LWT - Food Science and Technology 69 (2016) 82–90

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Sensory acceptance drivers of pre-fermentation dehydration and submerged cap red wines produced from *Vitis labrusca* hybrid grapes

Maurício B.M. de Castilhos [a, *], João Dimas Garcia Maia [b], Sergio Gómez-Alonso [c, d], Vanildo Luiz Del Bianchi [a], Isidro Hermosín-Gutiérrez [c]

[a] Bioprocess Laboratory, Engineering and Food Technology Department, São Paulo State University, São José do Rio Preto, São Paulo, Brazil
[b] Brazilian Agro-farming Research Agency EMBRAPA Grape and Wine, Jales, São Paulo, Brazil
[c] Instituto Regional de Investigación Científica Aplicada (IRICA), Universidad de Castilla-La Mancha, Avda. Camilo José Cela S/N, 13071, Ciudad Real, Spain
[d] Parque Científico y Tecnológico de Albacete, Passeo de la Innovación, 1, 02006, Albacete, Spain

ARTICLE INFO

Article history:
Received 16 June 2015
Received in revised form
20 November 2015
Accepted 14 January 2016
Available online 18 January 2016

Keywords:
Red wine
Drying
Submerged cap
Hybrid grapes
Sensory analysis
Acceptance drivers

ABSTRACT

The pre-fermentation dehydration (PD) and submerged cap (SC) treatments were evaluated as alternative winemaking for Brazilian red table wines produced from *Vitis labrusca* cultivar Bordô and hybrid cultivars Isabel, BRS Carmem and BRS Violeta. The influence of these treatments on the wine chemical profile and their contribution to sensory acceptance drivers has been evaluated. The pre-drying process tended to increase the total phenolic content (up to 1677 mg L^{-1} of gallic acid) and the dry extract of the wines (up to 47.89 g L^{-1}), considering them as full-bodied and more attractive to consumers. The univariate approach revealed slight influence of the alternative winemaking treatments on wine composition and sensory acceptance. However, PCA was successfully applied and showed that the positive effects of the pre-drying treatment on Bordô and BRS Carmem body acceptance, which was driven by acidity, dry extract and phenolic compounds. The results also suggested that submerged cap positively influenced almost all the sensory attributes of Isabel and BRS Violeta wines, which were driven by acidity and color features. The management of these winemaking processes needs to be assessed, since provides an intense acceptance for key sensory attributes considered as acceptance drivers for a target group of consumers.

1. Introduction

Brazil is considered a promising country in viticulture because of the existence of several regions that are emerging as great producers of *Vitis labrusca* grapes and their respective wines (Biasoto, Netto, Marques, & Da Silva, 2014; Lago-Vanzela et al., 2013). The wines elaborated from these grapes are known in Brazil as table wines and present a 'foxy' flavor, which is a typical feature very appreciated by Brazilian consumers (Jackson, 2008). Bordô is one of the most known table grapes in Brazil and presents high rusticity due to its high resistance to fungal diseases and powerful color, allowing its application on blends with colorless wines. Isabel cultivar is another grape with high acceptability due to the fruity juices and wines produced from this grape cultivar. However, the wines produced by this cultivar need to be blended with colorful wines in order to meet the market requirements (Maia & Camargo, 2005).

Despite the unique profile of the Brazilian table wines, *V. labrusca* grapes and their hybrids show certain disadvantages in comparison with *Vitis vinifera* grapes, such as lower soluble solids content and reduced color intensity (Camargo, Maia, & Nachtigal, 2005). Thus, new grape cultivars with high color potential and high soluble solids content in their optimal stage of ripening need to be developed in order to improve the quality of the wines produced from alternative winemaking processes by the enhancement of the anthocyanin extraction (Camargo & Ritschel, 2008).

In this context, the Brazilian Agro-farming Research Agency EMBRAPA Grape and Wine developed new cultivars with higher sugar contents and higher color indexes under normal growth conditions. 'BRS Violeta' is one of these grape cultivars and it is a result from the cross between 'BRS Rubea' and 'IAC 1398-21'

* Corresponding author. Engineering and Food Technology Department, São Paulo State University, Cristóvão Colombo Street, 2265, São José do Rio Preto, São Paulo, Brazil.
E-mail address: mbonattosp@yahoo.com.br (M.B.M. de Castilhos).

http://dx.doi.org/10.1016/j.lwt.2016.01.043
0023-6438/

presenting high sugar content (19–21 °Brix) and good color index expressed by its intense violet hue (Camargo et al., 2005). 'BRS Carmem' is another example, it was originated in 2008 from the cross between 'Muscat Belly A' and 'BRS Rubea', and produces red wines with an intense violet hue and typical raspberry aroma and flavor (Camargo & Ritschel, 2008).

The intense search for continuous improvement in Brazilian wines have promoted the application of variations in winemaking process. The grape pre-drying is one of the techniques that has been studied aiming at providing the enhancement of the phenolic extraction as a result of the irreversible damage in the grape skin caused by drying process, which transfers the phenolic compounds existent in the skin to the pulp, promoting their solubilization during the alcoholic fermentation (Marquez, Serratosa, Lopez-Toledano, & Merida, 2012).

Another variation was proposed by Bosso et al. (2011) who reported relevant results about color features and volatile compounds for Barbera wines submitted to submerged cap winemaking. It consisted in promoting the constant contact between pomace and grape juice, avoiding the pumping during the alcoholic fermentation. The aforementioned study showed that the submerged cap could enhance the phenolic extraction of the wines after soft pressing when compared to the traditional treatment.

Studies have shown interesting results about the correlation between the application of different winemaking procedures and sensory acceptance of red wines (Casassa, Bolcato, & Sari, 2015; Dooley, Threlfall, & Meullenet, 2012; Meillon et al., 2010). One study, in particular, has presented relevant results about the acceptability and preference drivers of red wines produced from hybrid grapes (Biasoto et al., 2014), which showed the high preference for wines with high sweetness and grape juice notes, as well as blackberry aroma/flavor and fruity notes, considering these features as preference drivers for these wines. In contrast, attributes such as woody, bitterness, dried fruits and vegetative notes contributed to the reduction of the wine acceptance.

In order to fulfill the lack of the studies concerning the assessment of preference drivers of red wines produced from hybrid grapes using alternative winemaking procedures, the aim of this study was to evaluate the enological and color parameters that contribute as acceptance drivers of red wines elaborated from four *V. labrusca*/hybrid grapes namely Bordô (*V. labrusca*), Isabel (*V. vinifera* × *V. labrusca*), BRS Violeta (complex hybrid from *V. labrusca*) and BRS Carmem (complex hybrid from *V. labrusca*) submitted to pre-drying and submerged cap treatments.

2. Material and methods

2.1. Wine samples

Twelve red wines were produced from three techniques: Traditional Bordô wine (TB), Pre-dried Bordô wine (PDB), Submerged Cap Bordô wine (SCB), Traditional Isabel wine (TI), Pre-dried Isabel wine (PDI), Submerged Cap Isabel wine (SCI), Traditional Violeta wine (TV), Pre-dried Violeta wine (PDV), Submerged Cap Violeta wine (SCV), Traditional Carmem wine (TC), Pre-dried Carmem wine (PDC) and Submerged Cap Carmem wine (SCC). The grapes were harvested in the city of Jales (20° 16′ 7″ South and 50° 32′ 58″ West), São Paulo state, Brazil, at their usual complete maturity levels and good sanitary conditions.

All the treatments followed the standard winemaking procedure described by De Castilhos, Cattelan, Conti-Silva, and Del Bianchi (2013). The wines were treated with 150 ppm of potassium metabisulfite (approximately 86.2 ppm of SO_2) and alcoholic fermentation was induced by inoculation with active dry *Saccharomyces cerevisiae* Y904 (Amazon Group®) in the proportion of 200 ppm. The submerged cap treatment provided the effect of the constant maceration of the grape's solid parts by using stainless steel screens. The screen was carefully placed inside the fermentation vessel involving all the solid part and dipping it into the must. The stainless steel screen was arranged in a way that its friction with the walls of the fermentation vessel was sufficient to inhibit the movement of the solid part to the upper side of the vessel resulted from the usual formation of carbon dioxide.

The pre-drying treatment was previously described by De Castilhos et al. (2013) and aimed at drying the grapes until reach 22 °Brix avoiding the chaptalization and promoting wines with an alcoholic content ranging from 8.6 to 14% (v/v) (Brasil, 2005). The average soluble solid contents for Bordô, Isabel, BRS Violeta and BRS Carmem grapes at the beginning of the drying process were 16.4 ± 0.4 °Brix, 16.4 ± 1.0 °Brix, 18.5 ± 0.4 °Brix and 17.5 ± 0.5 °Brix, respectively, and the percentages of water evaporated (in weight) were 20.9%, 22.2%, 12.7% and 16.8% achieving, at the final stage of drying, 22.5 °Brix, 22.9 °Brix, 22.6 °Brix and 22.6 °Brix, respectively. After drying, the grapes were subjected to the standard winemaking process described above, with the exception of the chaptalization step. All the winemaking trials, including both standard and alternative processes, were carried out in duplicate.

2.2. Conventional enological parameters

The following conventional enological parameters were measured: total and volatile acidities (TAC and VAC, as g L^{-1} tartaric acid and acetic acid, respectively) (Brasil, 2005); total dry extract (EXT) (g L^{-1}) (AOAC, 2005); reducing sugars (RSG) (g L^{-1}) by the Lane-Eynon method (AOAC, 2005) and alcoholic content (ALC) (% volume/volume) (AOAC, 2005).

2.3. Spectrophotometric measurements

Total phenolic content (PHEN) was determined by Folin-Ciocalteu method as mg L^{-1} of gallic acid (Slinkard & Singleton, 1977). The CIELab parameters, lightness (L^*), chroma (C^*), hue angle (h^*), redness ($a^* > 0$), greenness ($a^* < 0$), yellowness ($b^* > 0$) and blueness ($b^* < 0$), as well as the tonality (TON) and color intensity (INT) were determined according to Ayala, Echávarri, and Negueruela (1997) and the data were processed with the MSCV 7.1® software (Ayala, Echávarri, & Negueruela, 2012) using illuminant D65 and 10° visual field as references. Total anthocyanin content was estimated by the sulfur dioxide bleaching method (Ribéreau-Gayon & Stonestreet, 1965) and the concentration (mg L^{-1}) was determined on the basis of malvidin 3,5-diglucoside equivalents using their corresponding molar absorbance values (Ough & Amerine, 1988). All the enological parameters were obtained in triplicate.

2.4. Sensory acceptability

The sensory acceptability test was carried out in the Sensory Analysis Laboratory of the Food Technology and Engineering Department of the São Paulo State University. A panel of 96 untrained consumers evaluated the acceptance for appearance, aroma, body, flavor and overall acceptance attributes using a nine point verbal hedonic scale (1 = disliked extremely, 5 = neither liked nor disliked, 9 = liked extremely).

The sensory acceptability test was carried out in individual booths under white light at room temperature (23–25 °C) and the wine samples were presented in 30 mL transparent wineglasses containing 15 mL of sample at 18 °C with a glass of water for mouth rinsing. For this analysis, an incomplete block experimental design was used (Meilgaard, Civille, & Carr, 2006) and each panelist

evaluated seven of the twelve wines. The samples were presented in a monadic way, i.e., one sample at a time, in a randomized order, coded with random three-digit numbers.

This study was conducted according to the Research Ethics Committee of the Institute of Biosciences, Humanities and Exact Sciences, São Paulo State University (protocol n. 15159913.3.0000.5466).

2.5. Data analysis

The results were expressed as mean values ± standard deviation and analysis of variance (ANOVA) of the mean values obtained for the enological parameters and sensory attributes was performed followed by Tukey's posthoc test when $P < 0.05$. The correlation between the acceptance scores and frequency of consumption was performed by Pearson correlation test using the Minitab 17 (Minitab Inc.) software program at $P < 0.05$. The sensometric approach was applied to determine which enological parameter contributed as acceptance driver on each sensory attribute by the application of the Principal Component Analysis (PCA) using Statistica 10 software (StatSoft Inc.).

3. Results and discussion

3.1. Grape and winemaking parameters

Bordô, Isabel, BRS Violeta and BRS Carmem traditional and submerged cap wines were properly chaptalized by the insertion of 52.2 g of sucrose per L for both Bordô and Isabel wines, 33.5 g of sucrose per L and 42.3 g of sucrose per L for BRS Violeta and BRS Carmem wines, respectively. The results obtained for winemaking yield (L of wine/Kg of grapes) ranging from 31.08% to 48.61% for Bordô wine, 30.76%–54.54% for Isabel wine, 35.00%–63.25% for Violeta wine and 32.39%–54.16% for Carmem wine. Submerged cap wines accounted for the higher yield values and the pre-dried wines for the lower yield values, in agreement with previous study (De Castilhos et al., 2013).

3.2. Conventional enological parameters

The conventional enological parameters were influenced by the winemaking treatments ($P < 0.05$) (Table 1) and pre-dried wines presented higher values for total acidity (TAC) in comparison to traditional and submerged cap wines due to the concentration effect of the acids grape provided by the pre-dehydration (Marquez et al., 2012). However, in the case of Violeta wines, the submerged cap wines accounted for the higher value of TAC. The latter unexpected result could be probably explained by the precipitation of the excess potassium bitartrate during winemaking, since these wines presented high content in dry extract. All the wine samples showed volatile acidity values in accordance to the Brazilian legislation (below 1.2 g L^{-1} of acetic acid) (Brasil, 2005), ranging from 0.37 to 0.78 g L^{-1} (as acetic acid equivalents) and pre-drying and submerged cap presented the highest values for this parameter.

The alcoholic content reached appropriate values for young red wines (10.8–14.8% v/v). Bordô and Isabel pre-dried wines accounted for the lower alcoholic content and Violeta wine for the higher content. All the wines showed reducing sugar contents below 5.0 g L^{-1}, and according to the Brazilian legislation (Brasil, 2005), they were, therefore, considered as dry wines. The pre-drying procedure promoted a relevant increase on the dry extract for all wines and this result was expected since the dehydration process caused the concentration of the non-volatile soluble solids.

3.3. Overall phenolic composition and color features

The pre-drying winemaking for Bordô and Isabel grapes promoted the concentration of the phenolic compounds, showing higher values for the PDB and PDI wines when compared to the traditional and submerged cap treatments (Table 2). In contrast, Violeta wines presented no significant differences when the treatments were compared and PDC wine showed no significant differences from the traditional treatment. The Violeta grape, which is a *teinturier* cultivar, presents in its composition high contents of phenolic compounds that are distributed between skin and pulp (Rebello et al., 2013), suggesting that the expected phenolic concentration effect due to the drying process was not possible to be observed in PDV wine. The phenolic exchange provided by the maceration during alcoholic fermentation is not a simple partition phenomenon, since it is essential considering the initial concentration of phenolic compounds of the berry and other phenomena like copigmentation (Schwarz, Picazo-Bacete, Winterhalter, & Hermosín-Gutiérrez, 2005).

Most of the anthocyanins, except for Isabel wines, were bleached by sulfur dioxide, thus suggesting the occurrence of free anthocyanins and tannin-anthocyanin adducts (Ribéreau-Gayon & Stonestreet, 1965). Isabel wines presented the lowest values for

Table 1
Conventional enological parameters results (mean ± standard deviation).

Wines[a]	Enological parameter[b]				
	Total acidity (g L^{-1})	Volatile acidity (g L^{-1})	Alcohol content (%v/v)	Dry extract (g L^{-1})	Reducing sugar (g L^{-1})
TB	7.29 ± 1.13ab	0.58 ± 0.03b	11.73 ± 0.28a	29.25 ± 0.60b	3.73 ± 0.54a
PDB	8.03 ± 0.23a	0.73 ± 0.03a	10.80 ± 0.20b	39.41 ± 2.31a	2.90 ± 0.22a
SCB	6.65 ± 0.16b	0.59 ± 0.02b	10.90 ± 0.91ab	29.87 ± 1.58b	2.54 ± 0.21b
TI	5.89 ± 0.07c	0.46 ± 0.04b	13.26 ± 0.42a	20.95 ± 0.73b	2.67 ± 0.26b
PDI	8.35 ± 0.17a	0.55 ± 0.07a	12.36 ± 0.19b	29.16 ± 2.05a	3.94 ± 0.38a
SCI	6.49 ± 0.34b	0.56 ± 0.03a	13.08 ± 0.29a	21.01 ± 0.60b	3.73 ± 0.08a
TV	6.31 ± 0.59b	0.51 ± 0.03b	13.91 ± 0.85b	47.28 ± 6.13a	2.67 ± 0.26c
PDV	5.72 ± 0.29b	0.51 ± 0.03b	14.80 ± 0.26a	47.89 ± 1.41a	3.71 ± 0.23a
SCV	7.50 ± 1.03a	0.78 ± 0.08a	13.40 ± 0.29b	41.02 ± 1.77b	2.92 ± 0.30b
TC	7.00 ± 0.25b	0.57 ± 0.03a	12.81 ± 0.19a	29.08 ± 0.48b	3.28 ± 0.22b
PDC	8.17 ± 0.79a	0.37 ± 0.07b	12.41 ± 0.60a	34.26 ± 3.11a	4.28 ± 0.52a
SCC	6.00 ± 0.09c	0.49 ± 0.06a	11.75 ± 1.15a	27.24 ± 0.41b	3.44 ± 0.46ab

[a] TB: Bordô Traditional wine, PDB: Pre-drying Bordô wine, SCB: Submerged Cap Bordô wine, TI: Traditional Isabel wine, PDI: Pre-drying Isabel wine, SCI: Submerged Cap Isabel wine, TV: Traditional Violeta wine, PDV: Pre-drying Violeta wine, SCV: Submerged Cap Violeta wine, TC: Traditional Carmem wine, PDC: Pre-drying Carmem wine, SCC: Submerged Cap Carmem wine.

[b] Means followed by distinct letters in the same column differ by Tukey's test ($P < 0.05$).

Table 2
Results (mean ± standard deviation) of the phenolic composition and color features.

Color feature[b]	Wines[a]					
	TB	PDB	SCB	TI	PDI	SCI
Total polyphenols (mg L^{-1})	1446.4 ± 27.5c	1618.8 ± 22.8a	1509.8 ± 45.3b	675.7 ± 36.6b	1191.2 ± 80.1a	666.7 ± 37.7b
Total anthocyanins (mg L^{-1}, mv3,5diglc)	264.1 ± 69.7a	312.4 ± 78.8a	380.1 ± 19.7a	75.3 ± 1.8a	58.4 ± 2.2b	51.5 ± 2.4c
Bleachable anthocyanins (mg L^{-1}, mv3,5diglc)	172.6 ± 64.5ab	166.3 ± 80.7b	286.3 ± 16.2a	8.2 ± 0.6b	15.2 ± 1.7a	14.5 ± 1.0a
Non-bleachable anthocyanins (mg L^{-1}, mv3,5diglc)	91.5 ± 5.3b	146.1 ± 5.0a	93.8 ± 4.1b	67.1 ± 1.2a	43.2 ± 3.4b	37.0 ± 2.4c
Luminosity (L^*)	9.6 ± 1.1a	1.0 ± 0.2b	6.9 ± 0.07a	34.1 ± 4.1a	14.9 ± 7.9a	22.7 ± 4.5a
Redness (a^*)	37.75 ± 1.24a	7.37 ± 1.46b	35.04 ± 0.07a	44.27 ± 2.98a	30.57 ± 3.84b	32.27 ± 1.01b
Yellowness (b^*)	16.50 ± 1.93a	1.79 ± 0.37b	11.95 ± 0.21a	49.95 ± 1.85a	25.35 ± 13.45a	35.62 ± 6.04a
Chroma (C^*)	41.20 ± 1.90a	7.58 ± 1.51b	37.01 ± 0.13a	66.75 ± 3.35a	40.11 ± 11.42a	48.12 ± 5.15a
Hue angle (h^*)	23.56 ± 1.76a	13.69 ± 0.09c	18.82 ± 0.27b	48.47 ± 0.85a	37.98 ± 11.81a	47.61 ± 3.96a
Color intensity	24.12 ± 3.70a	19.22 ± 1.21ab	11.76 ± 0.51b	5.19 ± 0.65b	9.15 ± 0.28a	6.29 ± 0.58b
Tonality	3.42 ± 0.51a	0.94 ± 0.16b	0.91 ± 0.08b	1.30 ± 0.11a	1.77 ± 0.39a	1.43 ± 0.06a
Color feature[b]	TV	PDV	SCV	TC	PDC	SCC
Total polyphenols (mg L^{-1})	1702.7 ± 15.9a	1677.2 ± 71.5a	1670.4 ± 24.0a	1515.9 ± 43.5a	1483.2 ± 56.0a	1325.7 ± 60.3b
Total anthocyanins (mg L^{-1}, mv3,5diglc)	888.7 ± 53.6a	654.6 ± 85.1b	772.9 ± 37.7ab	275.7 ± 17.7a	199.6 ± 51.0b	314.7 ± 27.9a
Bleachable anthocyanins (mg L^{-1}, mv3,5diglc)	474.8 ± 93.3a	263.9 ± 41.2b	438.4 ± 33.3a	191.1 ± 18.8a	112.1 ± 47.5b	246.7 ± 25.8a
Non-bleachable anthocyanins (mg L^{-1}, mv3,5diglc)	413.9 ± 58.4a	390.7 ± 44.0a	334.5 ± 16.5a	84.6 ± 3.4a	87.5 ± 4.1a	68.0 ± 2.7b
Luminosity (L^*)	0.3 ± 0.07b	0.4 ± 0.07b	0.9 ± 0.07a	5.7 ± 0.9a	5.4 ± 3.6a	6.5 ± 1.0a
Redness (a^*)	2.42 ± 0.19b	3.18 ± 0.36b	6.83 ± 0.46a	31.38 ± 2.23a	26.98 ± 11.76a	33.05 ± 1.71a
Yellowness (b^*)	0.57 ± 0.04b	0.76 ± 0.09b	1.66 ± 0.12a	9.88 ± 1.51a	9.32 ± 6.42a	11.26 ± 1.80a
Chroma (C^*)	2.49 ± 0.21b	3.26 ± 0.37b	7.03 ± 0.48a	32.91 ± 2.58a	28.59 ± 13.19a	34.92 ± 2.20a
Hue angle (h^*)	13.43 ± 0.01b	13.49 ± 0.02b	13.68 ± 0.04a	17.43 ± 1.33a	17.91 ± 5.00a	18.76 ± 1.89a
Color intensity	26.65 ± 1.09a	25.34 ± 0.48a	24.03 ± 0.24a	15.25 ± 0.71a	20.96 ± 7.65a	11.55 ± 0.19a
Tonality	0.59 ± 0.04b	0.68 ± 0.04ab	0.97 ± 0.11a	1.55 ± 0.17a	2.67 ± 2.01a	1.12 ± 0.18a

[a] TB: Bordô Traditional wine, PDB: Pre-drying Bordô wine, SCB: Submerged Cap Bordô wine, TI: Traditional Isabel wine, PDI: Pre-drying Isabel wine, SCI: Submerged Cap Isabel wine, TV: Traditional Violeta wine, PDV: Pre-drying Violeta wine, SCV: Submerged Cap Violeta wine, TC: Traditional Carmem wine, PDC: Pre-drying Carmem wine, SCC: Submerged Cap Carmem wine.
[b] Means followed by distinct letters in the same row differ by Tukey's test ($P < 0.05$).

bleachable anthocyanin (average 19.35%) suggesting that these samples showed relevant amounts of polymeric anthocyanins and/or pyranoanthocyanins (Blanco-Vega, López-Bellido, Alía-Robledo, & Hermosín-Gutiérrez, 2011). This result was also in agreement with their highest values of yellowness (b^*).

The CIELab results showed that Violeta wines presented low values for luminosity (average 0.53 in a scale of 0–100; 0-black, 100-white), redness, yellowness and Chroma. These results were even lower than the previously reported results for Violeta young red wines (Lago-Vanzela et al., 2013); however, hue angle, tonality and color intensity were similar to those previous findings. Pre-drying treatment influenced the luminosity of the Bordô wines because grape drying causes the increase of browning pigments resulted from the Maillard reactions (melanoidins) (Marquez et al., 2012). The formation of these compounds in pre-dried wines also decreased the L^* and C^*.

The color parameters (C^*, L^*, a^*, b^*, and hue angle) of Isabel and Carmem wines presented no significant differences when the winemaking treatments were compared, except for Isabel redness, which was higher in TI than PDI and SCI wines. The pre-dried Bordô wine (PDB) presented the lowest values for all these parameters when compared to traditional (TB) and submerged cap wines (SCB). In the other hand, the color parameters of PDV wine have not differed from the TV wine and the SCV wine showed the highest values for all these parameters, differentiating them of the PDV and TV wines. In general, the pre-dried wines presented intermediate or lower values for the color parameters, showing or not significant differences when compared to traditional and submerged cap treatments, and this finding suggests that the phenolic compounds, responsible for the color features, were degraded by the use of heat as previously reported by Marquez et al. (2012).

3.4. Acceptability test

Ninety-six consumers (61 women, 63.54% and 35 men, 36.46%) assessed the acceptance of the wine samples. The average age of the panelists was 24.1 years old with a standard deviation of 6.03 (minimum of 18.0 and maximum of 56.0 years old). Of the total number of consumers who evaluated the wine samples, 18 (18.8%) reported a very low consumption of red wine, 22 (22.9%) reported a low consumption, 27 (28.1%) a moderate consumption, 19 (19.8%) a high consumption and 10 (10.4%) a very high consumption of red wine. In order to correlate the consumer consumption with the evaluation of each acceptance attribute for each sample, the consumers' frequency of wine consumption was transformed into scores: (1) very low consumption, (2) low consumption, (3) moderate consumption, (4) high consumption and (5) very high consumption.

In most cases, there was no significant correlation between the frequency consumption and the sensory acceptance scores, except for aroma for three samples: IT ($r = -0.276$; $P = 0.039$), ISC ($r = -0.271$; $P = 0.043$) and CARSC ($r = -0.306$; $P = 0.022$); flavor for VIOT sample ($r = 0.333$; $P = 0.012$) and overall acceptance for VIOT sample ($r = 0.345$; $P = 0.009$). The aforementioned aroma correlations showed negative Pearson coefficients and it indicated that the consumers who reported lower wine consumption assessed the higher aroma scores. For flavor and overall acceptance correlation, the Pearson coefficient was positive, i.e., the higher the frequency of consumption, the higher the scores for these attributes.

Wine aroma is one of the most difficult attributes for assessment by naïve consumers, since there are two ways to assess it: a direct way via nose and a retro nasal way. In addition, the perception of wine aroma can be influenced by other wine constituents, i.e., the effect of sugar and alcohol in increase and reduce the fruitiness, respectively (Jackson, 2009). Furthermore, other contextual factors such as taste, color intensity and other visual clues could influence the aroma perception (Sakai, Imada, Saito, Kobayakawa, & Deguchi, 2005).

The sensory attributes of Bordô, Violeta and Carmem wines

Table 3
Results (mean ± standard deviation) of the acceptability test/hedonic scale within 1–9 score.

Wines[a]	Sensory atributes[b]				
	Appearance	Aroma	Body	Flavor	Overall acceptance
TB	7.66 ± 1.25a	7.19 ± 1.54a	5.94 ± 1.77a	4.91 ± 2.26a	5.71 ± 1.96a
PDB	7.69 ± 1.47a	6.83 ± 1.81a	6.44 ± 1.76a	5.17 ± 2.35a	5.78 ± 2.06a
SCB	7.42 ± 1.26a	6.53 ± 1.73a	5.85 ± 1.88a	4.85 ± 2.18a	5.33 ± 2.02a
TI	5.89 ± 1.69a	6.01 ± 1.82a	5.51 ± 1.97a	4.96 ± 2.01a	5.33 ± 1.86ab
PDI	4.46 ± 1.94b	5.16 ± 1.81b	5.28 ± 2.20a	3.92 ± 2.21b	4.48 ± 2.00b
SCI	6.33 ± 1.75a	6.39 ± 1.71a	5.62 ± 1.89a	5.12 ± 2.35a	5.53 ± 2.07a
TV	7.51 ± 1.29a	5.35 ± 1.69a	5.82 ± 1.74a	3.42 ± 1.95a	4.44 ± 1.88a
PDV	7.32 ± 1.57a	5.08 ± 1.90a	5.14 ± 2.18a	3.35 ± 2.02a	4.30 ± 2.00a
SCV	7.62 ± 1.57a	5.60 ± 1.91a	5.28 ± 2.03a	4.00 ± 2.11a	4.94 ± 1.86a
TC	7.44 ± 1.42a	6.30 ± 1.75a	5.91 ± 1.98a	4.91 ± 2.28a	5.33 ± 1.94a
PDC	7.60 ± 1.10a	6.07 ± 1.74a	5.89 ± 1.58a	4.53 ± 2.23a	5.30 ± 1.94a
SCC	7.12 ± 1.50a	5.96 ± 2.00a	5.44 ± 2.23a	4.62 ± 2.33a	5.25 ± 2.11a

[a] TB: Bordô Traditional wine, PDB: Pre-drying Bordô wine, SPB: Submerged Cap Bordô wine, TI: Traditional Isabel wine, PDI: Pre-drying Isabel wine, SPI: Submerged Cap Isabel wine, TV: Traditional Violeta wine, PDV: Pre-drying Violeta wine, SPV: Submerged Cap Violeta wine, TC: Traditional Carmem wine, PDC: Pre-drying Carmem wine, SPC: Submerged Cap Carmem wine.
[b] Means followed by distinct letters in the same column differ by Tukey's test ($P < 0.05$).

showed no significant differences ($P > 0.05$) (Table 3) when the treatments were compared, except for Isabel wines, which presented significant differences for appearance, aroma, flavor and overall acceptance. For all these sensory attributes, PDI showed the lower scores and the TI and SCI wines presented no significant differences.

In general, the acceptance scores for most attributes suggested rather similarities between Bordô and Carmem wines and only the acceptance of aroma for the Bordô wines slightly surpassed, but not significantly, those for the Carmem samples. Despite the absence of significant differences, the Violeta wines showed a slightly trend to receive the lowest scores for all attributes, except for appearance. The results of the univariate approach (ANOVA results) showed no significant differences among the treatments and, therefore, it was not possible to indicate the sensory acceptance drivers for each wine. Thus, in order to obtain clearer results regarding the sensory attributes that drive the acceptance of each assessed wine, a sensometric approach was performed, nullifying the grape effect, i.e., the intrinsic features of each grape that could influence the sensometric results.

3.5. Sensometric approach

The main objective of the sensometric approach was to indicate which enological and color parameters could be considered as acceptance drivers for each wine only considering the winemaking effect. The sensometric approach usually gives results that are not usually noticed by univariate analysis and this approach is commonly applied in sensory studies involving acceptance drivers and consumers (Aquino et al., 2014; Geel, Kinnear, Kock, 2005; Sáenz-Navajas et al., 2016; Tenenhaus, Pagès, Ambroisine, & Guinot, 2005; Valentin, Parr, Peyron, Grose, & Ballester, 2016; Westad, Hersleth, Lea, 2004). As the effect of the cultivar may be discarded in order to restrict the treatment effect, the sensometric approach was performed by wine type, i.e., separately for each grape cultivar.

3.5.1. Bordô wines

According to the PCA results (Fig. 1A), PC1 explained 58.01% and PC2 explained 29.98% of the total variance. Both PC1 and PC2 explained 87.99% of the total variance. The PC1 differentiate the pre-drying (PDB) from the submerged cap (SCB) and traditional (TB) treatments and PC2 the traditional (TB) from the submerged cap (SCB) winemaking technique.

Two groups of variables explained the PC1. The first group was composed by total and volatile acidity (TAC and VAC), dry extract (EXT), total phenolic content (PHEN), non-bleachable anthocyanins (ANT non bleach) and two sensory acceptance attributes, body and flavor. The pre-dried Bordô wine (PDB) was covered by these features. The pre-drying procedure provided higher scores for body and flavor and the sensory acceptance drivers for these two sensory attributes were related to acidity, dry extract, as well as the total phenolic content and non-bleachable anthocyanins. This result corroborates previous findings of De Castilhos et al. (2013) who reported the intense correlation between the body acceptance, dry extract and phenolic compounds. In the same study, the influence of the acidity on flavor acceptance was also reported, showing that mainly the volatile acidity could increase the flavor enhancement. Furthermore, Sáenz-Navajas et al. (2016) also reported the influence of astringency promoted by tannins, which are quantified by total phenolic methodology (PHEN), as an acceptance driver for in-mouth sensations, corroborating these findings.

The second group was composed by the CIELab parameters and no sensory attribute was related to this group. Submerged cap wine (SCB) was covered by these properties. At the same time, the SCB was also covered by a group that explained the PC2, which was composed by total content of anthocyanins (ANT) and bleachable anthocyanin (ANT bleach). In both PCs there was not sensory attributes related with the aforementioned chemical properties. For this reason, it was suggested that SCB wine presented no sensory acceptance driver.

The other group of variables that explained the PC2 was composed by reducing sugars (RSG), tonality (TON), color intensity (INT) and the sensory attributes appearance, aroma and overall acceptance. The TB wine was covered by these properties. These results indicated that TB wine presented high scores for appearance, aroma and overall acceptance, which were driven by color intensity and tonality. Contextual factors such as color intensity and other visual clues could influence the aroma perception and acceptance (Zampini, Wantling, Phillips, & Spence, 2008) and this could be a possible explanation for this result. In this case, there is slight evidence associating the influence of the visual features of the wines in the high aroma acceptance. Reducing sugars could also influence the appearance of red wines, since its high concentration could allow the formation of a film in the wall during the turning of the cup, increasing the scores for appearance (Jackson, 2008). The alcohol content was the only chemical property that presented no relationship with any assessed PC.

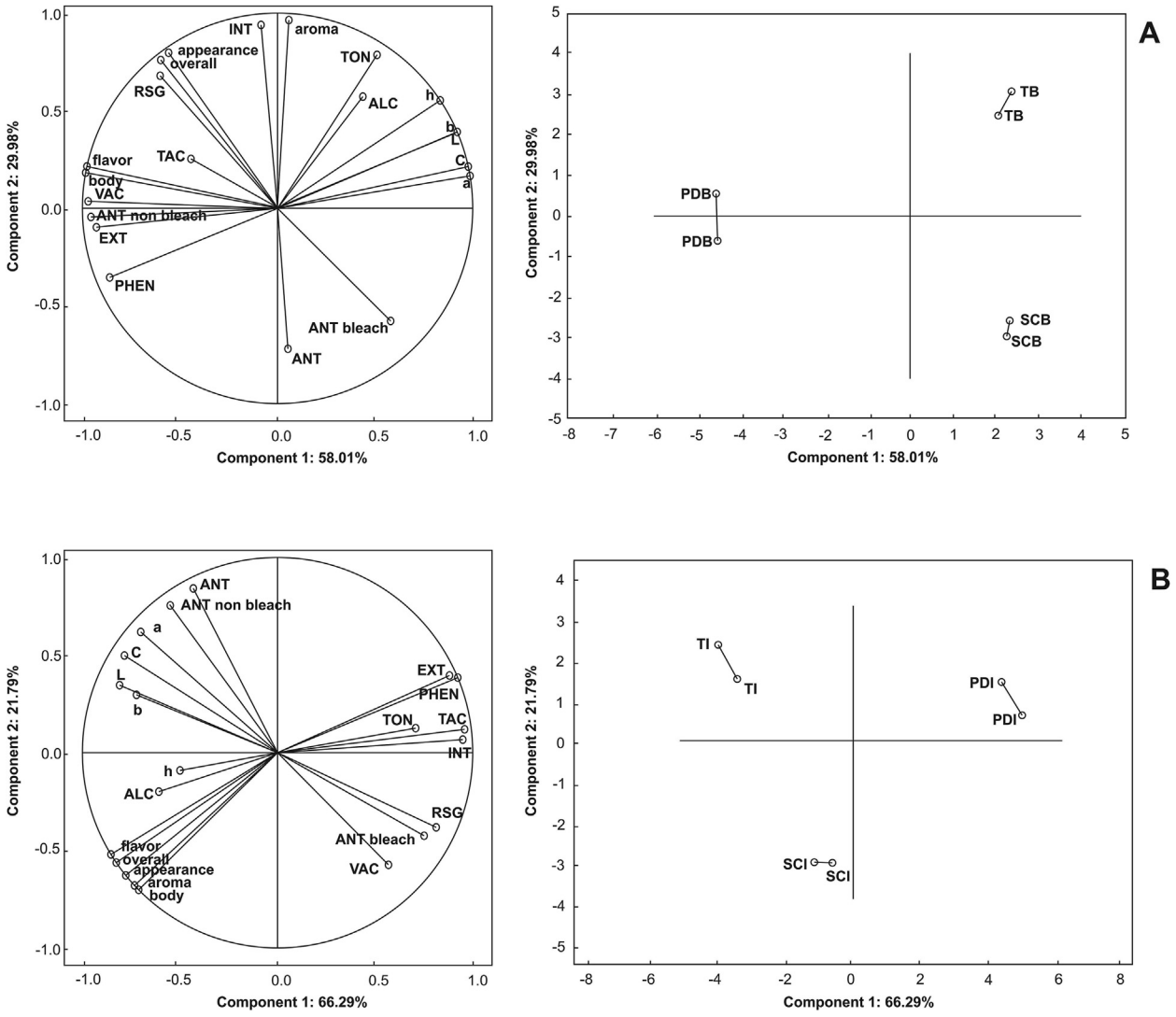

Fig. 1. Projection of the enological parameters, color features and sensory attributes and wine samples using PCA for Bordô (A) and Isabel wines (B). Abbreviations: TAC, total acidity; VAC, volatile acidity; FAC, fixed acidity; ALC, alcohol content; EXT, dry extract; RSG, reducing sugar; PHEN, total phenolic content; ANT, total anthocyanin content; ANT BLEACH, anthocyanin bleachable; ANT no BLEACH, anthocyanin non bleachable; L*, luminosity; a*, redness; b*, yellowness; C*, chroma; h*, hue angle; TON, tonality; INT, color intensity; TB, Bordô Traditional wine; PDB, Pre-dried Bordô wine; SCB, Submerged Cap Bordô wine; TI, Traditional Isabel wine; PDI, Pre-dried Isabel wine; SCI, Submerged Cap Isabel wine.

3.5.2. Isabel wines

PC1 explained 66.29% and PC2 explained 21.79% of the variance, totaling 88.08% of the total variance. The PC1 differentiate the pre-drying (PDI) from the traditional (TI) treatments and PC2 the traditional (TI) and pre-dried (PDI) from the submerged cap (SCI) winemaking technique.

Two groups of variables explained the PC1. The first was composed by alcohol content (ALC), all the CIELab parameters and all the sensory acceptance attributes. The traditional Isabel wine (TI) and submerged cap Isabel wine (SCI) were related with this group of variables. The results showed the potential of the submerged cap winemaking procedure for Isabel wines, since it presented high acceptance for all sensory attributes and no significant differences when compared to TI. This high acceptance was driven by the alcohol content, contributing to the fruity aroma and flavor (Ferreira, Fernández, Peña, Escudero, & Cacho, 1995), and by the color parameters showing an intense relationship of these properties on the appearance of the wine and mainly on overall acceptance. It was possible to suggest that the higher acceptance TI wines was also suggested by anthocyanin content (ANT and ANT non bleach), since this sample also showed strong relationship with this parameter in PC2.

This aforementioned result was probably associated with the chemical properties related with the appearance of the Isabel wines, since all the sensory attributes were closely linked with the CIELab parameters and anthocyanins. This result was in accordance with studies from Biasoto et al. (2014) and Sáenz-Navajas et al. (2016) who reported the intense relationship between the appearance and color parameters, considering them as acceptance drivers for appearance and also for overall acceptance.

The second group was composed by total acidity (TAC), dry extract (EXT), reducing sugars (RSG), phenolic content (PHEN), bleachable anthocyanins (ANT bleach), tonality and color intensity (TON and INT). This group of properties showed high correlation with pre-drying Isabel wine (PDI). The pre-drying technique presented no consumer drivers for Isabel wines, suggesting that this winemaking procedure presented no great potential for Isabel wines.

3.5.3. BRS Violeta wines

PC1 explained 64.47% and PC2 explained 20.81% (Fig. 2A), totaling 85.28% of the total variance explained. PC1 differentiate the submerged cap wines from the traditional and pre-dried wines. PC2 allowed the differentiation of the traditional from the pre-dried wines.

Two groups of variables explained the PC1. The first was composed by volatile acidity (VAC), CIELab parameters, tonality (TON) and four sensory attributes, appearance, aroma, flavor and overall acceptance. For this group it was possible to correlate the submerged cap wine (SCV). The aforementioned result suggested the high acceptance of all sensory attributes, except body, and they were driven by acidity, tonality and color features.

In addition, some evidences showed that submerged cap technique enhanced the acidity of the Violeta wine and its color features, resulting in a more attractive wine for the consumer. This result was in accordance with the findings of Bosso et al. (2011) who reported that the submerged cap winemaking improve the extraction of phenolic compounds and this technique increase the scores for color features. In addition, the visual clues also seemed to be a strong factor that influenced the acceptance of all mentioned sensory attributes (Zampini et al., 2008), suggesting that the visual features of the wines are responsible for calling the attention of consumers in an impactful way, resulting in the high acceptance of the other attributes.

The second group was composed by dry extract (EXT), reducing sugars (RSG), non-bleachable anthocyanins (ANT non-bleach) and color intensity (INT). The results suggested high correlation with traditional and pre-drying winemaking (TV and PDV). TV sample also presented strong relationship with total anthocyanin content (ANT), bleachable anthocyanins (ANT bleach) and body acceptance in PC2. Based on these results, the TV wine presented high body acceptance due to the EXT, RSG and anthocyanin content. This result corroborates the findings of De Castilhos et al. (2013). Pre-dried wine (PDV) presented no relationship with sensory attributes, suggesting the low potential of this winemaking procedure for Violeta wines. Otherwise, the submerged cap presented high acceptance for almost all sensory attributes, indicating its high

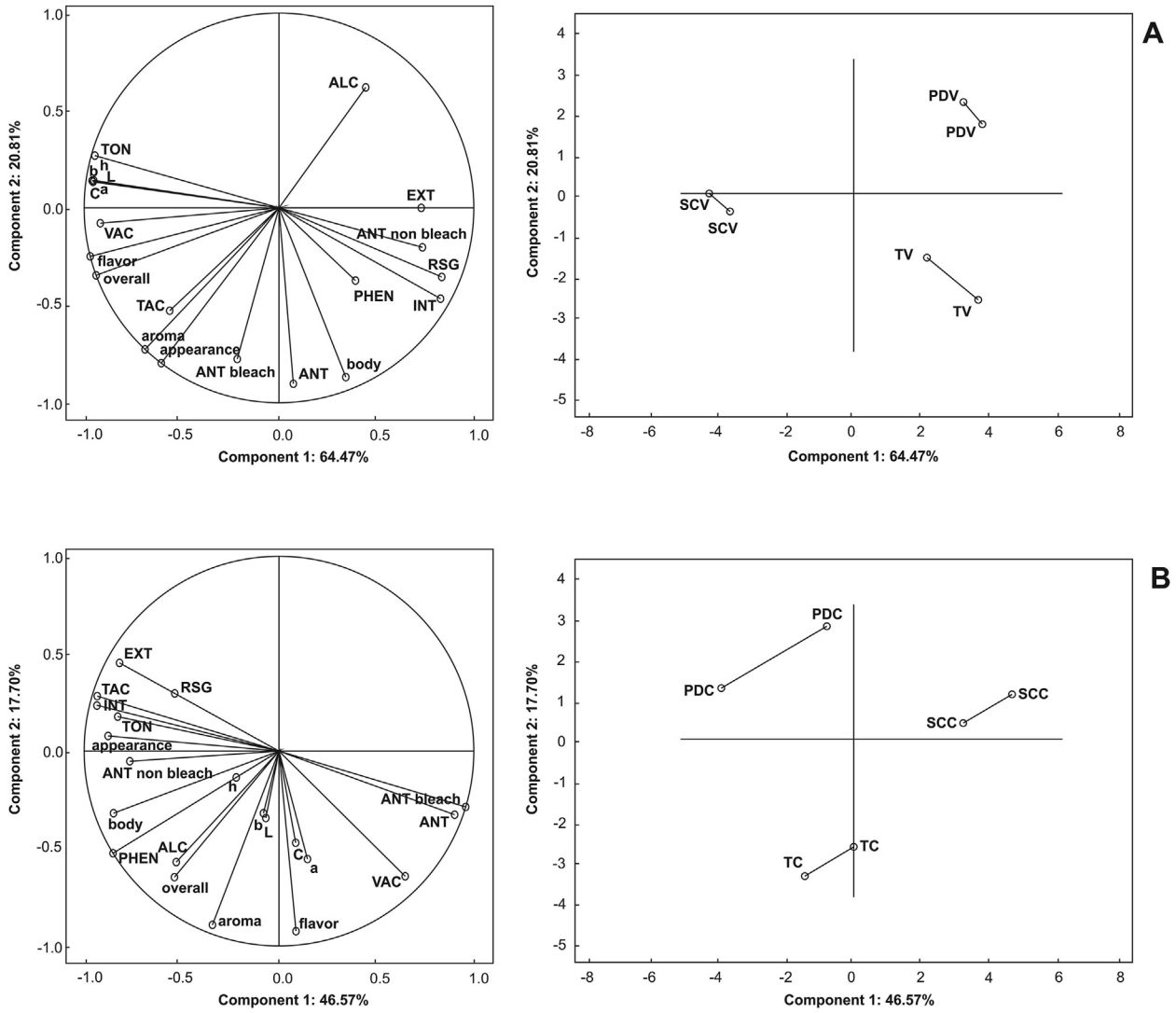

Fig. 2. Projection of the enological parameters, color features and sensory attributes and wine samples using PCA for Violeta (A) and Carmem wines (B).; Abbreviations: TAC, total acidity; VAC, volatile acidity; FAC, fixed acidity; ALC, alcohol content; EXT, dry extract; RSG, reducing sugar; PHEN, total phenolic content; ANT, total anthocyanin content; ANT BLEACH, anthocyanin bleachable; ANT no BLEACH, anthocyanin non bleachable; L*, luminosity; a*, redness; b*, yellowness; C*, chroma; h*, hue angle; TON, tonality; INT, color intensity; TV, Traditional Violeta wine; PDV, Pre-dried Violeta wine; SCV, Submerged Cap Violeta wine; TC, Traditional Carmem wine; PDC, Pre-dried Carmem wine; SCC, Submerged Cap Carmem wine.

potential in producing wines with an intense color.

3.5.4. BRS Carmem wines

The PC1 explained 46.57% and PC2 explained 17.70% of the total variance (Fig. 2B). Both PC1 and PC2 explained 64.27% of the total variance. PC1 allowed differentiating the submerged cap from the pre-dried samples and PC2 allowed distinguishing the alternative winemaking (PD and SC) from the traditional (T).

Two groups of variables explained PC1. The first group was composed by total acidity (TAC), dry extract (EXT), reducing sugars (RSG), total phenolic content (PHEN), non bleachable anthocyanins (ANT non bleach), tonality, color intensity and three sensory attributes, appearance, body and overall acceptance. Pre-dried Carmem wine (PDC) was covered by this group of variables. This result suggest that the pre-drying winemaking provided the enhancement of the body and the improvement of the appearance by the higher contents of dry extract and reducing sugars and by the higher contents of phenolic compounds and anthocyanins, respectively, corroborating the findings of De Castilhos, Conti-Silva, and Del Bianchi (2012). Jackson (2008) also reported the relevant influence of these both enological parameters on the body mouthfeel sensation. The second group of variables of PC1 was composed only by total anthocyanin content (ANT) and bleachable anthocyanins (ANT bleach) and the submerged cap sample (SCC) was covered by these chemical properties. No sensory attributes covered this wine sample.

The PC2 was composed by volatile acidity and two sensory attributes, aroma and flavor. The traditional Carmem wine (TC) was the sample covered by these features. In this case, the high acceptance of aroma and flavor was correlated with the volatile acidity of the TC sample, considering this chemical feature as a sensory acceptance driver for aroma and flavor. De Castilhos et al. (2013) reported the influence of volatile acidity on the aroma of Brazilian red table wines produced from Bordô and Isabel grapes. In addition, Biasoto et al. (2014) also reported the grape and fruity aromas as well as alcohol aroma as preference drivers for wines produced from hybrid grapes and the chemical compounds related to these sensory features are quantitated in volatile acidity such as all the volatile acids and their derivatives, being responsible for the aroma acceptance of red wines. The color features (CIELab) and alcohol content (ALC) did not contribute with the sensometric analysis.

4. Conclusions

The univariate analysis showed that alternative winemaking slightly influenced some of the conventional enological parameters; however, it was difficult to observe the real consumer drivers that guided the acceptance of all attributes. A sensometric approach, by the application of PCA, was successfully performed and demonstrated the high potential of the pre-drying winemaking in producing wines with higher body and flavor, both sensory attributes driven by dry extract, reducing sugars and acidity. Furthermore, submerged cap provided wines with higher acceptance for appearance, aroma and overall acceptance and these sensory acceptance attributes presented the total phenolic content, anthocyanins and CIELab parameters as acceptance drivers. In addition, it was possible to observe the influence of visual features on the acceptance of other sensory attributes, mainly aroma acceptance. Further studies have to be carried out aiming at providing clearer results about the influence of the intrinsic features of each grape cultivar, since the results could present few variations when the same winemaking procedure was assessed for different grape cultivars. This study allowed evaluating the management of the winemaking process, which could promote the enhancement of some chemical properties in order to guide the wine quality for better acceptance of consumer groups with unique quality requirements.

Acknowledgments

Author De Castilhos, M.B.M. thanks the Coordination for the Improvement of Higher Level Personnel (CAPES – Brazil) for the scolarschip in the Program of Doctoral Sandwich Abroad (PDSE). The authors are also grateful to the Brazilian Agro-farming Research Agency EMBRAPA Grape and Wine (Empresa Brasileira de Pesquisa Agropecuária, EMBRAPA Uva e Vinho) for providing the grapes for analysis. Author Gómez-Alonso, S. thanks the Fondo Social Europeo and the Junta de Comunidades de Castilla-La Mancha for co-funding his contract through the INCRECYT program. Also, authors Gómez-Alonso, S. and Hermosín-Gutiérrez, I. thank the Spanish Ministerio de Economía y Competitividad for financial support (project AGL2011-29708-C02-02).

References

Aquino, L. F. M. C., Silva, A. C. O., Freitas, M. Q., Felicio, T. L., Cruz, A. G., & Conte-Junior, C. A. (2014). Identifying cheese whey and adulterant in milk: limited contribution of a sensometric approach. *Food Research International, 62*, 233–237.

Association of Official Analytical Chemists (AOAC). (2005). *Official methods of analysis of the AOAC International. Washington* (p. 1141).

Ayala, F., Echávarri, J. F., & Negueruela, A. I. (1997). A new simplified method for measuring the color of wines. I. Red and rose wines. *American Journal of Enology and Viticulture, 48*, 357–363.

Ayala, F., Echávarri, J. F., & Negueruela, A. I. (2012). *MSCV 7.1 software*.

Biasoto, A. C. T., Netto, F. M., Marques, E. J. N., & Da Silva, M. A. A. P. (2014). Acceptability and preference drivers of red wines produced from *Vitis labrusca* and hybrid grapes. *Food Research International, 62*, 456–466.

Blanco-Vega, D., López-Bellido, F. J., Alía-Robledo, J. M., & Hermosín-Gutiérrez, I. (2011). HPLC-DAD-ESI-MS/MS characterization of pyranoanthocyanins pigments formed in model wine. *Journal of Agricultural and Food Chemistry, 59*, 9523–9531.

Bosso, A., Panero, L., Petrozziello, M., Follis, R., Motta, S., & Guaita, M. (2011). Influence of submerged-cap vinification on polyphenolic composition and volatile compounds of Barbera wines. *American Journal of Enology and Viticulture, 62*, 503–511.

Brasil. (2005). *Altera dispositivos da Lei n. 7678 de 8 de novembro de 1988*. Brasília: Diário Oficial da União.

Camargo, U. A., Maia, J. D. G., & Nachtigal, J. C. (2005). *BRS Violeta: nova cultivar de uva para suco e vinho de mesa* (p. 8). Bento Gonçalves: Embrapa Uva e Vinho.

Camargo, U. A., & Ritschel, P. (2008). New table and wine grape cultivars: world scenario with emphasis on Brazil. *Acta Horticulturae, 785*, 89–96.

Casassa, L. F., Bolcato, E. A., & Sari, S. E. (2015). Chemical, chromatic, and sensory attributes of 6 red wines produced with prefermentative cold soak. *Food Chemistry, 174*, 110–118.

De Castilhos, M. B. M., Cattelan, M. G., Conti-Silva, A. C., & Del Bianchi, V. L. (2013). Influence of two different vinification procedures on the physicochemical and sensory properties of Brazilian non-*Vitis vinifera* red wines. *Lebensmittei-Wissenschaft & Technologie, 54*, 360–366.

De Castilhos, M. B. M., Conti-Silva, A. C., & Del Bianchi, V. L. (2012). Effect of grape pre-drying and static pomace contact on physicochemical properties and sensory acceptance of Brazilian (Bordô and Isabel) red wines. *European Food Research and Technology, 235*, 345–354.

Dooley, L., Threlfall, R. T., & Meullenet, J. (2012). Optimization of blended wine quality through maximization of consumer liking. *Food Quality and Preference, 24*, 40–47.

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

Geel, L., Kinnear, M., & de Kock, H. L. (2005). Relating consumer preferences to sensory attributes of instant coffee. *Food Quality and Preference, 16*, 237–244.

Jackson, R. S. (2008). *Wine science: Principles and applications*. San Diego: Academic Press.

Jackson, R. S. (2009). *Wine tasting: A professional handbook*. California: Academic Press.

Lago-Vanzela, E. S., Rebello, L. P. G., Ramos, A. M., Stringheta, P. C., Da-Silva, R., García-Romero, E., et al. (2013). 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 Research International, 54*, 33–43.

Maia, J. D. G., & Camargo, U. A. (2005). Sistema de produção de uvas rústicas para processamento em regiões tropicais do Brasil. *Sistemas de Produção – Embrapa*

Uva e Vinho, 9.
Marquez, A., Serratosa, M. P., Lopez-Toledano, A., & Merida, J. (2012). Colour and phenolic compounds in sweet red wines from Merlot and Tempranillo grapes chamber-dried under controlled conditions. *Food Chemistry, 130*, 111–120.
Meilgaard, M., Civille, G. V., & Caar, B. T. (2006). *Sensory evaluation techniques* (4th ed). Boca Raton: CRC Press, 464.
Meillon, S., Viala, D., Medel, M., Urbano, C., Guillot, G., & Schlich, P. (2010). Impact of partial alcohol reduction in Syrah wine on perceived complexity and temporality of sensations and link with preference. *Food Quality and Preference, 21*, 732–740.
Ough, C. S., & Amerine, M. A. (1988). *Methods for analysis of musts and wines* (2nd ed., p. 377). Davis: John Wiley & Sons.
Rebello, L. P. G., Lago-Vanzela, E. S., Barcia, M. T., Ramos, A. M., Stringheta, P. C., Da-Silva, R., et al. (2013). Phenolic composition of the berry parts of hybrid grape cultivar BRS Violeta (BRS Rúbea × IAC 1398-21) using HPLC-DAD-ESI-MS/MS. *Food Research International, 54*, 356–366.
Ribéreau-Gayon, P., & Stonestreet, E. (1965). Le dosage des anthocyanes dans le vin rouge. *Bulletin de la Société Chimique de France, 9*, 2649–2652.
Sáenz-Navajas, M., Avizcuri, J. M., Echávarri, J. F., Ferreira, V., Fernández-Zurbano, P., & Valentin, D. (2016). Understanding quality judgments of red wines by experts: effect of evaluation condition. *Food Quality and Preference, 48*, 216–227.
Sakai, N., Imada, S., Saito, S., Kobayakawa, T., & Deguchi, Y. (2005). The effect of visual images on perception of odors. *Chemical Senses, 30*, 244–245.
Schwarz, M., Picazo-Bacete, J. J., Winterhalter, P., & Hermosín-Gutiérrez, I. (2005). Effect of copigments and grape cultivar on the color of red wines fermented after the addition of copigments. *Journal of Agricultural and Food Chemistry, 53*, 8372–8381.
Slinkard, K., & Singleton, V. L. (1977). Total phenol analysis: automation and comparison with manual methods. *American Journal of Enology and Viticulture, 28*, 49–55.
Tenenhaus, M., Pagès, J., Ambroisine, L., & Guinot, C. (2005). PLS methodology to study relationship between hedonic judgements and product characteristics. *Food Quality and Preference, 16*, 315–325.
Valentin, D., Parr, W. V., Peyron, D., Grose, C., & Ballester, J. (2016). Colour as a driver of Pinot noir wine quality judgments: an investigation involving French and New Zealand wine professionals. *Food Quality and Preference, 48*, 251–261.
Westad, F., Hersleth, M., & Lea, P. (2004). Strategies for consumer segmentation with application on preference data. *Food Quality and Preference, 15*, 681–687.
Zampini, M., Wantling, E., Phillips, N., & Spence, C. (2008). Multisensory flavor perception: assessing the influence of fruit acids and color cues on the perception of fruit-flavored beverages. *Food Quality and Preference, 19*, 335–343.