



Influence of two different vinification procedures on the physicochemical and sensory properties of Brazilian non-*Vitis vinifera* red wines

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ABSTRACT

The objective of this study was to evaluate the association between the physicochemical properties and sensory acceptance of Brazilian red wines by applying chemometric techniques. Therefore, three winemaking processes were carried out: a traditional winemaking process and two novel winemaking processes, pre-drying and static pomace. Significant differences could be identified amongst the physicochemical properties of the wines ($P < 0.001$). The sensory results showed greater acceptance of the wines made after pre-drying of the grapes or from the static pomace, as compared to commercial brands. Cluster analysis and Multidimensional Scaling were successfully applied and their results demonstrated the influence of the total phenolic content and color indexes on acceptance of the appearance of the wines. The odor was associated with the alcohol content, acidity, dry extract, total and reducing sugars and the body of the wines. The flavor was associated with several physicochemical properties which influenced the overall acceptance of the samples.

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1. Introduction

The quality of wine is affected by several factors such as the sanitary conditions of the grapes, the application of winemaking technologies, soil types, climate and weather conditions as well as the management of the vine (Lee, Lee, Kim, Kim, & Koh, 2006). These factors are responsible for determining the chemical properties of the wine and for providing sensory quality. The main chemical substances making up the wine are sugars, alcohols, organic acids, mineral salts, phenolic and nitrogen compounds and aromatic and volatile compounds, in addition to substances responsible for beverage turbidity such as pectins and gums (Jackson, 2008).

Abbreviations: TAC, total acidity; VAC, volatile acidity; FAC, fixed acidity; DENS, density; ALC, alcoholic content; EXT, dry extract; REXT, residual dry extract; ALC/REXT, relation between alcohol content and reduced dry extract; RSG, reducing sugars; TSG, total sugars; PHEN, total phenolic content; INT, color intensity; TON, hue; SUL, sulfate content; OD, optical density; TB, Traditional Bordo wine; TI, Traditional Isabel wine; PDB, Pre-dried Bordo wine; PDI, Pre-dried Isabel wine; SPB, Static Pomace Bordo wine; SPI, Static Pomace Isabel wine; CB, Commercial Bordo wine; CI, Commercial Isabel wine.

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These chemical compounds are influenced by the winemaking process and also by its variations. Studies have shown the existence of variations in winemaking, especially with respect to the use of pre-fermentation techniques such as carbonic maceration (Castillo-Sánchez, Mejuto, Garrido, & García-Falcón, 2006), wine clarification (Castillo-Sánchez et al., 2006; Pérez-Lamela, García-Falcon, Simal-Gándara, & Orriols-Fernández, 2007; Villano, Fernández-Pachón, Troncoso, & García-Parrilla, 2006) and the introduction of small oak chips into the must, replacing the practice of aging in oak barrels (Rodríguez-Bencomo, Ortega-Heras, Pérez-Magariño, González-Huerta, & González-SanJosé, 2008).

The physicochemical properties are determined in order to explain possible sensory changes (Chira, Pacella, Jourdes, & Teissedre, 2011), and this is one of the reasons why the relationship between the sensory and physicochemical profiles of wines has been the major goal of several enological scientific researches (Girard, Yuksel, Cliff, Delaquis, & Reynolds, 2001), in order to understand which physicochemical determinations influence the sensory attributes and how they are described (Thorngate, 1997). Some of these studies analyzed the relationship by applying methods such as quantitative descriptive analysis (Campo, Ballester, Langlois, Dacremont, & Valentin, 2010; Ortega-Heras, Pérez-Magariño, Cano-Mozo, & González-San José, 2010;

Parpinello, Versari, Chinnici, & Galassi, 2009) or by evaluating consumer preference using multivariate statistical tools such as the Principal Component Analysis (PCA) (Chira et al., 2011; Lee et al., 2006) or Cluster Analysis and Multidimensional Scaling (Green, Parr, Breitmeyer, Valentin, & Sherlock, 2011).

Charters and Pettigrew (2007) attempted to describe and evaluate the standard quality of wine based on a wide range of dimensions, some of which are difficult to measure and report, making their definition complex. Jover, Montes, and Fuentes (2004) divided the standard quality of wine into 15 dimensions divided into two clusters: eight extrinsic factors such as reputation, appellation, region, advertising and others factors and seven intrinsic factors related to physical features of the wine, such as age, color, chemical properties, aroma and harvest.

Other studies evaluated the relationship between the extrinsic (Green et al., 2011; Vázquez-Rowe, Villanueva-Rey, Moreira, & Feijoo, 2012) and intrinsic factors, in order to improve the quality of *Vitis vinifera* wines to a standard level (Bindon, Varela, Kennedy, Holt, & Herderich, 2013; García-Carpintero, Sánchez-Palomo, Gómez Gallego, & González-Viñas, 2011; Ortega-Heras et al., 2010; Parpinello et al., 2009). However, studies about the relationship amongst the intrinsic factors on *Vitis labrusca* wines are practically nonexistent, or restricted to an individual factor such as the chemical composition of the edible parts (flesh and skin) of Bordô grapes (Lago-Vanzela, Da-Silva, Gomes, García-Romero, & Hermosín-Gutiérrez, 2011). Hence, the relationship amongst the intrinsic factors comprises an interesting approach, allowing for the characterization of red table wines.

Furthermore, American cultivars (*Vitis labrusca*) are responsible for about 80–85% of the volume of grape production in Brazil (Nixdorf & Hermosín-Gutiérrez, 2010) and thus have a great influence on Brazilian wine production because of their nutritional effects. Scientific researchers have discovered that the habit of a daily intake of red table wine may be associated with longevity, due to the presence of resveratrol, which prevents the occurrence of cardiovascular diseases such as arteriosclerosis and thrombosis, controlling diabetes and reducing the risks of some types of cancer (German & Walzem, 2000; Goldfinger, 2003; Pendurthi, Williams, & Rao, 1999; Wang et al., 2006). For these and other reasons, table wines are widely studied in Brazil, but mentions of this type of raw material in the worldwide literature, and of its products and derivatives, are practically nonexistent. Of the American species cultivated in Brazil, wines made from Bordô and Isabel grapes are by far the most investigated (Nixdorf & Hermosín-Gutiérrez, 2010).

With the purpose of contributing to the enrichment of the scientific literature on wines from American cultivars, and of making up for the lack of studies related to these grapes, the major aim of this study was to investigate the relationship between the sensory attributes and the physicochemical properties of wines from two innovative winemaking processes in order to compare them with a traditional treatment. The wines produced using the novel treatments were expected to present greater acceptance as compared to commercial wines. Secondly, it was expected that the chemical properties of these wines would be in accordance with the Brazilian legislation, and finally that the specific chemical properties would be related to their respective sensory attributes.

2. Material and methods

2.1. Wine samples

The grapes were harvested in the city of Jales (20° 16' 6" South and 50° 32' 56" West), located in the northwest region of the State of São Paulo, Brazil. Six different red wines were produced and analyzed: Traditional Bordô wine (TB), Traditional Isabel wine (TI),

Pre-dried Bordô wine (PDB), Pre-dried Isabel wine (PDI), Static pomace Bordô wine (SPB) and Static pomace Isabel wine (SPI). The standard procedure for the production of the red wines consisted of de-stemming followed by manual crushing of the grapes. The must and pomace were placed in 10 L fermentation flasks, and a portion of the must removed for determination of the soluble solids in order to calculate the need for chaptalization. The Bordô and Isabel grapes presented 19.25 and 19.00°Brix, respectively, at the beginning of the winemaking processes. Sulfur dioxide was added to the must by the addition of 15 g of potassium metabisulfite per 100 kg of grapes, and alcoholic fermentation was induced by inoculation with active dry *Saccharomyces cerevisiae* in the proportion of 20 g of yeast per 100 L of must.

The must was macerated for 7 days, pumping twice a day, and subsequently dejuiced and chaptalized to 11°GL. After chaptalization, the must was properly racked three times at 10 day intervals, thus allowing for the spontaneous occurrence of the malolactic fermentation. The degree of malolactic fermentation was controlled by Thin Layer Chromatography (TLC), using 20 mL of 50% acetic acid and 50 mL of a solution containing 1 g of bromophenol blue per L of butanol as the mobile phase (Ribéreau-Gayon, Paynaud, Sudrad, & Ribéreau-Gayon, 1982). Between the second and third rackings, the wines were moved to a refrigerated ambient for 10 days in order to stabilize the tartrate. The wines were then bottled in 750 mL glass bottles and stabilized for 90 days.

The traditional wines followed the standard aforementioned process. The static pomace wines were submitted to a “constant pumping effect” during alcoholic fermentation by using stainless steel screens to maintain the pomace at the bottom of the reactor flask, allowing for constant contact between the pomace and the must. The traditional and static pomace musts all presented final soluble solids contents of 22.30°Brix, theoretically corresponding to 11°GL based on the relationship that 1.8°Babo (2.028°Brix) generates 1°GL (Jackson, 2008).

The pre-drying treatment aimed at drying the grapes to 22°Brix, avoiding the chaptalization process and promoting wines with an alcohol content from 8.6 to 14°GL, in accordance with the Brazilian legislation. Drying was carried out by the convective method, using a tray dryer with a temperature of 60 °C and an air flow of 1.1 m s⁻¹ (Doymaz, 2006; Torres, Díaz-Maroto, Hermosín-Gutiérrez, & Pérez-Coello, 2008).

The mass balance proposed in the pre-drying process was determined by the following mathematical relationships (1) to (4): ‘U’ being the moisture content of the grapes determined in a vacuum oven (60 °C for 24 h); ‘B’ the soluble solids content of the sample (°Brix) determined by refractometry; ‘m_{grape}’ the mass in grams of the dried grapes; ‘m_{water}’ the mass in grams of water in the representative sample; ‘m_{dry}’ the mass in grams of dry material in the sample; ‘m_{sugar}’ the mass in grams of sugar and ‘m_{others}’ the mass in grams of other substances in the sample:

$$m_{\text{water}} = m_{\text{grape}} \cdot U \quad (1)$$

$$m_{\text{dry}} = (1 - U) \cdot m_{\text{grape}} \quad (2)$$

$$m_{\text{sugar}} = m_{\text{water}} \cdot B \quad (3)$$

$$m_{\text{others}} = m_{\text{dry}} - m_{\text{sugar}} \quad (4)$$

In order to determine the amount of water necessary to evaporate from the grapes for them to reach 22°Brix ($B = 0.22$ g of soluble solids per gram of grape) at the end of the drying process, and considering that ‘m_{dry}’, ‘m_{others}’ and ‘m_{sugar}’ did not change

during the drying process, it was possible to determine the final drying stage from the following relationships (5)–(7):

$$m_{\text{water}} = m_{\text{sugar}}/B \quad (5)$$

$$U = m_{\text{water}}/(m_{\text{dry}} + m_{\text{water}}) \quad (6)$$

$$m_{\text{grape}} = m_{\text{water}}/U \quad (7)$$

The Bordô and Isabel pre-drying musts presented final soluble solids contents of 22.44°Brix and 22.24°Brix, respectively. After drying, the grapes were submitted to the standard winemaking process described above, with the exception of the chaptalization step. All winemaking processes were carried out in duplicate, i.e., two fermentation flasks for each type of wine.

2.2. Physicochemical analyses

The following physicochemical analyses were carried out: total (TAC) and volatile (VAC) acidity (meq L⁻¹ tartaric and acetic acid, respectively) using a pH meter, titration and a distiller (Tecnal TE0363); pH using a pH meter (Brasil, 1986); total dry extract (EXT) (g L⁻¹) using porcelain capsules and a thermostatic bath at 100 °C (A.O.A.C., 2005); total phenolic content (PHEN) (mg L⁻¹) using an absorbance spectrophotometer (Quimis Q798U) at 765 nm (Singleton & Rossi, 1965); sulfate content (SUL) (g L⁻¹) using the Marty semi-quantitative method with test tubes and a thermostatic bath at 100 °C (Brasil, 1986); reducing (RSG) and total (TSG) sugars by the Lane–Eynon method (g L⁻¹) using a Redutec determiner (Tecnal TE0861) (A.O.A.C., 2005); alcoholic content (ALC) (°GL) and density (DENS) (g cm⁻³) using pycnometer and analytical balance; (A.O.A.C., 2005) color index with the use of Millipore® filter and the spectrophotometer absorbance (Quimis Q798U) at 420, 520 and 620 nm (Amerine & Ough, 1986).

The fixed acidity (FAC) was calculated from the difference between the total and volatile acidities (Brasil, 1986). The residual dry extract (REXT) was determined from the relationship $\text{REXT} = \text{EXT} - (1 - \text{SUL}) - (1 - \text{TSG})$, REXT being the residual dry extract; EXT the total dry extract; SUL the sulfate content and TSG the total sugar content (Brasil, 1986). All the physicochemical results were obtained in triplicate. Thus six samples were collected for each type of wine, three measurements for each fermentation flask, in duplicate.

2.3. Sensory assessment

The sensory assessment was carried out with the six red wines (TB, TI, PDB, PDI, SPB and SPI) as well as 2 commercial red wines: Bordô varietal wine (CB) and Bordô-Isabel assemblage wine (CI), both from the Serra Gaúcha, Southern Brazil, benchmark in wines. The commercial wines were used in the sensory acceptance analysis in order to know if the winemaking process employed in Brazilian wineries (traditional) and mainly the alternative/innovative winemaking processes (pre-drying and static pomace) had great potential for consumer acceptance.

The sensory assessment was carried out at the Sensory Analysis Laboratory of the Food Technology and Engineering Department of the São Paulo State University. A panel of 80 untrained consumers examined the acceptance for the attributes of appearance, aroma, body, and flavor and the overall acceptance, using a nine point verbal hedonic scale (1 = disliked extremely, 5 = neither liked nor disliked and 9 = liked extremely) (Meilgaard, Civille, & Carr, 1999). The consumers carried out the sensory analyses in individual booths under white light with a room temperature from 23 to 25 °C

over three days, the wines being presented in 30 mL transparent glass cups containing 15 mL of sample at 25 °C.

An incomplete block experimental design was used (Meilgaard et al., 1999) and each panelist evaluated five of the eight wines. The samples were presented in a monadic and randomized order, coded with random three-digit numbers.

The ethical issues of the sensory analysis were approved by the Research Ethics Committee of the Institute of Biosciences, Humanities and Exact Sciences, São Paulo State University (process n. 0019.0.229.000-10).

2.4. Data analysis

2.4.1. Physicochemical and sensory data

The results from the physicochemical and sensory analyses were evaluated using a one-way Analysis of Variance (ANOVA) with the Tukey multiple comparison test when significant differences were observed.

2.4.2. Relationship between the physicochemical and sensory data (chemometric approach)

Ward's Hierarchical Cluster Analysis was applied to the chemometric approach. This method of clustering uses the Analysis of Variance to evaluate the distances between clusters. It attempts to minimize the Sum of Squares of the Euclidean distances of any two (hypothetical) clusters that can be formed at each step of the hierarchical agglomerative clustering process which minimizes the total within-cluster variance and maximizes the between-cluster variance (Ward, 1963).

The hierarchical cluster analysis generates a matrix containing the number of subjects grouped, and the shorter the distance between the subjects, the greater their similarity and relationship. All the data were standardized and analyzed by Multidimensional Scaling (MDS) using mean substitution as the deletion method. MDS is a multivariate technique that defines the optimum Euclidean representation of the subjects in a bidimensional space, enabling visualization of the relationship between the physicochemical and sensory data by way of a number of dimensions which represent the perceptions of each panelist concerning the attributes and physicochemical properties. The Cluster Analysis helps interpret the dimensions, because the clusters show the split between the sensory attributes and the physicochemical properties based on their Euclidean distance, which represents the similarity or dissimilarity between them (Hair, Black, Babin, Anderson, & Tatham, 2006).

All the statistical tests were applied with a significance level of 0.05 using the software Statistica version 7 (Statistica, 2004).

3. Results and discussion

3.1. Physicochemical analyses

Table 1 shows the results obtained for the physicochemical properties. The PDB, TB and PDI wines presented higher values for total acidity (TAC), of above 9.75 g L⁻¹. In this case, it was assumed that the pre-drying process, with evaporation of the water, contributed to the high acidity of these samples. For all the samples the volatile acidity (VAC) was within the maximum limit stipulated by the Brazilian legislation (Brasil, 1999).

The Bordô wines showed higher values for density (DENS) than the Isabel wines, regardless of the winemaking process. The samples PDI and SPI showed higher alcohol contents (ALC). Both the chaptalization and pre-drying processes resulted in alcohol contents of between 8.6°GL and 14°GL, as required by law.

The pre-drying process increased the total dry extract (EXT). Wines with a total dry extract between 20 and 30 g L⁻¹ are light-

Table 1
Chemical results (mean \pm standard deviation) of the red wines.

Determinations*	Wines**					
	TB	TI	PDB	PDI	SPB	SPI
TAC (g L ⁻¹)	10.1 \pm 0.09 ^b	8.4 \pm 0.51 ^c	11.4 \pm 0.45 ^a	10.0 \pm 0.27 ^b	9.0 \pm 0.37 ^c	8.2 \pm 0.26 ^c
VAC (g L ⁻¹)	0.3 \pm 0.05	0.3 \pm 0.05	0.2 \pm 0.03	0.2 \pm 0.08	0.2 \pm 0.06	0.3 \pm 0.1
FAC (g L ⁻¹)	9.8 \pm 0.05 ^b	8.0 \pm 0.55 ^c	11.1 \pm 0.46 ^a	9.7 \pm 0.26 ^b	8.8 \pm 0.38 ^{bc}	7.9 \pm 0.19 ^c
pH	3.3 \pm 0.01 ^{cd}	3.4 \pm 0.005 ^a	3.4 \pm 0.01 ^{bc}	3.3 \pm 0.01 ^d	3.4 \pm 0.01 ^{ab}	3.3 \pm 0.02 ^d
DENS (g cm ⁻³)	0.9982 \pm 0.0002 ^b	0.9938 \pm 0.0005 ^d	0.9996 \pm 0.0001 ^a	0.9948 \pm 0.0002 ^c	0.9981 \pm 0.0004 ^b	0.9936 \pm 0.0002 ^d
ALC (°GL)	10.7 \pm 0.29 ^b	9.7 \pm 0.30 ^c	10.4 \pm 0.02 ^{bc}	12.5 \pm 0.32 ^a	10.4 \pm 0.51 ^{bc}	11.7 \pm 0.15 ^a
EXT (g L ⁻¹)	30.8 \pm 0.76 ^b	20.3 \pm 0.76 ^d	36.3 \pm 1.60 ^a	27.3 \pm 0.57 ^c	28.6 \pm 1.04 ^{bc}	21.8 \pm 0.76 ^d
REXT (g L ⁻¹)	26.9 \pm 1.47 ^b	18.9 \pm 0.52 ^d	31.9 \pm 2.40 ^a	23.4 \pm 0.53 ^c	25.8 \pm 0.83 ^b	20.1 \pm 0.77 ^{cd}
ALC/REXT	3.1 \pm 0.21 ^c	4.0 \pm 0.04 ^b	2.6 \pm 0.19 ^d	4.2 \pm 0.15 ^{ab}	3.2 \pm 0.22 ^c	4.6 \pm 0.11 ^a
RSG (g L ⁻¹)	2.4 \pm 0.16 ^a	1.4 \pm 0.05 ^c	2.8 \pm 0.24 ^a	1.9 \pm 0.30 ^{ab}	2.4 \pm 0.13 ^a	1.8 \pm 0.09 ^{bc}
TSG (g L ⁻¹)	4.8 \pm 0.83 ^{ab}	2.3 \pm 0.24 ^d	5.3 \pm 0.92 ^a	4.8 \pm 0.11 ^{ab}	3.8 \pm 0.23 ^{bc}	2.7 \pm 0.06 ^{cd}
PHEN (mg L ⁻¹)	1232.7 \pm 2.98 ^b	506.6 \pm 1.79 ^f	1303.8 \pm 5.60 ^a	1038.8 \pm 5.19 ^d	1205.1 \pm 2.58 ^c	794.0 \pm 5.86 ^e
OD 420 nm	7.2 \pm 0.01 ^c	3.4 \pm 0.02 ^d	9.8 \pm 0.005 ^a	3.3 \pm 0.02 ^e	7.4 \pm 0.06 ^b	2.3 \pm 0.01 ^f
OD 520 nm	9.3 \pm 0.02 ^b	4.0 \pm 0.03 ^d	12.7 \pm 0.01 ^a	4.7 \pm 0.01 ^c	9.3 \pm 0.01 ^b	3.3 \pm 0.01 ^e
OD 620 nm	2.5 \pm 0.01 ^c	1.5 \pm 0.02 ^d	4.0 \pm 0.02 ^a	1.4 \pm 0.02 ^e	2.7 \pm 0.01 ^b	0.9 \pm 0.02 ^f
INT	19.1 \pm 0.02 ^c	9.0 \pm 0.07 ^e	26.5 \pm 0.02 ^a	9.5 \pm 0.02 ^d	19.4 \pm 0.08 ^b	6.7 \pm 0.01 ^f
TON	0.77 \pm 0.002 ^c	0.85 \pm 0.001 ^a	0.77 \pm 0.001 ^c	0.71 \pm 0.003 ^d	0.80 \pm 0.005 ^b	0.69 \pm 0.006 ^e
SUL (g L ⁻¹)	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7

*Means followed by different letters in the same row differ by Tukey test ($P < 0.001$). TAC, total acidity; VAC, volatile acidity; FAC, fixed acidity; DENS, density; ALC, alcoholic content; EXT, dry extract; REXT, residual dry extract; ALC/REXT, relation between alcohol content and residual dry extract; RSG, reducing sugars; TSG, total sugars; PHEN, total phenolic content; INT, color intensity; TON, hue; SUL, sulfate content, OD, optical density.

**TB, Traditional Bordô wine; TI, Traditional Isabel wine; PDB, Pre-dried Bordô wine; PDI, Pre-dried Isabel wine; SPB, Static Pomace Bordô wine; SPI, Static Pomace Isabel wine.

bodied (thin or watery) to the taste, while wines with a total dry extract above 30 g L⁻¹ can be considered full-bodied (Zoecklein, Fugelsang, Gump, & Nury, 1994). In the present case, the samples TB, PDB, SPB and PDI were considered full-bodied. This was considered to be an interesting result of the study, since the pre-drying winemaking process enhanced the body of the Isabel wine, which is considered as a light-bodied wine in its traditional form, as shown by the dry extract results for TI and SPI.

All the wines presented an alcohol content/residual dry extract (ALC/REXT) ratio below 4.8, a fact suggesting that none of the wines were tainted by chaptalization (Brasil, 1999). The total (TSG) and reducing (RSG) sugar levels were higher in the Bordô wines, showing similarity with the sample PDI, indicating the contribution of the practice of drying to the concentration of these sugars. The same could be observed for the total phenolic content (PHEN), highlighting sample PDI, which presented a similar total phenolic content to that of sample SPB. The sample SPI showed a higher total phenolic compound content than the wine TI, contradicting the conclusion of Jackson (2008) that the pumping process optimized the extraction of phenolic and colorant compounds.

The color indexes of the Bordô wines were higher than those of the Isabel wines. The results showed the effectiveness of the pre-drying process, since in addition to concentrating the grape soluble solids, it also concentrated the phenolic compounds and colorants, favoring a more attractive wine color with the indexes for the red hue (OD 520 nm) being higher than those for the yellow and

violet hues (OD 420 nm and OD 620 nm, respectively). The higher value found for the violet hue in the PDB sample was due to the higher concentration of anthocyanins in this wine.

It was expected that drying would be a negative factor for the color of the grapes and wines, since the anthocyanins would be degraded during this process due to the use of heat (Cacace & Mazza, 2003). However, the physicochemical results suggested the opposite, i.e., the colored compounds were concentrated, showing that the anthocyanins were present in the flavonoid (algycone) component bound to the sugar (Jackson, 2008), which represents an interesting result.

The stability of anthocyanins is influenced by the acylation degree of the molecule, since the higher the degree of acylation of the molecule, the greater the heat stability of the anthocyanin (Sapers, Taffer, & Ross, 1981). In their studies, Nixdorf and Hermosín-Gutiérrez (2010) and Lago-Vanzela et al. (2011) discovered that *Vitis labrusca* grapes presented a high proportion of coumaroylated anthocyanidin 3,5-diglucosides in their composition, which provided great resistance to the high temperatures applied during the drying process.

3.2. Sensory assessment

Eighty untrained consumers (43 women, 53.75% and 37 men, 46.25%) evaluated the acceptance of the wines. The average age of the panelists was 24.3 years old with a standard deviation of 8.4.

Table 2
Sensory results (mean \pm standard deviation) of red wines.

Attributes ^a	Wines*							
	TB	TI	PDB	PDI	SPB	SPI	CB	CI
^b Appearance	7.60 \pm 1.19 ^{aA}	6.50 \pm 1.16 ^{bcB}	7.48 \pm 1.37 ^{aA}	7.10 \pm 1.37 ^{abAB}	6.90 \pm 1.66 ^{abAB}	6.98 \pm 1.20 ^{abAB}	5.60 \pm 2.15 ^{cd}	5.32 \pm 1.77 ^d
Odor	6.22 \pm 1.70 ^{abc}	6.18 \pm 1.88 ^{abc}	6.62 \pm 1.51 ^a	6.30 \pm 1.21 ^{ab}	6.00 \pm 1.71 ^{abc}	6.40 \pm 1.64 ^{ab}	5.26 \pm 2.05 ^c	5.46 \pm 1.83 ^{bc}
^b Body	6.28 \pm 1.56 ^{aAB}	5.52 \pm 1.77 ^{abcB}	6.54 \pm 1.78 ^{aA}	5.92 \pm 1.65 ^{abcAB}	5.86 \pm 1.69 ^{abcAB}	6.06 \pm 1.54 ^{abAB}	5.18 \pm 1.71 ^{bc}	4.98 \pm 1.84 ^c
Flavor	4.72 \pm 2.03 ^{ab}	4.80 \pm 2.15 ^{ab}	5.28 \pm 2.05 ^a	4.88 \pm 1.81 ^{ab}	4.94 \pm 2.20 ^{ab}	5.40 \pm 1.94 ^a	4.00 \pm 2.19 ^b	3.90 \pm 1.91 ^b
Overall acceptance	5.68 \pm 1.77 ^{ab}	5.32 \pm 1.86 ^{abc}	5.98 \pm 1.75 ^a	5.60 \pm 1.51 ^{abc}	5.54 \pm 1.73 ^{abc}	6.06 \pm 1.61 ^a	4.66 \pm 1.89 ^{bc}	4.56 \pm 1.75 ^c

*TB, Traditional Bordô wine; TI, Traditional Isabel wine; PDB, Pre-dried Bordô wine; PDI, Pre-dried Isabel wine; SPB, Static Pomace Bordô wine; SPI, Static Pomace Isabel wine; CB, Commercial Bordô wine; CI, Commercial Isabel wine.

^a Means followed by different lowercase letters in the same row differ by Tukey test ($P < 0.001$), including commercial wines (CB and CI).

^b Means followed by different uppercase letters in the same row differ by Tukey test ($P < 0.05$), excluding commercial wines (CB and CI).

The results of the evaluation demonstrated that the wines produced using the novel and traditional winemaking processes presented greater acceptance than the commercial wines (Table 2), representing a positive outcome of the study.

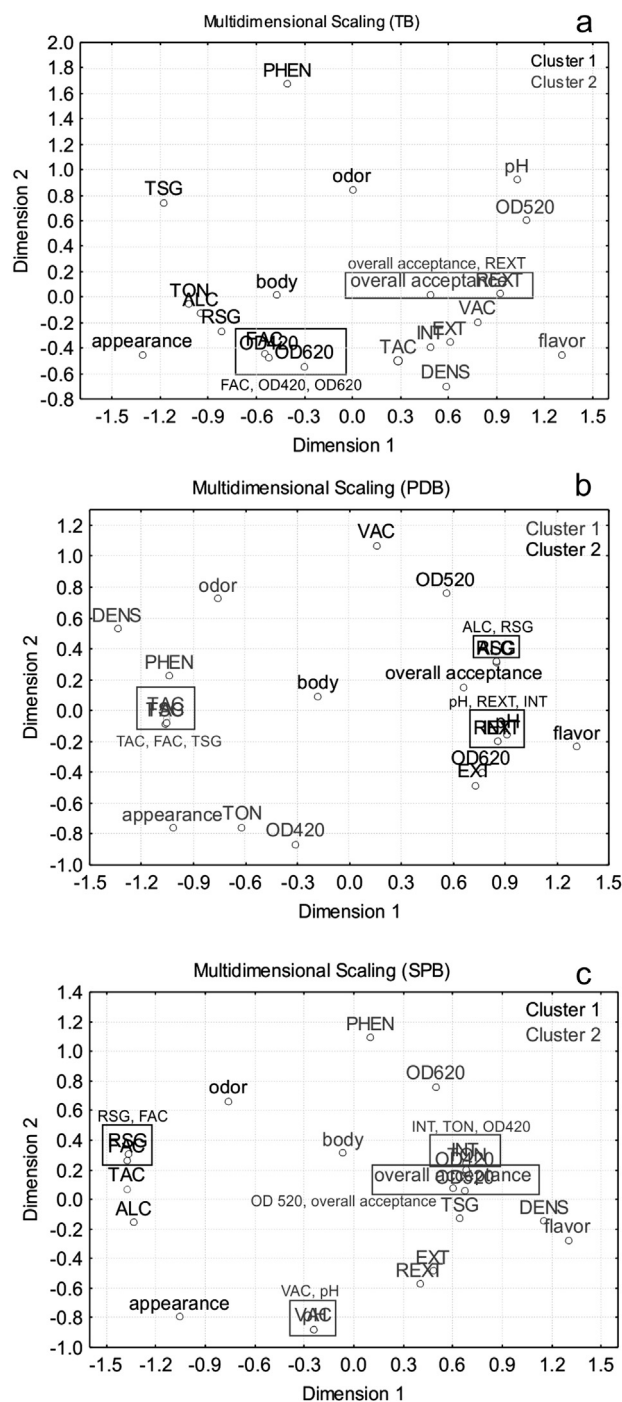
With respect to the wines from the novel and traditional treatments, there was emphasis on the acceptance of the appearance and body for the PDB, TB and SPI samples, showing significant differences amongst these samples ($P < 0.05$). This fact revealed that the acceptance of the innovative wines was fairly close to that of the traditional ones, representing another positive outcome of the study. Due to the difference found amongst the samples in the results for acceptance, especially with respect to the commercial wines, the multivariate analysis used to evaluate the relationship between the physicochemical properties and the sensory attributes was only applied to the samples produced using the novel and traditional winemaking processes.

The results of MDS analysis showed the split in the sensory attributes in dimension 1, reaffirming the results from the cluster analysis, and providing a better explanation of the results. Dimension 1 showed the division of the sensory attributes in all the wine samples, with appearance and odor in one cluster and flavor and overall acceptance in another one. Body acceptance was allocated in different clusters according to the sample analyzed. Dimension 2 presented a certain tendency for division of the physicochemical properties, showing that the properties related to wine density (DENS, RSG, TSG) were on the opposite side from the visual properties (TON, INT, OD). This result indicates that visual perception presented relevant dissimilarity in relation to the properties linked to wine density.

The data from the Bordô samples were divided into two distinct clusters (Fig. 1). Etaio, Elortondo, Albusu, Gaston, Ojeda and Schlich (2008) described the influence of the phenolic compounds and color parameters on the appearance of wines. The acceptance of the appearance of the Bordô wines was correlated with the parameters of color, optical density and total phenolic content, corroborating the results of the study mentioned above.

The alcohol content interfered in the odor, as described by Le Berre, Atanasova, Langlois, Etiévant, and Thomas-Danguin (2007), and the body showed an association with the total and reducing sugars, alcohol content and fixed acidity as described by Jackson (2008). The flavor was connected with the total and volatile acidity, total and residual dry extract, density and some parameters associated with the color of the wine, which, in addition, influenced the overall acceptance of the samples, since flavor and overall acceptance were always allocated in the same cluster.

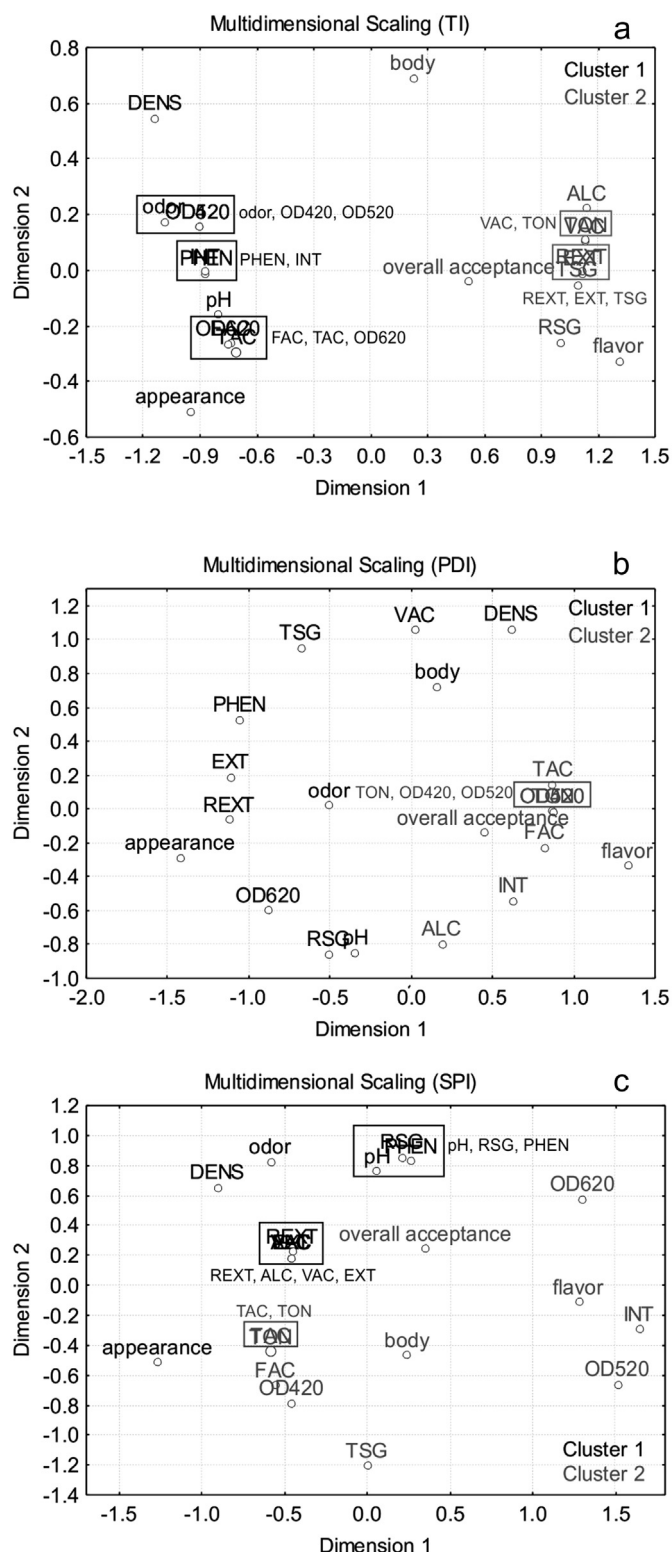
The total and fixed acidity positively influenced the release of the odor of the PDB wine since high acidity (low pH) enhances the release of odor due to hydrolysis of the glycosidic compounds (Baumes, 2009; Mira de Orduña, 2010). The appearance of the PDB wine was associated with the total phenolic content, color and OD at 420 nm, a result that was expected since these physicochemical properties are connected to visual perceptions. The reducing sugar content, as well as the total and residual dry extracts enhanced the body of the wines, confirming the results obtained by Yanniotis, Kotseridis, Orfanidou, and Petraki (2007). The flavor of the PDB wine was associated with the alcohol content, which, in turn, presented additional interference in the body of wine (Jones, Gawel, Frances, & Waters, 2008; Meillon et al., 2010). Overall acceptance was determined by the interaction of the determinations previously mentioned, in addition to the volatile acidity and the OD at 520 nm and 620 nm. The relationship between odor and alcohol content, as described by Escudero, Campo, Farina, Cacho, and Ferreira (2007), was observed in the TB and SPB samples, and the PDB sample presented a relevant relationship between odor and acidity. The acceptance of body was linked to the total and residual dry extracts



TAC, total acidity; VAC, volatile acidity; FAC, fixed acidity; DENS, density; ALC, alcoholic content; EXT, dry extract; REXT, residual dry extract; RSG, reducing sugars; TSG, total sugars; PHEN, total phenolic content; INT, colour intensity; TON, hue; OD, optical density; TB, Traditional Bordô wine; PDB, Pre-dried Bordô wine; SPB, Static Pomace Bordô wine.

Fig. 1. Bordô wines plotted in Multidimensional space: (a) Traditional (b) Pre-drying (c) Static pomace.

(Yanniotis, Kotseridis, Orfanidou, & Petraki, 2007); flavor and overall acceptance were influenced by the color parameters, total phenolic content, color indexes, total sugar content and density. The appearance and odor attributes were found in the same cluster for all the Bordô wine samples, probably due to the existence of a strong relationship between these sensory attributes and the alcohol content and acidity (total, volatile or fixed).



TAC, total acidity; VAC, volatile acidity; FAC, fixed acidity; DENS, density; ALC, alcoholic content; EXT, dry extract; REXT, residual dry extract; RSG, reducing sugars; TSG, total sugars; PHEN, total phenolic content; INT, colour intensity; TON, hue; OD, optical density; TI, Traditional Isabel wine; PDI, Pre-dried Isabel wine; SPI, Static Pomace Isabel wine.

Fig. 2. Isabel wines plotted in Multidimensional space: (a) Traditional (b) Pre-drying (c) Static pomace.

The Isabel wines also showed differences in the relationship between the physicochemical determinations and the sensory attributes (Fig. 2), indicating two distinct clusters for all the samples. The appearance of all the wines obtained from this cultivar was related to their total phenolic compounds, pH and some of the color indexes, except for the SPI sample which showed no association between the appearance and the color indexes. Furthermore, appearance seems to have been related to density in all the samples, probably due to the effect of wine viscosity as previously stated by Jackson (2009).

A relationship was found between acidity and the acceptance of odor for all the Isabel samples, for instance between total and fixed acidity in the acceptance of the odor of IT, and volatile acidity in the case of the PDI and SPI samples. Le Berre et al. (2007) showed the contribution of the alcohol content to the odor of wines, which could be observed in the SPI sample.

All the Isabel samples presented a relationship between the acceptance of body and the total and residual dry extracts or the total and reducing sugar contents (Yanniotis, Kotseridis, Orfanidou, & Petraki, 2007). The alcohol content was responsible for enhancing the acceptance of flavor (Meillon et al., 2010), and in addition, the acidity parameters also influenced this sensory attribute, assuming that these physicochemical determinations were essential for its acceptance. Regardless of the cultivar used to make the wines, a relationship could be seen between the color parameters and the attribute of flavor for the static pomace samples, indicating the influence of the constant contact between the pomace and must during maceration.

4. Conclusions

Chemometric methods were successfully used to show the designation of the chemical properties as a guide to the sensory acceptance of red wines. The sensory attributes of body and odor were directly influenced by the alcohol content and this relationship was more significant than the total and residual dry extract. The appearance was characterized by the color parameters, also responsible for flavor and overall acceptance. A relationship could be observed between the acidity parameters and odor acceptance in all samples, demonstrating that the wine acidity influenced the release of volatile compounds that characterized the pleasant odor of this beverage. The results revealed similarities between appearance and odor, and flavor and overall acceptance, in all the samples, regardless of the cultivar, since these attributes were located in the same cluster. Thus, any chemical property linked to the attribute of appearance can be considered as an influence on the attribute of odor and vice-versa, as also for flavor and overall acceptance. The PDB, SPB and SPI wines stood out from the traditional winemaking and commercial wines, showing great acceptance by the consumers, and could possibly be applied on large scale in Brazilian wineries in order to improve the quality of non-*V. vinifera* wines.

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