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*Article*

# LOOKING FOR TEMPORAL CHANGES IN THE SENSORY FEATURES OF DRY WINES UNDERLYING THE GRAND GOLD AWARDS IN INTERNATIONAL WINE CHALLENGES

## PESQUISA DE ALTERAÇÕES TEMPORAIS NAS CARACTERÍSTICAS SENSORIAIS DOS VINHOS SECOS SUBJACENTES AOS PRÉMIOS GRAND GOLD EM CONCURSOS INTERNACIONAIS DE VINHOS

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**SUMMARY**

Wine appreciation is subject to trends, dependent on wine sensory properties. The wines characterized by high ethanol content, deep colour, and dominated by oak notes have given way to less alcoholic and leaner styles. Nevertheless, these changes are only supported by anecdotal evidence. Therefore, the purpose of this work was to evaluate the differences in the most preferred wine styles. The scores of Grand Gold dry red and white wines were obtained from the online data of Mundus Vini challenge. The older period ranged from 2014 to 2016, while the most recent editions ranged from 2020 to 2023. The profile of red wines was synthesized in four sensory spaces, comprising Oakiness, Harshness, Freshness, and Funkiness. Overall, most preferred wines continued to have high ethanol content and high body, and were dominated by Oakiness. The main difference was related to the higher proportion of Funkiness in the wines from the more recent editions. A relatively small number of white wines were awarded Grand Gold in the latest editions. These wines were characterized by the sensory spaces of Freshness, Mellowed, Oakiness, and Funkiness. The main difference was related to the higher proportion of Oakiness in the more recent editions. Overall, the temporal analysis of Grand Gold wines did not show a significant variation in their style, continuing to be characterized by bold wines with high ethanol content, residual sugar and oak wood flavours.

**RESUMO**

A apreciação do vinho está sujeita a tendências, dependendo das propriedades sensoriais do vinho. Os vinhos caracterizados pelo elevado teor de etanol, cor intensa e dominados por notas de carvalho deram lugar a estilos menos alcoólicos e mais delgados. No entanto, estas mudanças são apenas apoiadas por relatos pessoais. Neste contexto, o objetivo deste trabalho foi avaliar as diferenças nos estilos de vinho mais preferidos. As pontuações dos vinhos tintos secos e brancos *Grand Gold* foram obtidas a partir dos dados *online* do concurso Mundus Vini. O período mais antigo abrangeu os anos de 2014 a 2016, enquanto as edições mais recentes foram de 2020 a 2023. O perfil dos vinhos tintos foi sintetizado em quatro espaços sensoriais, compreendendo perceções de Carvalho, Dureza, Frescura e de aromas defeituosos. No geral, a maioria dos vinhos preferidos continuou a ter alto teor de etanol e corpo elevado, sendo dominados pelas notas de madeira de carvalho. A principal diferença encontrou-se associada à maior proporção de aroma defeituosos nos vinhos das edições mais recentes. Um número relativamente pequeno de vinhos brancos foi premiado com *Grand Gold* nas edições mais recentes. Estes vinhos caracterizaram-se pelos espaços sensoriais de Frescura, Suavidade, Carvalho e de aromas defeituosos. A principal diferença deveu-se a uma maior proporção de Carvalho nas edições mais recentes. No geral, a análise temporal dos vinhos *Grand Gold* não mostrou uma variação significativa no seu estilo, continuando a caracterizar-se por vinhos intensos, com elevado teor de etanol, açúcar residual e aromas de madeira de carvalho.

**Keywords**: Wine competitions, consumer science, wine styles, sensory spaces, wine liking.
**Palavras-chave**: Concursos de vinho, ciência do consumidor, estilos de vinho, espaços sensoriais, apreciação do vinho.





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## INTRODUCTION

The international wine market is influenced by trends of different nature related to brand or origin reputation, heritage or culture, packaging or labelling, and sustainability or health concerns (Lockshin and Corsi, 2012; Sogari *et al.*, 2017; Loose and del Rey, 2024; Fuentes-Fernández and del Campo-Villares, 2025). Irrespective of the reasons that justify the purchasing decisions, the primary factor is dependent on wine sensory features among "sensory-oriented consumers" (Jürkenbeck and Spiller, 2021). Therefore, wine companies continuously seek to adapt their products to the most wanted wine styles (Pomarici *et al.*, 2017). As in other industries subjected to fashion, influencers play a crucial role in shaping consumer preferences (Martínez-Navarro and Sellers-Rubio, 2024). The effect of the wine critic Robert Parker is considered the best example of how influencers affect the sensory features that a wine must have to achieve commercial success (Jürkenbeck and Spiller, 2021). His best-scored red wines were high in ethanol, deep in colour, high in the body, dominated by oak notes, with smooth mouthfeel (del Rey and Loose, 2023). In white wines, oak notes or intense fresh fruitiness were the most preferred features (Malfeito-Ferreira *et al.*, 2019). Presently, there is a major shift globally towards lighter and refreshing wines, including white, rosé, sparkling and no-alcohol wines (del Rey and Loose, 2023; Pickering and Kemp, 2024). In niche markets, aged-worthy wines are no longer restricted to red wines but also include white wines (Marasà *et al.*, 2024; Sequeira and Malfeito-Ferreira, 2025) in what seems to be a return to the preferences described in previous sources (Harutyunyan and Malfeito-Ferreira, 2022). However, these illustrative changes, even if widely acknowledged by the popular press, have not been properly demonstrated. On the contrary, specialized magazine reviews continue to show that aged red wines are better rated than aged white wines, or that rosé wines are still marginal (Lee *et al.*, 2025). This endeavor is not easily handled using standard sensory protocols since the same wines change in time just as the same individuals of the tasting panel are not likely to be assembled in consecutive years and to keep their preferences.

The use of online data repositories and powerful statistical approaches has made it possible to interpret wine quality based on chemical composition (Yavas *et al.*, 2024). Crowd-sourcing platforms (e.g., Vivino) have been explored to assess professional and consumer preferences (Gastaldello *et al.*, 2024; Kopsacheilis *et al.*, 2024; Moreira *et al.*, 2024). Even if the quality of information may be questionable, when the available data is massive, individual judgment errors tend to cancel each other out when their judgments are aggregated (Kopsacheilis *et al.*, 2024). In addition, expert ratings collected from specialized magazines during wide time-series periods have been useful to study the effect of climate change on wine quality (Sadras *et al.*, 2007; Kumar *et al.*, 2023), to characterize the most prized sensory descriptors (Dong *et al.*, 2020) and to determine trends in wine types, regional popularity, age-ability or price (Lee *et al.*, 2025).

However, magazine reports have two major limitations regarding quality evaluation besides the expected divergence among professional tasters (Penagos-Londoño *et al.*, 2022). First, the distinction between "commercial quality" and "fine wine quality" is not acknowledged (Malfeito-Ferreira, 2021). Second, quality evaluation is based on the assumption that the quality standards are unchangeable during the periods under study. This drawback may explain the discrepant results when assessing the issue of climate change, as discussed by Whitnall and Alston (2025). These authors pointed out that most econometric studies show that hotter temperatures are not harmful to wine quality contrary to enological-viticultural studies. Even if a more precise weather model might be developed, another possible explanation for the apparent contradiction is that, in the former studies, quality might have been understood as the commercial one, and so warmer weather tends to favour the more appreciated bolder styles. With the trend shift to leaner styles, the opposite conclusions might be obtained since their recognition would lead to a clear damaging effect of the warmer periods. Thus, the question of how particular sensory features affect wine quality, or price, in econometric studies handling uncontrolled judgments, is still to be clarified.

Wine competitions are another source of a relatively high amount of data on quality assessment (Bitter, 2017; Bodington and Malfeito-Ferreira, 2018; Bélisle, 2025). Even if the number of wines is comparatively smaller than with econometric data, the tasting protocols are more controlled and the requirement for blind tasting is guaranteed, unlike with crowdsourcing and wine guide's results (Castriota *et al.*, 2013). For example, using the information from the Mundus Vini challenge, Malfeito-Ferreira *et al.* (2019) showed that the likelihood of being awarded a Grand Gold medal was consistent with the preference for the predictable bolder styles in red wines and for exotic fruit in white wines. It should be taken into account that wine competition results have several main limitations that must be acknowledged: (i) sample selection bias (producers choose which wines to submit), (ii) panel composition varies across years, and (iii) medal allocation is constrained (e.g., maximum percentage of awarded wines for each prize level). Nevertheless, given that the Mundus Vini tasting procedure has remained constant over the years and contains a flavour description, it would seem appropriate to compare the results across the different editions to

find evidence of any changing trends, having always in mind the abovementioned limitations. Therefore, the purpose of this study was to investigate the changes in the sensory characteristics of the wines awarded Grand Gold medals in large competitions. For this purpose, data from the 2020 to 2023 editions were compared to the equivalent results from the 2014 to 2016 editions of the Mundus Vini wine challenge.

## MATERIALS AND METHODS

### Data collection

The outputs of the Mundus Vini wine challenges (2020-2023 editions) were retrieved from the site https://www.meininger.de/en/mundus-vini/results (accessed from March to May 2024) as formerly described (Malfeito-Ferreira *et al.*, 2019). These authors provided the results from the older editions (2014-2016). Briefly, the wines were selected from the still dry wine category among those awarded Grand Gold medals. The judges were considered by the challenge organization as experts, comprising oenologists, specialist retailers, specialist journalists, and scientists from more than 40 countries in each edition. The tasting sheet followed the 100-point scheme of the International Organisation of Vine and Wine (OIV, 2009). Grand Gold is awarded to wines with at least 95 points, while Gold and Silver are given when the scores are equal to or higher than 90 and 85, respectively. The number of products given an award in the competition is limited to 40 percent of the participating samples with the highest scores in their respective category. Therefore, the minimum number of points required to win a medal may increase. The published information on the number of judges and wines subjected to the recent editions is shown in Table I.

The data obtained included the brand, winery, vintage year, price (€), basic chemical analysis (ethanol content (% v/v), residual sugar (g/L), total acidity (g/L tartaric acid) and the sensory profile included flavour descriptors and indicators of overall quality (Malfeito-Ferreira *et al.*, 2019). Occasional missing values regarding chemical composition and price were replaced by values published on the producer website or in the Wine Searcher database (Wine-searcher, 2025), as suggested by Goldstein *et al*. (2008).

### Statistical analysis

Data were analysed across four separate categories: chemical, sensory attributes, overall quality (body, complexity, harmony and potential) and price. To compare the basic composition of the wines and sensory scores, an analysis of variance was performed on the chemical parameters with pair-wise mean separation by Tukey's HSD ($p < 0.05$). The Chi-square test ($p < 0.05$) was used to compare percentual compositions. Pearson correlations were performed between sensory and chemical parameters. Given that, the periods under comparison had different numbers of wines (unbalanced design), least square (LS) means were calculated. Cluster analysis was performed using agglomerative hierarchical clustering (AHC) with Euclidean distance as dissimilarity measure and Ward's method of agglomeration. The ideal number of clusters was automatically set by the Hartigan index. All analyses were performed using XLSTAT® statistical analysis software version 2024.4.0 (Lumivero, Denver, USA).

**Table I**

Number of judges, tasted wines and respective awards retrieved from Mundus Vini website concerning challenges held from 2020 to 2023

| Edition | Number of judges | Number of wines | Grand Gold | Gold | Silver |
|---|---|---|---|---|---|
| **Summer 2023** | 140 | - | 22 | 878 | 776 |
| **Spring 2023** | 268 | >7500 | 70 | 1920 | 1031 |
| **Summer 2022** | 130 | - | 23 | 980 | 671 |
| **Spring 2022** | 264 | 7555 | 43 | 1685 | 1294 |
| **Summer 2021** | >120 | >4500 | 36 | 971 | 811 |
| **Spring 2021** | -[a] | 7300 | 49 | 1546 | 1339 |
| **Summer 2020** | 120 | ~4500 | 13 | 919 | 849 |

[a] Not indicated.

## RESULTS AND DISCUSSION

### Chemical characterization and price of the Grand Gold awards

The utilization of external sources (e.g. wine-searcher.com) to obtain chemical compositions and retail prices constitutes a limitation since it introduces uncertainty because values may not correspond to the exact samples evaluated (Goldstein *et al*., 2008).

*Red wines*

The chemical parameters of Grand Gold red wines are listed in Table II. Overall, average ethanol contents varied between 13.9 % (v/v) and 14.6 % (v/v), ranging from 12.5 % (v/v) in the 2021 Summer edition to 16 % (v/v) in the Spring editions of 2021 and 2023. The reported mean residual sugar varied from 1.9 to 3.2 g/L, with maximum values of 8.0 g/L and 11.1 g/L in two editions. The mean total acidity varied from 5.5 g/L to 5.8 g/L, attaining 7.4 and 8.2 g/L as maximum values in two editions. These values fall in the range of the chemical analysis results reported by Malfeito-Ferreira *et al.* (2019) for the five editions of Mundus Vini between Spring 2014 and Spring 2016.

**Table II**

Chemical analysis and price of Grand Gold red wines

| Edition | Number of wines | Ethanol (%v/v) | | Residual sugar (g/L) | | Total acidity (g/L) | | Price (€) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean±sd[a] | Range | Mean±sd | Range | Mean±sd | Range | Mean±sd | Range |
| **2023 Summer** | 9 | 14.5±0.2 | 14.0-15.0 | 3.2±2.2 | 0.9-8.0 | 5.6±0.4 | 5.2-6.2 | 32.5±28.1 | 12-100 |
| **2023 Spring** | 37 | 14.4±0.8 | 13.5-16.0 | 2.2±1.2 | 0.6-5.8 | 5.5±0.6 | 4.7-6.9 | 27.1±17.9 | 10-100 |
| **2022 Summer** | 14 | 14.4±0.5 | 13.5-15.0 | 1.9±1.3 | 0.7-4.5 | 5.8±0.5 | 5.0-6.8 | 27.8±17.1 | 7.5-60 |
| **2022 Spring** | 26 | 13.9±2.5 | 13.0-15.0 | 2.4±2.3 | 0.6-3.7 | 5.7±1.1 | 4.5-8.2 | 30.4±20.7 | 9-100 |
| **2021 Summer** | 22 | 14.3±0.6 | 12.5-15.0 | 2.6±1.9 | 1.1-5.8 | 5.5±0.7 | 4.5-6.0 | 20.8±12.3 | 2.4-50 |
| **2021 Spring** | 29 | 14.6±0.5 | 14.0-16.0 | 2.2±2.1 | 0.2-11.1 | 5.7±0.8 | 4.6-7.4 | 32.2±19.8 | 6-85 |
| **2020 Summer** | 4 | 14.4±0.4 | 14.0-15.0 | 1.9±1.5 | 0.1-4.0 | 5.6±1.2 | 3.5-6.7 | 30.7±20.6 | 10.9-60 |

[a] Standard deviation.

Concerning ethanol content, there was only one wine with 12.5 % (v/v) (Summer 2021) while there were five wines with 16% (v/v), two from Spring 2021 and three from Spring 2023. Moreover, there were nine wines with, or more than, 5 g/L residual sugar, over the limit of 4 g/L to be considered as dry (OIV, 2025). Therefore, the claimed trend to higher appreciation for less alcoholic and drier wines (del Rey and Loose, 2023) was not apparent from the competition results, in accordance with other reports using big data (Kurtanjek, 2024). As in the older editions, the recognition of Amarone style wines (e.g. high in ethanol and residual sugar), from Valpolicella or other Italian regions (Solis *et al.*, 2024), contributed to explain these results. These temporal comparisons are limited by lack of panel consistency. Indeed, the level of expertise influences wine characterization (Sáenz-Navajas *et al.*, 2015; Barton *et al.*, 2020) and panel composition was not constant in both periods.

The variation in retail prices demonstrated that Grand Gold red wines range from cheap wines to relatively costly wines, with mean values ranging from about 20 € to 33 €, as commonly acknowledged (Paroissien and Visser, 2020). Nevertheless, Kaimann *et al.* (2023) found that prices and product ratings were significantly correlated when using a large amount of data from a specialized magazine. Most likely, the price range in the magazine reviewed wines is larger, but it is also known that these reviews barely underscore expensive wines to avoid discussion on their judgements.

*White wines*

The number of awarded white wine was smaller in the present editions which is not aligned with the increasing demand for whites since 2002 (OIV, 2024). The chemical analysis of the Grand Gold white wines is shown in Table III. In the Summer of 2020, there were no Grand Gold medals attributed to white wines. Given the low number of samples, the origin of the wines was also listed. The older editions presented a higher number of wines with similar chemical average values, with ethanol varying from 12.5 to 14.0 % (v/v) and occasional residual sugar over 2 g/L (Malfeito-Ferreira *et al.*, 2019). Therefore, the change to more acidic styles with less ethanol was not evidenced. There seems to be much less Grand Golds awarded to white than to red wines, contradicting the claimed higher present recognition of white wines (del Rey and Loose, 2023), even if the

proportion could not be calculated since the total number of entries was not reported. These results are in accordance with the scores of another international large challenge, in which wines with higher ethanol and higher residual sugar were better scored (Livat *et al.*, 2024). Interestingly, two wines with about 6 to 8 years old were worthy of a Grand Gold (Table III) that might indicate the return to aged white wines as described by Marasà *et al.* (2024). Nevertheless, the difference in panel composition (Sáenz-Navajas *et al.*, 2015; Barton *et al.*, 2020) might also explain, at least partially, these differences.

**Table III**

Chemical analysis and price of Grand Gold white wines in the 2021 to 2023 editions of the Mundus Vini challenge

| Editions | Country/Region/Vintage | Variety[a] | Ethanol (%v/v) | Residual sugar (g/L) | Total Acidity (g/L) | Price (€) |
|---|---|---|---|---|---|---|
| **2023 Summer** | Spain/Montilla-Moriles 2021 | Pedro Ximénez (Oak) | 14.0 | 1.4 | 7.0 | 18.9 |
| | Italy/Sicily 2022 | Grillo | 13.0 | 4.0 | 6.2 | 12.7 |
| | Spain/Rioja 2017 | Viura (Oak) | 13.0 | 2.2 | - | 18.0 |
| **2023 Spring** | New Zealand/Marlborough 2014 | Pinot Gris (Oak) | 13.0 | 3.3 | 5.4 | 40.0 |
| | Greece/Macedonia 2021 | Assyrtiko | 13.5 | 1.0 | 6.2 | 22.9 |
| | Greece/Crete 2021 | Vidiano | 14.0 | 1.3 | 5.6 | 16.4 |
| **2022 Summer** | Bulgaria/Daubian Plain 2021 | Sauvignon Blanc | 13.0 | 1.7 | 6.4 | 12.0[b] |
| **2022 Spring** | Australia/Adelaide Hills 2019 | Chardonnay (Oak) | 13.0 | 1.5 | 7.6 | 23.0 |
| **2021 Summer** | Luxembourg 2019 | Riesling | 12.5 | 6.2 | 6.8 | 12.9 |
| | Italy/Lazio 2020 | Bellone | 13.5 | 3.0 | 6.2 | 7.0 |
| **2021 Spring** | Spain/ Mancha 2019 | Chardonnay (Oak) | 13.0 | 0.8 | 5.7 | 5.5 |

[a] Mention to barrique ageing by the producer, [b] Average price from Wine-searcher (2025)

The absence of rosé wines from Grand Gold medals is in accordance with the results from another large international competition (Livat *et al.*, 2024) or specialized magazine reviews (Lee *et al.*, 2025). Thus, rosé wines seem to continue to be underscored when compared to dry white and red wines. The fact these wines are not expected to have ageing potential (Lee *et al.*, 2025) might contribute to this output, having in mind the before mentioned limitation due to different panel composition.

## Sensory characterization of the Grand Gold awards

*Red wines*

The average sensory characterization of the Grand Gold red wines of the seven Mundus Vini editions from 2020 to 2023 is shown in Table IV, in comparison with the five editions from 2014 to 2016. The one-way ANOVA using the older and more recent editions as explanatory variables showed that higher mean scores were observed for 'Red berries', 'Cherry', 'Acidity', 'Coffee-Chocolate', 'Minty-Eucalyptus', 'Jammy', 'Smoky', and 'Green-Vegetative' in the latest editions. On the contrary, older editions showed higher scores for 'Astringency' and 'Sweetness', while there were no differences concerning 'Spicy', 'Oak', 'Dried fruits', 'Bitterness' and 'Barnyard'. Despite these sensory differences, the overall quality ratings were similar for 'Body', 'Complex' and 'Potential', and only marginally different for 'Harmonious'. These responses suggest that the judges rated quality independently from the perceived flavours.

The comparison with the results of the older editions is illustrated in Figure 1a, evidencing the similarity in the flavour descriptors despite the statistical differences.

*White wines*

The average sensory characterization of the Grand Gold white wines of the six Mundus Vini editions from 2021 to 2023 is shown in Table V, in comparison with the five editions from 2014 to 2016. The one-way ANOVA using the older and more recent editions as factors showed that the higher mean scores were observed for 'Green-Vegetative', 'Oak' and 'Astringency' in the latest editions. Despite these differences, the sensory features elicited similar overall quality ratings for all quality indicators as depicted in Figure 1b.

## Inference of sensory description from chemical composition

Malfeito-Ferreira *et al.* (2019) showed that the chemical composition of Grand Gold and Gold red wines was fairly correlated with some flavour descriptors. Indeed, 'Spicy', 'Smoky', 'Coffee-Chocolate' and 'Oak' were positively and highly correlated with ethanol content. Likewise, all the overall quality parameters were highly correlated with ethanol, evidencing the predicted higher appreciation for bold wines dominated by oak wood flavours. Then, it would be interesting to examine if

these correlations were still observed. Table VI shows the correlations between the chemical composition of each wine and the values of the sensory and overall quality responses for both periods. The most relevant changes were related to the decrease in the correlations with ethanol content and residual sugar. The higher correlations with ethanol regarding 'Cherry', 'Smoky', 'Coffee-Chocolate' in 2014-2016 editions were not observed in 2020-2023. Likewise, absent or lower correlations were obtained between residual sugar for 'Jammy', 'Dried fruits', 'Smoky', 'Coffee-Chocolate' and 'Red berries' in the more recent editions. It may be hypothesized that the perceptual interactions with chemical composition varied with time among the Grand Gold awarded wines. These results suggest that the behavior of the earlier tasting panels was better predicted from chemical composition, in accordance with the preference for the so-called high ethanol and bold "fruit bombs".

**Table IV**

Least square (LS) means and range of the scores given to Grand Gold red wines in the older (2014-2016) and more recent (2020-2023) Mundus Vini editions

| Category | Descriptor | 2020-2023 Editions | | 2014-2016 Editions | | Pr > F[b] |
|---|---|---|---|---|---|---|
| | | Mean | Range[a] | Mean | Range | |
| **Flavour** | Red berries | 5.79 | 5.97-5.62 | 5.27 | 5.53-5.01 | **0.001** |
| | Cherry | 5.08 | 5.27-4.89 | 4.48 | 5.76-4.19 | **0.001** |
| | Spicy | 4.86 | 5.03-4.68 | 4.64 | 4.90-4.38 | 0.169 |
| | Acidity | 4.53 | 4.70-4.36 | 4.21 | 4.47-3.96 | **0.040** |
| | Coffee-Chocolate | 4.61 | 4.81-4.41 | 4.24 | 4.54-3.94 | **0.041** |
| | Oak | 4.09 | 4.29-3.90 | 4.10 | 4.39-3.81 | 0.993 |
| | Minty-Eucalyptus | 4.01 | 4.24-3.78 | 3.24 | 3.59-2.90 | **0.000** |
| | Astringency | 3.92 | 4.14-3.70 | 4.42 | 4.74-4.09 | 0.012 |
| | Dried Fruits | 3.96 | 4.18-3.74 | 3.74 | 4.08-3.41 | 0.284 |
| | Jammy | 3.89 | 4.07-3.70 | 3.54 | 3.82-3.27 | **0.044** |
| | Smoky | 3.74 | 3.94-3.54 | 3.07 | 3.37-2.76 | **0.000** |
| | Bitterness | 2.18 | 2.35-2.02 | 1.96 | 2.21-1.72 | 0.145 |
| | Sweetness | 2.20 | 2.38-2.02 | 2.60 | 2.87-2.83 | 0.015 |
| | Green-Vegetative | 2.15 | 2.35-1.95 | 1.52 | 1.82-1.22 | **0.001** |
| | Barnyard | 1.66 | 1.87-1.45 | 1.61 | 1.92-1.29 | 0.763 |
| **Overall evaluation** | Harmonious | 6.31 | 6.45-6.16 | 6.05 | 6.26-5.83 | **0.049** |
| | Body | 6.26 | 6.41-6.12 | 6.12 | 6.33-5.90 | 0.272 |
| | Complex | 6.13 | 6.28-5.99 | 6.06 | 6.28-5.85 | 0.617 |
| | Potential | 6.05 | 6.23-5.87 | 5.80 | 6.08-5.53 | 0.145 |

[a] Range: upper bound 95%-lower bound 95%, [b] Significance set at $p < 0.05$ and indicated in bold.

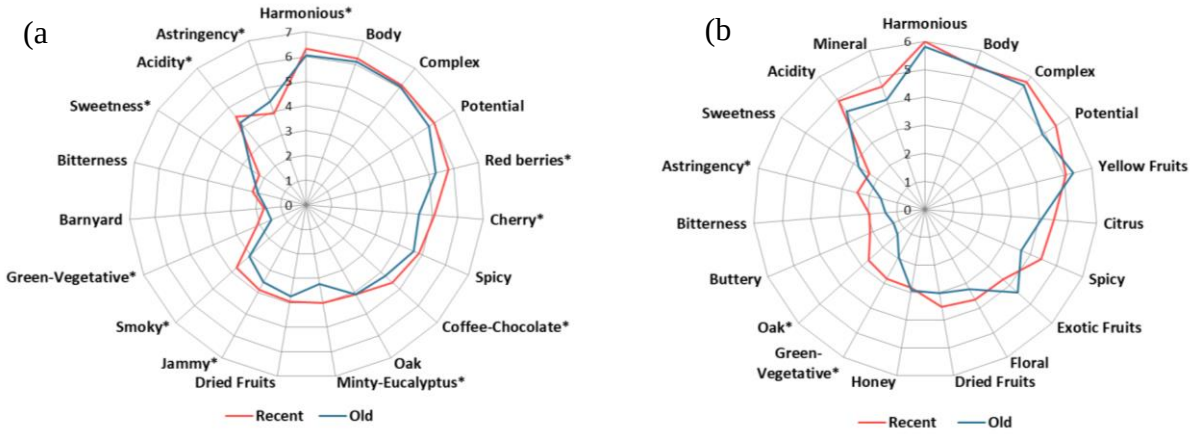


**Figure 1.** Representation of the sensory profile and overall evaluation of the Grand Gold red (a) and white (b) wines in the older (2014-2016, blue line) and more recent (2020-2023, red line) editions of Mundus Vini wine challenge (*p<0.05).

**Table V**

Least square (LS) means and range of the scores given to Grand Gold white wines in the older and more recent Mundus Vini editions

| Category | Descriptor | 2020-2023 Editions | | 2014-2016 Editions | | Pr > F[b] |
|---|---|---|---|---|---|---|
| | | Mean | Range[a] | Mean | Range | |
| **Flavour** | Yellow Fruits | 5.07 | 5.69-4.45 | 5.34 | 5.85-4.82 | 0.566 |
| | Acidity | 4.90 | 5.52-4.29 | 4.44 | 4.85-4.03 | 0.236 |
| | Mineral | 4.64 | 5.37-3.90 | 4.14 | 4.61-3.67 | 0.268 |
| | Citrus | 4.51 | 5.13-3.89 | 4.08 | 4.47-3.69 | 0.250 |
| | Spicy | 4.41 | 5.04-3.78 | 3.66 | 4.14-3.17 | 0.093 |
| | Exotic Fruits | 3.69 | 4.60-2.78 | 4.38 | 4.79-3.96 | 0.124 |
| | Floral | 3.66 | 4.33-2.98 | 3.25 | 3.64-2.85 | 0.290 |
| | Dried Fruits | 3.52 | 4.48-2.56 | 3.04 | 3.55-2.53 | 0.347 |
| | Honey | 2.84 | 3.58-2.10 | 2.94 | 3.43-2.45 | 0.816 |
| | Green-Vegetative | 2.82 | 3.55-2.09 | 1.95 | 2.37-1.52 | **0.041** |
| | Oak | 2.68 | 4.07-1.29 | 1.32 | 1.96-0.69 | **0.049** |
| | Astringency | 2.45 | 3.13-1.77 | 1.59 | 2.03-1.16 | **0.043** |
| | Sweetness | 2.34 | 2.96-1.72 | 2.78 | 3.20-2.36 | 0.264 |
| | Buttery | 2.11 | 2.98-1.24 | 1.21 | 1.70-0.73 | 0.068 |
| | Bitterness | 1.95 | 2.55-1.34 | 1.40 | 1.78-1.02 | 0.135 |
| **Overall Quality** | Harmonious | 5.99 | 6.63-5.36 | 5.80 | 6.15-5.46 | 0.583 |
| | Body | 5.36 | 5.84-4.89 | 5.41 | 5.77-5.05 | 0.885 |
| | Complex | 5.75 | 6.23-5.26 | 5.60 | 6.00-5.20 | 0.682 |
| | Potential | 5.46 | 6.05-4.86 | 4.89 | 5.37-4.42 | 0.192 |

[a] Range: upper bound 95%-lower bound 95%, [b] Significance set at $p < 0.05$ and indicated in bold.

**Table VI**

Pearson correlation coefficients between the average red wine sensory and analytical measures for the older (2014-2016) and more recent (2020-2023) Mundus Vini editions

| Variables | Residual sugar (g/L) | | Total acidity (g/L) | | Ethanol (%v/v) | |
|---|---|---|---|---|---|---|
| | Recent | Older | Recent | Older | Recent | Older |
| **Chemical composition** | | | | | | |
| **Residual sugar** | — | — | | | | |
| **Total acidity** | 0.230** | 0.359** | — | — | | |
| **Ethanol** | 0.245** | 0.404** | 0.094 | 0.374** | — | — |
| **Flavour descriptors** | | | | | | |
| **Cherry** | -0.267** | 0.135 | -0.079 | 0.25* | 0.029 | 0.267* |
| **Jammy** | -0.066 | 0.307* | -0.020 | 0.318* | 0.060 | 0.241 |
| **Dried Fruits** | -0.047 | 0.293* | 0.002 | 0.317* | -0.006 | 0.231 |
| **Spicy** | -0.026 | -0.069 | -0.012 | 0.245 | 0.007 | -0.074 |
| **Smoky** | -0.007 | 0.273* | -0.06 | 0.208 | -0.106 | 0.336** |
| **Coffee-Chocolate** | -0.062 | 0.332** | -0.017 | 0.252* | -0.003 | 0.310* |
| **Oak** | -0.003 | 0.130 | 0.001 | 0.055 | 0.120 | 0.048 |
| **Barnyard** | -0.087 | -0.010 | -0.074 | 0.110 | -0.197* | 0.205 |
| **Acidity** | -0.046 | -0.053 | 0.189* | -0.103 | 0.074 | -0.248 |
| **Sweetness** | 0.325*** | 0.576*** | 0.05 | 0.339** | 0.185* | 0.296* |
| **Bitterness** | -0.039 | -0.028 | -0.046 | 0.05 | -0.024 | 0.175 |
| **Astringency** | -0.023 | 0.078 | 0.019 | 0.166 | 0.261** | 0.126 |
| **Green Vegetative** | -0.131 | -0.019 | 0.033 | -0.040 | 0.064 | 0.037 |
| **Minty Eucaliptus** | 0.015 | 0.189 | 0.08 | 0.167 | -0.103 | 0.214 |
| **Red berries** | -0.130 | 0.254* | -0.091 | 0.191 | 0.044 | 0.053 |
| **Overall Quality** | | | | | | |
| **Harmonious** | 0.003 | -0.029 | 0.002 | -0.085 | -0.031 | -0.127 |
| **Body** | 0.124 | 0.093 | 0.103 | 0.252* | 0.045 | 0.140 |
| **Complex** | -0.022 | 0.089 | 0.129 | -0.127 | -0.041 | 0.004 |
| **Potential** | 0.153 | -0.027 | 0.169* | -0.024 | 0.103 | -0.086 |

*p<0.05, **p<0.01, ***p<0.001.

Concerning white wines, there were less significant correlations among chemical and sensory parameters (Table VII). However, despite the low number of wines in recent editions, there were significant and predictable correlations between residual sugar and 'Sweetness' (Han *et al.*, 2022) and total acidity and 'Astringency' (Wang *et al.*, 2024). As with red wines, older editions showed a higher number of significant correlations.

Overall, since average chemical composition was similar between both periods, these observations justify looking for variations in the sensory profiles within Grand Gold awards.

**Table VII**

Pearson correlations between the white wine sensory and analytical measures for the older (2014-2016) and more recent (2021-2023) Mundus Vini editions

| Variables | Residual sugar (g/L) | | Total acidity (g/L) | | Ethanol (%v/v) | |
|---|---|---|---|---|---|---|
| | Recent | Older | Recent | Older | Recent | Older |
| **Chemical composition** | | | | | | |
| **Residual Sugar** | - | | | | | |
| **Acidity** | 0.028 | 0.608*** | - | - | | |
| **Ethanol** | -0.586 | -0.392* | -0.208 | -0.618*** | - | - |
| **Flavour descriptors** | | | | | | |
| **Yellow Fruits** | -0.057 | 0.365 | 0.057 | 0.322 | -0.088 | -0.001 |
| **Exotic Fruits** | 0.187 | -0.171 | -0.424 | -0.197 | -0.331 | 0.159 |
| **Floral** | 0.157 | -0.361 | -0.318 | -0.058 | -0.100 | 0.168 |
| **Dried Fruits** | 0.249 | 0.159 | 0.244 | 0.027 | -0.408 | 0.218 |
| **Spicy** | -0.481 | -0.023 | 0.333 | 0.187 | 0.175 | -0.106 |
| **Honey** | -0.010 | 0.060 | 0.314 | 0.113 | -0.143 | -0.038 |
| **Oak** | -0.164 | -0.531** | 0.346 | -0.536** | -0.291 | 0.413* |
| **Buttery** | -0.313 | -0.460* | 0.456 | -0.447* | -0.321 | 0.190 |
| **Acidity** | 0.323 | 0.332 | 0.043 | 0.555 | 0.000 | -0.541 |
| **Sweetness** | 0.610* | 0.216 | -0.211 | -0.047 | -0.385 | 0.005 |
| **Bitterness** | 0.362 | -0.363 | 0.269 | -0.131 | -0.357 | -0.020 |
| **Astringency** | 0.066 | -0.036 | 0.624* | 0.405* | -0.346 | -0.289 |
| **Green-Vegetative** | -0.058 | -0.373 | -0.268 | -0.126 | 0.269 | -0.199 |
| **Mineral** | 0.131 | 0.271 | 0.047 | 0.382* | -0.135 | -0.498** |
| **Citrus** | 0.038 | 0.081 | -0.129 | 0.016 | 0.220 | -0.222 |
| **Overall Quality** | | | | | | |
| **Harmonious** | 0.233 | 0.138 | -0.243 | -0.033 | -0.224 | -0.021 |
| **Body** | -0.233 | -0.315 | -0.290 | -0.434* | -0.228 | 0.408* |
| **Complex** | -0.130 | -0.184 | 0.124 | -0.168 | -0.253 | 0.099 |
| **Potential** | -0.154 | -0.063 | -0.135 | -0.118 | -0.282 | -0.166 |

*p<0.05, **< p<0.01, ***, p<0.001.

## Wine clustering according to sensory profile

*Red wines*

To provide a deeper insight into likely changes in the inference of quality from sensory perception, an agglomerative hierarchical clustering (AHC) was performed for all wines in both periods as a function of the intensity of perception for each flavour descriptor. The dendrogram is shown in Figure 2, evidencing the clustering of the red wines according to their flavour similarity.

The comparison of the flavour descriptors of each wine cluster is summarized in Table VIII.

The differences in flavour scores were significant for all cases evidencing that the average profile reported before (Figure 1a) comprised different nuances. The pair-wise differences (Tukey HSD test) were observed between at least two of the clusters.

The AHC now using the flavour scores as variables is shown in Figure 3. When the dendrogram was partitioned in 4 clusters, each cluster could be attached to a sensory space in a fair consistent form (Barbe *et al.*, 2021). Cluster 1 included the typical descriptors of red wines fresh fruit ('Cherry', 'Red berries') (Garbay *et al.*, 2023) and was coined as 'Freshness'. Cluster 2, named as Oakiness, included aromas related to oak ageing ('Oak', 'Coffee-chocolate', 'Smoky', 'Dried fruits', 'Minty-eucalyptus') and over ripen fruit ('Dried fruits', 'Jammy'), as broadly reported by others (Szolnoki *et al.*, 2011). Cluster 3 corresponded to the taste perception of 'Acidity' and the mouthfeel sensation of 'Astringency', with mutual perceptual interactions (Li *et al.*, 2025), and was called Harshness. The aroma 'Spicy' appeared in this cluster without any known perceptual inference with these two in-mouth perceptions. Finally, wine flaws ('Green-vegetative', 'Bitterness', and 'Barnyard') and 'Sweetness' that may interact among each other (Li *et al.*, 2025), composed Cluster 4. It is noteworthy that these off-flavours were detected in wines awarded Grand Gold medals. Recently, Malfeito-Ferreira (2022) proposed the term Funkiness to describe off-flavours associated with the highly prized concept of minerality. Therefore, this cluster was defined as Funkiness, since this concept reflects the perception of flavours associated to off-flavours but that do not penalize wine appreciation.

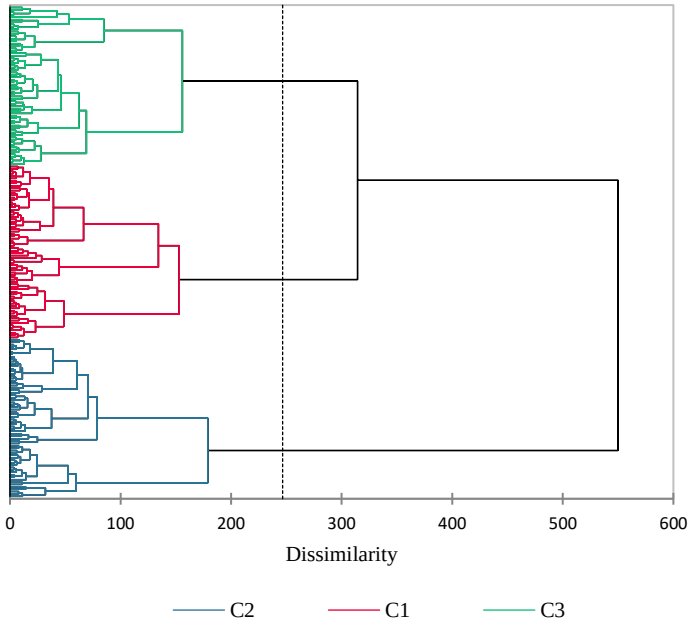


**Figure 2.** Agglomerative hierarchical clustering (AHC) of Grand Gold red wines according to their flavour description (wines are not referenced for the sake of clarity). Vertical dashed line indicates the automatic truncation level according to the Hartigan index.

**Table VIII**

Flavour characterization of the Grand Gold red wine clusters

| Flavour attribute | Cluster[a] | | | Pr > F(Model)[b] |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| **Red berries** | 4.84 b | 6.21 a | 5.92 a | **<0.0001** |
| **Cherry** | 4.19 b | 5.27 a | 5.28 a | **<0.0001** |
| **Acidity** | 4.31 ab | 4.29 b | 4.71 a | **0.029** |
| **Spicy** | 4.30 b | 5.22 a | 4.88 a | **<0.0001** |
| **Oak** | 3.76 b | 4.24 a | 4.32 a | **0.009** |
| **Coffee-Chocolate** | 3.74 c | 5.25 a | 4.57 b | **<0.0001** |
| **Minty-Eucalyptus** | 3.24 b | 5.02 a | 3.11 b | **<0.0001** |
| **Jammy** | 3.07 c | 3.96 b | 4.38 a | **<0.0001** |
| **Dried Fruits** | 2.93 b | 4.46 a | 4.39 a | **<0.0001** |
| **Smoky** | 2.91 c | 4.30 a | 3.44 b | **<0.0001** |
| **Astringency** | 3.63 b | 4.26 a | 4.37 a | **0.001** |
| **Sweetness** | 2.10 b | 2.28 ab | 2.60 a | **0.024** |
| **Bitterness** | 1.75 b | 2.31 a | 2.32 a | **0.000** |
| **Green-Vegetative** | 1.47 b | 3.158 a | 1.29 b | **<0.0001** |
| **Barnyard** | 1.31 b | 2.236 a | 1.42 b | **<0.0001** |

[a] Different letters in the row indicate pair-wise differences ($p<0.05$) by the Tukey HSD test, [b] Bold indicates significant differences ($p<0.05$) among LS means.

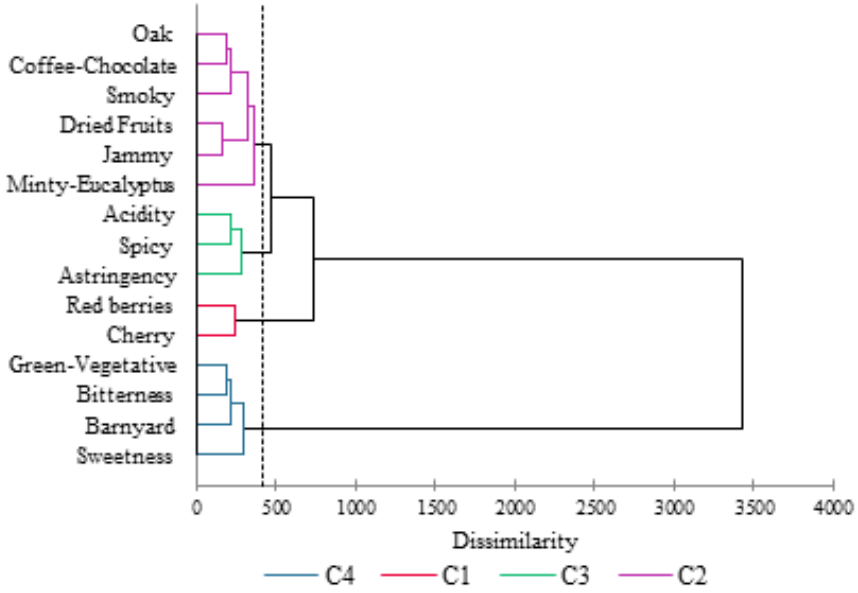


**Figure 3.** Agglomerative hierarchical clustering (AHC) of the flavour descriptors Grand Gold red wines from 2014-2016 and 2020-2023 editions (C1, Freshness, C2, Oakiness, C3, Harshness, C4, Funkiness). Vertical dashed line indicates the automatic truncation level according to the Hartigan index.

Overall, the similarities obtained by AHC were predictable, and so these flavour families may be understood under the concept of sensory conceptual spaces, which are in accordance with the synthetic nature of flavour perception (Malfeito-Ferreira, 2021). Then, the weight of each family in the aroma profile of each cluster may be calculated by the sum of the scores of each flavour. The results are listed in Table IX together with the corresponding overall quality, price and chemical composition. The results showed that only 'Harmonious' was slightly different among the wine clusters.

**Table IX**

Sensory, quality and chemical characterization of the Grand Gold red wines clustered according to their flavour description.

| Category | Family | Cluster[a] | | | Pr > F(Model)[b] |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | |
| **Flavour** | Oakiness | 19.62 c | 27.23 a | 24.19 b | **<0.0001** |
| | Harshness | 12.25 b | 13.78 a | 13.96 a | **<0.0001** |
| | Freshness | 9.01 b | 11.48 a | 11.20 a | **<0.0001** |
| | Funkiness | 6.64 c | 9.99 a | 7.62 b | **<0.0001** |
| **Quality** | Body | 6.03 | 6.26 | 6.37 | 0.064 |
| | Harmonious | 6.01 b | 6.23 ab | 6.46 a | **0.011** |
| | Complex | 5.92 | 6.21 | 6.23 | 0.063 |
| | Potential | 5.79 | 6.14 | 6.01 | 0.173 |
| | Price | 27.6 | 26.7 | 41.6 | 0.162 |
| **Chemical** | Residual Sugar | 2.4 | 2.1 | 2.8 | 0.132 |
| | Acidity | 5.5 | 5.7 | 5.6 | 0.462 |
| | Ethanol | 14.3 | 14.4 | 14.4 | 0.722 |

[a] Different letters in the row indicate pair-wise differences ($p<0.05$) by the Tukey HSD test, [b] Bold indicates significant differences ($p<0.05$) among LS means.

Szolnoki *et al.* (2011) also found three sensory clusters that influenced differently the quality of Bordeaux wines. Highest quality was associated with full-body wines dominated by oak, while the other two clusters (fresh wines and perfumed wines) gathered wines with lower quality scores. In the present work, the fresher descriptors were higher in the more recent editions (Table IV) while oak was similar in both periods considering all responses together. The clustering process showed that this overall behaviour consisted of two different responses regarding Oakiness. Indeed, the sensory

clusters corresponded to a deeper distinction among the highest quality scores (Table X). Therefore, among the bold Grand Gold dry red wines dominated by Oakiness: (a) Cluster 1 included cleaner and smoother wines, with less intensity and harmony; (b) Cluster 2 involved wines with higher funky notes, dominated by oak; (c) Cluster 3 comprised samples with noticeable oak and less Funkiness. These results evidence a sensory continuum among the Grand Gold wines´ flavour mainly modulated by the perception of Oakiness and Funkiness. The number of wines of the three clusters is shown in Table X, evidencing higher percentages of cleaner wines in the older editions and of funkier ones in the recent editions. These observations are in accordance with the present higher leniency of the wine press towards the perception of off-flavours (Pelonnier-Magimel *et al.*, 2020). Even among experts, the association of faults with an organic mode of production was shown to elicit higher quality scores under controlled experiments (Romano *et al.*, 2020).

**Table X**

Synthetic characterization and percentage composition of the wine clusters of the recent and older editions of the Mundus Vini challenges

| Wine cluster | 2020-2023 Editions | 2014-2016 Editions | Synthetic description |
|---|---|---|---|
| **1** | 29.1 (41) | **49.2** (31) | Less intense and harmonious, smoother and cleaner wines |
| **2** | **39.0** (55) | 17.5 (11) | Harmonious bold wines dominated by oak with funky nuances |
| **3** | 31.9 (45) | 33.3 (21) | Harmonious bold wines dominated by oak with less funky nuances |
| **All** | 100 (141) | 100 (63) | Bold wines dominated by oakiness |

Number of wines in brackets. Bold number indicates higher proportions in the row by Chi-square test at $p < 0.05$.

*White wines*

The same strategy was applied to white wines, and the AHC dendrogram is shown in Figure 4. Table XI summarizes the flavour composition of each wine cluster, evidencing significant differences for 'Spicy', 'Acidity', 'Dried fruits', 'Honey', 'Oak', 'Buttery', 'Astringency' and 'Bitterness'. The clustering of the flavour descriptors is shown in Figure 5, enabling the definition of four sensory spaces (Freshness, Mellowed, Oakiness and Funkiness) (Table XII). Freshness encompassed the fresh fruity and floral aromas ('Citrus', 'Exotic fruits', 'Yellow fruits', and 'Floral'), usually applied to whites when using transparent glasses (Nguyen and Durner, 2023) and the corresponding acid taste (Lee *et al.*, 2025). 'Mineral' is also a descriptor associated with Freshness and bears a positive quality significance (Malfeito-Ferreira, 2022). The Mellowed family comprised 'Honey', 'Dried fruit' and 'Sweetness', being related to proper ageing (Marasà *et al.* 2024). 'Oak' and 'Buttery' are consistent with the influence of ageing in barrel (Nguyen and Durner., 2023). The Funkiness family comprises 'Green-vegetative' aroma (Paissoni *et al.*, 2025) and in-mouth perceptions of 'Bitterness' and 'Astringency' (Gawel *et al.*, 2017), which are known to interact (Nguyen and Durner, 2023), and are not expected to be noticeably perceived in conventional white wines.

The wine clusters were distinguished by the flavour intensity given to Mellowed and Oakiness: (a) Cluster 1 comprised samples with higher oak and mellowed flavours, (b) Cluster 2 included wines with little Oakiness and less Mellowed flavours, and (c) Cluster 3 represented fresher wines with Mellowed flavours and rather little oak perception. The overall quality parameters were similar across all clusters while Cluster 3 showed higher residual sugar. These results are broadly consistent with the Chenin styles considered as dry, semi-dry unwooded and semi-dry wooded, based on numerous tasting notes of a wine journalist (Valente *et al.*, 2018).

The number of wines in each cluster reflects the most preferred sensory features (Table XIII). The sensory descriptors were only significantly higher in more recent editions for 'Oak', 'Green-Vegetative' and 'Astringency' (Table V). The clustering according to sensory spaces further demonstrated that the higher perception of Oakiness was present only in one cluster (Table XIII) probably enhanced by the higher proportion of oaky wines (6 out of 11 samples). Overall, it seems that the Grand Gold white wines did not follow the supposed present tendency to appreciate more wines dominated by fresh flavours or minerality in detriment of oaky flavours. The low number of white wines submitted to the more recent editions represents a limitation to these inferences. Certainly, the comparison between both periods was done with a set of wines in which the different flavour profiles were not present in the same proportion. In addition, the tasting panels from both periods should have had different composition regarding expertise with likely influence on quality appreciation.

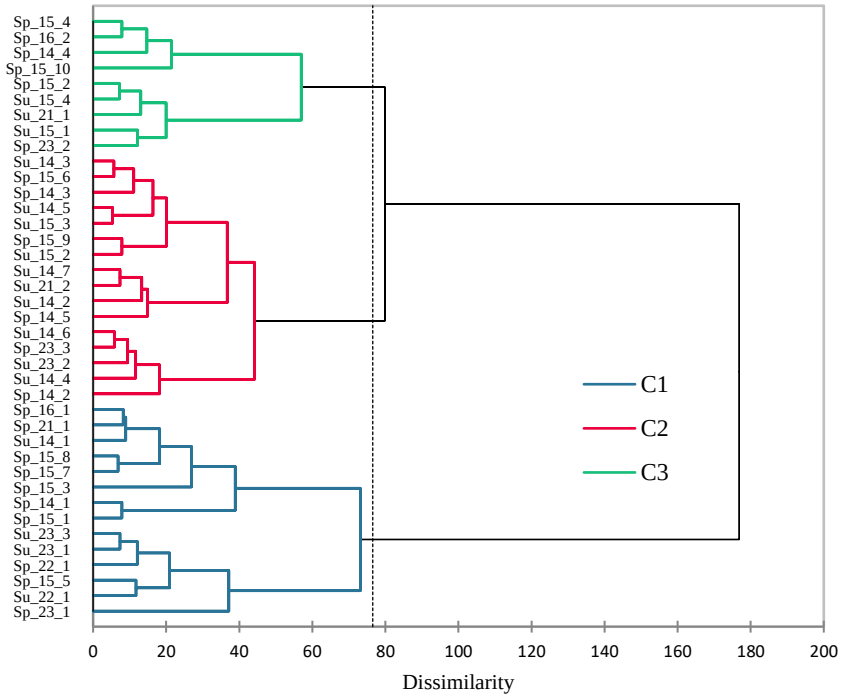


**Figure 4.** Agglomerative hierarchical clustering (AHC) of Grand Gold white wines according to their flavour description (sample codes: Sp, spring edition; Su, summer edition; 14 to 23, vintage years from 2014 to 2023; 1 to 10, wine number in each vintage year). Vertical dashed line indicates the automatic truncation level according to the Hartigan index.

**Table XI**

Flavour characterization of the Grand Gold white wine clusters

| Flavour attribute | Cluster[a] | | | Pr > F(Model)[b] |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| **Yellow Fruits** | 5.31 | 4.89 | 5.84 | 0.197 |
| **Spicy** | 4.63 a | 3.34 b | 3.63 ab | **0.012** |
| **Acidity** | 4.11 b | 4.42 b | 5.57 a | **0.003** |
| **Mineral** | 4.08 | 4.08 | 4.96 | 0.181 |
| **Exotic Fruits** | 4.07 | 4.12 | 4.47 | 0.743 |
| **Citrus** | 4.01 | 4.08 | 4.72 | 0.230 |
| **Dried Fruits** | 3.94 a | 2.51 b | 3.16 ab | **0.019** |
| **Honey** | 3.84 a | 1.78 b | 3.50 a | **<0.0001** |
| **Oak** | 3.59 a | 0.80 b | 0.39 b | **<0.0001** |
| **Floral** | 3.09 | 3.69 | 3.19 | 0.271 |
| **Buttery** | 2.84 a | 0.85 b | 0.42 b | **<0.0001** |
| **Sweetness** | 2.34 | 2.53 | 3.38 | 0.067 |
| **Astringency** | 2.24 a | 0.94 b | 2.78 a | **<0.0001** |
| **Green Vegetative** | 2.11 | 2.61 | 1.59 | 0.121 |
| **Bitterness** | 1.56 ab | 1.17 b | 2.23 a | **0.039** |

[a] Different letters in the row indicate pair-wise differences ($p<0.05$) by the Tukey HSD test, [b] Bold indicates significant differences ($p<0.05$) among LS means.

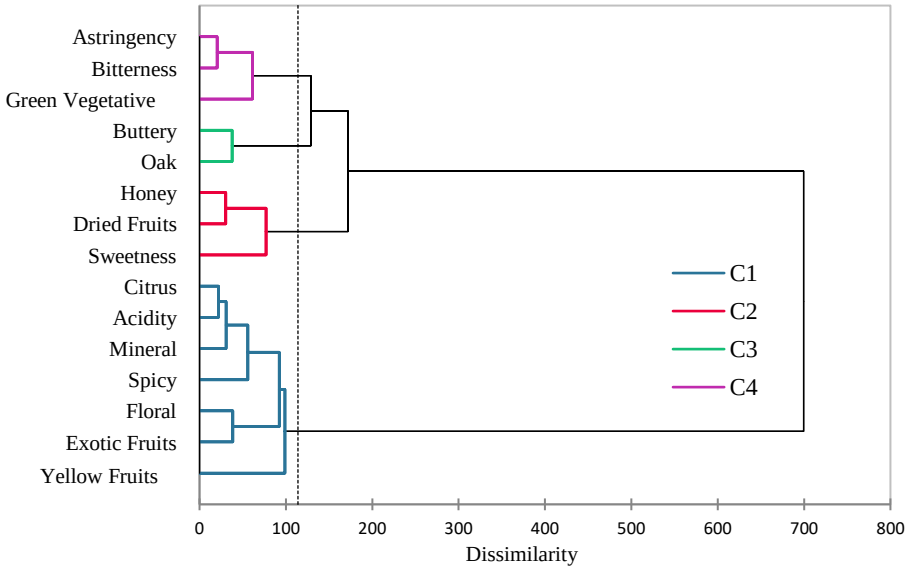


**Figure 5.** Agglomerative hierarchical clustering (AHC) of the flavour descriptors Grand Gold white wines from 2014-2016 and 2021-2023 editions (C1, Freshness, C2, Mellowed, C3, Oakiness, C4, Funkiness). Vertical dashed line indicates the automatic truncation level according to the Hartigan index.

**Table XII**

Sensory, quality and chemical characterization of the Grand Gold white wine clustered according to their sensory space description

| Category | Family | Cluster[a] | | | Pr > F(Model)[b] |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | |
| **Flavour** | Freshness | 29.29 ab [b] | 28.61 b | 32.38 a | 0.120 |
| | Mellowed | 10.11 a | 6.81 b | 10.03 a | **<0.0001** |
| | Oakiness | 6.43 a | 1.65 b | 0.81 b | **<0.0001** |
| | Funkiness | 5.91 | 4.75 | 6.60 | 0.156 |
| **Quality** | Body | 5.56 | 5.26 | 5.39 | 0.656 |
| | Potential | 5.15 | 4.92 | 5.13 | 0.854 |
| | Harmonious | 5.78 | 5.91 | 5.89 | 0.931 |
| | Complex | 5.66 | 5.39 | 6.06 | 0.273 |
| | Price | 15.6 | 14.6 | 18.5 | 0.526 |
| **Chemical** | Residual Sugar | 2.770 b | 3.913 ab | 5.231 a | 0.057 |
| | Acidity | 6.127 | 6.110 | 7.354 | 0.105 |
| | Ethanol | 13.321 | 13.313 | 12.778 | 0.101 |

[a] Different letters in the row indicate pair-wise differences ($p<0.05$) by the Tukey HSD test, [b] Bold indicates significant differences ($p<0.05$) among LS means.

**Table XIII**

Synthetic characterization and percentage composition of the wine clusters of the recent and older editions of the Mundus Vini challenges

| Wine cluster | 2020-2023 Editions | 2014-2016 Editions | Synthetic description |
|---|---|---|---|
| **1** | **54.5** (6) | 28.6 (8) | Oaked and mellowed |
| **2** | 27.3 (3) | **46.4** (13) | Unoaked less intense and smoother |
| **3** | 18.2 (2) | **25.0** (7) | Unoaked fresher and sweeter |
| **All** | 100 (11) | 100 (28) | Fresh fruitiness with occasional oak |

Number of wines in brackets. Bold numbers indicate higher proportions in the row by Chi-square test at $p < 0.05$.

## CONCLUSIONS

The results reported demonstrate that identifying temporal changes in the most liked sensory features of wine remains a challenge for sensory researchers. This work showed that the expected recent style trends favouring less alcoholic and lighter wines could not be fully observed using the data retrieved from Mundus Vini competitions over the years. In particular, regarding red and white wines: (i) the

relative proportion of Grand Gold white wines did not increase when compared with the much higher proportion Grand Gold red wines, (ii) the oak related flavours continued to be dominant in most of the wines awarded Grand Gold, (iii) decreasing ethanol content and lower residual sugar were not evidenced among awarded wines. In terms of red wines, the single observation consistent with claimed present trends was the apparent higher leniency towards the perception of off-flavours in present editions. Overall, the results of a large international competition did not evidence the presumed increasing appreciation of leaner styles, with less ethanol, body, residual sugar and oak flavours. It is important to ascertain whether the competition results are accurate indicators of these trends or whether the trends have, in fact, changed significantly.

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The Use of Artificial Intelligence (AI)-Assisted Technology was restricted to improve English spelling and language clarity.

## REFERENCES

Barbe J.-C., Garbay J., Tempère S., 2021. The Sensory Space of Wines: From Concept to Evaluation and Description. A Review. *Foods*, **10**, 1424.

Barton A., Hayward L., Richardson C., McSweeney M., 2020. Use of different panellists (experienced, trained, consumers and experts) and the projective mapping task to evaluate white wine. *Food Qual. Pref.*, **83**, 103900.

Bélisle F., 2025. Are Canada's best wines from Ontario or British Columbia? An analysis of the All Canadian Wine Championships results, 2010–2022. *J. Wine Res.*, **36**, 298-307.

Bitter C., 2017. Wine Competitions: Reevaluating the Gold Standard. *J. Wine Econ.*, **12**, 395-404.

Bodington J., Malfeito-Ferreira M., 2018. The 2016 Wines of Portugal Challenge: General implications of more than 8,400 wine-score observations. *J. Wine Res.*, **28**, 313-325.

Castriota S., Curzi D., Delmastro M., 2013. Tasters' bias in wine guides' quality evaluations. *Appl. Econ. Lett.*, **20**, 1174–1177.

Del Rey R., Loose S., 2023. State of the International Wine Market in 2022: New market trends for wines require new strategies. *Wine Econ. Policy*, **12**, 3–18.

Dong Z., Guo X., Rajana S., Chen B., 2020. Understanding 21st Century Bordeaux Wines from Wine Reviews Using Naïve Bayes Classifier. *Beverages*, **6**, 5.

Fuentes-Fernández R., del Campo-Villares J.L., 2025. Exploring the Market for Dealcoholized Wine in Spain: Health Trends, Demographics, and the Role of Emerging Consumer Preferences. *Beverages*, **11**, 41.

Garbay J., Cameleyre M., Riquier L., Barbe J.-C., Lytra G., 2023. Development of a New Method for the Quantitative Analysis of Aroma Compounds Potentially Related to the Fruity Aroma of Red Wines. *J. Agric. Food Chem.*, **71**, 13066-13078.

Gastaldello G., Schäufele-Elbers I., Schamel G., 2024. Factors influencing wine ratings in an online wine community: The case of Trentino–Alto Adige. *J. Wine Econ.*, **19**, 19-40.

Gawel R., Smith P. A., Cicerale S., Keast R., 2017. The mouthfeel of white wine. *Crit. Rev. Food Sci. Nutr.*, **58**, 2939–2956.

Goldstein R., Almenberg J., Dreber A., Emerson J.W., Herschkowitsch A., Katz J., 2008. Do More Expensive Wines Taste Better? Evidence from a Large Sample of Blind Tastings. *J. Wine Econ.*, **3**, 1-9.

Han S., Yang J., Choi K., Kim J., Adhikari K., Lee J., 2022. Chemical Analysis of Commercial White Wines and Its Relationship with Consumer Acceptability. *Foods*, **11**, 603.

Harutyunyan M., Malfeito-Ferreira M., 2022. Historical and Heritage Sustainability for the Revival of Ancient Wine-Making Techniques and Wine Styles. *Beverages*, **8**, 10.

Jürkenbeck K., Spiller A., 2021. Importance of sensory quality signals in consumers' food choice. *Food Qual. Pref.*, **90**, 104155.

Kaimann D., Bru B., Frick B., 2023. Ratings meet prices: The dynamic relationship of quality signals. *J. Wine Econ.*, **18**, 226-244.

Kopsacheilis O., Analytis P., Kaushik K., Herzog S., Bahrami B., Deroy O., 2024. Crowdsourcing the assessment of wine quality: Vivino ratings, professional critics, and the weather. *J. Wine Econ.*, **19**, 285-304.

Kumar A. P., Meriluoto L., Watt R., 2023. New evidence on using expert ratings to proxy for wine quality in climate change research. *J. Wine Res.*, **34**, 101–121.

Kurtanjek Ž., 2024. Causal Artificial Intelligence Models of Food Quality Data. *Food Technol. Biotechnol.*, **62**, 102-109

Lee J., Park J. Y., Back R. M., Nutta M.W., 2025. Expert wine reviews: exploring trends in wine quality indicators. *J. Wine Res.*, **36**, 85–103.

Li Y., Zhang Q., Liu X., Bian X., Li J., Meng N., Liu M., Huang M., Sun B., Li J., 2025. Flavor Interactions in Wine: Current Status and Future Directions From Interdisplinary and Crossmodal Perspectives. *Compr. Rev. Food Sci. Food Saf.*, **24**, e70199.

Livat F., Remaud H., Fernández-Olmos M., 2024. Factors explaining differences in wine experts' ratings: The case of gender, credentials, occupation and peer effects. *Food Res. Int.*, **191**, 114689.

Lockshin, L., Corsi, A., 2012. Consumer behaviour for wine 2.0: A review since 2003 and future directions, *Wine Econ. Policy*, **1**, 2-23.

Loose, S.M., del Rey, R., 2024. State of the International Wine Markets in 2023. The wine market at a crossroads: Temporary or structural challenges? *Wine Econ. Policy*, **13**, 3–14.

Malfeito-Ferreira M., 2021. Fine wine flavor perception and appreciation: Blending neuronal processes, tasting methods and expertise. *Trend. Food Sci. Technol.*, **115**, 332-346.

Malfeito-Ferreira M., 2022. Wine Minerality and Funkiness: Blending the Two Tales of the Same Story. *Fermentation*, **8**, 745.

Malfeito-Ferreira M., Diako C., Ross C. F., 2019. Sensory and chemical characteristics of 'dry' wines awarded gold medals in an international wine competition. *J. Wine Res.*, **30**, 204–219.

Marasà G., Ferreira J., Mota M., Malfeito-Ferreira M., 2024. Understanding the Mellowing Effect of Bottle Aging on the Sensory Perceptions of Varietal Dry White Wines. *Beverages*, **10**, 78.

Martínez-Navarro J., Sellers-Rubio R., 2024. Three decades of research on wine marketing. *Heliyon*, **10**, e30938,

Moreira D., Reis L., Cortez P., 2024. Using Machine Learning to Predict Wine Quality and Prices: A Demonstrative Case Using a Large Tabular Database. *IEEE Access*, **12**, 182296-182309.

Nguyen T., Durner D., 2023. Sensory evaluation of wine aroma: Should color-driven descriptors be used? *Food Qual. Pref.*, **107**, 104844.

OIV, 2009. OIV standard for international wine competitions and spirituous beverages of vitivinicultural origin (OIV-CONCOURS 332A-2009) and Guidelines for granting OIV patronage of international wine and spirituous beverages of vitivinicultural origin competitions. International Organisation of Vine and Wine (eds.), Paris, France.

OIV, 2024. Focus OIV 2023 – Evolution of the world wine production and consumption by colour. International Organisation of Vine and Wine (OIV), Parvis de l'UNESCO, 21000 Dijon, France.

OIV, 2025. International Code of Oenological practices. Available at : https://www.oiv.int/standards/international-code-of-oenological-practices/part-i-definitions/wines (accessed 18.06.2025).

Paissoni M.A., Boido M., Margotti P., Giacosa S., Río Segade S., Gerbi V., Rolle L., Schuessler C., Jung R., Rauhut D., 2025. Exploring the Sensory Typicity of Timorasso Wines: Physicochemical and Sensory Characteristics of Seven Consecutive Vintages. *Foods*, **14**, 591.

Paroissien E., Visser M., 2020. The Causal Impact of Medals on Wine Producers' Prices and the Gains from Participating in Contests. *Am. J. Agron. Econ.*, **102**, 1135-1153.

Pelonnier-Magimel É., Mangiorou P., Darriet P., de Revel G., Jourdes M., Marchal A., Barbe J., 2020. Sensory characterization of bordeaux red wines produced without added sulfites. *OENO One*, **54**, 687–697.

Penagos-Londoño G. I., Ruiz-Moreno F., Sellers-Rubio R., del Barrio-García S., Casado-Díaz A. B., 2022. Consistency of expert product reviews: an application to wine guides. *Wine Econ. Policy*, **11**, 51–60.

Pickering G.J., Kemp B., 2024. Understanding Sparkling Wine Consumers and Purchase Cues: A Wine Involvement Perspective. *Beverages*, **10**, 19.

Pomarici E., Lerro M., Chrysochou P., Vecchio R., Krystallis A., 2017. One size does (obviously not) fit all: Using product attributes for wine market segmentation. *Wine Econ. Policy*, **6**, 98-106.

Romano M., Chandra M., Harutyunyan M., Savian T., Villegas C., Minim V., Malfeito-Ferreira M., 2020. Off-flavors and unpleasantness are cues for the recognition and valorization of organic wines by experienced tasters. *Foods*, **9**, 105.

Sadras V.O., Soar C.J., Petrie P.R., 2007. Quantification of time trends in vintage scores and their variability for major wine regions of Australia. *Aust. J. Grape Wine Res.*, **13**, 117-123.

Sáenz-Navajas M.-P., Avizcuri J.-M., Ballester J., Fernández-Zurbano P., Ferreira V., Peyron D., Valentin D., 2015. Sensory-active compounds influencing wine experts' and consumers' perception of red wine intrinsic quality. *LWT - Food Sci. Technol.*, **60**, 400-411.

Sequeira M., Malfeito-Ferreira M., 2025. Consumer mental recognition of the sensory space of dry white wines "mellowed" by aging. *Ciência Téc. Vitiv.* **40**, 29–38.

Sogari, G., Pucci, T., Aquilani, B., Zanni, L., 2017. Millennial generation and environmental sustainability: The role of social media in the consumer purchasing behavior for wine. *Sustainability*, **9**, 1911.

Solis J., Luzzini G., Slaghenaufi D., Ugliano M., 2024. Dimethyl Sulfide (DMS) in Amarone Wines: Influence of Aging, Withering, Grape Variety, and Geographical Origin. *J. Agric. Food Chem.*, **72**, 1978-1984.

Szolnoki G., Hoffmann D., Herrmann R., 2011. Quantifying the influence of product design on perceived taste and purchase intent for wine using a characteristics model. *German J. Agric. Econ.*, **60**, 1 – 19.

Valente C., Bauer F., Venter F., Watson B., Nieuwoudt H., 2018. Modelling the sensory space of varietal wines: Mining of large, unstructured text data and visualisation of style patterns. *Sci. Rep.*, **8**, 4987.

Wang S., Mantilla S., Stokes J., Smith P., Smyth H., 2024. pH dominates the temporal perception of astringency sub-qualities and saliva friction response – A study under iso-pH and iso-titratable acidity conditions in model wine. *Food Hydrocoll.*, **146**, 109274.

Whitnall S., Alston J., 2025. Climate, weather, and collective reputation: Implications for California's wine prices and quality. *J. Wine Econ.*, **20**, 122-167.

Wine-searcher, 2025. Available at: https://www.wine-searcher.com/ (accessed 20.05.2025).

Yavas C. E., Kim J., Chen L., 2024. Mastering Precision in Pivotal Variables Defining Wine Quality via Incremental Analysis of Baseline Accuracy. *IEEE Access*, **12**, 105429-105459.