# Volatile composition and aromatic descriptors of red wines from different regions of Bulgaria aged with oak chips

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## Abstract

**Introduction**.The aim of the present study was to define the volatile composition and related aromatic descriptors in red wines from different regions of Bulgaria, aged with oak chips.

**Materials and methods**. Four red wines provided by the commercial network were analyzed. A different oak aging technology was applied. Gas chromatography-flame ionization detection was used to determine the volatile compounds. Organoleptic evaluation and descriptive analysis of the red wines were made.

**Results and discussion**. The highest total accumulation of volatile compounds in the analyzed commercial red wines obtained in contact with oak wood was found in Cabernet Franc wine. The most significant levels of total higher alcohols were also found in it. The ester fraction was quantitatively dominant in the Cabernet Sauvignon/Merlot wine, and the most terpenes were identified in the complex Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot blend. Main higher alcohols in red wines were 2-methyl-1-butanol, 3-methyl-1-butanol, 1-propanol and 1-butanol. The ester fraction was quantitatively dominated by ethyl acetate. The terpene fraction was represented by linalool, linalool oxide, and nerol. A major aldehyde was acetaldehyde, found at levels that positively affect the fruity aroma of the red wines. Methyl alcohol was found at levels significantly below the threshold of its normally permissible presence in red wines. Wines from the commercial network had different sensory characteristics in terms of color, aroma and taste, as well as characteristic aromatic descriptors, which was due to the different type and quantity of oak wood used, as well as the duration of contact.

**Conclusions**. All the studied wines showed a complex and varied volatile profile and different aromatic descriptors due to the varietal characteristics of the grapes used, the soil and climatic conditions of each specific harvest and region and the specific influence of the applied method of contact with oak wood.

## Introduction

The aging of wines with oak wood is a technological practice widely used in winemaking nowadays. It initiates significant changes in the wine composition, which are expressed in the main several aspects: it complicates the aroma by accumulating new aromatic compounds in the wine; has a stabilizing effect on the wine color characteristics; has a positive effect on the clarification process (Mártinez-Gil et al., 2022). The contact with wood leads to a significant change of the wine volatile fraction through the accumulation of different compounds (specific to oak) that affect both the taste qualities of the wine and its aroma (Pérez-Juan and Luque de Castro, 2015). There are various studies concerning the application of oak wood in different forms and techniques. It is applied at various stages in the vinification process, as well as during storage and wine aging. González-Centeno et al. (2021) investigated the volatile composition and sensory profile of Merlot red wines in contact with oak wood applied in different forms during the fermentation and aging processes. It was found that the larger contact surface of the oak leads to the extraction and accumulation in the wine of high levels of specific aromatic compounds that intensify the aroma with two main descriptors – vanilla and spice. Cerdan et al. (2004) studied the accumulation of volatile compounds in two red wines (Cabernet Sauvignon and Merlot) during their aging in oak barrels for periods of 17 and 18 months, respectively. It was observed that Merlot wine extracted more specific compounds from the wood than Cabernet Sauvignon. Based on this, it was concluded that when aging red wines in oak barrels, it is not only the origin of the oak, its age and degree of roasting, but also the specific composition of the wine in contact that matters for the complexity of the wine's aroma. Perez-Prieto et al. (2002) found that when wines were aged in new and used American and French oak barrels, there was less accumulation of vanillin and lactones when the wine was in contact with a used barrel. Also, the volatile profile of wines aged in smaller barrels is significantly different from that of larger capacity barrels. Perez-Prieto et al. (2002) classified the detected concentration of *cis*-lactone in the wines as the most significant difference between the American and French oak used. Dimitriu et al. (2017) found that when Fetjaska Negra wines were aged for 1.5 and 3 months in oak barrels, the degree of wood roasting and contact time significantly influenced the aromatic and phenolic profile. Del Fresno et al. (2020) investigated the evolution in the volatile composition of wines aged for 8 months in oak barrels and found significant changes in the concentrations of volatile phenols, furans and phenolic aldehydes during the aging process. Herjavec et al. (2007) found an increase in furfural, 5-methylfurfural, guaiacol, eugenol and *cis*- and *trans*-lactones in Vugawa wines aged in oak barrels produced from *Quercus petrea* and *Quercus robur* wood. Lu et al. (2024) investigated the modification in the aroma of a dry wine aged in American, French and Slovakian oak barrels with different degrees of roasting and identified 30 oak-associated compounds, the amounts of which increased in the wine with increasing contact time, and the descriptors characterizing the wines were associated with prominent caramel, floral, fruity, smoky, roasted, and leather aromas.

The aim of the present study was to define the volatile composition and related aromatic descriptors in red wines from different regions of Bulgaria aged with oak chips.

## Materials and methods

### Researched wines /variety, harvest, region/ and contact with oak chips

The study was conducted in 2023. Four red wines provided by the commercial network were analyzed. A different oak aging technology was applied. The information about the examined wines is as follows:

Cabernet Franc red wine (town of Varna, region of Northern Bulgaria), harvest 2021. The wine was in contact with medium-roasted French oak chips, at a dose of 1 g/l. The duration of contact was 8 months.

Syrah red wine (town of Varna, region of Northern Bulgaria), harvest 2021. The wine was in contact with medium-roasted French oak chips, at a dose of 1 g/l. The duration of contact was 2–2.5 months.

Cabernet Sauvignon/Merlot red wine (town of Asenovgrad, Southern Bulgaria region), harvest 2019. The wine was in contact with American, highly roasted, medium-sized oak chips. The duration of contact was 3–4 months.

Red wine Carmenere (50%)/Cabernet Sauvignon (30%)/Cabernet Franc (20%)/Merlot (10%) (town of Harmanli, Southern Bulgaria region), harvest 2022. The wine was in contact with French oak chips, medium roasted, in a dose of 0.3 g/l. The duration of contact was 3 months.

### Gas chromatographic analysis (GC-FID)

The content of the main volatile compounds was determined based on a stock standard solution prepared in accordance with IS 3752:2005 method. The method describes the preparation of a standard solution of one congener, but the preparation step was followed to prepare a solution of more compounds. The standard solution in the present study included the following compounds (purity > 99.0%): acetaldehyde, ethyl acetate, methanol, 2-propanol, isopropyl acetate, 1-propanol, 2-butanol, propyl acetate, 1-butanol, isobutyl acetate, ethyl butyrate, 2-butyl acetate, 2-methyl-1-butanol, 3-methyl-1-butanol, 4-methyl-2-pentanol, 1-pentanol, pentyl acetate, 1-hexanol, ethyl hexanoate, hexyl acetate, 1-heptanol, linalool oxide, dimethyl succinate, phenyl acetate, linalool, ethyl caprylate, 2-phenylethanol, α-terpineol, nerol, ß-citronellol, geraniol, ethyl decanoate. The prepared standard solution containing all compounds was injected in an amount of 2 µl into a gas chromatograph Varian 3900 (Varian Analytical Instruments, Walnut Creek, California, USA) with a capillary column VF max MS (30 m, 0.25 mm ID, DF= 0.25 µm), equipped with flame ionization detector (FID). The carrier gas was helium. Hydrogen to support combustion was supplied to the chromatograph via a hydrogen bottle. The injection was manual, using a microsyringe. The gas chromatographic determination parameters were: injector temperature – 220°C, detector temperature – 250°C, initial oven temperature – 35°C/1 min retention, rise to 55°C with a step of 2°C/min for 11 min, rise to 230°C with a step of 15°C/min for 3 min. Total chromatography time – 25.67 min. After the retention times of the compounds in the standard solution were determined, the identification and quantification of the volatile compounds in the wines were conducted. The volatile composition was determined based on the injection of wine distillates. Samples were injected in an amount of 2 µl into a gas chromatograph and identification and quantification of volatile compounds was performed.

**Sensory profile and aroma descriptors**

Nine members of the tasting commission in the Institute of Viticulture and Enology participated in the organoleptic analysis. The samples were evaluated on a 100–point scale, including the following indicators: color, aroma, taste and general impressions. When processing the results, the highest and lowest obtained marks were removed. To define the aromatic and taste wines characteristics, as a result of their contact with oak wood, the method of the main characteristics was used, through a descriptive analysis (Prodanova, 2008).

## Results and discussion

The data on the detected volatile compounds in the analyzed red wines are presented in Table 1.

**Total content of volatile compounds and individual higher alcohols**

By the total accumulation of volatile compounds in red wines, Cabernet Franc dominated, 422.56±70.93 mg/l. The Cabernet Sauvignon/Merlot and Syrah variants showed very close concentration of volatile compounds, and Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot accumulated the lowest levels of volatile compounds, 157.09±20.89 mg/l, comparing it to the other three red wines.

This trend was preserved regarding the found total content of higher alcohols too, but the differences between the variants were smaller. The most significant total content of higher alcohols, 273.34±30.17 mg/l, was found in Cabernet Franc.

The main representatives of the higher alcohols fraction identified in all red wines were 2-methyl-1-butanol, 3-methyl-1-butanol, 1-propanol and 1-butanol. The highest amount of these four main higher alcohols was characterized by 3-methyl-1-butanol. In Cabernet Franc wine, it was found in the highest concentration, 120.27±13.89 mg/l, followed by Cabernet Sauvignon/Merlot with an almost twice lower concentration, 69.98±8.83 mg/l. The other two variants showed similar levels in the quantitative presence of this higher alcohol. Martinez-Gil et al. (2022) studied the changes occurring in red wines during the aging process in oak barrels for 12 months at different levels of oxygen transmission. It was found that 3-methyl-1-butanol was the higher alcohol present in the highest concentration. Its variation in the studied variants ranged from 234.50±2.61 mg/l to 292.10±4.07 mg/l. The concentrations found in the present study were lower. Slightly lower concentrations of 3-methyl-1-butanol, ranged from 36.77±0.53 mg/l to 42.25±2.25 mg/l, were found by Slaghenaufi et al. (2021) in a study of the volatile composition of single-varietal red wines from San Pietro in Cariano, Italy.

The second /by concentration/ higher alcohol identified in all analyzed red wines was 1-butanol. It was present in the highest amount in Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot, 50.33±10.03 mg/l. Its concentrations in Cabernet Sauvignon/Merlot and Cabernet Franc wines were very close, and the lowest amount of this higher alcohol, 31.41±9.56 mg/l, was identified in Shiraz. The amount of this component normally varies in wines from 1.00 to 64.00 mg/l (Chobanova, 2012). Slaghenaufi et al. (2021) found a variation of 1-butanol from 82.16±2.28 mg/l to 155.50±2.65 mg/l in seven red wines from the San Pietro in Cariano region, Italy. Kim et al. (2018) investigating the aromatic compounds in 11 red wines from introduced varieties grown in the Republic of Korea found the presence of 1-butanol in only two of the studied wines – Chancellor and Marchel, and in very low concentrations, respectively 99.10 μg/l and 13.59 μg/l.

**Table 1**

**Volatile compounds in commercial red wines obtained by contact with oak wood**

| Identified compounds, mg/l | Red wines | | | |
|---|---|---|---|---|
| | Cabernet Sauvignon/ Merlot | Cabernet Franc | Carmenere/ Cabernet Sauvignon/ Cabernet Franc/Merlot | Shiraz |
| Acetaldehyde | 27.77±0.00 | 52.27±7.47 | 8.92±0.00 | 57.65±4.26 |
| Methanol | 3.13±0.39 | 7.37±3.79 | 12.28±5.10 | 6.55±0.41 |
| 2-methyl-1-butanol | 15.34±1.02 | 25.03±5.98 | 11.17±1.77 | 7.05±2.78 |
| 3-methyl-1-butanol | 69.98±8.83 | 120.27±13.89 | 44.84±1.24 | 42.29±12.82 |
| 4-methyl-1-pentanol | nd | 1.60±0.00 | 0.95±0.19 | nd |
| 1-propanol | 0.70±0.23 | 7.60±1.42 | 1.58±0.22 | 5.91±0.49 |
| 1-pentanol | nd | nd | nd | 0.65±0.23 |
| 1-butanol | 49.57±15.63 | 46.48±5.48 | 50.33±10.03 | 31.41±9.56 |
| 2-butanol | 6.50±3.90 | 41.99±2.62 | 2.50±0.00 | nd |
| 1-hexanol | nd | 30.37±0.78 | nd | nd |
| 2-phenylethanol | nd | nd | nd | 48.67±7.01 |
| Total higher and aromatic alcohols | 142.09±29.61 | 273.34±30.17 | 111.37±13.45 | 135.98±32.89 |
| Ethyl acetate | 53.91±4.69 | 18.90±8.52 | 22.60±2.26 | 34.31±4.90 |
| Pentyl acetate | 40.26±6.71 | nd | nd | nd |
| Propyl acetate | nd | nd | nd | 1.51±0.00 |
| Isopropyl acetate | nd | 2.78±0.46 | nd | nd |
| Isobutyl acetate | nd | nd | nd | nd |
| Phenyl acetate | 29.18±1.36 | nd | nd | nd |
| Ethyl hexanoate | nd | nd | nd | 20.52±1.02 |
| Ethyl butyrate | nd | 2.32±1.35 | 1.02±0.00 | 1.66±0.55 |
| Ethyl decanoate | nd | 64.88±19.08 | nd | 9.26±0.93 |
| Total esters | 123.35±12.76 | 88.88±29.41 | 23.62±2.26 | 67.26±7.40 |
| Linalool oxide | nd | 0.23±0.05 | nd | nd |
| Linalool | 0.23±0.06 | 0.47±0.04 | 0.90±0.08 | nd |
| Nerol | nd | nd | nd | 0.12±0.01 |
| Geraniol | nd | nd | nd | nd |
| Total terpenes | 0.23±0.06 | 0.70±0.09 | 0.90±0.08 | 0.12±0.01 |
| Total content | 296.57±42.82 | 422.56±70.93 | 157.09±20.89 | 267.56±44.97 |

Note: Cabernet Sauvignon/Merlot, harvest 2019, Asenovgrad, Southern Bulgaria; Cabernet Franc, harvest 2021, Varna, Northern Bulgaria; Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot, harvest 2022, Harmanli, Southern Bulgaria; Shiraz, harvest 2021, Varna, Northern Bulgaria.

*nd – not detected

2-methyl-1-butanol ranked third by the concentration presence in the analyzed wines. It was found in the highest amount, 25.03±5.98 mg/l, in Cabernet Franc. Its concentration was the lowest, 7.05±2.78 mg/l, in Shiraz. Dimitriu et al. (2019) investigated the effect of different types of oak chips (American and French) applied at different doses (3 and 5 g/l) and different contact times with the chips (1.5 to 3 months) with Fetjaska Negra wine

(Romania) on its aromatic composition. The determined content of 2-methyl-1-butanol varied between the variants from 531.00±7.00 mg/l to 571.00±1.00 mg/l. The content of 2-methyl-1-butanol in the present study was lower. Martinez-Gil et al. (2022) when studying changes in the composition of red wines in oak barrels at different oxygen transmission found a variation in the content of 2-methyl-1-butanol between the variants from 58.55±1.20 mg/l to 74.05±1.27 mg/l.

1-propanol was also identified in the four red wines studied. The highest concentration, 7.60±1.42 mg/l, was found in Cabernet Franc wine, followed by Shiraz, 5.91±0.49 mg/l. In the other two wines, its contents were lower, and in the Cabernet Sauvignon/Merlot variant, this higher alcohol was found in the lowest amount, 0.70±0.23 mg/l. Different studies of red wines in contact with oak wood found a variation of this higher alcohol from 26.85±2.20 mg/l to 34.58±0.52 mg/l and from 36.00±0.20 mg/l to 40.00±1.00 mg/l, levels which were higher than those found in the present study (Dimitriu et al., 2019; Martinez-Giletal., 2022). In Spanish red wines of traditional varieties, it was found to vary from 19.48±0.71 mg/l to 30.18±6.94 mg/l (Cortés-Diéguez et al., 2015). The data obtained in the present study on the presence of 1-propanol in the analyzed red wines correlated with the results of Zhang et al. (2012), who investigated young red Merlot wines from different regions of China and determined 1-propanol content from 4.152 mg/l to 9.723 mg/l.

1-pentanol and 1-hexanol were found in two of the examined wines – Shiraz and Cabernet Franc, respectively in concentrations of 0.65±0.23 mg/l and 30.37±0.78 mg/l. At low and close to established concentrations, 1-pentanol was identified in Cabernet Sauvignon and Cabernet Gernischt red wines from a region in China, at concentrations of 0.1767 mg/l and 0.1468 mg/l, respectively (Jiang and Zhang, 2010). The same authors found 1-hexanol in the two studied red wines at concentrations of 4.01 mg/l and 2.54 mg/l, respectively – levels that were significantly lower than those found in the present study. 1-hexanol imparts a grassy aroma and was also found in another study on the volatile composition of red wines from China in amounts from 0.80 to 3.70 mg/l (Zhang et al., 2012). The levels of this alcohol found in the present study were higher.

2-butanol was identified in three of the red wines studied. This component was not identified only in Shiraz wine. Its highest levels, 41.99±2.62 mg/l, were found in Cabernet Franc. The lowest amounts, 2.50±0.00 mg/l, were found in Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot.

2-phenylethanol was identified only in Shiraz wine in the amount of 48.67±7.01 mg/l. It is an aromatic alcohol characterized by a rose aroma. 2-phenylethanol was found in concentrations from 19.80±1.11 mg/l to 26.67±1.67 mg/l in single-varietal red wines from Italy (Slaghenaufi et al., 2021). According to Chobanova (2012), phenylethanol can be found in wine in very wide concentration ranges - from 10.00 to 150.00 mg/l. The data obtained in the present study correlated with this range.

**Total content of esters and individual representatives**

Regarding the total esters accumulation, their amount, 123.35±12.76 mg/l, was highest in Cabernet Sauvignon/Merlot red wine. Cabernet Franc also showed high esters levels, 88.88±29.41 mg/l, and the lowest concentration of esters, 23.62±2.26 mg/l, was found in Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot. Manolache et al. (2018) studied red wines from four varieties from Romania and found a variation in the total ester content from 11.16±0.03 mg/l to 41.16±0.54 mg/l, which was consistent with that found in Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot in the present study. The remaining varieties of red wines studied showed a higher total content of esters.

The main ester was ethyl acetate. It was present in the highest amount, 53.91±4.69 mg/l, in Cabernet Sauvignon/Merlot wine. In the other variants, it changed from 18.90±8.52 mg/l (Cabernet Franc) to 34.31±4.90 mg/l (Shiraz). The data obtained for this ester correlated with those established by Dimitriu et al. (2019), who investigated the influence of oak chips and arcs with different roasting degrees on the aromatic composition of red wines from the Fetjaska Negra variety grown in Romania. The period of contact with the wood was 1.5 to 3 months. In the experimental variants, they found a variation in ethyl acetate content from 28.0±1.0 mg/l to 34.0±1.0 mg/l, which was actually not significant between the control and experimental variants. The data on the concentration presence of this ester in the present study also correlated with that established by Martinez-Gil et al. (2022). They investigated the evolution in aromas of red wines aged in oak barrels for periods of 3, 6, 9 and 12 months at different oxygen transmission and found a variation in ethyl acetate content from 47.12±0.11 mg/l to 85.75±1.50 mg/l, with the lowest level in the control variant (0 months). All concentrations of ethyl acetate found in the present study were in a range having a positive effect on the aroma of the studied wines – with the appearance of fruity nuances.

Ethyl butyrate was detected in three of the red wines tested. It was missing only in the Cabernet Sauvignon/Merlot variant. Its difference between the three experimental variants was not large, and it varied between them from 1.02±0.00 mg/l (Carmener/Cabernet Sauvignon/Cabernet Franc/Merlot) to 2.32±1.35 mg/l (Cabernet Franc). In the study of Dimitriu et al. (2019) this ester was found in lower amounts ranging from 0.250±0.006 to 0.532±0.037 mg/l. Lower levels were found also by Česnik et al. (2015) in a study of 82 wines from the Kras region, Slovenia, from three harvests (2011-2013). The ethyl butyrate in them varied from 0.08±0.014 mg/l to 0.11±0.052 mg/l.

Other established esters were pentyl acetate, which was identified only in Cabernet Sauvignon/Merlot variant at a concentration of 40.26±6.71 mg/l; propyl acetate identified only in Shiraz variant with amount of 1.51±0.00 mg/l; isopropyl acetate – found in Cabernet Franc in an amount of 2.78±0.46 mg/l; phenyl acetate – present in Cabernet Sauvignon/Merlot in the amount of 29.18±1.36 mg/l; and ethyl decanoate, which was found in two of the examined wines – Cabernet Franc and Shiraz in amounts of 64.88±19.08 mg/l and 9.26±0.93 mg/l, respectively.

**Total content of terpenes and individual representatives**

The highest total terpene content, 0.90±0.08 mg/l, in the studied red wines was found in the Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot variant. Cabernet Franc also showed high levels, 0.70±0.09 mg/l. The levels of total terpenes identified were low, 0.23±0.06 mg/l, in Cabernet Sauvignon/Merlot, and Shiraz showed the lowest, 0.12±0.01 mg/l, total terpene content. Monoterpenes are responsible for the so-called muscat aroma and accordingly in muscat varieties they are contained in an amount on average up to about 6.0 mg/l, in non-muscat aromatic varieties their concentration varies from 1.0 to 4.0 mg/l, and in neutral varieties their amount are lower than 1.0 mg/l (Mateo and Jimenez, 2000). Data for total monoterpene content found in the present study were in agreement with the above ranges and characterize the wines from the investigated varieties as neutral.

The linalool was the terpene identified in three of the wines studied. It was absent only in Shiraz wine. The highest linalool amount, 0.90±0.08 mg/l, was identified in Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot. In Cabernet Franc it was present in a concentration of 0.47±0.04 mg/l, and its lowest levels were identified in Cabernet Sauvignon/Merlot, 0.23±0.06 mg/l. Gonzalez et al. (2022) identified linalool content in red wines aged in pine barrels ranging from 0.01±0.00001 mg/l to 0.16±0.005 mg/l. The results

in the present study regarding the amount of this terpene were higher. Linalool gives a characteristic jasmine aroma (Chobanova, 2012).

The linalool oxide is obtained by oxidation of linalool. It was found only in Cabernet Franc at a concentration of 0.23±0.05 mg/l, and nerol was present only in Shiraz at an amount of 0.12±0.01 mg/l. Nerol is contained in wines in concentrations from 0.014 to 0.45 mg/l (Chobanova, 2012). The data obtained in the present study correlated with this range.

**Acetaldehyde and methanol concentrations in the analyzed wines**

Acetaldehyde was found in the highest amount, 57.65±4.26 mg/l, in Shiraz wine. Its concentration was slightly lower, 52.27±7.47 mg/l, in Cabernet Franc, and the lowest levels, 8.92±0.00 mg/l, were found in Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot. Martinez-Gil et al. (2022) found a variation in acetaldehyde concentration during storage of red wines in oak barrels over a period of 12 months, from 10.00±0.82 mg/l to 36.25±9.74 mg/l. The content of acetaldehyde in white and red wines averaged between 20.00 to 40.00 mg/l, respectively, with minimum and maximum levels ranging from 1.00 mg/l to 232.00 mg/l (Morneau, 2006). The data in the present study were in agreement with those stated by the cited authors.

Methanol is a normal component of wine volatiles. In red wines, it is allowed in a concentration of up to 300.00 mg/l (Chobanova, 2012). In the analyzed red wines, it was found in low amounts, below the maximum permissible threshold. It varied between the four red wines studied from 3.13±0.39 mg/l (Cabernet Sauvignon/Merlot) to 12.28±5.10 mg/l (Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot).

**Wines sensory evaluation**

The sensory profile and established aroma descriptors of the four wines are presented in Figures 1–3.

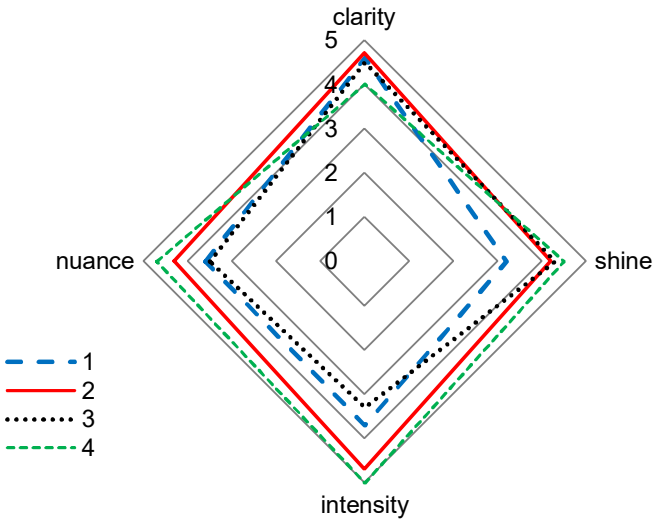


**Figure 1. Colour evaluation:**
1 – Cabernet Sauvignon/ Merlot, harvest 2019, Asenovgrad;
2 – Shiraz, harvest 2021, Varna;
3 – Cabernet Franc, harvest 2021, Varna;
4 – Carmenère/Cabernet Sauvignon/Cabernet Franc/Merlot, harvest 2022, Harmanli

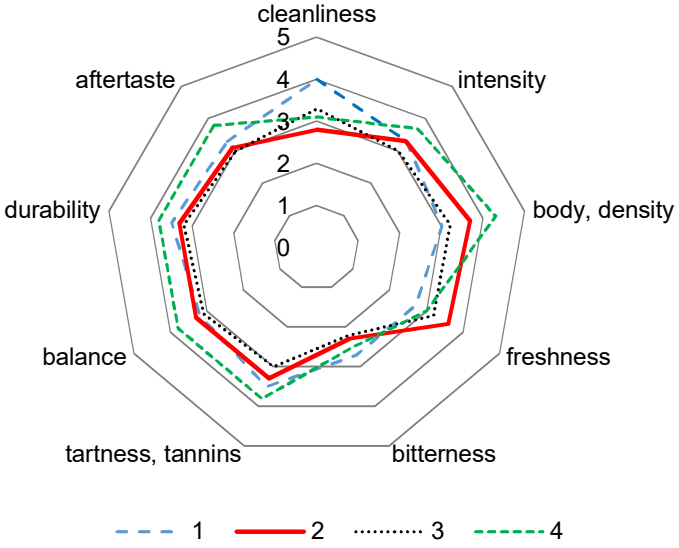


**Figure 2. Flavor evaluation**

1 – Cabernet Sauvignon/ Merlot, harvest 2019, Asenovgrad;
2 – Shiraz, harvest 2021, Varna;
3 – Cabernet Franc, harvest 2021, Varna;
4 – Carmenère/Cabernet Sauvignon/Cabernet Franc/Merlot, harvest 2022, Harmanli

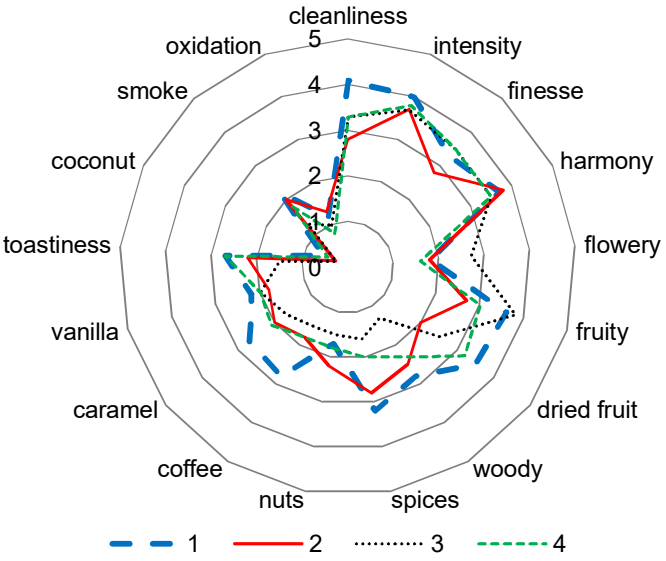


**Figure 3. Aromatic descriptors evaluation**

1 – Cabernet Sauvignon/ Merlot, harvest 2019, Asenovgrad;
2 – Shiraz, harvest 2021, Varna;
3 – Cabernet Franc, harvest 2021, Varna;
4 – Carmenère/Cabernet Sauvignon/Cabernet Franc/Merlot, harvest 2022, Harmanli

In connection with aroma, all samples have good intensity, finesse and harmony. Different but characteristic aroma descriptors were identified. In Cabernet Franc, harvest 2021, floral and fruity notes were more intense, despite 8 months of contact with oak chips. The 2019 Cabernet Sauvignon/Merlot wine exhibited more prominent aromas of dried fruit, spice, coffee, caramel, toastiness and smokiness. The aroma of spices also stands out in the Shiraz sample, harvest 2021, and of toast bread – in all samples. In connection with taste the blend Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot, harvest 2022, showed the best characteristics in terms of the specified descriptive indicators. This sample had the best intensity, density, tartness, balance, persistence and aftertaste. Cabernet Sauvignon/Merlot, harvest 2019, and Cabernet Franc, harvest 2021 had the best purity of taste. In terms of bitterness, tartness, balance, persistence and aftertaste, Cabernet Sauvignon/Merlot, Shiraz and Cabernet Franc had similar characteristics.

## Conclusions

The highest total accumulation of volatile compounds in the analyzed commercial red wines obtained in contact with oak wood was found in Cabernet Franc wine. The most significant levels of total higher alcohols were also found in it. The ester fraction was quantitatively dominant in the Cabernet Sauvignon/Merlot wine, and the most terpenes were identified in the complex Carmenere/Cabernet Sauvignon/Cabernet Franc/Merlot blend.

Main higher alcohols in red wines were 2-methyl-1-butanol, 3-methyl-1-butanol, 1-propanol and 1-butanol. The ester fraction was quantitatively dominated by ethyl acetate. The terpene fraction was represented by linalool, linalool oxide and nerol.

A major aldehyde was acetaldehyde, found at levels that positively affect the fruity aroma of the red wines.

Methyl alcohol was found at levels significantly below the threshold of its normally permissible presence in red wines.

Wines from the commercial network had different organoleptic characteristics in terms of color, aroma and taste, as well as characteristic aromatic descriptors, which was due to the different type and quantity of oak wood used, as well as the duration of contact. All the studied wines showed a complex and varied volatile profile, due to the varietal characteristics of the grapes used, the soil and climatic conditions of each specific harvest and region and the specific influence of the applied method of contact with oak wood.

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