Hernandez Maria (Orcid ID: 0000-0003-4378-4178)

Wine quality and berry size: a case study with Tempranillo Tinto progenies

Cristina Manso-Martínez [a], María Pilar Sáenz-Navajas [b], Cristina M. Menéndez [a, c], María M. Hernández [a, c *]

ABSTRACT

Background: Small berry size is normally associated with quality wine production. However, the contribution of grapevine variety and environment on sensory quality has not been well established. Herein, genotypes from two intra-specific hybrid populations were categorised by size according to berry diameter and weight: small (< 13.5 mm, <1.5g), and large (>16 mm, >2g). Chemical and sensory attributes of wines produced in two consecutive vintages (2017 and 2018) from each size category were characterised. Perceived intrinsic wine quality was judged by 20 wine professionals.

Results: Consistently, wines obtained from small berry genotypes presented higher proportions of phenolic compounds, deeper colour and were judged higher in quality regardless genetic background and vintage. Perceived quality was positively correlated with anthocyanin and phenolic content. Wines presented high sensory variability differing in nine and seven attributes in each vintage. Small berry size genotypes produced sweeter, fruitier wines with greater astringency; whereas wines from larger berries were perceived as more alcoholic and with lower positive aroma intensities. Berry size influenced colour and phenolic compounds more than genotype or environment.

Conclusion: Small berry size genotypes drove high-quality judgements in both years, thus providing a predictor of wine categories in order to meet different market demands.

Keywords: Cabernet-Sauvignon, Garnacha Tinta intraspecific hybrids, *Vitis vinifera*

INTRODUCTION

Wine grapes are considered to be one of the world's most valuable crops [1]. Wine grape value is closely tied to the quality of the wines produced; currently reaching a production of 250 million hL [2]. Grape berries are rich in secondary metabolites such as anthocyanins, flavonols, norisoprenoids, terpenoids, and flavanols which affect wine quality by determining colour, aroma, and flavour [3].

Skin-to-flesh ratio influences grape composition and quality with higher concentrations of phenolic compounds in small berries [4]. However, the direct relationship between berry size and wine quality is still highly debated [5,6]. Recent studies have reported that berry skin thickness plays a major role on the skin-to-flesh ratio [7], therefore accounting for the controversy. Moreover, several authors stated that berry size had no influence on grape and wine quality, while viticulture practices such as pruning [8,9], and environmental conditions [10] are major drivers in vine metabolism, hence grape composition [11] not berry size per se [6].

One of the limitations in the study of berry size and composition is variability. Mean and range values of both parameters are the result of complex interactions among genotype, environmental factors, such as temperature or light, their interactions, and cultural practices [12]. Variability is present within berries, among berries within a cluster, among clusters on a vine, and among vines within a vineyard [11]. Sink competition at the tip of a cluster produces lower weight berries than in the centre or shoulder [13]. Berry weight shows high genetic diversity within the *Vitis* genus, ranging from <0.5 to >10 g [14].

Cultivar is a key factor in berry size and composition [15]. Genetic variability and plasticity allow the adaptation of existing cultivars to specific growing regions to produce distinct wine styles from one cultivar [11]. However, the wine industry is based on very tight genotype × environment interactions, with a limited number of *Vitis vinifera* cultivars. Thus, only 12 varieties constitute 70–90% of hectares in many countries; representing 1% of total diversity [16]. Recently, potential wine quality has been evaluated from intraspecific [17] as well as interspecific crosses [,18,19] in order to broaden the sensory and agronomic variability to adapt to new market preferences and environmental scenarios.

Thus, the objective of this study was to assess the effect of berry size, genetic background, and environment on the chemical and sensory properties of wines in two different vintages. Two genotype groups differing in average berry size were selected from two segregating populations: Garnacha Tinta × Tempranillo Tinto and Cabernet Sauvignon × Tempranillo Tinto. The chemical and sensory attributes of wines derived from both categories were evaluated. Intrinsic quality, which refers exclusively to the organoleptic properties of the wine, was scored as a single attribute and thus a holistic approach was followed [20]. This approach considers quality as an integrated percept [21]. This is supported by the fact that perceived quality is the result of the integration of sensory stimuli (visual, olfactory, taste, trigeminal somatosensory and thermal perception) rather than the sum of individual discrete sensations. In this context, we hypothesised that small berry genotypes would generate wines with sensory properties driving higher perceived quality, regardless of vintage or genetic background.

MATERIALS AND METHODS

Plant material and agronomic evaluation

Twenty and twenty-six intraspecific hybrids were selected according to their berry size among two and one wine-grape populations in 2017 and 2018, respectively. Both F_1

populations were obtained from controlled crosses between Tempranillo Tinto (VIVC:12350) (male parent) and Garnacha Tinta (VIVC 4461) (female parent) with 130 plants and between Tempranillo Tinto (male parent) and Cabernet Sauvignon (VIVC 1929) (female parent) with 80 plants. Since 2003, both progenies (one plant per genotype) had been grown on their own roots; first flowering and fruiting in 2007, as described in Song et al. [22]. Both populations had been previously genotyped for SSRs and SNP markers in order to discard individuals resulting from self-pollinations and foreign pollen sources.

Ripening date was set at technological maturity (23.4 ºBrix) by measuring 10 berries randomly taken from both sides of the vine. Mean berry weight (BW, g) of each genotype was calculated at harvest by sampling 200 berries from representative clusters. A set of 110 berries were squeezed and Total Soluble Solids (TSS) expressed as Brix degree were determined with an Atago Master-Baume refractometer (Atago, Tokio, Japan); pH and titratable acidity (g L^{-1} tartaric acid) were measured with a TitroMatic 1S-1B (Crison, Barcelona, Spain). Three sets of 30 berries per plant were frozen at -20 ºC to determine berry morphology. Berry length (BL, mm) and berry diameter (BD, mm) were measured with a Mitutuyo digital calibre. Berry shape coefficient (BS) was calculated as the ratio between length and diameter [14].

Selection of genotypes was based on data from three previous vintages. Genotypes with berry weights less than 1.5 g with diameters and lengths less than 14 mm constituted the small berry size. Large berry size was characterised by weights greater than 2 g with diameters and lengths greater than 16 mm. As a result, in 2017, 11 genotypes were selected as small berry size from the pool of both populations with 4 from a Garnacha × Tempranillo progeny and 7 from the Cabernet × Tempranillo population, whereas large berry genotypes were all selected from Garnacha × Tempranillo progeny. In 2018 the analysis was performed only in the Garnacha × Tempranillo offspring because it was the worst-case scenario being that the average berry size was larger and the average anthocyanin content was lower. Fourteen and 12 genotypes matched the criteria of small and large berry sizes, respectively both within the Garnacha × Tempranillo population.

Vinifications

In two consecutive vintages, microvinifications of each category, small (SMB) and large (LGB) berries, were elaborated in duplicate; Tempranillo and Garnacha in triplicate. Grapes from each sample (10 kg for each berry size group, 25 kg for parents) were destemmed, crushed, and vinified in the Instituto de Ciencias de la Vid y del Vino experimental winery (Logroño, Spain) and vinifications were performed as detailed in Manso-Martínez et al.[17]

Physicochemical characterization of wines

Official OIV practices [23] were used to assess oenological traits. By an accredited laboratory, in accordance with standard UNE-EN ISO/IEC 17025 (Estación Enológica de Haro, La Rioja, Spain), reducing sugars (RS, g L^{-1}), malic acid (MA, g L^{-1}), free dioxide sulphur (Free SO2, mg L^{-1}), volatile acidity (VA, g L^{-1} of acetic acid), % ethanol (% Eth, v / v), pH, titratable acidity (TA, g L^{-1} of tartaric acid), anthocyanin content (ANT, mg L^{-1}), total polyphenolic index (TPI), colour intensity (CI), and CIELAB coordinates whose values correspond to the degree of wine lightness (L_{10}*) and the degree of red (when a_{10}* > 0), green (when a_{10}* < 0), yellow (when b_{10}* > 0), and blue colour (when b_{10}* < 0) were analysed [24].

Sensory characterisation of wines

In random and distinct arrangements, panellists were given twenty millilitres of each sample covered with plastic Petri dishes (labelled with 3-digit random codes) in clear glasses to evaluate quality; in black glasses for descriptive analysis. Evaluations, recorded on paper, were carried out by unpaid panellists in individual tasting booths in a ventilated, air-conditioned, tasting room. Samples were served at room temperature (approximately 20 ºC). Panellists rinsed with water and pectin solution (1 g L^{-1}) between samples to minimize carry over effects as described by Colonna et al.[25]

Wine quality judgement

Twenty winemakers from La Rioja (Spain) (11 women, average age of 45 years, 5-35 years of experience in wine tasting) participated in the study. Each participant evaluated the overall intrinsic quality of 10 wines each year in one session (average 50 min). They were instructed to place the samples in a 15 cm-non-structured continuous scale according to their global quality perception based on visual, olfactory, and in-mouth cues. They tasted all samples and were firstly instructed to identify the two samples representing the extremes in the sample set (highest and lowest quality). The relative degrees of quality of the remaining samples were ranked and scored with distances from the extremes.

Descriptive analysis

Seventeen participants (12 women, average age of 24 years) were selected to carry out the final descriptive session of wines based on their performance during training. They attended 5 sessions, 1.5 hours each, throughout a three-week period in February 2018 and

2019. The training consisted of four training sessions and one session to describe the wines using Rate-all-that-apply (RATA) methodology [26] as fully detailed in Manso-Martínez et al.[17]. Shortly, trained panellists were asked to firstly evaluate aroma terms by directly smelling (i.e., orthonasal olfaction) and to rate the intensity of the terms that applied to the sample on a seven-point (1 = not intense; 7 = very intense). Similarly, and in a second step, they were instructed to taste each sample and evaluate taste and trigeminal attributes. A total of 22 aroma (red, black, white, tropical and dried fruits, citric, floral, spicy, liquorice, roasted, smoked, vanilla, vegetal, fresh and dried grass, cooked vegetables, balsamic, reduction, alcohol, oxidation, mushroom/earthy, leather), three taste (sweet, bitter, sour) and three (body, alcohol, astringency) trigeminal terms conformed the list of attributes. A value of 0 was attributed by the experimenter to the terms that were not considered to apply to the sample. The attributes in the list were presented in a random order, different for each assessor, to avoid primacy biases.

Statistical analysis

One-way ANOVAs were calculated on variables to evaluate differences among SMB and LGB categories and parents. To find discriminant sensory attributes for the wines, two-way ANOVAs (panellists as random and wines as fixed factors) were calculated for the 28 terms and the four wines (Tempranillo, Garnacha, SMB, LGB). To evaluate the differences between SMB and LGB two-way ANOVAs (panellists as random and wines as fixed factors) were calculated with the 28 terms and these two groups. Pair-wise comparisons (Fischer test) were applied (5% risk) to the discriminant terms found in at least one of the vintages to detect significant effects.

Two principal Component Analyses (PCA), one for each vintage, were calculated with mean ratings (averaged across panellists) of the significant sensory descriptors for all the samples. The effect of vintage and wines was evaluated with a three-way ANOVA (participants as random, wines and vintage as fixed factors and second order interactions) followed by a Student–Newman–Keuls post-hoc pairwise comparison (95%) test. All analyses were carried out with SPSS 25, XLSTAT and SPAD software (version 5.5, CISIA-CESRESTA, France).

RESULTS AND DISCUSSION

Berry morphology and grape juice characterisation

The influence of berry size on wine chemical and sensory parameters was evaluated for parents and SMB and LGB groups, as previously described. SMB and LGB did not share the same genotypes in either year, only one genotype was collected in both years for SMB; whilst for LGB, 50% of the samples were common to both vintages. In 2018 the study was carried out only with genotypes from the Garnacha × Tempranillo population, so SMB resulted of a greater size due to the Garnacha parent (1.24 ± 0.36 g in 2017 and 1.55 ± 0.35 g in 2018). This approach was taken in order to assess the effect of the worst-case scenario in terms of berry size; therefore, enhancing the relevance of berry size selection per se, regardless genetic background.

In both years, berry parameters were significantly different among categories with the exception of berry shape (Table 1). Parental varieties showed intermediate values compared to both categories with the exception of berry shape; Garnacha presented the most elongated berries while Tempranillo and SMB genotypes had the roundest. Berry weight from SMB was significantly different from Garnacha, Tempranillo, and LGB.

Given that the Cabernet Sauvignon parent could not be evaluated and 7 out of the 11 small berry size genotypes proceeded from a Cabernet Sauvignon × Tempranillo progeny in 2017, values obtained from the literature were used for comparison. Gil et al.[4], reported mean berry weight values of 1.4 g for Cabernet Sauvignon grapes, lower berry weight than either Garnacha or Tempranillo; similar to the SMB category in the present study.

For must parameters in 2018 smaller berries retained more acidity than larger ones which was similar to that found by Gil et al.[4] and Barbagallo et al.[15]. In both years, Garnacha presented higher titratable acidity than Tempranillo, whilst Holt et al. [9] reported similar pH (3.4 - 3.6) and titratable acidity (4.5 - 5.2 g L^{-1}) values in Cabernet Sauvignon compared to Tempranillo. In 2017, small berry group showed greater differences respect to Tempranillo or Garnacha than 2018, possibly due to the presence of the genetic background of Cabernet Sauvignon in the sample pool, which meant that genetic determinism seemed to have a great influence on traits related with berry size and must.

Physicochemical characteristics

Wine composition parameters for both vintages are shown in Table 2, reproducibility of replicated tanks was confirmed based on physicochemical variables (Supplementary Fig. A.1), therefore averaged data are presented. Larger differences were detected in 2017 likely due to Cabernet Sauvignon background influence. In both years, LGB generated wines with consistently higher malic acid content similar to that of Friedel et al.[5] Smaller berries present inherently less malic acid probably due to higher malic respiration during maturation. Titratable acidity was higher in LGB wines, as was also observed in juice samples from LGB group in 2018; presumably because tartaric acid is accumulated mainly in flesh while content in skin is negligible. Consequently, larger berries should have higher content even though a dilution effect may also be present [27]. LGB wines also presented lower levels of reducing sugars and ethanol content than the small-berry wines in 2017, which is similar to that found by Friedel et al.[5], Melo et al.[27], in which smaller berries had higher sugar content yielding wines with more ethanol.

In both vintages SMB wines presented higher anthocyanin content, TPI, and deeper colour than LGB wines. A significant correlation between anthocyanin content and berry size has been widely reported [27,28] due to higher skin/pulp ratios of smaller berries, hence, higher accumulation of phenolic compounds. Tempranillo showed higher TPI, CI and anthocyanin content than Garnacha, whose values were lower than in both SMB and LGB categories (Table 2). Holt et al. [9] and Gil et al.[4] found Cabernet Sauvignon to present total phenolic index values of 50 - 60 and anthocyanin contents of 400 - 600 mg $^{-1}$L, similar to the values found for Tempranillo in the present research.

Anthocyanins are responsible for young wine colour [29]. Herein CI increased when anthocyanidins increased, and the Hue value (calculated as the ratio of Absorbance at 420 nm-yellow to 520 nm-red) also decreased slightly, as happening in wines derived from small berries in 2018 and in Tempranillo both years, indicating a higher contribution of the red component to the CI in this category as reported by Gil et al.[4] and Melo et al.[27].

The traits with the greatest environmental influence were pH, titratable acidity and those related to colour. Garnacha wines seemed to be less influenced by weather conditions than Tempranillo. Anthocyanidin content of Tempranillo was particularly high in 2017 possibly due to the fact that 2017 was warmer and drier than 2018, as reported Ferrer Gallego et al. [30]. In Garnacha, volatile acidity was higher in 2018. These results showed that traits as titratable acidity and pH, seemed to be more influenced by environmental factors, others as anthocyanidins content or volatile acidity by genotype * environment interaction, and others as reduction sugar and alcoholic content were higher in wines from small berries when warmer and drier environmental conditions.

Sensory characterisation of wines

Wine quality judgement

The expert panel quality scores for wines elaborated in 2017 and 2018 are presented in Fig. 1. Quality ranges of very low/low (1.2 ± 0.1) correspond to Garnacha while high/very high perceived quality (8.1 ± 0.3) was achieved by Tempranillo in both vintages. Wines made from LGB genotypes presented lower perceived quality in both vintages compared to wines made from SMB (Fig. 1). The consistency between years reflects the correlation between berry size and wine intrinsic quality perceived by wine professionals independent of weather conditions or genetic background. The LGB genotypes in 2018 were selected from the Garnacha × Tempranillo population with lower genetic variability for berry size. Tempranillo cv. presented the highest perceived quality scores in both years. Due to the fact that Cabernet Sauvignon wines were not available, we could not assess how they would have affected the sensory evaluation of SMB wines in 2017 which, without them, received a higher perceived quality score.

Descriptive analysis

From the sensory descriptions of the trained panel, nine and six sensory attributes differed statistically among the Tempranillo, Garnacha, SMB and LGB wines ($p < 0.05$) between 2017 and 2018, respectively (Table 3). According to ANOVA these attributes were “alcoholic aroma”, “liquorice” and “astringency” in both years, and “cooked vegetables”, "fresh grass", "white fruit", "roasted", "vegetal" and "oxidation" in 2017, and "dried grass", "reduction" and "sweetness" in 2018. The attributes that differed among the wines (Table 3) were represented in a PCA for each year (Fig. 2) together with perceived quality scores.

Fig. 2.A. contains the sensory profile of the 2017 wines. Total variance of 78% was explained by the first two principal components. The four groups of samples were separately projected highlighting their distinct sensory profiles. Tempranillo was mainly characterised by its fruity character ("white fruit") and high a*/b* ratio, which suggests that the colour of Tempranillo wines was mainly red with low yellow nuances. Garnacha samples presented high L*, thus high lightness (or low darkness in terms of colour), and in general presented low scores in all aroma descriptors. The high- and low-perceived quality scores for Tempranillo and Garnacha samples, respectively, could be due to colour properties, because Spanish experts, in absence of evident aroma defaults, consider colour to be an important cue driving wine quality, which is well in accordance with previous studies carried out with wine professionals from Rioja area [21].

High a*/b* ratios and low L* have already been related to high quality perception of young red wines [21]. The LGB wines were described with terms such as "cooked vegetables", "fresh grass", "vegetal" and "alcoholic", which are generally considered to be defect nuances. The SMB wines were projected on the opposite side of the plot and linked to positive liquorice aroma and higher astringency, which has already been linked to high perceived quality exemplars by wine experts [31].

The PCA results (Fig. 2.B) show that the two first principal components accounted for 92% of the total variance, and PC1 distinguished Garnacha from the rest of the samples. Garnacha presented high lightness, together with reductive notes, which most likely determined their low-perceived quality score. Generally, reduction was attributed to a lower polyphenolic content, thus a higher tendency to generate aldehydes linked to oxidation nuances in wine [32]. In the upper side of the plot, LGB wines were mainly associated with alcoholic aroma nuances and presented low scores for the rest of attributes, which suggests that even though these wines presented no aroma default, they were scored low in perceived quality due to their lack of positive attributes. Distinctly, TE and SMB samples were projected close together with higher sweetness and perceived quality scores.

In the PCA, the perceived quality arrow is located in both vintages opposite to lightness (L*), confirming the results of the correlation analysis (Table 2). Thus, lightness, % ethanol, volatile acidity were negatively correlated ($r = -0.9$, $p < 0.01$) to perceived quality scores, while anthocyanin content, colour index, and TPI were positively correlated ($r = 0.9$, $p < 0.01$), similar to previous studies [21].

Fig. 3 illustrates the sensory profiles of SMB and LGB wines, interestingly SMB wines presented significantly higher positive aroma nuances scores and mouthfeel sensations related to “red fruits” ($F = 10.91$, $p < 0.01$) and “astringency” ($F = 42.90$, $p < 0.001$) in year 2017 (Fig. 3.A), and to “white fruits” ($F = 3.51$, $p < 0.1$) and “sweetness” ($F = 5.06$, $p < 0.05$) in the 2018 vintage (Fig. 3.B). Sensory data revealed that SMB and Tempranillo wines presented similar characteristics in both vintages; sharing adequate “astringency” and “dried fruit” notes in 2017 and “sweetness” and fruity notes in 2018.

The LGB wines were characterised by “fresh grass”, “cooked vegetables” and “vegetal” notes in 2017 (Fig. 3.A) and were alcoholic in nose in 2018 (Fig. 3.B). “Cooked vegetables” is considered to be an off-flavour present in oxidised wines[33] which can trigger aroma deterioration, loss of citric and fresh aromas among others[32]. The LGB wines were perceived to be more alcoholic due to the absence of other aromas.

Compared to the SMB wines, the lower phenolic content present in both vintages of LGB made these wines more susceptible to oxidation [34], and could be related, among other reasons to the higher yield presented by these vines in 2017 (data not shown). “Vegetal aromas” are commonly related to high productivity values [35] which could have promoted the low-perceived quality scores obtained for LGB wines. Melo et al.[27] found that Syrah wines made from larger berries were described as watery; similar to the higher alcoholic perception due to dilution of aroma compounds detected in the present study.

Interactions between vintage and wine samples

Table 4 shows the vintage, wine, and vintage * wine interactions of the statistically different sensory attributes in ANOVA test (table 2). Wines from 2017 resulted more alcoholic in nose due to warmer weather conditions, while “white fruit” perception (normally associated to Tempranillo variety) and sweetness were higher in 2018 (Supplementary Fig. B.1). Wine * vintage interactions were found for the most of parameters, except reduction, alcoholic and white fruit. Garnacha gave higher values for “liquorice” in 2018 and Tempranillo for “astringency”, “oxidation” and “cooked vegetables” in 2017 vintage (Supplementary Fig. B.1). The performance of SMB and LGB groups could not be assessed for vintage since samples integrating each group varied with years.

CONCLUSIONS

This is the first study addressing the influence of berry size on wine quality by comparing wines derived from intraspecific hybrids differing in berry weight. Results confirm our initial hypothesis that small berry size was a main driver of quality judgements carried out by wine professionals independently of the vintage, environmental conditions, and genetic backgrounds. SMB wines consistently reached higher phenolic and anthocyanin contents, deeper colour, and higher sensory scores. Despite differences in genetic background, all SMB wines were characterised with higher “sweetness”, “astringency”, and “fruity” notes compared to LGB wines, which were perceived as more “alcoholic” and to contain some off-flavours such as “cooked vegetables” notes in the sensorial analysis. The fact that the two berry-size categories originated from different genotypes in both vintages strengthened the conclusion of the study. Even within the worst-case scenario, when selection was made among Garnacha offspring, being the larger-berry sized and lower anthocyanin content parental compared to Cabernet-Sauvignon, SMB wines were perceived as higher quality exemplars. These results could be useful to design selection strategies in the vineyard in order to diversify wine styles.

ACKNOWLEDGEMENTS

Financial support from Viveros Provedo and ADER 2017_IDD_I_00041 is gratefully acknowledged. CM-M thanks the Spanish MINECO for her predoctoral (FPI-BIO2014-59324-R) The authors thank Purificación Fernández-Zurbano, Sara Ferrero, Cristina Pesquera, Isis Pinilla, and Juan Carlos Ezquerro for support in wine making and sensory panel organization. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Cristina Manso-Martínez: Conceptualization, Investigation, Methodology, Data curation, Writing- Original draft preparation. **María Pilar Sáenz-Navajas**: Methodology, Validation, Writing - Review & Editing. **Cristina M. Menéndez**: Conceptualization, Methodology, Writing - Review & Editing, Supervision, **María M Hernández**: Visualization, Investigation, Writing - Review & Editing**,** Funding Adquisition, Supervision**.**

REFERENCES

1 FAO. The future of food and agriculture: Trends and challenges (Online). Food and Agriculture Organization of the United Nations (2017). Available: http://www.fao.org/3/a-i6583e.pdf

2 OIV. State of the Vitiviniculture World Market April 2018. International Organisation of Vine and Wine (2018).

3 Wong DCJ, Lopez Gutierrez R, Dimopoulos N, Gambetta GA, Castellarin SD. Combined physiological, transcriptome, and cis-regulatory element analyses indicate that key aspects of ripening, metabolism, and transcriptional program in grapes (*Vitis vinifera* L.) are differentially modulated accordingly to fruit size. *BMC Genomics* **14**:416 (2016).

4 Gil M, Pascual O, Gómez-Alonso S, García-Romero E, Hermosín-Gutiérrez I, Zamora F, et al. Influence of berry size on red wine colour and composition. *Aust J Grape Wine Res* **21**:200–212 (2015).

5 Friedel M, Sorrentino V, Blank M, Schüttler A. Influence of berry diameter and colour on some determinants of wine composition of *Vitis vinifera* L. cv. Riesling. *Aust J Grape Wine Res* **22**:215–225 (2016).

6 Xie S, Tang Y, Wang P, Song C, Duan B, Zhang Z, et al. Influence of natural variation in berry size on the volatile profiles of *Vitis vinifera* L. Cv. Merlot and Cabernet Gernischt grapes. *PLoS One* **13**: e0201374 (2018).

7 Gil M, Úbeda C, del Barrio-Galán R, Peña-Neira, A. Impact of berry size at harvest on red wine composition: A winemaker's approach. *J Sci Food Agr* **100**: 836–845 (2020).

8 Roby G, Harbertson JF, Adams DA, Matthews MA. Berry size and vine water deficits as factors in winegrape composition: Anthocyanins and tannins. *Aust J Grape Wine Res* **10**:100–107 (2004).

9 Holt HE, Francis IL, Field J, Herderich MJ, Iland PG. Relationships between berry size, berry phenolic composition and wine quality scores for Cabernet Sauvignon (*Vitis vinifera* L.) from different pruning treatments and different vintages. *Aust J Grape Wine Res* **14**:191–202 (2008).

10 Van Leeuwen C, Destrac-Irvine A, Ollat N. Modified grape composition under climate change conditions requires adaptations in the vineyard. *J Int Res Sci Vigne Vin* **51**:147–154 (2017).

11 Dai ZW, Ollat N, Gomès E, Decroocq S, Tandonnet JP, Bordenave L, et al. Ecophysiological, genetic, and molecular causes of variation in grape berry weight and composition: A review. *Am J Enol Vitic* **62**:413–425 (2011).

12 Keller M. The Science of Grapevines. The Science of Grapevines. Elsevier Inc.;

(2010).

13 Tarter ME, Keuter SE. Effect of rachis position on size and maturity of Cabernet Sauvignon berries. *Am J Enol Vitic* **56**:86–89 (2005).

14 Houel C, Martin-Magniette ML, Nicolas SD, Lacombe T, Le Cunff L, Franck D, et al. Genetic variability of berry size in the grapevine (*Vitis vinifera* L.). *Aust J Grape Wine Res* **19**:208–220 (2013).

15 Barbagallo MG, Guidoni S, Hunter JJ. Berry Size and Qualitative Characteristics of *Vitis vinifera* L. cv. Syrah. *South African J Enol Vitic* **32**:129–136 (2016).

16 Wolkovich EM, García de Cortázar-Atauri I, Morales-Castilla I, Nicholas KA, Lacombe T. From Pinot to Xinomavro in the world’s future wine-growing regions. *Nat Clim Change* **8**:29–37 (2018).

17 Manso-Martínez C, Sáenz-Navajas MP, Hernández MM, Menéndez CM. Sensory profiling and quality assessment of wines derived from Graciano × Tempranillo selections. *LWT - Food Sci Technol* **127**:109394 (2020).

18 Lago-Vanzela ES, Rebello LPG, Ramos AM, Stringheta PC, Da-Silva R, García-Romero E, et al. Chromatic characteristics and color-related phenolic composition of Brazilian young red wines made from the hybrid grape cultivar BRS Violeta (“BRS Rúbea”×"IAC 1398-21"). *Food Res Int* **54**:33–43 (2013).

19 Biasoto ACT, Netto FM, Marques EJN, Da Silva MAAP. Acceptability and preference drivers of red wines produced from *Vitis labrusca* and hybrid grapes. *Food Res Int* **62**:456–466 (2014).

20 Hopfer H, Heymann H. Judging wine quality: Do we need experts, consumers or trained panelists? *Food Qual. Prefer.* **32**:221-233 (2014).

21 Sáenz-Navajas MP, Avizcuri JM, Echávarri JF, Ferreira V, Fernández-Zurbano P, Valentin D. Understanding quality judgements of red wines by experts: Effect of evaluation condition. *Food Qual Prefer*. **48**:216–27 (2016).

22 Song S, Hernández MM, Provedo I, Menéndez CM. Segregation and associations of enological and agronomic traits in Graciano × Tempranillo wine grape progeny (*Vitis vinifera* L.). *Euphytica* **195**:259–277 (2014).

23 OIV, Compendium of internationals methods of wine and must analysis. International (Online) Organisation of Vine and Wine, Paris. (2003). Available: http://www.oiv.int/en/technical-standards-and-documents/methods-of-analysis/compendium-of-international-methods-of-analysis-of-wines-and-musts-2-vol. Accessed 31 May 2020.

24 Ayala F, Echávarri JF, Negueruela AI. A new simplified method for measuring the color of wines. I. Red and rose wines. *Am J Enol Vitic* **48**:357–63 (1997).

25 Colonna AE, Adams DO, Noble AC. Comparison of procedures for reducing astringency carry-over effects in evaluation of red wines. *Aust J Grape Wine Res* **10**:26–31 (2010).

26 Ares G, Bruzzone F, Vidal L, Cadena RS, Giménez A, Pineau B, et al. Evaluation of a rating-based variant of check-all-that-apply questions: Rate-all-that-apply (RATA). *Food Qual Prefer* **36**:87–95 (2014).

27 Melo MS, Schultz HR, Volschenk CG, Hunter JJ. Berry Size Variation of *Vitis vinifera* L. cv. Syrah: Morphological Dimensions, Berry Composition and Wine Quality. *South African J Enol Vitic* **36**:1–10 (2016).

28 Mirás-Avalos JM, Buesa I, Yeves A, Pérez D, Risco D, Castel JR, et al. Unravelling

the effects of berry size on 'Tempranillo' grapes under different field practices. *Ciência Técnica Vitivinícola* **34**:1–14 (2019).

29 He F, Mu L, Yan GL, Liang NN, Pan QH, Wang J, Reeves MJ, Duan CQ. Biosynthesis of anthocyanins and their regulation in coloured grapes. *Molecules,* **15**: 9057-9091 (2010).

30 Ferrer-Gallego R, Hernández-Hierro J M, Rivas-Gonzalo JC, Escribano-Bailón MT. Influence of climatic conditions on the phenolic composition of *Vitis vinifera* L. cv. Graciano. *Anal Chim Acta* **732**: 73–77 (2012).

31 Sáenz-Navajas MP, Ballester J, Pêcher C, Peyron D, Valentin D. Sensory drivers of intrinsic quality of red wines. Effect of culture and level of expertise. *Food Res Int*. **54**:1506–18 (2013).

32 Bueno M, Carrascón V, Ferreira V. Release and Formation of Oxidation-Related Aldehydes during Wine Oxidation. *J Agric Food Chem* **64**:608–617 (2016).

33 Escudero A, Hernández-Orte P, Cacho J, Ferreira V. Clues about the role of methional as character impact odorant of some oxidized wines. *J Agric Food Chem.* **48**:4268–72 (2000).

34 Gambuti A, Siani T, Picariello L, Rinaldi A, Lisanti MT, Ugliano M, et al. Oxygen exposure of tannins-rich red wines during bottle aging. Influence on phenolics and color, astringency markers and sensory attributes. *Eur Food Res Technol* **243**:669–680 (2017).

35 García-Muñoz S, Muñoz-Organero G, Fernández-Fernández E, Cabello F. Sensory characterisation and factors influencing quality of wines made from 18 minor varieties (*Vitis vinifera* L.). *Food Qual Prefer* **32**:241–52 (2014).

Table 1. Berry and must parameters of selections with small (SMB) and large (LGB) berry size in 2017 and 2018 vintages

	Vintage 2017								**Vintage 2018**							
	N	**SMB**	**N**	**LGB**	**N**	**GAR**	**N**	**TE**	**N**	**SMB**	**N**	**LGB**	**N**	**GAR**	**N**	**TE**
BL	11	13.3±1.10**a	9	16.1 ± 1.2b	3	17.12 ± 0.23b	4	15.40±0.61b	14	13.92 ± 1.26**a	12	15.7 ± 0.70b	3	15.64 ± 1.68b	4	14.08 ± 1.18ab
BD	11	13.2 ± 1.20*a	9	15.8 ± 1.0b	3	15.62 ±0 .21b	4	15.19 ±0.47b	14	14.18 ± 1.3**a	12	15.79 ± 0.79b	3	14.47 ± 1.28ab	4	14.47 ± 0.73a
BS	11	1.01 ± 0.04*a	9	1.02 ± 0.02a	3	1.10 ± 0.00b	4	1.01 ± 0.01a	14	0.98 ± 0.04*b	12	1.00 ± 0.03b	3	1.08 ± 0.03a	4	0.97 ± 0.04b
BW	11	1.24±0.36**a	9	2.04 ± 0.36b	3	2.01 ±0.29b	4	1.72 ± 0.35b	14	1.55 ± 0.35**a	12	2.06 ± 0.26b	3	1.79 ± 0.37ab	4	1.62 ± 0.30a
ºBrix	11	22.96 ± 2.62	9	23.11±1.90	3	24.43 ±1.405	4	24.16 ± 2.23	14	22.67 ± 1.62*a	12	23.09 ± 1.95a	3	24.33 ± 1.39b	4	23.52 ± 2.05ab
pH	11	3.18 ± 0.71ab	9	3.32±0.73ab	3	3.27 ±0.08b	4	3.55 ± 0.23a	14	3.25 ± 0.62*a	12	3.30 ± 0.62a	3	3.26 ± 0.09a	4	3.58 ± 0.19b
TA	11	4.98 ± 1.69ab	9	4.77±1.52ab	3	6.17 ±1.00b	4	4.84 ± 0.76a	14	4.83 ± 1.56*a	12	5.34 ± 1.31b	3	5.36 ± 1.60ab	4	4.30 ± 0.93a

** reflect statistical differences at 0.01 level, * at 0.05. BL berry length, BD berry diameter, BS berry shape, BW berry weight, TA titratable acidity (g L^{-1} of tartaric acid)

Table 2. Composition and colour of wines made from small berry (SMB), large berry (LGB) hybrid genotypes and Garnacha Tinta (GAR) and Tempranillo Tinto (TE) parents for 2017 and 2018 vintages. Means ± SD (calculated for duplicate tanks in hybrids and triplicate in parents) and ranges for chemical and colour parameters. Spearman correlation coefficient with the sensorial quality.

	Vintage 2017						**Vintage 2018**					
	SMB	**LGB**	**GAR**	**TE**	**Range**	**Quality**	**SMB**	**LGB**	**GAR**	**TE**	**Range**	**Quality**
MA (g L^{-1})	1.3 ± 1.3a	3.3 ± 0.0b	2.4 ± 0.0ab	3.3 ± 0.1b	1.3-3.3	0.73**	3.2 ± 0.0b	3.4 ± 0.1c	2.8 ± 0.1a	3.4 ± 0.1c	2.8-3.4	0.82**
TA (g L^{-1})†	5.1 ± 0.7a	6.0 ± 0.0b	4.6 ± 0.1a	5.7 ± 0.1b	4.6-6.0	-0.22*	6.7 ± 0.0	6.7 ± 0.1	7.0 ± 0.1	7.0 ± 0.2	6.7-7.0	-0.42
RS (g L^{-1})	2.9 ± 0.1b	2.1 ± 0.1a	2.7 ± 0.2b	2.9 ± 0.1b	2.1-2.9	0.15	2.0 ± 0.0	2.3 ± 0.3	2.1 ± 0.0	2.5 ± 0.3	2.0-2.5	0.29
% ETH (v/v)	13.5 ± 0.2b	13.0 ± 0.1a	13.4 ± 0.0b	15.0 ± 0.1c	13.0-15.0	-0.77*	12.3 ± 0.0a	12.8 ± 0.3b	14.2 ± 0.1c	13.0 ± 0.1b	12.3-14.2	-0.75*
VA (g L^{-1}) ‡	0.3 ± 0.1a	0.4 ± 0.0b	0.2 ± 0.0a	0.3 ± 0.0a	0.2-0.4	-0.43*	0.2 ± 0.0a	0.3 ± 0.0a	0.8 ± 0.1c	0.5 ± 0.1b	0.2-0.8	-0.73*
FSO$_2$ (mg L^{-1})	34.5 ± 2.1c	27 ± 1.4b	21.3 ± 1.5a	21 ± 1.7a	21.0-34.5	0.65**	29.5 ± 5.0b	24.0 ± 1.4b	10.3 ± 0.6a	22.7 ± 1.5b	10.3-29.5	0.78**
pH	4.05 ± 0.0a	4.06 ± 0.0a	3.99 ± 0.06a	4.18 ± 0.03b	3.99-4.18	0.45	3.80 ± 0.0	3.84 ± 0.00	3.85 ± 0.02	3.83 ± 0.06	3.80-3.85	-0.32
ANT (mg L^{-1})	438 ± 21c	374 ± 19b	191.7 ± 17a	744.7 ± 31d	192-745	0.93**	442.5 ± 7c	300.5 ± 5b	193.3 ± 3a	490.7 ± 28.9c	19-491	0.91**
TPI	47.0 ± 0.3c	37 ± 1.3b	24.3 ± 1.9a	57.2 ± 0.9d	24.3-57.2	0.89**	48.2 ± 1.6c	38.5 ± 0.2b	27.6 ± 1.2a	42.8 ± 3.9bc	27.6-48.2	0.92**
L*	27.8 ± 0.1b	31.7 ± 1.8c	61.7 ± 2.dc	8.5 ± 1.7a	8.5-61.7	-0.93**	22.4 ± 0.0a	34.4 ± 0.4b	44.0 ± 0.8c	19.2 ± 3.0a	19.2-44.0	-0.94**
CI	5.0 ± 0.0b	4.4 ± 0.2b	1.8 ± 0.1a	12.2 ± 1.1c	1.8-12.2	0.92**	6.4 ± 0.1b	4.0 ± 0.1a	3.1 ± 0.1a	8.0 ± 1.1c	3.1-8.0	0.90**
HUE	0.8 ± 0.0b	0.8 ± 0.0b	1.0 ± 0.0c	0.7 ± 0.0a	0.7-1.0	-0.92**	0.7 ± 0.0b	0.8 ± 0.0c	0.9 ± 0.0d	0.6 ± 0.0a	0.6-0.9	-0.91**
a$_{10}$*/b$_{10}$*	1.9 ± 0.0a	2.1 ± 0.0ab	2.0 ± 0.2a	2.7 ± 0.3b	1.9-2.7	0.32*	1.7 ± 0.0a	2.5 ± 0.1b	1.7 ± 0.1a	1.7 ± 0.1a	1.7-2.5	-0.12

Data expressed as means ± SD (n = 2 and n = 3 for GAR and TE) and ranges. Means followed by different letters in the same column differ by LSD test ($p < 0.05$). Abbreviations: MA: malic acid, TA: titratable acidity, RS: reducing sugars, %ETH: percentage of ethanol, VA: volatile acidity, FSO_2: free dioxide sulphur, ANT: anthocyanin content, TPI: total polyphenolic index, L*: lightness, CI: colour intensity, and a^*_{10}/b^*_{10}: red/yellow. Level of significance for quality at *$p < 0.05$, **$p < 0.01$.

[†] TA expressed as g L^{-1} tartaric acid. [‡] VA expressed as g L^{-1} acetic acid.

Table 3. Two-way ANOVAs (panellists as random factor and wines as fix factors) calculated on the 28 sensory attributes of wines elaborated in 2017 and 2018 vintages.

	2017			**2018**		
	F	**p**	**Sig.**	**F**	**p**	**Sig.**
Cooked vegetables	12.81	< 0.0001	***	0.544	0.653	ns
Fresh grass	4.36	0.01	**	1.018	0.386	ns
Floral	0.77	0.51	ns	1.352	0.260	ns
Reduction	0.10	0.90	ns	8.371	< 0.0001	***
Alcoholic	3.90	0.01	**	4.997	0.002	**
White fruit	3.31	0.02	*	1.154	0.330	ns
Citric	1.34	0.26	ns	1.282	0.282	ns
Smoked	0.82	0.48	ns	0.367	0.777	ns
Dried fruit	2.54	0.06	ns	0.504	0.680	ns
Red fruit	0.10	0.90	ns	2.275	0.082	ns
Roasted	2.70	0.05	*	1.093	0.354	ns
Spiced	0.61	0.61	ns	0.672	0.570	ns
Vegetal	11.93	< 0.0001	***	0.636	0.593	ns
Tropical fruit	1.79	0.15	ns	1.541	0.206	ns
Leather	1.60	0.19	ns	2.509	0.061	ns
Black fruit	0.10	0.90	ns	1.376	0.252	ns
Dried grass	1.81	0.15	ns	2.612	0.050	*
Balsamic	2.23	0.09	ns	0.529	0.663	ns
Oxidation	3.94	0.01	**	0.259	0.855	ns
Mushroom	2.36	0.07	ns	0.746	0.527	ns
Vanilla	0.92	0.43	ns	1.192	0.315	ns
Liquorice	3.15	0.03	*	11.117	< 0.0001	***
Astringency	29.51	< 0.0001	***	3.548	0.016	*
Sourness	1.64	0.18	ns	0.279	0.840	ns
Alcoholic	1.64	0.18	ns	0.808	0.491	ns
Body	0.10	0.90	ns	0.634	0.594	ns

Bitterness	0.03	0.99	ns	0.500	0.683	ns
Sweetness	0.79	0.50	ns	11.522	< 0.0001	***

Significance at *p < 0.05, **p < 0.01, ***p < 0.001; ns, not significant.

Table 4. Two-way ANOVA calculated with wine and year as fixed factors and their interaction for descriptors with significant effect in at least one vintage.

	Wine		**Year**		**Wine * Year**	
	F	**p**	**F**	**p**	**F**	**p**
Cooked vegetables	5.445	0.001	0.135	0.713	5.747	0.001
Fresh grass	0.571	0.634	0.776	0.379	3.287	0.021
Dried grass	0.950	0.330	0.273	0.845	3.258	0.022
Vegetal	5.793	0.001	1.797	0.181	6.027	0.001
Reduction	18.061	< 0.0001	1.728	0.190	0.837	0.474
Alcoholic	4.285	0.006	13.898	0.000	1.806	0.146
Oxidation	3.455	0.017	2.799	0.095	2.987	0.031
White fruit	1.196	0.312	8.808	0.003	1.501	0.214
Liquorice	4.614	0.004	4.014	0.046	9.188	< 0.0001
Astringency	15.566	< 0.0001	73.600	< 0.0001	26.212	< 0.0001
Sweetness	8.564	< 0.0001	99.407	< 0.0001	9.353	< 0.0001

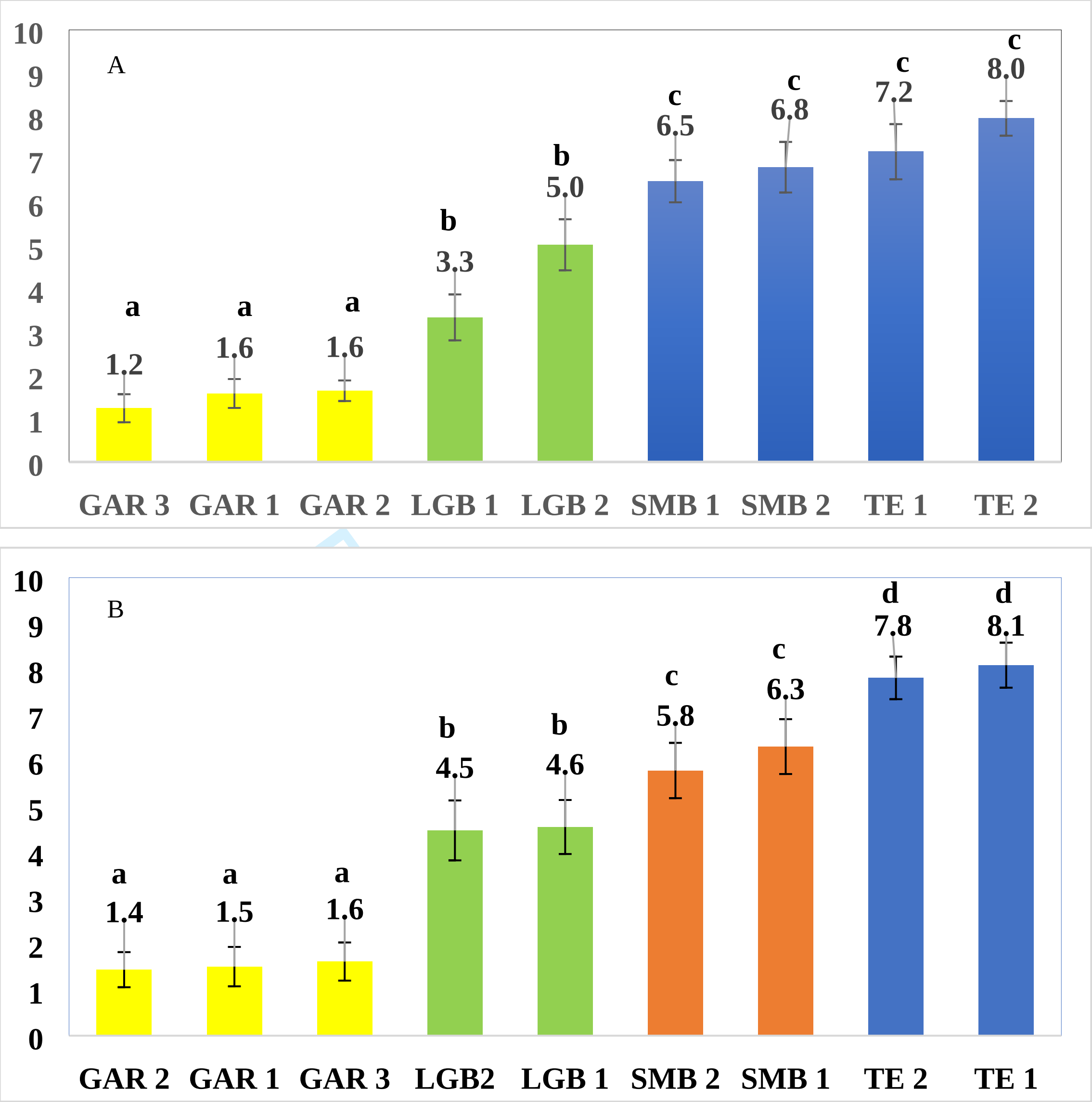
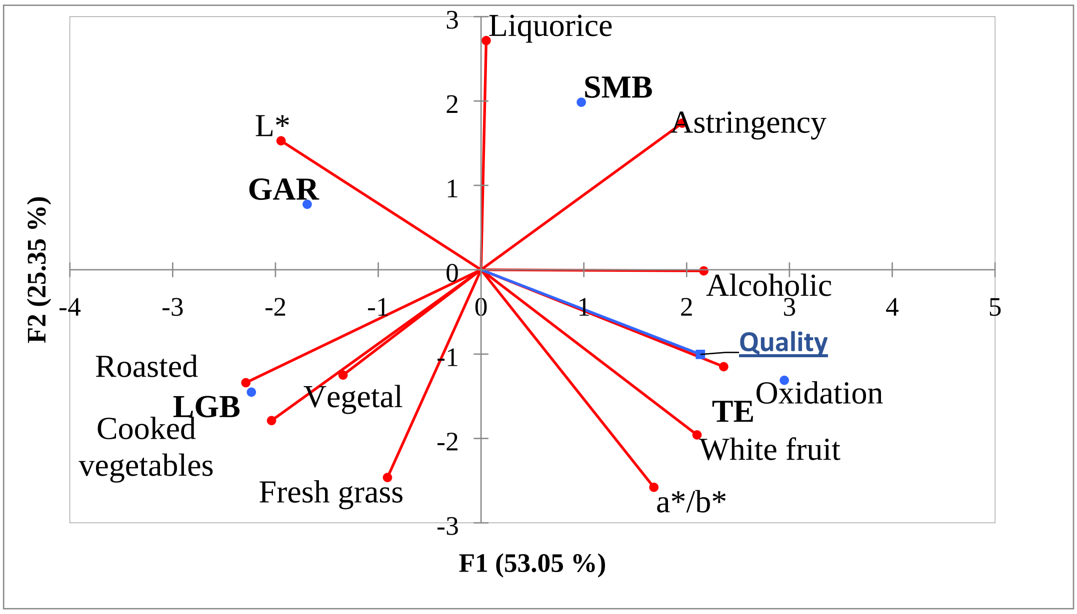
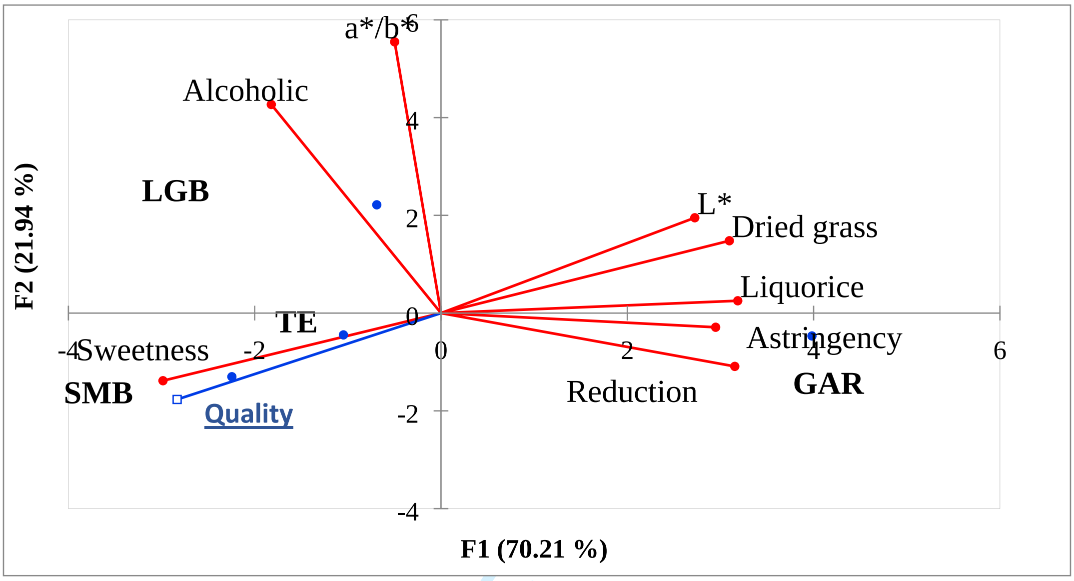

A
10
9
8
7
6
5
4
3
2
1
0
a 1.2
a 1.6
a 1.6
b 3.3
b 5.0
c 6.5
c 6.8
c 7.2
c 8.0
GAR 3
GAR 1
GAR 2
LGB 1
LGB 2
SMB 1
SMB 2
TE 1
TE 2
B
10
9
8
7
6
5
4
3
2
1
0
a 1.4
a 1.5
a 1.6
b 4.5
b 4.6
c 5.8
c 6.3
d 7.8
d 8.1
GAR 2
GAR 1
GAR 3
LGB2
LGB 1
SMB 2
SMB 1
TE 2
TE 1

Fig. 1


Liquorice
SMB
Astringency
L*
GAR
Alcoholic
Quality
Roasted
LGB
Vegetal
Oxidation
TE
Cooked vegetables
White fruit
Fresh grass
a*/b*
F2 (25.35 %)
F1 (53.05 %)
3
2
1
0
-1
-2
-3
-4
-3
-2
-1
0
1
2
3
4
5

A


a*/b*
Alcoholic
LGB
L*
Dried grass
Liquorice
TE
Sweetness
Astringency
SMB
Reduction
GAR
Quality
F2 (21.94 %)
F1 (70.21 %)
6
4
2
0
-2
-4
-4
-2
0
2
4
6

B

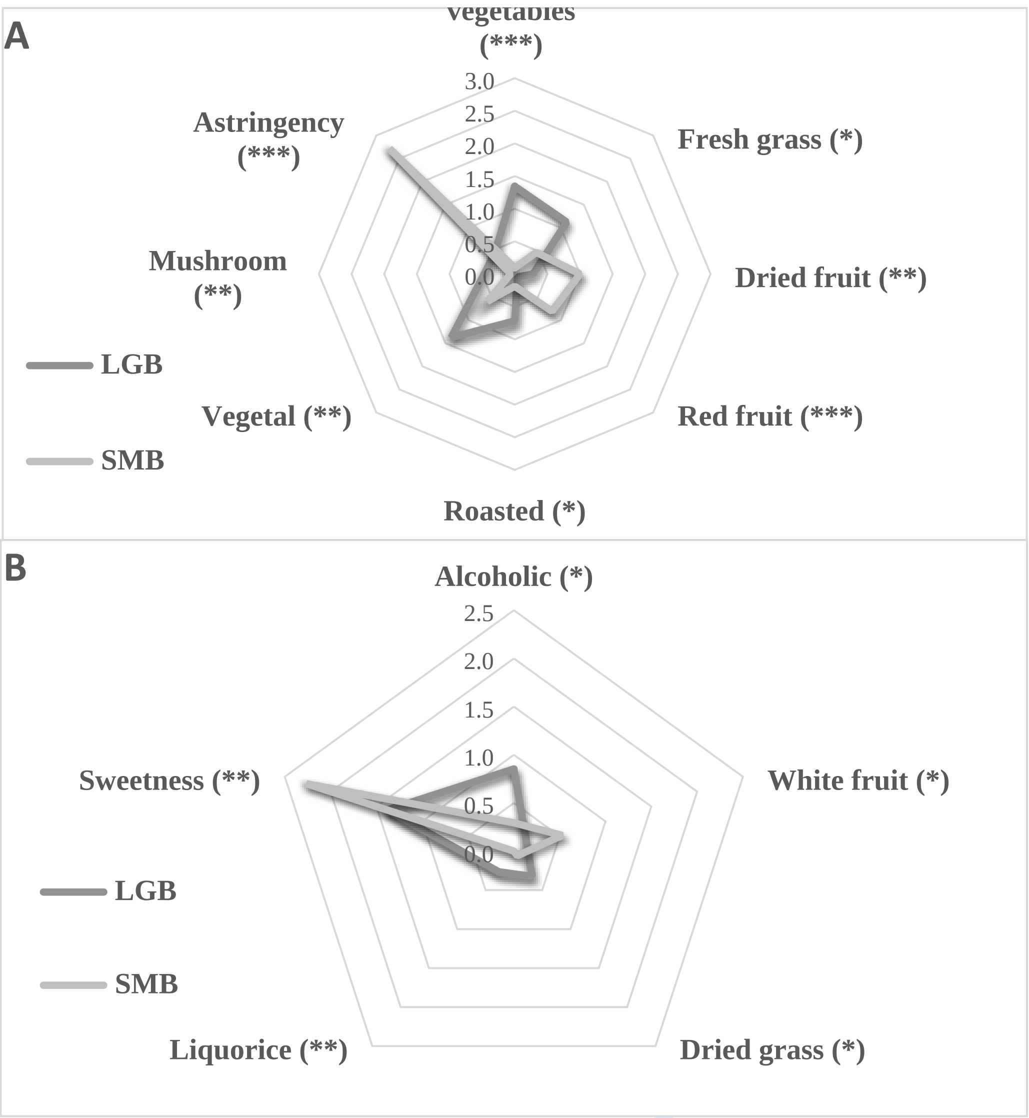

A
vegetables (***)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Fresh grass (*)
Dried fruit (**)
Red fruit (***)
Roasted (*)
Vegetal (**)
Mushroom (**)
Astringency (***)
LGB
SMB
B
Alcoholic (*)
2.5
2.0
1.5
1.0
0.5
0.0
White fruit (*)
Dried grass (*)
Liquorice (**)
Sweetness (**)
LGB
SMB

Fig. 3.

Fig. 1. Mean sensory quality scores in 2017 (A) and 2018 (B), being: small berry size (SMB) and large berry size (LGB) groups, Garnacha Tinta (GAR) and Tempranillo Tinto (TE). Error bars are calculated as standard deviation / (number of panellists)$^{0.5}$. Numbers 1 and 2 indicate replicate tanks (n = 2 for each category, n = 3 for GAR and TE). **Different letters indicate statistical differences with LSD test in quality scores at 0.05 level.

Fig. 2. Principal component analysis biplot with sensory attributes that differed between samples for each year and colour (L* and a/b) as active variables and quality scores as supplementary variable in 2017 (A) and 2018 (B).

Fig. 3. Average values of the sensory profile of wines made from SMB and LGB in 2017 (A) and 2108 (B). Significant differences according to two-way ANOVA (panellists as random and wines as fix factors) at 0.01 ***, 0.05 ** and 0.1 *.