SENSORY CHARACTERIZATION OF *VITIS VINIFERA* CV. MALBEC WINES FROM SEVEN VITICULTURE REGIONS OF ARGENTINA

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ABSTRACT

Fifty-six Malbec wines from seven Argentine viticulture regions (Valles Calchaquíes, Mendoza del Este, Mendoza del Sur, Patagonia, Alto Río Mendoza, Valle de Uco and San Juan), of the 2004 vintage, were evaluated by sensory descriptive analysis using a panel of 10 not-sighted assessors. "Non-commercial" samples were obtained using standardized conditions, not aging and produced with grapes corresponding to each viticulture region. Malbec wines from same regions exhibited particular characteristics. Valles Calchaquíes wines had strong herbal, spicy, sweet pepper aromas and pungency in contrast to San Juan wines that showed fruity, strawberry, honey and citrus aromas. Mendoza del Este and Valle de Uco wines were associated with cooked fruit, raisin, floral and sweetness attributes as opposed to Mendoza del Sur and Patagonia wines which were characterized by sourness, bitterness, persistency and astringency, and not by aroma attributes. Alto Río Mendoza wines were characterized by pungency, sweet pepper and bitterness.

PRACTICAL APPLICATIONS

Sensory profiling of "non-commercial" Malbec wines developed in this research could be used as a tool to differentiate and classify Argentine

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Controlled Denominations of Origin (DOC). Wines with DOC have important value in the market and they are original country representative in the world. The results of this study suggest that Malbec wines from some of the regions located in latitudes 31–33° (San Juan, Mendoza del Este and Valle de Uco; Argentina) were associated with the most desired sensory characteristics. Out of these latitudes, wine-making process would have more importance on Malbec wine quality.

INTRODUCTION

Malbec is a red wine with origins in southern France. It lost its popularity in its French birthplace because of the weather of the region, causing the grapes to deteriorate and not produce a quality wine. Known as Cot in most viticultural countries, in Argentina Malbec is the most common name. The French agricultural engineer Michel Pouget first introduced it in the country in the mid-nineteenth century because it showed good adaptation to the foothill region irrigated by the waters of the Mendoza River. Malbec is a frail variety demanding specific ecological conditions and vineyard management techniques, and does not reach the development of its varietal characteristics in all regions. It requires wide night–day temperature variation and cool nights. Maximum mean day temperatures should not be higher than 30C during the months of ripening; otherwise, color intensity and total polyphenols in grapes might decrease. Some Mendoza regions gather all the mentioned climatic conditions, which account for the great success of Malbec in this province (Dengis 1995; Fanzone 2002).

Among its sensory characteristics, its intense red color with purple hues stands out. The most common aromatic descriptors are plum, red fruit and spice. It sometimes shows herbal, usually related to unbalanced strains. Viticultural management should try to avoid such herbal that tends to produce bitterness and undesired rapid evolution of the wine (Boidron *et al.* 1995). Although Malbec has become the typical Argentine red wine, it is necessary to reach an agreement on processing standards, grape maturity, maceration and bottle- and barrel-aging periods.

Argentine vineyards lie between the southern latitude parallels of 22–42° where a desert climate produces arid growing conditions. Irrigation by water obtained from the plentiful, eternal snows of the Andes Mountain Range, and the combination of warm, sunny days and often very cold nights create an especially healthy environment for vines.

Wine regions of Argentina are group in three principal areas:

(1) Northwest area: This area encompasses the provinces of Salta and La Rioja. The vineyard areas account for about 4% of Argentina's wine

production, and are located in a group of valleys formed by the mountain ranges in the north of the country.

(2) Central west area: This area comprises vineyards located in the provinces of Mendoza and San Juan, which together produce over 90% of Argentine wine. Soils are calcareous, but the lack of organic matter restricts vigorous vine growth. Such conditions are excellent for the production of high-quality wine.

(3) South area: In the evocatively named Patagonia region of Argentina lie some of the world's most southerly located vineyards. Rio Negro province accounts for some 3% of total production. Typical desert soils and wide temperature variations make a special environment for vineyards capable of producing quality wine.

Each vine-growing region is marked by its own particular attributes, and even within each region, there are areas with different climatic and soil characteristics, which enable the cultivation of different vines and the production of a wide variety of wine styles.

Several works have been carried out to classify different wine varieties for their geographic origin, vintage and wine state by sensory and/or compositional analysis. In this way, Chardonnay wine has been extensively investigated (e.g., Moio *et al.* 1993; Arrhenius *et al.* 1996; Cliff and Dever 1996; Zamora and Guirao 2002, 2004; Schlosser *et al.* 2005). Pinot Noir has been studied by Guinard and Cliff (1987). Riesling wine was characterized by Fischer *et al.* (1999) and by Douglas *et al.* (2001). De La Presa-Owens and Noble (1995) studied Macabeo, Xarel.lo and Parellada varieties from the Penedès region of Spain. Heymann and Noble (1987) worked with commercial Cabernet Sauvignon wines from California. Noble and Shannon (1987) investigated Zinfandel wines. Andrews *et al.* (1990) studied Seyval Blanc wines. Vilanova and Soto (2005) established the aromatic descriptors of young Mencía wines from different geographic areas of Ribeira Sacra appellation of origin controlled in Galicia (NW Spain).

In spite of the mentioned works, few studies were reported for Malbec wines. Fanzone (2002) identified the chemical components and its source of origin (varietal, prefermentative or fermentative) of Malbec wine from grapes cultivated in an experimental plot in Luján de Cuyo (part of Alto Río Mendoza region).

Wine composition depends on many factors such as grape variety, geographic origin and wine-making process. In the present study, geographic origin was selected and the wine-making process was minimized through the standardization of vinification systems. Sensory profiling of Malbec wines could be used as a tool to differentiate and classify Argentine-controlled denominations of origin (DOC). Wines with DOC have important value in the market, and they

are original country representative in the world. This research was conducted to further the understanding of regional effects on Argentine Malbec wines and contribute to produce clearly distinctive wines on a consistent basis.

The aim of this work was the sensory characterization of "noncommercial" Malbec wine from seven viticulture regions of Argentina, and evaluate the possible differentiation according to geographic origin.

MATERIALS AND METHODS

Wine Samples

Fifty-six Malbec wines of the same type (2004 vintage) from the following Argentine viticulture regions were used for the study: Valles Calchaquíes (Salta province), Mendoza del Este, Mendoza del Sur, Patagonia (Neuquén and Río Negro provinces), Alto Río Mendoza , Valle de Uco (Mendoza province) and San Juan. Table 1 shows the geographical location of the seven viticulture regions.

Samples were especially obtained from fermentation tanks and elaborated under standardized conditions without wood treatment, carbonic gas or additives, malolactic fermentation, with alcoholic graduation between 12.5 and 14.0%. Moreover, each wine was produced using 100% Malbec grapes from the specified region. These standardized conditions guaranteed that all wines were not subjected to the winemakers' practices which would modify the sensory profile of the finished wine. From now on, we use the term "noncommercial" to name the standardized samples used for the study.

TABLE 1.
GEOGRAPHICAL LOCATION OF THE SELECTED VITICULTURE REGIONS FROM ARGENTINA

Region	Latitude (° S)	Longitude (° W)	Altitude (m)
1. Valles Calchaquíes (Cafayate)	25.52–26.11	65.38–66.11	1,238–2,000
2. Mendoza del Este (San Martín, Junín, Rivadavia, Santa Rosa, La Paz)	33.04–33.28	67.33–68.19	500–770
3. Mendoza del Sur (San Rafael, Gral. Alvear)	34.58–35.00	67.39–68.40	620–745
4. Patagonia (San Patricio del Chañar, Alto Valle del Río Negro)	38.35–39.01	67.40–68.20	240–300
5. Alto Río Mendoza (Luján de Cuyo, Maipú, Carrodilla)	32.59–33.02	68.46–68.53	832–860
6. Valle de Uco (Tunuyán, Tupungato, La Consulta, San Carlos)	33.22–33.45	69.02–69.77	870–1,250
7. San Juan (Tulum, Ullum, Pedernal, Calingasta)	31.19–31.59	68.42–69.26	630–1,350

Panel Training

Ten paid, not-sighted assessors (four females and six males, 21–55 years old) from the panel of Staffing and Training Group (S & TG), Buenos Aires consulting company, were trained in descriptive analysis of Malbec wines (10 h). The assessors had prior training in descriptive analysis of perfumery products and foods (cheese, milk and mayonnaise). Mucci *et al.* (2005) compared the discrimination ability (for various food samples), between this not-sighted panel and a panel of sighted assessors, and found no differences. The not-sighted assessors permitted evaluation of the wines only by taste and smell, without influence of visual attributes; several studies have shown that color greatly impacts the ability of subjects to identify food and beverages (Zellner *et al.* 1991; Delwiche 2004). However, the elimination of visual input with a blindfold does not significantly alter flavor from that of a colorless solution (Zellner and Kautz 1990), indicating that while color can alter perceived taste, smell and flavor ratings, the elimination of visual input does not eliminate the perception of flavor (Delwiche 2004).

During the training period, judges performed the following tasks: (1) odor and taste identification using standard solutions (Table 2); (2) ordering tastes in ascending scale using different levels for sweetness, sourness and bitterness as shown in Table 2; (3) attribute generation of different wine samples with the aid of standards; (4) matching of aromas; and (5) use of structured scales.

Sensory Evaluation

The experiment was divided into two phases: (1) Triangle test (ASTM 1977) was performed to compare wines intraregion (28 pairs by region) and developed information about the characteristics of samples. During tests, 25 sessions of 5 h each (3 h in the morning and 2 h in the afternoon), the assessors were required to pick the sample which they believe to be different and describe what attributes were perceived; the panel leader recorded the results. (2) Descriptive analysis (ASTM 1992; Stone and Sidel 1993) was made using 9-point intensity scales. The panel leader recorded the scores in an oral way. An initial list of descriptors was made by computing the number of times (frequency mention); a term was chosen by the participants in the triangle tests when the responses were correct. All samples (50 mL) were poured from a single bottle (750 mL), presented at 18 $\pm$ 2C in tulip-shaped transparent glasses, covered with glass petri dishes and identified by random three-digit codes. The samples were expectorated, and mineral water was provided for oral rinsing along with unsalted crackers. A randomized incomplete block design was used to evaluate all the wines. Eight samples were presented (one for each region) for the session in the morning (2.5 h) and the duplicate in the afternoon (2.5 h).

TABLE 2.
AROMA AND TASTE STANDARD COMPOSITION

Attribute	Composition*
Fruity	20 µL Fruit extract (Firmenich)
Citrus	20 µL Citral (Fluka)
Strawberry	20 µL Strawberry extract (Firmenich)
Plum	20 µL Plum extract (Firmenich)
Raisin	20 µL Raisin extract (Firmenich)
Almond	20 µL Almond extract (Firmenich)
Nutty	50 g Ground nuts
Toasted	20 µL Toasted extract (Firmenich)
Cooked fruit	20 µL Cooked fruit extract (Firmenich)
Floral	20 µL Floral extract (Firmenich)
Lactic	20 g Natural yogurt
Honey	20 µL Honey extract (Firmenich)
Peach	20 µL Peach extract (Firmenich)
Herbal	20 µL Herb extract (Firmenich)
Caramelized	20 µL Caramel extract (Firmenich)
Yeasty	20 µL Yeast extract (Firmenich)
Sweet pepper	20 g Ground sweet pepper
Spicy	20 µL Spicy extract (Firmenich)
Leather	Piece of leather cow
Sweetness	1.5 and 3.0% sucrose (food grade)
Sourness	0.2, 0.4 and 0.6% tartaric acid (Alcor)
Bitterness	0.004 and 0.008% caffeine (Merck)

* For 100 mL solution of wine base.
Firmenich, Bs. As., Argentina; Fluka, Neu-Ulm, Germany; Alcor, Bs. As., Argentina; Merck, Darmstadt, Germany.

Data Analysis

The binomial distribution was used to calculate the significant level for the triangle test, based on a number of correct answers. Analysis of variance (ANOVA) was carried out to assess attributes significantly different among wines from different regions using the general linear model command in SPSS version 13.0 (SPSS, Inc., Chicago, IL). The variability of each descriptor was studied using a model where assessor and wine were considered as random factors, region and replication as fixed factors and wine nested in region. Multiple means comparisons were carried out by Tukey's honestly significantly different test at $P < 0.05$. A more conservative test such as Tukey was used to reduce the probability of error (finding a significant difference when there is none). A principal component analysis (PCA) was conducted to examine the relationship among attributes and regions. Covariance matrix was used because all the attributes were measured on the same structured scale (Borgognone *et al.* 2001), and the minimum eigenvalue was set at 1.

RESULTS AND DISCUSSION

Triangle Test

The final list of descriptive terms was selected based on a criterion that attributes be mentioned at least once by all the assessors in the same region. The following attributes were selected for descriptive analysis: fruity, citrus, strawberry, plum, raisin, nutty, cooked fruit, floral, honey, peach, herbal, caramelized, spicy, leather and sweet pepper (15 aromas); persistency (duration); pungency (trigeminal); sweetness, sourness and bitterness (three tastes); and astringency and body (mouthfeel sensations).

Sensory Profile

ANOVA. Outlier's detection, checked by means of the box plot analysis, revealed that nutty, peach, caramelized and leather aromas had very scattered values; therefore, they were omitted.

ANOVA of mixed model for attribute scores (56 samples: eight wines × seven regions) showed that assessor effect was a significant ($P < 0.001$) source of variation for all attributes. These results indicated that the judges did not evaluate the samples in the same fashion, probably because they used different parts of the scale for the same physiological perceptions. The judges showed a good reproducibility because replication factor was only significant ($P < 0.05$) for raisin (F [1, 6] = 29.968), which was perceived by seven assessors. Region effect was highly significant ($P < 0.001$) for strawberry, spicy, cooked fruit, honey, herbal, sweet pepper, astringency, sweetness, sourness and bitterness; very significant ($P < 0.01$) for fruity and floral; and significant ($P < 0.05$) for citrus, raisin, persistency and pungency, but not for plum and body. Wine × assessor interactions were not significant with exception of the attributes sweetness (F [63, 975] = 1.988) and bitterness (F [63, 975] = 2.137); ($P < 0.001$). This indicates a good consensus among assessors. In relation to sweetness and bitterness, the interaction could happen because the samples were very similar in these sensory properties, and the assessors could not differentiate easily among them. To verify this observation, wines were examined to differentiate from each other by a given attribute. ANOVA and Tukey's test ($P < 0.05$) were performed with the 56 wines for sweetness and bitterness. Only two wines were significantly less sweet than the others. On the other hand, one wine was significantly sweeter. As regard to bitterness, only four out of 56 wines were less bitter and one was significantly bitterer than others. Later, this was just the same less sweet. So, the two "extreme wines" (in as regard each attribute) were evaluated by a new ANOVA. No significant interactions were found in neither sweetness (F [9, 9] = 1.984) nor

bitterness (F [9, 9] = 10.414). These data show that – for these two attributes and for the wines selected – the judges were in agreement.

Intraregional wine variability was not significant, except for cooked fruit ($P < 0.01$), astringency ($P < 0.001$) and sweetness ($P < 0.001$). Therefore, intraregional differences were greater than those among regions for the mentioned attributes.

Means of attributes which showed significant differences among regions are presented in Table 3 (based on the averages for the wines within regions). As observed, wines of Valles Calchaquíes region had significantly less fruity, strawberry and honey aromas, and greater spicy, herbal, sweet pepper and pungency attributes than those of the San Juan region. All attributes of Mendoza del Este and Valle de Uco regions did not show significant differences between them, and the same was observed between Patagonia and Mendoza Sur. Mendoza del Este and Valle de Uco were associated to cooked fruit, raisin, floral and sweetness attributes opposite to Mendoza del Sur and Patagonia, which were characterized by sourness, bitterness, persistency and astringency, and not by aroma attributes. With regard to Alto Río Mendoza, this region had significantly less citrus and floral aromas, and greater sweet pepper and bitterness than the other regions. Fanzone (2002) characterized Malbec wines from Luján de Cuyo (part of Alto Río Mendoza region) by herbal, floral and fruity aromas. In the present work, wines from this region had middle intensity of herbal and fruity aromas; and low intensity of floral aroma.

PCA

Figure 1 shows the PCA of 16 attributes that presented significant discrimination across viticulture regions and the means of eight wines for each region, as it was exposed in Table 3. This analysis was performed to illustrate graphically the correlations between ratings given to the different descriptors and regions.

The first two principal components accounted for 71.6% of the total variance among the regions. Small angles between fruity and strawberry reflected a great degree of correlation between these attributes (Fig. 1), and it could be interpreted as the fruity global aroma is highly integrated for strawberry. Bitterness was inversely correlated with sweetness and gave a good correlation with astringency. It can be seen that pungency was highly correlated with sweet pepper, consistent with the same trigeminal sensation. Honey and citrus correlations could be indicated of assessor's confusion; they used the two terms as synonyms.

Correlation of cooked fruit aroma and sweetness taste could be interpreted as a cognitive phenomenon of associative learning (Zamora and Guirao 2002). It is commonly observed that certain odors smell sweet (Dravnieks

TABLE 3.
MEAN SENSORY SCORES AND STANDARD ERROR MEAN OF MALBEC WINES FROM SELECTED REGIONS

Descriptor	Valles Calchaquíes	Mendoza del Este	Mendoza del Sur	Patagonia	Alto Río Mendoza	Valle de Uco	San Juan
Aroma							
Fruity	2.54 ± 0.24^{a}	3.05 ± 0.38^{ab}	3.57 ± 0.54^{ab}	3.39 ± 0.33^{ab}	3.38 ± 0.20^{ab}	3.74 ± 0.35^{b}	3.83 ± 0.27^{b}
Citrus	2.51 ± 0.21^{ab}	2.72 ± 0.42^{ab}	2.97 ± 0.36^{ab}	3.01 ± 0.22^{ab}	2.23 ± 0.16^{a}	2.84 ± 0.23^{ab}	3.02 ± 0.62^{b}
Strawberry	3.03 ± 0.19^{a}	3.08 ± 0.23^{a}	4.01 ± 0.57^{ab}	3.72 ± 0.51^{ab}	3.50 ± 0.20^{a}	3.64 ± 0.44^{ab}	4.94 ± 0.25^{b}
Spicy	3.87 ± 0.24^{b}	3.49 ± 0.59^{ab}	3.33 ± 0.35^{ab}	3.04 ± 0.52^{ab}	3.54 ± 0.27^{ab}	3.34 ± 0.48^{ab}	2.88 ± 0.32^{a}
Cooked fruit	3.14 ± 0.35^{ab}	3.74 ± 0.40^{b}	3.32 ± 0.45^{ab}	2.74 ± 0.43^{a}	3.06 ± 0.29^{ab}	3.51 ± 0.48^{ab}	2.89 ± 0.56^{ab}
Floral	2.96 ± 0.20^{ab}	3.86 ± 0.34^{b}	3.49 ± 0.39^{ab}	3.15 ± 0.41^{ab}	2.86 ± 0.18^{a}	3.52 ± 0.48^{ab}	3.56 ± 0.50^{ab}
Honey	2.45 ± 0.27^{a}	3.32 ± 0.28^{ab}	3.05 ± 0.41^{ab}	2.84 ± 0.32^{ab}	3.39 ± 0.38^{ab}	3.12 ± 0.52^{ab}	3.61 ± 0.50^{b}
Herbal	4.50 ± 0.32^{b}	3.52 ± 0.59^{ab}	2.88 ± 0.48^{a}	3.03 ± 0.41^{ab}	3.63 ± 0.39^{ab}	3.27 ± 0.54^{ab}	2.80 ± 0.43^{a}
Sweet pepper	3.66 ± 0.34^{ab}	3.02 ± 0.42^{ab}	3.24 ± 0.36^{ab}	3.00 ± 0.43^{ab}	4.17 ± 0.19^{b}	3.41 ± 0.54^{ab}	2.90 ± 0.63^{a}
Raisin	2.61 ± 0.25^{a}	3.19 ± 0.36^{ab}	2.85 ± 0.36^{a}	3.22 ± 0.30^{ab}	3.35 ± 0.34^{ab}	3.88 ± 0.64^{b}	2.92 ± 0.21^{ab}
Taste and mouthfeel							
Astringency	4.78 ± 0.27^{a}	4.58 ± 0.34^{a}	5.68 ± 0.63^{bc}	6.40 ± 0.16^{c}	5.83 ± 0.44^{bc}	4.71 ± 0.29^{a}	5.01 ± 0.35^{ab}
Persistency	5.18 ± 0.27^{ab}	4.71 ± 0.22^{a}	5.58 ± 0.23^{b}	5.61 ± 0.28^{b}	5.08 ± 0.23^{ab}	4.96 ± 0.23^{ab}	4.99 ± 0.25^{ab}
Sweetness	3.16 ± 0.28^{ab}	2.93 ± 0.36^{ab}	2.84 ± 0.37^{ab}	2.43 ± 0.17^{a}	2.61 ± 0.08^{a}	3.64 ± 0.15^{b}	2.90 ± 0.36^{ab}
Sourness	5.29 ± 0.31^{ab}	4.79 ± 0.24^{ab}	5.55 ± 0.24^{b}	4.82 ± 0.18^{ab}	5.12 ± 0.29^{ab}	4.59 ± 0.40^{a}	5.06 ± 0.21^{ab}
Bitterness	4.30 ± 0.29^{a}	4.32 ± 0.34^{a}	4.76 ± 0.48^{ab}	5.37 ± 0.20^{ab}	5.61 ± 0.30^{b}	4.59 ± 0.23^{a}	4.68 ± 0.29^{a}
Pungency	3.50 ± 0.31^{b}	2.79 ± 0.15^{ab}	3.12 ± 0.29^{ab}	3.09 ± 0.11^{ab}	3.18 ± 0.11^{ab}	3.05 ± 0.27^{ab}	2.49 ± 0.24^{a}

Scores are based on a 9-point unstructured score sheet. Means within rows followed by different letters denote those sensory attributes where regions differed significantly at $P < 0.05$ according to Tukey's test.

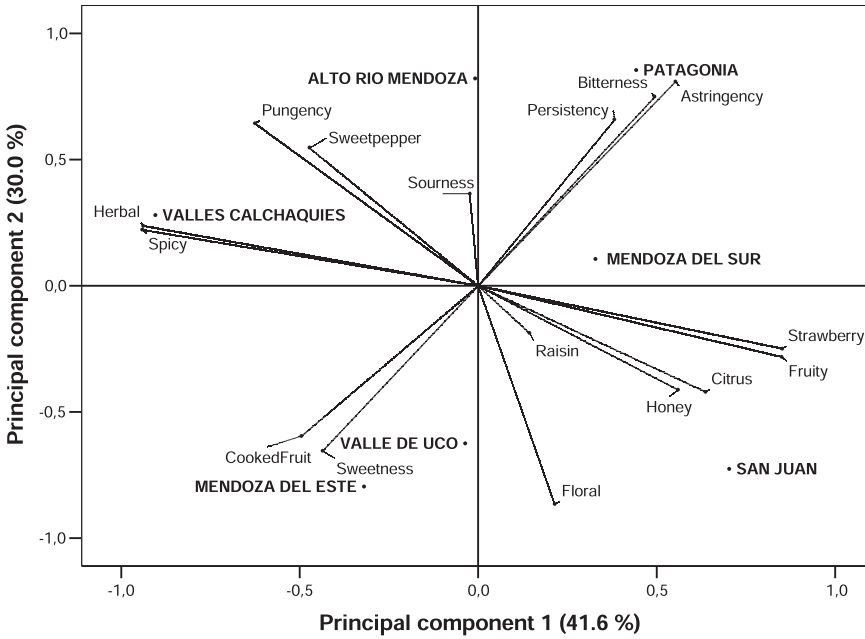

FIG. 1. PRINCIPAL COMPONENT ANALYSIS OF AROMA AND MOUTHFEEL ATTRIBUTES FOR MEAN SCORES OF EIGHT WINES FROM EACH VITICULTURE REGION ANALYZED

1985). Such sweet-smelling odors have the ability, when mixed with sucrose in solution, to make the mixture appear sweeter than sucrose alone (Frank and Byram 1988; Cliff and Noble 1990; Clark and Lawless 1994). This effect, named sweetness enhancement, is lawfully related to the degree to which an odor smells sweet (Stevenson *et al.* 1999). Therefore, it is probable that cooked fruit has been perceived as the sweetest aroma.

The greatest differences between regions were observed in the least intensity of fruity aromas from Valles Calchaquíes wines compared to San Juan wines (along principal component 1); and the least intensity of sweetness and floral from Alto Río Mendoza wines compared to Mendoza del Este and Valle de Uco wines (along principal component 2).

CONCLUSIONS

Descriptive analysis successfully delineated regional differences of "non-commercial" Malbec wines from seven regions of Argentina when a region was contrasted with another region. Valles Calchaquíes exhibited strong

herbal, spicy, sweet pepper aromas and pungency in contrast with San Juan that showed fruity, strawberry, honey and citrus aromas. Mendoza del Este and Valle de Uco were associated to cooked fruit, raisin, floral and sweetness attributes opposite to Mendoza del Sur and Patagonia, which were characterized by sourness, bitterness, persistency and astringency, and to a lesser extent fruity aromas. Finally, Alto Río Mendoza was characterized by pungency, sweet pepper and bitterness.

The intensity of plum and body was similar for all the wines analyzed; it would indicate that these attributes were Malbec grape characteristics.

The results of this study suggest that Malbec wines from some of the regions located in latitudes 31–33° (San Juan, Mendoza del Este and Valle de Uco; Argentina) were associated with the most desired sensory characteristics. Out of these latitudes, Malbec wines exhibited strong herbal and the mixture "bitterness–sourness–astringency" characteristics.

The Malbec wines evaluated in the present work are representative of vintage 2004; further investigations would be necessary to determine the influence of vintage on aromatic and mouthfeel profile.

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