile composition and aromatic sensory properties of Tempranillo Blanco wines was studied during three consecutive vintages. Carbonic maceration led to wines of higher pH, volatile acidity and lower titratable acidity, whereas ethanol content remained unaffected. A significant change in the volatile profile of wines was also observed when carbonic maceration was applied. Carbonic maceration produced wines with significantly higher contents of alcohols and carbonyl compounds, and lower concentrations of C_6 alcohols and volatile acids. However, total content of ethyl esters and acetates and volatile phenols in wines were not affected. The effect of the winemaking process also had an influence on the odor activity value (OAV), where twelve volatile compounds reached values > 1; accounting for the highest total OAV from carbonic macerated wines. The OAV analysis from ethyl esters and acetates showed an increase of fruity odor on Tempranillo Blanco wines when carbonic maceration was applied. In the sensory analysis, the ripe fruit descriptor exhibited maxima geometric mean (GM %) for carbonic macerated wines, whereas the seed fruit and floral notes were exhibited to be higher in conventionally produced wines. Partial least square (PLS) regression applied to aroma active compounds and aroma sensory descriptors showed how carbonic macerated wines presented higher aromatic intensity and ripe fruit descriptors. Citrus, tropical and seed fruit attributes were associated to wines conventionally made.

The results obtained suggest carbonic maceration in Tempranillo Blanco wines to be an alternative to the traditional winemaking to obtain wines with intense ripe fruit features. Therefore, it would increase the diversification and differentiation of white wines. However, further studies need to be developed aiming at the evaluation of the effect of carbonic maceration on the other wine chemical compounds.

5. References

Aleixandre-Tudo, J.L., Weightman, C., Panzeri, V., Nieuwoudt, H.H., & du Toi, W.J. (2015). Effect of skin contact before and during alcoholic fermentation on the chemical and sensory profile of South African Chenin Blanc white wines. *South African Journal of Enology and Viticulture, 36,* 366–377.

Balda, P., & Martínez de Toda, F. (2017). *Variedades minoritarias de vid en La Rioja*. (1th ed.). Logroño: Consejería de Agricultura, Ganadería y Medio Ambiente.

Bayonove, C., Cordonnier, R., & Ratier, R. (1974). Localisation de l'arome dans la baie de raisin: variétés Muscat d'Alexandrie et Cabernet-Sauvignon. *Comptes rendus de l'Académie d'Agriculture de France, 60*, 1321-1328.

Belitz, H. D., & Grosch, W. (1999). *Food chemistry*. (2nd ed.). Berlin: Springer-Verlag.

Bitteur, S., Tesniere, C., Sarris, J., Baumes, R., Bayonove, C., & Flanzy, C. (1992). Carbonic anaerobiosis of muscat grapes. I. Changes in the profiles of free and bound volatiles. *American Journal of Enology and Viticulture, 43,* 41-48.

Boidron, J. N., Chatonnet, P., & Pons, M. (1988). Influence du bois sur certaines substances odorantes des vins. *Connaissance Vigne Vin, 22,* 275–293.

Cameleyre, M., Lytra, G., Tempere, S., & Barbe, J. C. (2015). Olfactory impact of higher alcohols on red wine fruity ester aroma expression in model solution. *Journal of Agricultural and Food Chemistry, 63,* 9777−978.

Castro Mejías, R., Natera Marín, R., García Moreno, M. V., & García Barroso, C. (2003). Optimisation of headspace solid-phase microextraction for the analysis of volatile phenols in wine. *Journal of Chromatography A, 995,* 11–20.

Dourtoglou, V.G., Yannovits, N. G., Tychopoulos, V. G., & Vamvakias, M. M. (1994). Effect of storage under CO_2 atmosphere on the volatile, amino acid, and pigment constituents in red grape (*Vitis vinifera* L. Var. Agiorgitiko). *Journal of Agricultural and Food Chem*istry, *42,* 338-344.

Ducruet, V. (1984). Comparison of the headspace volatiles of carbonic maceration and traditional wine. *LWT - Food Science and Technology, 17,* 217-221.

Ducruet, V., Flanzy, C., Bourzeix, M., & Chambroy, Y. (1983). Les constituants volatils des vins jeunes de maceration carbonique. *Sciences des Aliments, 3,* 413-426.

Edwards, C.G., Beelman, R.B., Bartley, C.E., & McConnell, A.L. (1990). Production of decanoic acid and other volatile compounds and the growth of yeast and malolactic bacteria during vinification. *American Journal of Enology and Viticulture, 41,* 48–56.

Etaio, I., Meillon, S., Pérez-Elortondo, F. J., & Schlich, P. (2016). Dynamic sensory description of Rioja Alavesa red wines made by different winemaking practices by using Temporal Dominance of Sensations. *Journal of the Science of Food and Agriculture, 96,* 3492–3499.

Etiévant, P. X. (1991). Wine. In H. Maarse (Ed.), *Volatile compounds in food and beverages* (pp. 483–546). New York: Marcel Dekker Inc.

Ferreira, V., Fernandez, P., Pena, C., Escudero, A., & Cacho, J. F. (1995). Investigation on the role played by fermentation esters in the aroma of young Spanish wines by multivariate analysis. *Journal of the Science of Food and Agriculture, 67,* 381-392.

Ferreira, V., Lopez, R., & Cacho, J.F. (2000). Quantitative determination of the odorants of young red wines from different grape varieties. *Journal of the Science of Food and Agriculture, 80,* 1659–1667.

Francis, I.L., & Newton, L. (2005). Determining wine aroma from compositional data. *Australian Journal of Grape and Wine Research, 11,* 114–126.

Gambetta, J.M., Bastian, S.E.P., Cozzolino, D., & Jeffery, D.W. (2014). Factors influencing the aroma composition of Chardonnay wines. *Journal of Agricultural and Food Chemistry, 62,* 6512–6534.

Kotseridis, Y., & Baumes, R. (2000). Identification of impact odorants in Bordeaux red grape juice, in the commercial yeast used for its fermentation, and in the produced wine. *Journal of Agricultural and Food Chemistry, 48,* 400–406.

Moreno, D., Valdés, E., Uriarte, D., Gamero, E., Talaverano, I., & Vilanova, M. (2017). Early leaf removal applied in warm climatic conditions: Impact on Tempranillo wine volatiles. *Food Research International, 98,* 50–58.

OIV (2015). *Compendium of international methods of wine and must analysis.* Paris: International Organisation of Vine and Wine.

Olejar, K. J., Fedrizzi, B., & Kilmartin, P. A. (2016) Enhancement of Chardonnay antioxidant activity and sensory perception through maceration technique. *LWT Food Science and Technology, 65,* 152-157.

Olejar, K.J., Fedrizzi, B., & Killmartin, P.A. (2015). Antioxidant activity and phenolic profiles of Sauvignon Blanc wines made by various maceration techniques. *Australian Journal of Grape and Wine Research, 21,* 57-68.

Oliveira, J.M., Faria, M., Sá, F., Barros, F., & Araújo, I.M. (2006). C6-alcohols as varietal markers for assessment of wine origin. *Analytica Chimica Acta, 563,* 300–309.

Pace, C., Giacosa, S., Torchio, F., Río Segade, S., Cagnasso, E., & Rolle, L. (2014). Extraction kinetics of anthocyanins from skin to pulp during carbonic maceration of wine grape berries with different ripeness levels. *Food Chemistry, 165*, 77–84.

Perestrelo, R., Fernandes, A., Albuquerque, F.F., Marques, J.C., & Câmara, J.S. (2006). Analytical characterization of the aroma of Tinta Negra Mole red wine: identification of the main odorants compounds, *Analytica Chimica Acta, 563,* 154–164.

Pineau, B., Barbe, J. C., Van Leeuwen, C., & Dubourdieu, D. (2007). Which impact for b-damascenone on red wines aroma. *Journal of Agricultural and Food Chemistry, 55,* 4103–4108.

Rapp, A., & Versini, G. (1991). Influence of nitrogen compounds in grapes on aroma compounds of wine. In *International Symposium on Nitrogen in Grapes and Wine* (pp. 156–164). Davis: American Society for Enology and Viticulture.

Ricardo-da-Silva, J. M., Cheynier, V., Samsom, A., & Bourzeix, M. (1993). Effect of pomace contact, carbonic maceration, and hyperoxidation on the procyanidin composition of Grenache blanc wines. *American Journal of Enology and Viticulture, 44,* 168-172.

Rocha, S. M., Rodrigues, F., Coutinho, P., Delgadillo, I., & Coimbra, M. A. (2004). Volatile compositon of Baga red wine. Assessment of the identification of the would-be impact odourants. *Analytica Chimica Acta, 513,* 257–262.

Saerens, S. M. G., Delvaux, F., Verstrepen, K. J., Van Dijck, P., Thevelein, J. M., & Delvaux, F. R. (2008). Parameters affecting ethyl ester production by *Saccharomyces cerevisiae* during fermentation, *Applied and Environmental Microbiology, 74,* 454–561.

Salinas, M. R., Alonso, G. L., Navarro, G., Pardo, F., Jimeno, J., & Huerta, M. D. (1996). Evolution of the aromatic composition of wines undergoing carbonic maceration under different aging conditions. *American Journal of Enology and Viticulture, 47*, 134-144.

Spranger, M. I., Clímaco, M. C., Sun, B., Eiriz, N., Fortunato, C., Nunes, A., et al. (2004). Differentiation of red winemaking technologies by phenolic and volatile composition. *Analytica Chimica Acta, 513,* 151–161.

Tesniere, C., & Flanzy, C. (2011). Carbonic maceration wines: characteristics and winemaking process. *Advances in Food and Nutrition Research, 63,* 1–15.

Tesniere, C., Baumes, R., Bayonove, C., & Flanzy, C. (1989). Effect of simulated alcoholic fermentation on aroma components of grape berries during anaerobic metabolism. *American Journal of Enology and Viticulture, 40,* 183-188.

Vilanova, M., Campo, E., Escudero, A., Graña, M. Masa, A., & Cacho, J. (2012). Volatile composition and sensory properties of *Vitis vinifera* red cultivars from North West Spain: Correlation between sensory and instrumental analysis. *Analytica Chimica Acta, 720,* 104–111.

Vilanova, M., Genisheva, Z., Bescansa, L., Masa, A., & Oliveira, J. M. (2009). Volatile composition of wines from cvs. Blanco lexítimo, Agudelo and Serradelo (*Vitis vinifera*) grown in Betanzos (NW Spain). *Journal of the Institute of Brewing, 115,* 35-40.

Vilanova, M., Genisheva, Z., Masa, A., & Oliveira, J.M. (2010). Correlation between volatile composition and sensory properties in Spanish Albariño wine. *Microchemical Journal, 95,* 240-246

Zaldivar, E. (2017). *Caracterización químico-sensorial en vinos blancos y tintos del atributo mineralidad.* Tesis doctoral. Logroño: Servicio de Publicaciones, Universidad de La Rioja.

Figure captions

Figure 1. Principal components analysis (PCA) on volatile compounds with significant differences among conventional winemaking (CW) and carbonic maceration (CM) during 2014, 2015 and 2016 vintages.

Figure 2. Partial least squares regression (PLS) product space volatile compounds with OAV > 0.2 and aroma descriptors on Tempranillo Blanco wines produced by conventional winemaking (CW) and carbonic maceration (CM) during 2014, 2015 and 2016 vintages. Aroma descriptors: aromatic intensity, seed fruit, citrus fruit, tropical fruit, ripe fruit, floral, herbaceous, mineral, and yeasty. Volatile compounds: V1, 3-methyl-1-butanol; V2, 2-phenylethanol; V3, 3-methyl-1-pentanol; V4, E-3-hexen-1-ol; V5, Z-3-hexen-1-ol; V6, ethyl butyrate; V7, isoamyl acetate; V8, ethyl hexanoate; V9, hexyl acetate; V10, ethyl octanoate; V11, ethyl decanoate; V12, 2-phenylacetate; V13, 2+3-methylbutanoic acid; V14, hexanoic acid; V15, octanoic acid; V16, decanoic acid; V17, dodecanoic acid; V18, hexadecanoic acid; V19, 4-vinilguaiacol; V20, 4-vinylphenol.

Tables

Table 1. Standard enological parameters of Tempranillo Blanco wines produced by conventional winemaking (CW) and carbonic maceration (CM) during 2014, 2015 and 2016 vintages and significance of winemaking (W) factor according to one-way ANOVA.

	CW-14	CM-14	CW-15	CM-15	CW-16	CM-16	Mean		Anova
							CW	CM	W
Ethanol[1]	13.10	12.90	13.50	13.90	13.40	13.10	13.33	13.30	ns
G+F[2]	0.13	0.01	0.04	0.01	0.04	0.04	0.07	0.02	**
pH	3.25	3.32	3.01	3.15	3.20	3.39	3.16	3.29	*
TA[3]	6.45	6.12	8.20	7.15	7.30	6.54	7.32	6.60	*
VA[4]	0.14	0.18	0.22	0.37	0.21	0.28	0.19	0.28	*
A420[5]	0.14	0.28	0.12	0.21	0.15	0.26	0.14	0.25	***

[1]Ethanol: mL ethanol for 100 mL of wine at 20ºC; [2]G+F: sum of glucose plus fructose as g/L; [3]VA: volatile acidity as g acetic acid/L; [4]A420: absorbance at 420 nm.

Level of significance: *, ** and *** indicates significance at *p*<0.05, *p*<0.01 and *p*<0.001 respectively; ns indicates no significant difference.

Table 2. Concentration (µg/L) of volatile compounds and volatile families of Tempranillo Blanco wines produced by conventional winemaking (CW) and carbonic maceration (CM) during 2014, 2015 and 2016 vintages and significance of winemaking (W) factor according to one-way ANOVA.

Volatile compounds	CW-14	CM-14	CW-15	CM-15	CW-16	CM-16	Mean		Anova
							CW	CM	W
2-Methyl-1-propanol	360	888	581	1170	603	1117	515	1058	***
3-Methyl-1-butanol	11864	18735	11200	29720	23103	27718	15389	25391	***
2-Phenylethanol	5359	9664	7304	14096	7442	8355	6702	10705	**
3-Methyl-1-pentanol	69.1	21.5	248	46.8	nd	nd	159	34.2	ns
Methionol	28.9	14.7	99.5	66.3	37.5	70.7	55.3	50.6	ns
Total alcohols	17681	29323	19432	45099	31186	37260	22819	37239	***
1-Hexanol	280	177	293	148	651	375	408	233	***
E-3-Hexen-1-ol	11.5	7.7	284	nd	nd	nd	148	7.7	ns
Z-3-Hexen-1-ol	68.1	44.2	156	47.6	nd	nd	112	45.9	*
Total C6 alcohols	360	229	733	195	651	375	668	287	**
Ethyl butyrate	483	293	nd	2428	440	664	461	1128	**
Isoamyl acetate	9449	6004	4337	19306	11769	7731	8519	11014	ns
Ethyl hexanoate	1483	799	722	1027	836	581	1014	802	*
Hexyl acetate	619	52.5	nd	85.9	333	110	476	82.9	***
Ethyl octanoate	2792	1816	475	1990	2029	1010	1766	1605	ns
Ethyl decanoate	796	276	377	301	606	117	593	232	***
2-Phenylacetate	721	409	591	1142	704	352	672	634	ns
Total ethyl esters and acetates	16343	9650	6502	26280	16717	10565	13499	15498	ns
2+3-Methylbutanoic acid	nd	nd	220	59.9	nd	nd	200	59.9	**
Hexanoic acid	1798	846	2122	1298	1941	1143	1954	1096	ns
Octanoic acid	5308	2235	6840	2931	7739	3457	6629	2874	*
Decanoic acid	1820	1248	2885	806	2468	797	2391	950	**
Geranic acid	109	148	nd	286	761	597	435	343	**
Dodecanoic acid	171	114	366	94.2	102	74.9	213	94.2	ns
Hexadecanoic acid	123	166	318	225	117	156	186	183	ns
Total volatile acids	9328	4757	12751	5701	13128	6224	12027	5600	*
4-Vinilguaiacol	23.6	55.3	235	48.4	26.0	71.5	94.7	58.4	ns
4-Vinylphenol	13.2	210	368	77.9	78.8	128	153	139	ns
Total phenol volatiles	36.8	265	602	126	105	200	248	197	ns
Acetoine	26.2	198	nd	84.5	nd	nd	26.2	160	***

Level of significance: *, ** and *** indicates significance at *p*<0.05, *p*<0.01 and *p*<0.001 respectively; ns indicates no significant difference. nd: non detected

Table 3. Odor activity values of compounds reaching a concentration above the odor threshold (OAV > 1) in Tempranillo Blanco wines produced by conventional winemaking (CW) and carbonic maceration (CM).

Volatile compounds	Odor descriptor	Odor threshold	Reference	CW	CM
3-Methyl-1-butanol	Alcohol, Banana	7000	3	2	4
Ethyl butyrate	Papaya, butter, sweetish, apple	20	4	23	56
Isoamyl acetate	Banana	30	2	284	367
Ethyl hexanoate	Apple, fruity, sweetish	14	4	72	57
Ethyl octanoate	Apple, fruity, sweetish	5	4	353	321
Ethyl decanoate	Fruity, Strawberry	200	3	3	1
2-Phenylacetate	Floral	250	2	3	3
2+3-Methylbutanoic	Cheese, sweety	33	3	7	2
Hexanoic acid	Goaty, fatty acid, vegetable oil	420	1	5	3
Octanoic acid	Goaty, fatty acid, vegetable oil	500	1	13	6
Decanoic acid	Waxy, tallowy, rancid, soapy	1000	1	2	1
4-Vinylguaiacol	Clove, Curry	40	1	2	1

[1]: Ferreira et al. (2000); [2]: Francis, & Newton (2005); [3]: Etiévant (1991): [4] Vilanova et al. (2009)

Table 4. Geometric mean (% GM) of aromatic sensory descriptors of Tempranillo Blanco wines produced by conventional winemaking (CW) and carbonic maceration (CM) during 2014, 2015 and 2016 vintages and significance of winemaking (W) factor according to one-way ANOVA.

	CW-14	CM-14	CW-15	CM-15	CW-16	CM-16	Mean		Anova
							CW	CM	W
Aromatic intensity	**83**	**83**	**73**	**88**	**63**	**100**	**76**	**90**	ns
Seed fruit	**88**	**35**	**71**	**64**	**77**	**36**	**79**	**45**	*
Citrus	**57**	**31**	**55**	**44**	**42**	**18**	**51**	**31**	ns
Tropical	**74**	**57**	**60**	**52**	**79**	**32**	**71**	**47**	ns
Ripe fruit	**52**	**83**	**62**	**83**	**45**	**75**	**53**	**80**	**
Floral	**50**	**29**	**63**	**31**	**70**	**11**	**61**	**24**	*
Herbaceus	**15**	**14**	**27**	**34**	**18**	**14**	**20**	**21**	ns
Mineral	7	**26**	**31**	0	**12**	**12**	**17**	**13**	ns
Yeasty	**19**	**48**	**45**	**30**	**46**	**42**	**37**	**40**	ns

Descriptors with GM > 10% are highlighted in bold letters.

Level of significance: *, ** and *** indicates significance at *p*<0.05, *p*<0.01 and *p*<0.001 respectively; ns indicates no significant difference.

Figure 1.

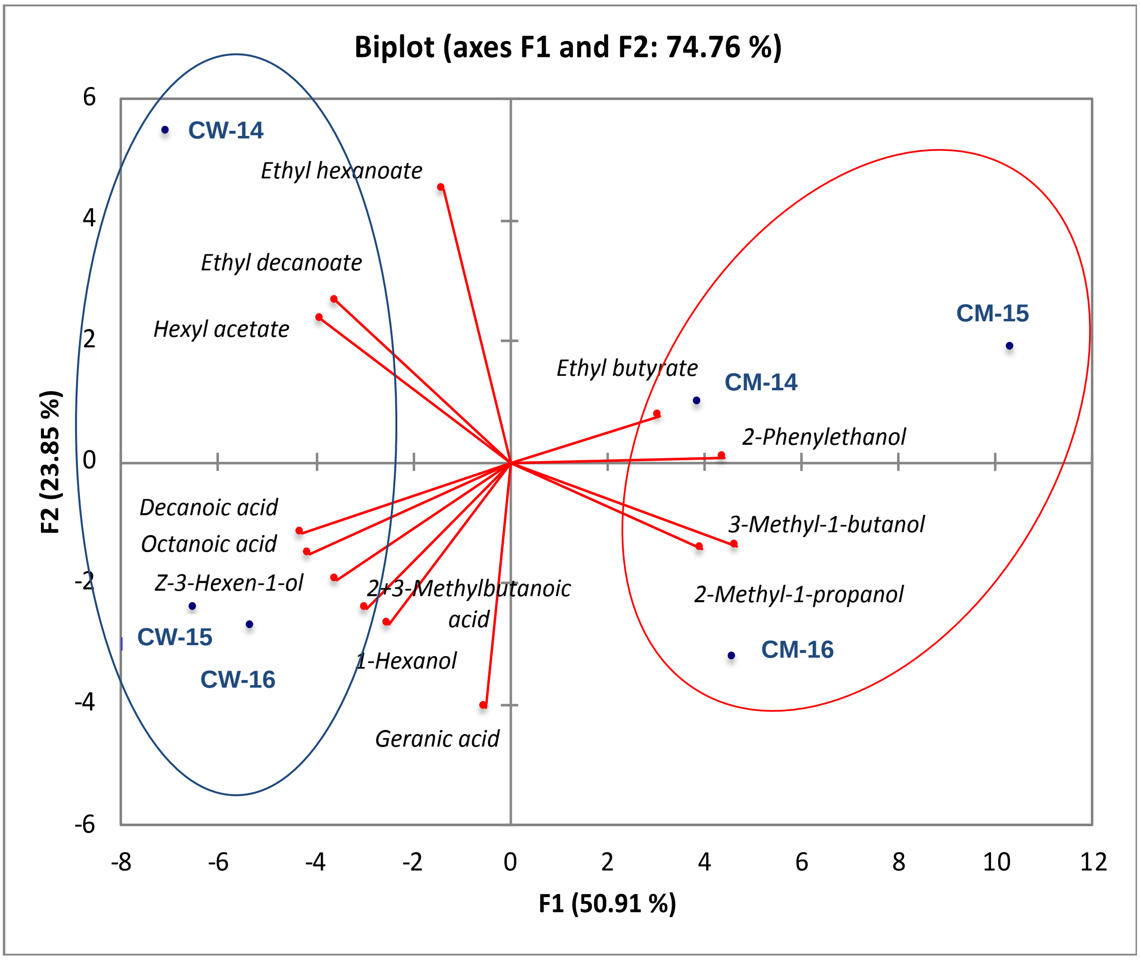
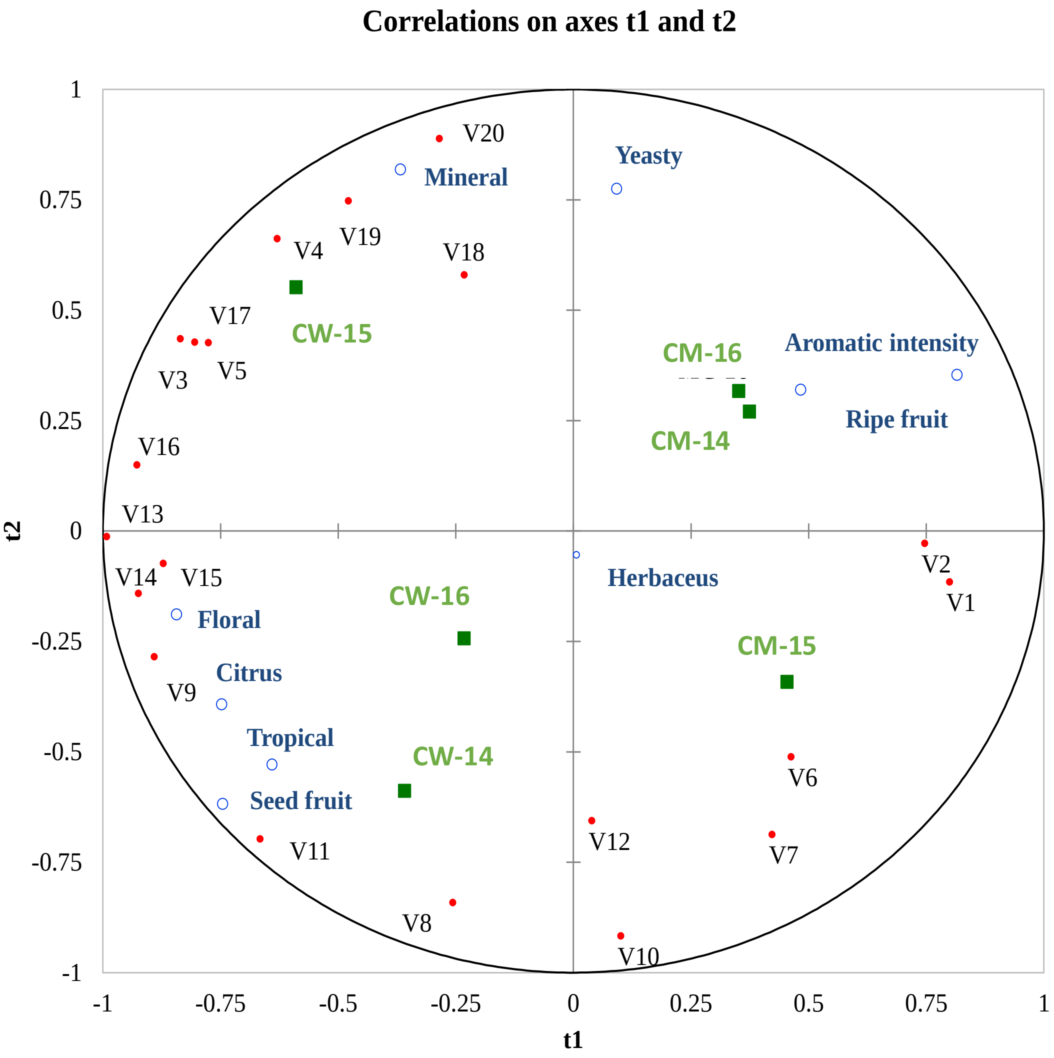

Biplot (axes F1 and F2: 74.76 %)
F2 (23.85 %)
F1 (50.91 %)
6
4
2
0
-2
-4
-6
-8
-6
-4
-2
0
2
4
6
8
10
12
CW-14
CW-15
CW-16
CM-14
CM-15
CM-16
Ethyl hexanoate
Ethyl decanoate
Hexyl acetate
Ethyl butyrate
2-Phenylethanol
Decanoic acid
Octanoic acid
Z-3-Hexen-1-ol
2+3-Methylbutanoic acid
1-Hexanol
Geranic acid
3-Methyl-1-butanol
2-Methyl-1-propanol

Figure 2.


Correlations on axes t1 and t2
t2
t1
1
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
-1
-1
-0.75
-0.5
-0.25
0
0.25
0.5
0.75
1
V20
Mineral
Yeasty
V19
V4
V18
CW-15
V17
V5
V3
CM-16
Aromatic intensity
Ripe fruit
CM-14
V16
V13
V14
V15
Herbaceus
V2
V1
Floral
CW-16
CM-15
Citrus
V9
Tropical
CW-14
V6
Seed fruit
V11
V12
V7
V8
V10