iVES OENO One vine & wine

DOI: https://doi.org/10.20870/oeno-one.2024.58.4.8207

OPEN ACCESS

15TH INTERNATIONAL TERROIR CONGRESS MENDOZA, ARGENTINA

ORIGINAL RESEARCH ARTICLE

Argentine Malbec market: Comparative study of general chemical parameters and sensory properties within low, medium and high price segments

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This article is published in cooperation with the XVth International Terroir Congress, 18-22 November 2024, Mendoza, Argentina.

Guest editors: Federico Berli, Jorge Prieto and Martín Fanzone.

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Associate editor:
Federico Berli

Received:
21 June 2024

Accepted:
4 October 2024

Published:
6 November 2024

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ABSTRACT

Malbec, Argentina's emblematic wine, is appreciated worldwide for its unique characteristics and distinctive organoleptic profile. As demand for Malbec wines increases locally in Argentina and international markets, there is a need to better understand the relationship between the price of these wines and their chemical and sensory characteristics. The aim of this study was to describe and quantify the sensory attributes and chemical parameters (in particular, phenolics) of Argentinean Malbec wines of different price segments. In order to observe the differences between each price range, the eight best-selling wines from the low, medium, and high price categories were analysed. Wine general analytical parameters and phenolics composition were determined and a descriptive analysis was performed with a trained panel. The results show that it was only possible to differentiate between the high- and low-price ranges. Both ranges exhibited variability, including different types of wines. Significant differences were identified in several parameters, such as O.D.280, titratable acidity, malic acid, volatile acidity, alcohol, glucose and total sugars. There were also significant differences in anthocyanins, LPP, SPP, TPP and tannins. The high-price range was characterised by higher alcohol content, greater polyphenol concentration and greater colour intensity. Sensorially, they were distinguished by the descriptors wood, astringency and colour. The low-price range was associated with low colour intensity and higher total sugar content. This is the first study to clearly establish the sensory differences among different price ranges of Argentine wines. Our study demonstrated that wine pricing is not determined in a subjective or arbitrary manner; rather, wines produced for a specific segment are intentionally designed to achieve the desired sensory and chemical characteristics.

KEYWORDS: Terroir 2024, Malbec, wine, Argentine market, price segments, chemical properties, sensory properties

INTRODUCTION

Malbec, Argentina's emblematic wine, is appreciated worldwide for its unique characteristics and distinctive organoleptic profile. In 2023, 51 % of the total Malbec wine sold was distributed within the domestic market, while 49 % was exported. Notably, Malbec accounted for 64 % of all Argentine wine exports (I.N.V., 2024). As the demand for Malbec wines continues to rise both domestically in Argentina and internationally, it is becoming increasingly important to understand the relationship between their prices and their chemical and sensory characteristics. This knowledge could be of significant benefit to wine producers, enabling them to optimise production processes, improve wine quality and strategically position their products on the market to maximise profitability.

Research studies around the world have explored the relationship between the chemical and sensory characteristics of wines in terms of various attributes, such as price, region of origin, vineyard management and even the impact of global climate change. Bruwer and Johnson (2010) demonstrated that wine characteristics, such as grape variety, barrel aging and physicochemical and sensory attributes, significantly influence wine price. Other authors (Boselli *et al*., 2004), who focused on the appellation d'origine contrôlée (DOC) of Italian wines and their sensory profiles, underlined the methodological rigour required for this type of analysis. Moreover, Lecocq and Visser (2006) examined the complex interactions between wine prices and intrinsic and extrinsic characteristics of wines on the French market. They highlighted the significant role of consumer preferences and the chemical composition of wines in determining market prices, underlining the importance of both technical and perceptual considerations in pricing strategies. Similarly, Cox (2009) explored red wine consumption patterns in an Australian urban setting, identifying variability in consumer perceptions and a lack of clear correlation between perceived quality and purchase intentions. This emphasises the need for robust methods to accurately measure wine enjoyment and consumer behaviour.

In research focusing locally on wines produced in Mendoza, Argentina, Antoniolli *et al*. (2011) showed that the relationship between the consumer willingness-to-pay price and blind tasting quality of Mendoza wines is not always direct. Fanzone *et al*. (2011); Fanzone *et al*. (2012) determined that Malbec wines have a higher polyphenolic content compared to other varieties, and they conducted the first characterisation of individual phenolic compounds from Mendoza, Argentina. Orrego (2014) explored European consumers' willingness to pay for Argentine Malbec, focusing on its geographical origin. This work provided a deep understanding of the perceived quality and value of Malbec wines in the international context. Additionally, another contribution to this topic was the study of the hedonic prices of Argentine wines on the U.S. market to evaluate the effects of the most important wine attributes on price (San Martín *et al*., 2008).

Similar to our study, Cáceres *et al*. (2012) studied wines and grapes from the Cabernet-Sauvignon variety across three different price categories and found no correlation between higher prices and polyphenol concentration. Differences were observed only in tannin concentration. An and Yu (2023) studied the influence of sensory attributes on the estimated price of Pinot Noir wines in New Zealand, analysing 78 commercial wines. They conducted a descriptive analysis with a trained panel along with phenolic analyses. They found that the descriptors aging potential and oak influence had a significant impact on the prices estimated by experts. Working specifically with the Malbec variety, Fanzone *et al*. (2012) studied the phenolic and polysaccharide composition across three price ranges (high, medium, and low) for Malbec and Cabernet-Sauvignon wines. Fanzone conducted a comprehensive study of phenolic groups and individual phenolic compounds; however, the sensory analysis had some limitations, including a low number of training sessions and the evaluation of only colour and mouthfeel descriptors without using any reference standards.

While previous studies have provided valuable insights, particularly in the area of phenolic compounds, there is still a lack of comprehensive information at the sensory level, and even more so in linking phenolic composition with sensory attributes in Malbec wines. In this context, our study aimed to describe and quantify the sensory attributes and chemical parameters (in particular, phenolics) of Argentinean Malbec wines from different price segments. To observe the differences between each price range, the eight best-selling wines from the low, medium and high price categories were analysed both chemically and sensorially.

MATERIALS AND METHODS

1. Wine samples

Eight representative wines were analysed within the three price ranges of the most commercialised Malbec wines on the Argentine market (Scentia, 2022), and both the general analytical analyses and the sensory evaluation were carried out in triplicate. The wine samples were selected based on the criteria that they were among the best-selling wines on the market and labelled as Malbec, which ensures that at least 85 % of the wine is made from Malbec grapes. No classification by region or other factors were considered in the selection process. According to best-selling wine rankings (Scentia, 2022), most of the selected Malbec wines were sourced from Mendoza, with some originating from the provinces of San Juan and Salta. The most recent available vintages for each label were requested. Table 1 shows the retail prices as well as the market share percentage (Scentia, 2022). These wines fell within the following price categories: Low-range Malbec 2.00 to 5.65 U$D, Mid-range Malbec 5.66 to 14.00 U$D, and High-range Malbec over 14.01 U$D (prices in 2021). The price intervals were established according to the Argentinean market categorisation of wines labelled as Varietals, Reserva and Gran Reserva.

TABLE 1. The most commercialised Malbec wines on the Argentine market.

Price range	Segment Price	% in segment
Low	U$D 2.00 – 3.60	8,10 %
Low	U$D 2.00 – 3.60	5,70 %
Low	U$D 2.00 – 3.60	5,30 %
Low	U$D 2.00 – 3.60	5,00 %
Low	U$D 3.61 – 5.65	17,70 %
Low	U$D 3.61 – 5.65	11,60 %
Low	U$D 3.61 – 5.65	10,40 %
Low	U$D 3.61 – 5.65	5,60 %
Medium	U$D 5.66 – 10.00	9,30 %
Medium	U$D 5.66 - 10.00	7.00 %
Medium	U$D 5.66 - 10.00	6,90 %
Medium	U$D 5.66 - 10.00	6,80 %
Medium	U$D 10.01 - 14.00	30,40 %
Medium	U$D 10.01 - 14.00	11,30 %
Medium	U$D 10.01 - 14.00	10,50 %
Medium	U$D 10.01 - 14.00	5,70 %
High	U$D 14.01 - 18.00	22,90 %
High	U$D 14.01 - 18.00	17,90 %
High	U$D 14.01 - 18.00	13,10 %
High	U$D 18.01 - 25.00	36,70 %
High	U$D 18.01 - 25.00	29,00 %
High	U$D 18.01 - 25.00	7,90 %
High	Up to U$D 25.01	26,90 %
High	Up to U$D 25.01	8,70 %

To conduct the chemical analyses, 50 mL samples were taken from each wine in Falcon tubes. Immediately after sampling, the aliquots of each sample were frozen at – 20 ° C until analysis (2 months aprox.).

2. Wine general analytical parameters

The general parameters analysed were volatile acidity (g/L), alcohol content (% v/v), glucose (g/L), fructose (g/L), total residual sugars (g/L), titratable acidity (g/L), pH, lactic acid (g/L), malic acid (g/L), density and absorbance at 280nm (OD 280nm). These were determined using an IRTF Foss WineScan TM Model OenoFoss 2017 (Foss), located at the Instituto Nacional de Tecnología Agropecuaria (INTA) Wine Research Center.

3. Global phenolics and CIELAB parameters

Wine samples were centrifuged (11,000 g × 5 min) and filtered through with 0.22-mm membranes (Microclar, Buenos Aires, Argentina) before analysis. Absorbance measurements were made with a Perkin-Elmer UV–visible Spectrophotometer Model Lambda 25 (PerkinElmer, Hartford, CT). Tannins were analysed by protein precipitation (Harbertson *et al*., 2003). Anthocyanins, small polymeric pigments (SPP), large polymeric pigments (LPP) and total polymeric pigments (TPP) were measured as previously described (Harbertson *et al*., 2003). Iron reactive phenolics (total phenols) were analysed following the method described by Heredia et al. (2006).

CIELAB parameters L*(lightness), C^*_{ab} (saturation), h_{ab} (tone) and the a*b* (red/green; yellow/blue) coordinates were calculated from the absorption spectra using colorscience package (Gama and Davis, 2019) in R, following the recommendations of the Commission Internationale de L'Eclairage (CIE Standard - International, 2007).

4. Sensory analysis

To determine the sensory characteristics of different ranges of wines, a descriptive analysis was performed (Lawless and Heymann, 2010). The sensory panel consisted of 12 volunteer participants (6 male, 6 female) aged between

TABLE 2. Reference standards for the 28 attributes of aroma, taste and mouthfeel.

Aromas	Reference standard [a]
Floral	1.5 g Fresh Cape jasmine flowers (Gardenia Jasminoides) 1.5 g "rose" (Rosa Europeana)
Violet flowers	3 g Fresh "Violet" flowers (Viola Odorata)
Fruity	2.5 g Red apple, 2.5 g Pear, 2.5 g Banana, 2.5 g Plum. All fresh cut into 1cm x 1cm cubes
Red fruit	2.5 g Plum, 2.5 g Strawberry, 2.5 g Cherry, 2.5 g Blueberries. All fresh cut into 1cm x 1cm cubes
Plum	10 g Fresh plum cut into 1cm x 1cm cubes
Cooked fruit	10 g Apple and pear compote
Jam	10 g Plum jam, "La Campagnola" brand
Mint	5 g Fresh mint leaves cut in half
Balsamic	2.5 g Fresh mint leaves cut in half, 2.5 g Eucalyptus Camaldulensis capsules
Green pepper	10 g Fresh green pepper cut into 1cm x 1cm cubes
Clove	2 g Dried clove buds (Syzygium Aromaticum), "Indias" brand
Pepper	2 g Black peppercorns (Piper Nigrum), "Indias" brand
Wood	2.5 g Untoasted French oak chips, 2.5 g Untoasted American oak chips (Quercus sp), "Arpex" brand
Vanilla	3 drops of artificial vanilla essence brand "Indias" in 10mL of mineral water, "Eco de Los Andes"brand
Toffee	10 g Milk caramel, "La Serenísima"brand
Chocolate	10 g 70 % chocolate, "Águila" brand
Tobacco	1 g. Blond cigarette tobacco, "Marlboro" brand
Butter	10 g. Unsalted butter, "La Serenísima" brand
Animal leather	10 g. Strip of vegetable-tanned leather (Tanned without synthetic chemicals)
Dry earth	10 g. Fine dry air-exposed loam soil from EEA INTA Mendoza
Walnut	10 g. Walnut halves, cut with a knife
Taste and mouthfeel	**Reference standard [b]**
Acidity	Solution of Tartaric Acid 0.5 g/L (L-(+)-Tartaric Acid), "Derivados Vínicos" Brand
Bitter	Solution of Quinine Sulfate 0.01 g/L Brand TRB Pharma
Burning sensation	15 % v/v Vodka Brand Absolut in mineral water, "Eco de Los Andes" brand
Astringency	Solution of Aluminium Ammonium Sulfate 1 g/L, "Anedra Research AG S.A." Brand
Sweet	Solution of Sucrose 2 g/L, "Ledesma" Brand
Spicy	Solution of 1 g/L Fresh Hot Pepper (Capsicum annuum) very finely cut with a knife
Mouth volume	Solution of 1.3 g/L CMC (Carboxymethylcellulose),"Arpex" Brand

(a) All references were prepared in numbered glass containers of 100cc, each equipped with a lid. There was no visual access to the interior content.

(b) All references were tasted in technical glasses (ISO 3591:1985).

21 and 60 years. All of them had extensive experience in wine sensory analysis, either because they had been in in other wine sensory panels or because they were part of the wine industry. All panelists signed a consent form with the INTA. The study was approved by the INTA ethics committee.

Panelists participated in eight 45-minute training sessions over three weeks. During these sessions, each wine was tasted at least twice. Subsets of wines were presented to the panelists during the training sessions, and they were asked to define all perceived attributes. Panelists established the final list of descriptors to be evaluated by consensus. A reference standard for each descriptor was created, as detailed in Table 2. By the end of the training, all the panelists were able to recognise each of the reference standards blindly.

Evaluations were conducted at the Wine Research Center INTA Mendoza using black technical glasses (ISO, 1985) with random 3 digits code. To evaluate the colour of the wines, differently coded transparent glasses were used. Aliquots of wine (30 mL) at room temperature were poured into wine glasses and covered with plastic lids to trap the volatiles. Eight wines per session were evaluated using a Williams Latin square design to control carryover effects. All the wines were evaluated in triplicate. For each descriptor, panelists had to rate the intensity of each wine on a scale from 1 to 10. To collect the data from the panelists, the R package *LibreSense* was used (https://github.com/anibalacatania/LibreSense). Panel performance was monitored by assessing the correlation of panelists with the panel mean and by their contribution to the panelist × wine interaction for each

attribute. The panelists did not receive any details about the study to reduce bias.

5. Data analysis

The statistical analyses were conducted using R (R Core Team, 2023). The packages used were ggplot2 (Wickham, 2016), agricolae (De Mendiburu, 2021) and FactoMineR (Le *et al*., 2008). The chemical data were analysed using one-way ANOVA. For the sensory data, an ANOVA using the effects of judge, range and session was used. In order to assess wine significance with the mean square of all interaction terms containing wine as the error, a pseudo-mixed test was also conducted for the ANOVA. Tukey's honestly significant difference was used in all cases (HSD) test ($\alpha = 0.05$). The relationship between significant chemical and sensory variables ($p < 0.05$) was analysed by multiple factor analysis (MFA)

RESULTS AND DISCUSSION

1. Wine general analytical parameters

Figure 1 shows the effect of Malbec price ranges on the general analytical parameters. Significant differences were identified for several parameters, such as O.D.280, titratable acidity, malic acid, lactic acid, volatile acidity, alcohol, glucose and total sugars.

Regarding sugars, significant differences were found in terms of glucose levels and total sugar content. Low-range wines contained higher levels of sugar compared to high-range wines. Several studies have demonstrated that sugar content in wines, also known as residual sugars, has a direct impact on the perception of sweetness and body on the palate (Jackson, 2008; Marchal *et al*., 2013). Other authors have found that high-range wines tend to have less residual sugar compared to mid-range or low-range wines (Bruwer and Johnson, 2010; Hjelmeland *et al*., 2013). Winemakers of high-range wines frequently aim to produce more balanced and complex flavour profiles. This can be accomplished by maintaining low levels of residual sugars, thereby preventing the wine from having an overpowering sweetness that could obscure its subtle flavours and aromas (Pigman, 2012; Ribéreau-Gayon *et al*., 2006).

Additionally, low-range wines showed significantly higher levels of malic acid compared to those in the Medium and High ranges. This can be explained by the tendency for high-range wines to undergo malolactic fermentation. The alcohol and volatile acidity values tended to be higher in the mid-range and high-priced wines. This can be attributed to several factors: the trend in Argentina, where grapes with higher sugar content are harvested for mid-range and high-priced wines, the aging process (Rodríguez-Rodríguez and Gómez-Plaza, 2012; Simó Hernando, 2021) and malolactic fermentation, which, as previously mentioned, more frequently in mid-

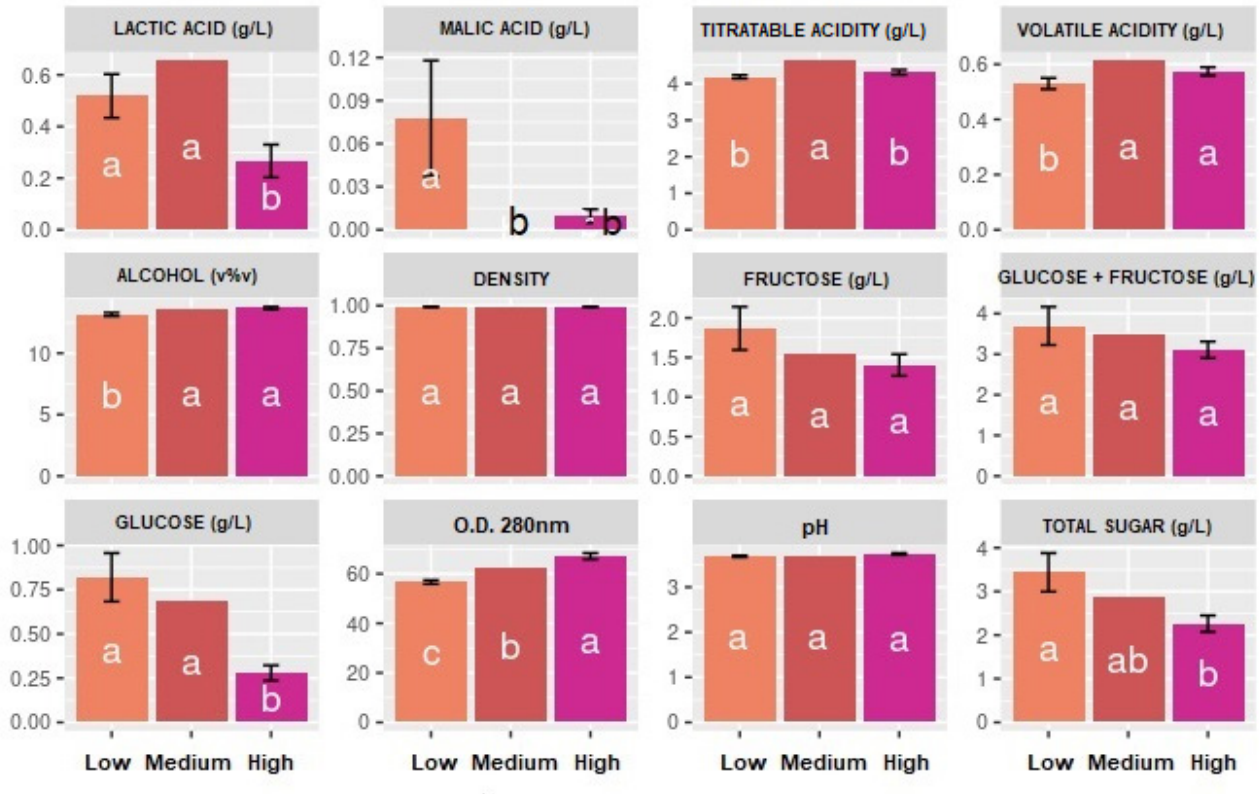


FIGURE 1. Analysis of variance of General analytical parameters for three price ranges of Malbec wine (Low, Medium and High). The different letters for each range indicate significant differences (Fisher's LSD test, $p < 0.05$). Error bars represent the standard error.

range and high-range wines. Finally, Absorbance at 280 nm (O.D. 280) was the only parameter that showed differences across all three price ranges. This is in line with other studies that have found a positive relationship between perceived quality and the increased concentration of wines as their price increases (Fanzone *et al*., 2012; Gawel and Godden, 2008).

These results are important as they demonstrate a relationship between some chemical parameters and the different price ranges of the wines.

2. Global phenolics and CIELAB parameters

Figure 2 shows the differences between the three price ranges of Malbec wines in terms of phenolic compounds. There were significant differences in anthocyanins, LPP, SPP, TPP and tannins.

Regarding anthocyanin concentration, the high-price range exhibited the highest concentrations, while the mid-price range showed significantly lower values. Anthocyanin plays a crucial role in determining the colour of red wines and significantly contributes to sensory characteristics (Jackson, 2008; Parpinello *et al*., 2009). Anthocyanins are not the only compounds that explain wine colour. Using a PLS model, Catania *et al*. (2021) explained the CIELAB colour parameters through anthocyanins and individual pigments, and found that in micro-oxygenated wines, the compounds that most significantly explained the colour were those related to the timing of the micro-oxygenation process. Several studies show a direct correlation between wine colour intensity and price (Fanzone *et al*., 2012; Lecocq and Visser, 2006). On the other hand, tannins exhibit different behaviour, with wines from the high-range exhibiting a higher concentration of tannins than those from the medium-price range. These data suggest that high-range wines may come from riper grapes, and may also be due to viticultural practices that increase the accumulation of tannins in grapes, as well as winemaking conditions that aim to achieve higher tannin extraction in the wine. Additionally, the origin of Malbec grapes plays a significant role in the concentration of tannins (Fanzone *et al*., 2012).

Regarding TPP values, a clear pattern is observed. Wines in the high-price category show the highest TPP values, a gradual decrease in the mid-price range, and finally, the lowest in the low-price range. Consistent with this, higher levels of LPP are observed in the high-price category of wines, while the lowest values are found in the mid and low-price categories. This phenomenon can be explained by the fact that an increased extraction of phenolic compounds combined with micro-oxygenation occurring in the barrel can facilitate the formation of ethanol or acetaldehyde bridges between anthocyanins and tannins. This, in turn, contributes to the stability of the wine's colour profile. It is important to note that these compounds are found in wines that have undergone more intense extraction processes from the grape skins and seeds, and slow oxygen ingress in the barrels (Boido *et al*., 2011). Consistent with the previous results, SPP was lower in the low-range, differentiating it from the mid-range and high-price categories. Based on these results, we can conclude that polymeric pigments are highly useful for differentiating between price ranges.

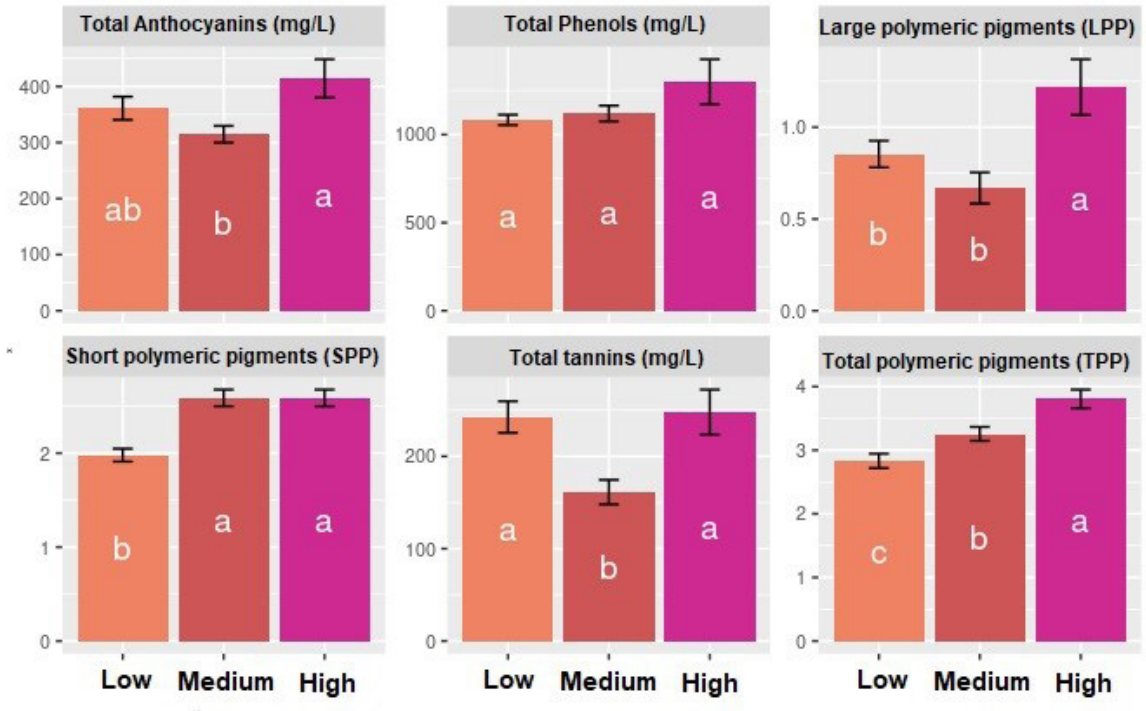


FIGURE 2. Analysis of variance of phenolic compounds for three price ranges of Malbec wine (Low, Medium and High). The different letters for each range indicate significant differences (Fischer LSD Test, $p < 0.05$). Error bars represent the standard error.

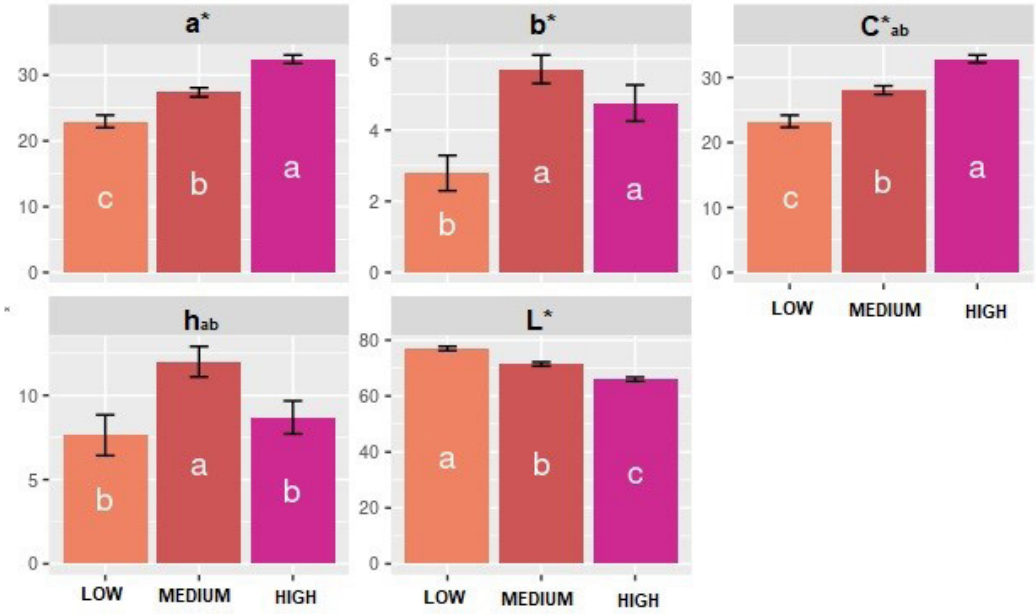


FIGURE 3. Analysis of variance of CIELAB parameters for three price ranges of Malbec wine (Low, Medium, High). The different letters assigned to each range indicate statistically significant differences (Fisher's LSD test, $p < 0.05$). The error bars represent the standard error.

To evaluate the influence of range price on colour, CIELAB parameters were determined (Figure 3). High-range wines exhibited the highest red colour component (a*), whereas low-range wines showed the lowest. The differences between the three price ranges are statistically significant, with high-range wines tending to exhibit a more reddish hue; which is to be expected due to their bottling evolution, which aligns with the characteristics of production and aging for the different price ranges analyses (Durner and Ganss, 2010; Hjelmeland *et al*., 2013).

High and mid-range wines share the highest yellow colour component (b*) with no statistically significant differences between them, while low-range wines have the lowest value. This suggests that mid- and high-range wines tend to have a more yellowish tint compared to low-range wines. This is consistent with research by various authors (De Beer *et al*., 2008; Casassa and Harbertson, 2014) on the a* parameter described above.

High-range wines displayed the highest chroma values (C^*_{ab}), while low-range wines showed the lowest. The difference between the three ranges was statistically significant, suggesting that high-range wines tend to have more intense and saturated colours compared to those in the mid-range, and significantly less so than those in the low-range.

As expected, low-range wines exhibited the highest brightness (L*), and high-range wines the lowest, with this difference being statistically significant. This observation correlates with the fact that higher-priced wines have a higher concentration of polyphenols, especially anthocyanins, resulting in more intensely coloured wines. This relationship is reflected in the analyses of polyphenols and absorbance at 280nm, correlating with polyphenol content (O.D.280) conducted in this study.

3. Sensory analysis

There were significant differences in terms of the descriptors floral, animal leather, wood, fruity, nut, astringency, colour intensity, red hue and violet hue.

Low-range wines were perceived as having the highest intensity in the descriptors fruity and floral but the lowest in the descriptor wood. The former two were found to be positive, while the latter was less intense in the Low Range than in the Medium and High Ranges (Goode, 2021; Jackson, 2008; Rodríguez-Rodríguez and Gómez-Plaza, 2012). The detection of fruity aromas in wine (such fresh or ripe fruit notes) can be linked to the presence of esters, terpenes and aldehydes within the aromatic matrix, their concentrations being influenced by factors including grape variety, climate, grape maturity, viticultural and oenological practices and the fermentation process (Jackson, 2008). Furthermore, floral nuances, such as aromas of white or violet flowers, can be attributed to phenolic volatile compounds and terpenoids present in the grapes that are released during fermentation (Casassa and Harbertson, 2014; López *et al*., 2018). Authors like Goode (2021) highlight that fresh and fruity red wines often undergo shorter fermentations at lower temperatures to preserve the fruity flavours (Vine and Harkness, 2010). These concepts contribute to the fact that lower-priced Malbec styles tend to display more fruity and less tannic characteristics, making them ideal for rapid market entry.

Additionally, it was found that the descriptor astringency had greater intensity in the high price range. Descriptors

TABLE 3. Analysis of variance of sensory parameters for three price ranges of Malbec wine (Low, Medium, and High). The different letters for each range indicate significant differences (Fisher's LSD Test, $p < 0.05$). The values represent the mean ± standard error.

Descriptor	Ranges			P-values	
	Low	Medium	High	Range	Range x panelist
Floral	1.94 ± 0.14 a	1.56 ± 0.13 b	1.41 ± 0.12 b	0,001	0,399
Animal leather	1.24 ± 0.11 b	1.39 ± 0.11 ab	1.64 ± 0.12 a	0,031	0,394
Red fruit	2.14 ± 0.14 a	1.94 ± 0.13 a	2.10 ± 0.13 a	0,303	0,228
Vanilla	1.29 ± 0.10 a	1.32 ± 0.10 a	1.31 ± 0.10 a	0,962	0,387
Pepper	0.88 ± 0.10 a	1.01 ± 0.09 a	1.01 ± 0.09 a	0,359	0,008
Plum	2.01 ± 0.14 a	2.11 ± 0.14 a	2.24 ± 0.15 a	0,234	0,723
Wood	1.48 ± 0.13 b	2.09 ± 0.14 a	2.39 ± 0.14 a	0	0,896
Butter	0.92 ± 0.09 a	1.00 ± 0.11 a	1.10 ± 0.10 a	0,296	0,504
Jam	1.35 ± 0.13 a	1.31 ± 0.12 a	1.2 ± 0.12 a	0,79	0,538
Tobacco	0.75 ± 0.09 a	1.00 ± 0.10 a	0.93 ± 0.10 a	0,073	0,532
Clove	0.54 ± 0.07 a	0.45 ± 0.06 a	0.61 ± 0.08 a	0,164	0,27
Chocolate	0.78 ± 0.09 a	0.71 ± 0.08 a	0.88 ± 0.10 a	0,225	0,179
Cooked fruit	1.46 ± 0.13 a	1.45 ± 0.13 a	1.22 ± 0.12 a	0,119	0,41
Green pepper	0.59 ± 0.08 a	0.66 ± 0.08 a	0.68 ± 0.08 a	0,689	0,921
Balsamic	1.07 ± 0.11 ab	1.00 ± 0.10 b	1.28 ± 0.11 a	0,083	0,79
Toffee	0.55 ± 0.08 a	0.43 ± 0.07 a	0.45 ± 0.06 a	0,289	0,409
Dry earth	0.46 ± 0.08 b	0.55 ± 0.09 ab	0.71 ± 0.10 a	0,049	0,449
Violet	0.84 ± 0.11 a	0.68 ± 0.09 a	0.78 ± 0.09 a	0,161	0,003
Fruity	2.20 ± 0.15 a	1.77 ± 0.14 b	1.73 ± 0.14 b	0,001	0
Mint	0.51 ± 0.06 a	0.47 ± 0.06 a	0.47 ± 0.05 a	0,747	0,109
Nut	0.46 ± 0.07 b	0.62 ± 0.08 ab	0.73 ± 0.09 a	0,032	0,17
Astringency	3.71 ± 0.12 b	3.93 ± 0.12 b	4.53 ± 0.13 a	0	0,04
Acidity	3.46 ± 0.11 a	3.38 ± 0.12 a	3.43 ± 0.11 a	0,863	0,025
Bitter	0.62 ± 0.07 a	0.71 ± 0.08 a	0.76 ± 0.09 a	0,381	0,584
Sweet	1.37 ± 0.12 a	1.30 ± 0.12 a	1.21 ± 0.12 a	0,295	0,316
Heat	0.79 ± 0.09 a	0.85 ± 0.09 a	0.85 ± 0.08 a	0,706	0,67
Mouthfeel	2.46 ± 0.14 a	2.50 ± 0.14 a	2.67 ± 0.13 a	0,255	0,015
Spicy	0.63 ± 0.10 a	0.54 ± 0.09 a	0.66 ± 0.09 a	0,296	0,736
Color intensity	3.90 ± 0.10 c	4.44 ± 0.10 b	5.67 ± 0.12 a	0	0
Violet hue	2.96 ± 0.15 b	2.52 ± 0.13 c	3.41 ± 0.16 a	0	0,582
Red hue	3.24 ± 0.16 ab	3.53 ± 0.16 a	2.97 ± 0.15 b	0,007	0,503

such as animal leather, balsamic, astringency, dry earth, red hue and nut also showed differences in some price ranges (Issa-Issa *et al*., 2019; Sánchez-Córdoba *et al*., 2021). The richness of polyphenols and more pronounced colour intensity in aging wines is a widely documented phenomenon in the oenological literature. Researchers like Kennedy and Glories (2006) and Ivanova *et al*. (2012) have emphasised that tannins significantly contribute to the structure or astringency and to the colour stability of aging red wines. Finally, significant differences were found among the three price ranges for the descriptors colour intensity and violet hue. This implies that these descriptors have a distinctive influence on the perception of wines at each price level (Boido *et al*., 2006; Catania *et al*., 2021).

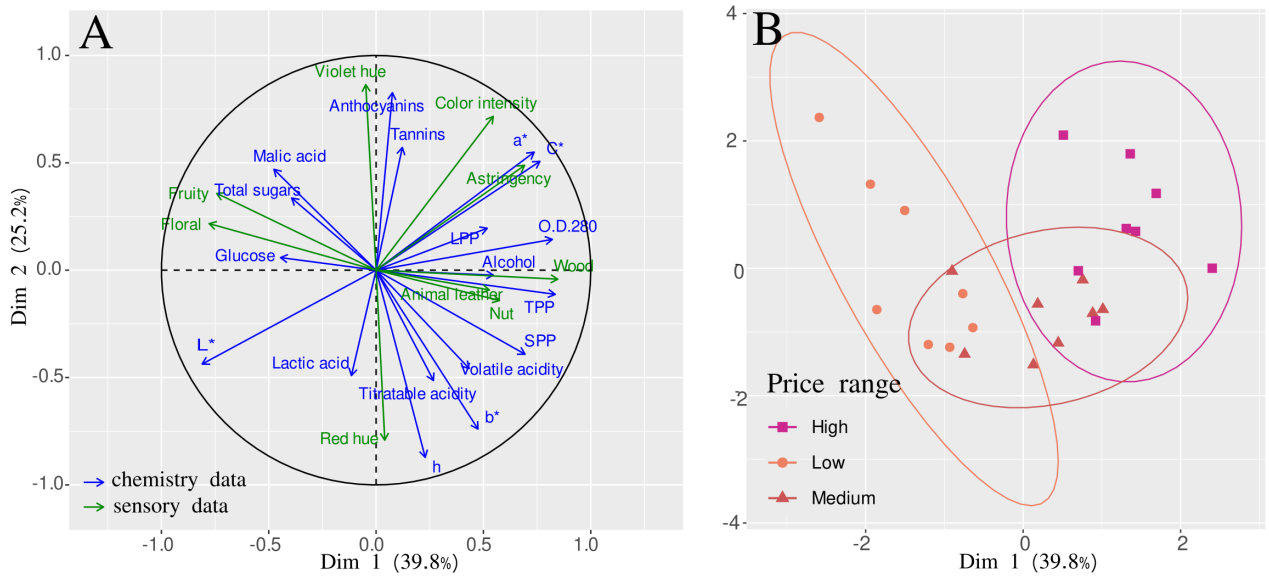


FIGURE 4. Multiple factor analysis (MFA) of significant chemical and sensory attributes. A) Circle plot of MFA correlations among significant chemical attributes (blue) and sensory attributes (green), and B) MFA individual plot showing wine scores.

4. Multiple factor analysis

The relationship between significant ($p < 0.05$) chemical and sensory attributes was analysed by multiple factor analysis. Figure 4 shows correlation plot (A) and wine score (B). The first two components explained 65 % of the variability.

The high-range wines were characterised by wood, animal leather, nut, astringency, colour intensity and violet hue. The degree of overlap between vectors indicates the strength of the relationship between chemical and sensory variables (Figure 4A). As expected, astringency was correlated with the tannin content of the wines. Similarly, violet hue showed a correlation with anthocyanins, while colour intensity was linked to the CIELAB parameters a* and b*. The red hue was associated with h_{ab}, as well as with descriptors such as wood and animal leather, which were in turn correlated with polymeric pigments. On the other hand, the low-range wines were correlated with fruity and floral notes. These descriptors were correlated with L, malic acid and sugar. Interestingly, the fruit and floral sensory descriptors showed a negative correlation with aging-related descriptors, such as wood, animal leather and polymeric pigments. Finally, the wines in the mid-price range were characterised by h_{ab} and b*, volatile acidity and tartaric acidity

Figure 4B shows the individuals wine scores from the different price ranges. Ninety-five percent confidence ellipses were constructed, thus non-overlapping ellipses indicate statistically significant differences. There were differences between the high and low-range. In the case of the high-price range, the ellipse was more dispersed; this reflects the variability in this category, with price ranges above 14.01 U$D. For wines in the medium-price range, the ellipse was more compact, indicating a greater similarity among these wines in terms of their sensory and chemical characteristics.

In the medium-price range, there is an overlap with the low- and high-range, but with a greater influence of other descriptors typical of more evolved or structurally complex wines, such as nut, animal leather and red hue. The interaction between phenolic compounds, such as tannins, and lignans present in oak wood leads to the formation of complexes that release olfactory descriptors like almonds and nuts. Furthermore, the influence of indigenous or added microorganisms during the winemaking process, such as native yeasts, has been discussed by Esteve- Zarzoso *et al.* (2001). These microorganisms can produce volatile compounds, such as fatty acids or ethyl phenols, which contribute to animal leather notes. These characteristics may be associated with a more complex style of wines found in wines that have undergone some oak aging, or which are also called Reserva. In the medium wine range, we find characteristics attributable to wines from the low range and others similar to the high price range.

CONCLUSION

This is the first study to clearly establish the sensory differences between different price ranges of Malbec Argentine wines. The results show that it was only possible to differentiate between the high- and low-price ranges. Both segments exhibited some variability, including different types of wines. The mid-price wines showed very little variability and overlapped with both the high- and low-ranges. The high-price range was characterised by higher alcohol content, polyphenol concentration and colour intensity. Sensorially, they were distinguished by the descriptors wood, astringency and colour. The low-price range was associated with low colour intensity and higher total sugar content. The most closely related sensory descriptors were floral and fruity, but they did not significantly explain this range.

Our study demonstrated that wine pricing is not determined in a subjective or arbitrary manner; rather, wines produced for a specific segment are intentionally designed to achieve the desired sensory and chemical characteristics. We were able to identify distinctive descriptors that differentiated various wine ranges and explained pricing based on specific sensory and chemical characteristics. These results provide invaluable information based on scientific evidence and objective criteria, which could be applied in the wine industry to enhance quality and improve marketing strategies and product positioning. Further research is required on the subject, as well as on its connection to viticultural practices, environmental factors, winemaking techniques and the aging process. It would also be important to conduct preference and acceptance studies, linking the information to the results of descriptive analyses to determine which descriptors consumers prefer in each price range.

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