Journal of Agricultural Science; Vol. 10, No. 12; 2018
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Phenolic Compounds and Polyamines in Grape-Derived Beverages

Hector Alonzo Gomez-Gomez[1], Igor Otavio Minatel[2], Cristine Vanz Borges[2], Marcia Ortiz Mayo Marques[3], Evandro Tadeu da Silva[4], Gean Charles Monteiro[5], Marlon Jocimar R. da Silva[5], Marco Antonio Tecchio[5] & Giuseppina Pace Pereira Lima[2]

[1] Departamento de Tecnología de Alimentos, Universidad Nacional de Agricultura, Barrio El Espino, Catacamas, Honduras

[2] Institute of Bioscience, Department of Chemistry and Biochemistry, São Paulo State University, Botucatu, São Paulo, Brazil

[3] Agronomic Institute, Campinas, São Paulo, Brazil

[4] Institute of Bioscience, Center of Stable Isotopes, São Paulo State University, Botucatu, São Paulo, Brazil

[5] School of Agriculture, Department of Horticulture, São Paulo State University, Botucatu, São Paulo, Brazil

Correspondence: Giuseppina Pace Pereira Lima, Institute of Bioscience, Department of Chemistry and Biochemistry, São Paulo State University Botucatu, CEP 18618-000, São Paulo, Brazil. Tel: 55-149-9143-4868. E-mail: finalima@gmail.com

Received: August 23, 2018 Accepted: September 26, 2018 Online Published: November 15, 2018

doi:10.5539/jas.v10n12p65 URL: https://doi.org/10.5539/jas.v10n12p65

The research is financed by São Paulo Research Foundation (Grant 2016/22665-2) and National Council for Scientific and Technological Development (CNPq, Brazil) (Grant 305177/2015-0).

Abstract

Isotopic analyses and chromatographic analysis (phenolic compounds and biogenic amines), can be applied to investigate the functional and nutritional quality in different grape juices and wines. These beverages when produced exclusively from grapes contain bioactive compounds. In this way, the isotopic analysis, as well as the determination of phenolic compounds and biogenic amines were performed with the aim of verify the functional quality of juices and wines produced with *Vitis vinifera* and *Vitis labrusca* grapes. The samples that were analyzed consisted of four whole juices, two nectars, two *V. vinifera* wines, and two *V. labrusca* wines. Regarding the isotopic analyses, only one nectar, among the beverages studied, presented the addition of sugar from C4 plants. Wines from *V. vinifera* showed the highest content of biogenic amines and phenols; whereas, the highest content of anthocyanins were found in *V. labrusca.* The levels of biogenic amines and phenolic compounds were variable between samples, and recommendations for consumers should be made considering several conditions, such as physiological state, age, consumption, among others. Anthocyanins and biogenic amines, as well as isotopic analyses, can be applied as tools to measure the quality of grape derived beverages.

Keywords: biogenic amines, grape juice, isotopic analyses, phenolic compound, wine

1. Introduction

Grape juices and wines consumption had increased in the whole world and represents an interesting source of antioxidants provided by phenolic compounds and other molecules. The major factor influencing the chemical composition of grape beverages is its purity; whereas, other factors as variety, ripeness, climate, and soil (Belmiro et al., 2017) can also contribute to variations in the content of bioactive compounds, as phenolic compounds. The *t*-resveratrol or other phenolic compounds present in grapes and its derivatives, as gallic and chlorogenic acid, show antioxidant and anti-inflammatory activity (Asci et al., 2017). The anthocyanins, a polyphenol compound with many biological functions, also are used to detect adulteration in wines (Burns et al., 2002).

The biogenic amines (BA) are molecules used as quality indicators because depending on the molecule present in the food, it can cause potential adverse reactions (Linares et al., 2016). The BAs are nitrogen compounds of low molecular weight, synthesized by the primary metabolism of the plants, microorganisms and animals. In humans, the BAs perform important effects in the cell physiology. Putrescine, spermine and spermidine are

related to the cell proliferation and differentiation. Due to its positive charges in physiological pH they are capable of interact with negatively charged molecules (nucleic acids, proteins and phospholipids), maintaining the cell functionality and improving healing process. In opposition, the levels of some BAs, as putrescine, tyramine, cadaverine, spermine, and spermidine, found in beverages derived from grapes, might induce physiological disturbs depending on the individual's state of health (Tofalo et al., 2016). Histamine and tyramine are BAs that negatively affect the biological functions, promoting diarrhea, allergies, asthma/shortness of breath and migraine (Linares et al., 2016). Due to the toxicity of histamine, many European countries established maximum limits for this compound in wines (values between 2.0-10.0 mg/L) (Linares et al., 2016). In addition, the presence of histamine, tyramine and cadaverine is related to low-quality during processing or storage, and can be used as quality markers (Tofalo et al., 2016). Other BAs as dopamine and serotonin, considered neurotransmitters, were detected in wines in levels between 0.20-1.00 mg/L (Souza et al., 2005). In fruit juices, the serotonin levels are variable (Preti et al., 2016a) and, in wines, their levels are often non-detectable (Preti et al., 2016b).

In some beverages, carbohydrates from other sources, such as sugarcane, are added during the production process. In order to identify the addition of sugar from plants (C4) other than grapes (C3), the isotopic analysis can be used (Calderone & Guillou, 2008). Applying this technique is possible to determine the carbon concentration regarding plants of the C3 photosynthetic cycle (as grape) and of the C4 photosynthetic cycle (as sugarcane) (Calderone & Guillou, 2008). When the addition of different sugars occurs, the isotopic analysis results in relative isotopic enrichment value ($\delta^{13}C$) that exceeds the values established in the legislation for grape beverages.

In view of the importance of the analysis of bioactive compounds present in grape-derived beverages, as well as the validation of the composition, we determined the profile of phenolic compounds and biogenic amines and performed an isotopic analysis in beverages derived from *Vitis vinifera* and *Vitis labrusca* grapes.

2. Materials and Methods

2.1 Materials

Samples consisted of four whole juices—two elaborated in our laboratory (Isabel whole juice and BRS Cora whole juice) and two commercial (WJ1 and WJ2); one nectar (N) and one low-calorie nectar (LCN). The juices produced in the laboratory were obtained from Isabel (*Vitis labrusca*) and BRS Cora grapes (hybrid of *Vitis labrusca* x *Vitis vinifera*), by hot pressing of the grapes (Hot Press), followed by pasteurization (80 ^{o}C, 3 min). Among the alcoholic beverages, commercial samples from Cabernet Sauvignon wine (CSW) and Merlot wine (MW), and two young red wines from *Vitis labrusca* (YW1 and YW2) were analyzed. These samples were acquired in the local market and chosen according to the consumption and price (Table 1). The analyzes were performed in triplicate.

Table 1. Non-Alcoholic and alcoholic grape beverages

Sample	Commercial price ($US)*	Grape used	Specie
Isabel whole juice	-	Isabel	*Vitis labrusca*
BRS Cora whole juice	-	BRS Cora	Hybrid
Whole juice 1 (WJ1)	5.00	Isabel and Concord	*Vitis labrusca*
Whole juice 2 (WJ2)	5.00	Isabel and Bordo	*Vitis labrusca*
Nectar (N)	2.50	Hybrid grape	*Vitis labrusca*
Low-calorie nectar (LCN)	1.00	Hybrid grape	*Vitis labrusca*
Young wine 1 (YW1)	5.00	Isabel and Concord	*Vitis labrusca*
Young wine 2 (YW2)	5.00	Isabel and Bordo	*Vitis labrusca*
Cabernet Sauvignon wine (CSW)	10.00	Cabernet Sauvignon	*Vitis vinifera*
Merlot wine (MW)	8.00	Merlot	*Vitis vinifera*

Note. *Approximate value.

2.2 Quality Analysis

The juices and wines quality parameters were obtained from the pH (model HI 4221, Hanna Instruments, Brazil), soluble solids (SS) (in ^{o}Brix, digital refractometer Atago RX5000, Tokyo, Japan) and titratable acidity (TA), according to methodology described in OIV (OIV, 2016).

2.3 Extraction and Characterization of the Biogenic Amines by HPLC

Putrescine, spermidine, spermine, histamine, cadaverine, tyramine, serotonin, and dopamine were extracted (thrice) and isolated according to the method described by Flores and Galston (1982) modified by Lima et al. (2008). Briefly, the samples were homogenized in perchloric acid (5% v/v) during 30 min at 4 °C, centrifuged (8,000 × *g*, 20 min at 4 °C), and then 4.5 mol/L Na_2CO_3 and 9.3 mmol/L dansyl chloride in acetone were added to supernatant. The samples were incubated in the dark during 1 hour at room temperature. After the addition of 0.87 mol/L proline (99%), the samples were kept at room temperature for 60 min. The toluene was used to extract the BA. Finally, the toluene aliquots of the samples were dried under nitrogen line and resuspended in 1.5 mL of acetonitrile and injected (20 µL) onto HPLC (Ultimate 3000 BioRS, Dionex-Thermo Fisher Scientific Inc., USA), equipped with a diode array detector (set to 225 nm), column ACE 5 C18 (Advanced Chromatography Technologies, UK) (5 µm, 25 cm × 4.6 mm) and gradient flow of 0.7 mL/min, according to Dadáková et al. (2009). The chromatograph gradient was established with different proportions of (A) acetonitrile at 100% and (B) acetonitrile 50% as follows: 0-2 min, 40% A; 2-4 min, 60% A; 4-8 min, 65% A; 8-12 min, 85% A; 12-15 min, 95% A; 15-21 min, 85% A; 21-22 min, 75% A; 22-25 min, 40% A. Amines identification were performed by comparing the retention time and the UV spectrum of each compound with commercial standard. Calibration curves were prepared for each commercial standard.

2.4 Phenolic Compounds Analyses by UPLC

Grape beverages samples were filtrated through membrane filters (PTFE, 0.45 µm, Millipore, MA, EUA) and injected (20 µL) in an UPLC system (Ultimate 3000 BioRS, Dionex-Thermo Fisher Scientific Inc., USA), equipped with a diode array, with flow of 0.6 mL/min, using a column Acclaim^{TM} RSLC 120 C18 (Thermo Scientific™, USA) (2.2 µm, 2.1 × 50 mm), in temperature of 39 ºC, according to the method of Natividade et al. (2013) with some modifications. Briefly, the mobile phase consisted in the solution of phosphoric acid 0.85% (solvent A) and acetonitrile 100% (solvent B). The gradient was initiated with 100% solvent A and adjusted as follows: 0-2.5 min, 96% solvent A; 2.5-7.5 min, 92% solvent A; 7.5-15 min, 88% solvent A; 15-18 min, 85% solvent A; 18-20 min, 80% solvent A; 20-21 min, 75% solvent A; 21-22min, 65% solvent A; 22-24 min, 35% solvent A; 24-25 min, 96% solvent A and hold at 96% solvent A for 3 min.

Twenty phenolic compounds (gallic acid, trans-cinnamic acid, caffeic acid, chlorogenic acid, *p*-coumaric acid, trans-ferulic acid, rutin, quercetin, 3-O-methylquercetin, kaempferol, *t*-resveratrol, luteolin, catechin, cyanidin 3,5-diglucoside, delphinidin 3-O-glucoside, cyanidin 3-O-glucoside, pelargonidin 3-O-glucoside, malvidin 3,5-diglucoside, peonidin 3-O-glucoside and malvidin 3-O-glucoside) were quantified by comparing its retention times and the UV spectrum to commercial standards. Calibration curves were prepared for each commercial standard.

2.5 Total Phenols

Total phenols content was determined using Folin-Ciocalteu reactive, according to Minussi et al. (2003) with some modifications. In 100 µL of samples (properly diluted), were added 250 µL of the carbonate-tartrate solution (200 g Na_2CO_3 and 12 g $Na_2C_4H_4O_6.2H_2O$ in 1 L of distilled water) and 50 µL of the Folin-Ciocalteu reagent. The sample absorbance was determined in 765 nm after 30 min of reaction. Gallic acid calibration curve was prepared and the results expressed as gallic acid equivalents (mg GAE/L).

2.6 Carbon Relative Research Design

The carbon relative isotopic enrichment value ($\delta^{13}C$) was obtained in the Isotopic Ratio Mass Spectrophotometer (IRMS) (Delta S-Finnigan MAT, Bremen, Germany). The $^{13}C/^{12}C$ ratio of the sample in relation to the international standard Pee Dee Belemnite (PDB) was calculated by the equation described below:

$$\delta^{13}C \text{ (sample, standard)} = \frac{\text{R sample} - \text{R standard}}{\text{R standard}} \times 10^3 \quad (1)$$

Where, $\delta^{13}C$: the relative isotopic enrichment of the sample in relation to the PDB standard; R: the isotopic ratio $^{13}C/^{12}C$ of the sample and of the PDB standard.

Samples (0.6 µL) of each beverage (in triplicate) were added to 5.0 × 3.5 mm capsules (Elemental Microanalysis), sealed and placed in an Elemental Analyzer (EA 1108-CHN-Fisons Instruments, Rodano, Italy)

for burning at 1020 ºC to release CO_2. The CO_2 generated was analyzed in an IRMS and compared with standard CO_2 (PDB) to determine the relative isotopic enrichment by IRMS.

In the isotopic analysis of ^{13}C from sugars present in beverages, the methodology of extraction and purification was used according Koziet et al. (1993). Briefly, an aliquot of 100 mL of each beverage were centrifuged during 10 min for remove insoluble solids. Subsequently, 4 g $Ca(OH)_2$ were added to the supernatant followed by heating until the temperature of 90 ºC. The samples were centrifuged again in order to remove the residue containing acids. Further, H_2SO_4 (1 mol/L) was added to the supernatant until pH 5, the mixture was heated until the temperature of 90 °C, and it was cooled at 4 ºC for 12 h, for the removal of the excess of calcium ($CaSO_4$). The resulting solution, containing purified sugar was isotopically analyzed determining the $\delta^{13}C$.

2.7 Statistical Analysis

Grape beverages (five samples of each beverage) were evaluated in triplicate. The mean values were calculated and the variance analysis (ANOVA) followed by multiple comparison (Tukey test), $p < 0.05$, were performed using Statgraphics Centurion (version XVII). The analysis of principal components, cluster analyses and correlation analyses were performed using the software XLSTAT-version 2017 (Addinsoft, France).

3. Results and Discussion

3.1 Quality Analysis

The total soluble solids (SS) and titratable acidity (TA) values (Table 2) obtained are similar to the quality and identity patterns recommended (MAPA, 2017) and similar to the values described in many studies with juices and wines (Preti et al., 2016b; Burin et al., 2010), around 14 ^{o}Brix and 100 meq/L of TA. The lowest values of pH occur in the nectars, while the juices elaborated in our laboratory presented a higher pH (3.23). Wines with higher commercial values elaborated with *V. vinifera* presented higher pH than the young wines. All samples analyzed presented pH below 4, as described in other studies with wines (Preti et al., 2016b) and juices (Burin et al., 2010). In beverages, particularly in the ones produced from grapes, the color is provided by the anthocyanins, which are related to consumer preference. The stability of these substances is directly affected by the pH. All these physicochemical parameters are indicators of good quality of the products and are in accordance with the reported parameters in the literature (Preti et al., 2016b; Burin et al., 2010).

The nectar (N) presented the lowest isotopic values ($\delta^{13}C$-18.36) (Table 2), indicating that the highest percentage of carbon in this beverage comes from plants with C4 carbon fixation pathway (63%) and thus, contains the lowest grape (Koziet et al., 1993). In contrast, in low-calorie nectar, the value found ($\delta^{13}C$-28.12) demonstrated a high percentage of C from the C3 plant, revealing that it does not contain sugar from C4 plants, i.e., no carbohydrate (sucrose) from sugarcane was added, which is a common practice in the beverages elaboration in Brazil. In addition, this sample presented the lowest SS levels comparing to the other juices. The values found for N are below the recommendation that establishes a 50% limit of non-grape substances as sugarcane carbohydrates (MAPA, 2017). The results obtained for juices elaborated with BRS Cora and Isabel grapes, demonstrate that the juices were elaborated exclusively with grapes, without addition of sugarcane carbohydrate and can be taken as a parameter of comparison for the other analyzed juices.

In spite of the wines from *V. labrusca* (YW1 and YW2-low commercial value), presenting carbon of C4 plants, they are close to the values permitted (MAPA, 2017) differently from what was observed in the Merlot wine, which presents 15% of the carbon of non C3 plants. According to the Brazilian legislation, dry red wines must contain 70% of grape (30% addition of sugar of C4 plant) (MAPA, 2017). In the CSW, we found the high percentage of C from C3 plants, which allows us to affirm that this wine certainly was produced exclusively from grapes, and may contain all of its bioactive compounds.

3.2 Biogenic Amines in Grape Juice and Wine

Putrescine, spermine, serotonin, dopamine and histamine were detected in all the juices samples. In opposition, spermidine and cadaverine were not detected in Isabel whole juice and tyramine was not found in the nectars (Table 3). Serotonin, spermine and putrescine were the main amines identified that occurred in most of the juices. BRS Cora and WJ2 presented the highest content of total amines. BRS Cora contain the highest spermine levels, while the WJ2 contain the highest serotonin contents, representing around 55% of the total value for both of the juices ($p < 0.05$). WJ2 juices (commercial) also showed high contents of putrescine and cadaverine.

The BRS Cora juice made with a hybrid Brazilian grape with good characteristics for the production of dry wines, showed considerable levels of serotonin and putrescine, comparing to the other analyzed materials. However, this is the beverage with the highest concentration of tyramine ($p < 0.05$), which is an amine considered allergenic (Linares et al., 2016). As tyramine was detected in both Isabel and in BRS Cora juices and

in WJ2 occurs the highest contents of histamine, its ingestion can cause allergic reactions, migraine, diarrhea, among others (Linares et al., 2016). In order to avoid these symptoms, it is recommended a consumption below 100 mg/kg of food or 2 mg/L of alcoholic beverages as the red wine (ten Brink et al., 1990). In the Isabel grape juice, the main cultivar destined for juice production in Brazil, there was a high dopamine content, when compared to the BRS Cora juice ($p < 0.05$). The difference in the BA contents among the juice samples might be related to the difference in the content (%) of grape used in the preparation of each beverage. In addition, other factors can affect the content of some molecules, such as the feedstock, the high variability of grape and the processing methods used in the production (Cecchini & Morassut, 2010).

The BA contents found in the wines, besides the one mentioned for the non-alcoholic beverages, can be attributed to the sanitary conditions during the elaboration and the used cultivar grape, influencing directly biogenic amines levels. CSW and Merlot are produced from *V. vinifera*, while the red wines WY1 and WY2 are made from *V. labrusca*, which can contain different levels of biogenic amines, as well as desirable or undesirable qualities for the consumers.

Table 2. Parameters of quality and results of the δ13C relative isotopic enrichment of the grape beverages and its respective percentage of carbon in C3 plants

Sample	pH	Acidity (Meq/L)	°Brix	Ethanol (%v/v)*	$d^{13}C$	% C of C3	% grape**
Isabel whole juice	3.28±0.00*	116.0±0.0	14.13±0.06	NA	-27.68±0.05	100	100
BRS Cora whole juice	3.19±0.01	154.5±3.5	16.27±0.06	NA	-29.20±0.16	100	100
Whole juice 1 (WJ1)	3.12±0.01	122.0±0.0	16.43±0.06	NA	-27.93±0.13	100	100
Whole juice 2 (WJ2)	3.23±0.01	93.0±0.0	14.53±0.06	NA	-28.08±0.19	100	100
Nectar (N)	2.87±0.02	73.0±1.4	13.63±0.06	NA	-18.36±0.18	37	50
Low-calorie nectar (LCN)	3.03±0.03	63.0±0.0	5.77±0.12	NA	-28.12±0.12	100	50
Young wine 1 (YW1)	3.51±0.00	115.5±0.7	6.73±0.06	10	-24.26±0.11	78	70
Young wine 2 (YW2)	3.30±0.01	94.5±1.4	6.53±0.06	10	-24.19±0.04	77	70
Cabernet Sauvignon wine (CSW)	3.55±0.01	75.0±0.0	8.53±0.25	13.5	-27.44±0.05	98	70
Merlot wine (MW)	3.63±0.01	69.0±5.6	8.23±0.06	13	-25.35±0.15	85	70

Note. * Alcoholic degree as reported by wine manufacturer. ** Minimum grape percentage in accordance with the Brazilian legislation or as expected for these products. NA: not applicable. Results expressed as means±standard deviation (n = 3).

Table 3. Biogenic amines (mg/L) in non-alcoholic and alcoholic grape beverages

Beverage	Putrescine	Spermidine	Spermine	Serotonin	Dopamine	Histamine	Tyramine	Cadaverine	∑
Isabel whole juice	3.67d*	0.00b	8.13b	1.67d	4.60a	0.36b	1.91b	0.0d	20.33
BRS Cora whole juice	7.04b	0.89a	32.10a	12.51b	2.08b	0.38b	2.28a	0.72b	58
Whole juice 1	0.17e	0.00b	0.97c	5.76c	0.05e	0.41b	0.15c	0.64b	8.16
Whole juice 2	17.73a	0.42a	0.66c	35.25a	0.98c	3.30a	0.18c	4.99a	63.51
Nectar	0.55e	0.91a	0.17c	1.69d	0.14d	0.36b	0.00d	0.14c	3.97
Low-calorie nectar	4.07c	0.75a	0.42c	0.68e	0.15d	0.36b	0.00d	0.04d	6.47
Young wine 1	15.58C	1.17C	0.69C	1.33C	0.30C	3.01A	0.18C	0.17B	22.44
Young wine 2	6.09D	1.82B	1.42B	0.64C	0.84B	1.27B	0.00D	0.24B	12.3
Cabernet Sauvignon wine	17.55B	4.29A	19.41A	47.54A	2.62A	0.08C	0.27B	0.71A	92.46
Merlot wine	21.78 A	4.20A	19.27A	27.01B	2.34A	0.25C	0.68A	0.74A	76.27

Note. * Means followed with lowercase letters for juice and uppercase to wine in the same column are statistically different (Tukey test, $p < 0.05$).

From the biogenic amines analyzed in wines (Table 3), only tyramine was not detected in YW2. In wines made from *V. labrusca*, putrescine was the most representative amine, with 70% and 50% of the total BA on YW1 and YW2, respectively. Histamine, cadaverine and tyramine appear in lower concentrations, with values below 5 mg/L for all of the samples. The consumption of these wines, similarly to what was found for the non-alcoholic

beverages, would provide significant levels of putrescine, spermine and spermidine. Both CSW as MW presented higher values of dopamine when compared to wines made from *V. labrusca*.

During the fermentation process, the synthesis of some biogenic amines can be influenced by the many stages, contributing to the different contents found in this study (Rodriguez-Naranjo et al., 2013). Another factor that can influence directly in the content is the aging process, which affects directly the composition and the quantity of BA (Moreno-Arribas & Polo, 2009). Finally, edapho-climatic conditions and grape production can affect the BA profile, influencing directly in the quality of these beverages (Landete et al., 2005) particularly in Brazil, where there is generally a larger amount of rainfall in the winemaker regions during the season of grape production.

3.3 Phenolic Compounds Profile in Grape Juices

Most of the twenty analyzed phenolic compounds were detected in all of the samples (Table 4), except cyanidin 3,5-diglucoside, which was not observed in the Isabel grape juice and pelargonidin 3-O-glucoside, that was not found in WJ1, WJ2 and Isabel juice. The BRS Cora juice was the sample that presented the highest content of individual phenolics, followed by the WJ2, WJ1, N, LCN and the Isabel grape juice with the lowest concentration. In the BRS Cora juice, the main group of phenolic compounds identified was the anthocyanins, representing 60% of the total individual compounds. Delphinidin 3-O-glucoside occurred in more than 50% of this classification. Other substances as the cyanidin 3,5-diglucoside, gallic acid and catechin also showed high values, contributing to the content found in the total sum of the analyzed phenolic compounds. Not in all the analysis of the *t*-resveratrol content in grape juice showed significant variations.

In the Isabel grape juice, the phenolic acids appear in high contents (85.29 mg/L), following by the anthocyanins (74.39 mg/L). Among the phenolic acids, the chlorogenic and gallic acid are the most representative molecules, corresponding to 16.61% and 15.09%, respectively, corresponding to the total phenolic compounds analyzed. The rutin content is 7.64%, while the anthocyanins delphinidin 3-O-glucoside, malvidin 3,5-diglucoside, malvidin 3-O-glucoside appear in significant amounts, corresponding to 10.23%, 9.81%, and 8.68%, respectively.

Whole juices (WJ1 and WJ2) presented a higher cyanidin 3,5-diglucoside content compared to the other juices. WJ1 and WJ2 also contain higher contents of malvidin 3,5-diglucoside (34.50 mg/L-WJ1 and 34.70 mg/L-WJ2), chlorogenic acid (WJ1-94.38 mg/L; WJ2 100.99 mg/L) and catechin (WJ1-124.98 mg/L and WJ2-162.15 mg/L). These juices presented higher total phenolic compounds, except when compared with BRS Cora juices. The highest catechin content occurs in N (99.54 mg/L) comparing to the low-calorie nectar (LCN) (47.57 mg/L), as well as with gallic acid (N-61.48 mg/L and LCN-35.73 mg/L) and chlorogenic acid (N-51.40 mg/L and LCN-44.12 mg/L) and both presented contents similar to cyanidin 3,5-diglucoside (N-35.15 mg/L and LCN-34.86 mg/L) and delphinidin 3-O-glucoside (N-23.26 mg/L and LCN-23.09 mg/L). The results of these four analyzed beverages (WJ1, WJ2, N and LCN) possibly are due to the grapes used or to the blending of different materials, but with similar genetic characteristics, as observed in the obtained profile, mainly of the anthocyanins, confirming that these beverages industrially processed were made from *V. labrusca* or hybrid grapes, the main grapes produced in Brazil destined to the juice elaboration.

The phenolic compounds (individual and total phenolic) found in the Isabel grape juice, could explain the results obtained for commercial samples, once this cultivar is the most produced grape in Brazil. These data can be used for new cultivars development in Brazil, *e.g.*, the BRS Cora grape that has several beneficial compounds (Natividade et al., 2013). Malvidin 3,5-diglucoside, cyanidin 3,5-diglucoside, delphinidin 3-O-glucoside and malvidin 3-O-glucoside, are the main anthocyanins found in grape juices produced in Brazil (Granato et al., 2015). In relation to the values found for the diglucoside molecules, the occurrence help explain that the grapes used in these beverages are American or hybrid (Burns et al., 2002). It is also important to consider that there are other factors that can contribute to differ the profiles in the phenolic compounds found, as for example, the processing method, the region, the production method of the grape and the quantity or percentage of grape used to elaborate the beverage (Belmiro et al., 2017; Koziet et al., 1993).

Table 4. Phenolic compounds profile (mg/L) in grape juices

Compound	Isabel whole juice	BRS Cora whole juice	Nectar	Low-calorie nectar	Whole juice 1	Whole juice 2
Anthocyanins						
Cyanidin 3,5-diglucoside	0.00±0.00 ^{c}	169.64±15.83 ^{a}	35.15±0.17 ^{b}	34.86±0.11 ^{b}	50.84±0.71 ^{b}	48.97±0.35 ^{b}
Delphinidin 3-O-glucoside	23.48±0.31 ^{b}	234.76±3.99 ^{a}	23.26±0.12 ^{b}	23.09±0.10 ^{b}	24.26±0.13 ^{b}	24.13±0,06 ^{b}
Cyanidin 3-O-glucoside	1.64±0.43 ^{b}	23.98±0.95 ^{a}	0.53±0.08 ^{bc}	0.37±0.09 ^{c}	1.27±0.12 ^{bc}	1.00±0.02 ^{bc}
Pelargonidin 3-O-glucoside	0.00±0.00 ^{b}	0.25±0.05 ^{a}	0.21±0.05 ^{a}	0.20±0.05 ^{a}	0.00±0.00 ^{b}	0.00±0.00 ^{b}
Malvidin 3,5-diglucoside	22.52±0.90 ^{b}	4.57±0.59 ^{c}	1.18±0.20 ^{d}	1.84±0.27 ^{d}	34.50±0.77 ^{a}	34.70±0.46 ^{a}
Peonidin 3-O-glucoside	6.83±1.15 ^{a}	0.26±0.03 ^{b}	0.16±0.02 ^{b}	0.31±0.08 ^{b}	0.44±0.02 ^{b}	0.23±0.01 ^{b}
Malvidin 3-O-glucoside	19.93±2.31 ^{a}	3.30±0,00 ^{b}	3.43±0.02 ^{b}	3.65±0.04 ^{b}	4.63±0.13 ^{b}	3.76±0.06 ^{b}
Flavonols						
Rutin	17.53±7.59 ^{c}	35.19 ±2.66 ^{a}	22.83±1.04 ^{bc}	21.07±0.96 ^{bc}	36.85±3.10 ^{a}	27.83±1.66 ^{ab}
Quercetin	1.99±0.07 ^{c}	3.30±0,25 ^{b}	2.40±0.24 ^{c}	2.52±0.03 ^{c}	4.32±0.30 ^{a}	3.85±0.16 ^{ab}
3-O-Methylquercetin	0.27±0.08 ^{c}	0.19±0.09 ^{c}	0.77±0.14 ^{c}	0.61±0.16 ^{c}	5.11±0.42 ^{a}	4.10±0.34 ^{b}
Kaempferol	1.83±0.32 ^{c}	0.42±0.04 ^{d}	2.47±0.06 ^{b}	1.87±0,08 ^{c}	0.36±0.03 ^{d}	3.28±0.32 ^{a}
Phenolic acids						
Gallic acid	34.63±3.37 ^{c}	89.45±4.13 ^{a}	61.48±3.33 ^{b}	35.73±4.18 ^{c}	42.84±12.42 ^{c}	61.94±1.34 ^{b}
Trans-cinnamic acid	0.40±0.31 ^{bc}	1.13±0.05 ^{a}	0.19±0.06 ^{c}	0.10±0.02 ^{c}	0.35±0.07 ^{bc}	0.63±0.06 ^{b}
Caffeic acid	6.50±0.12 ^{d}	12.03±0.83 ^{c}	7.15±0.57 ^{d}	4.80±0.20 ^{e}	19.24±0.56 ^{a}	15.65±0.67 ^{b}
Chlorogenic acid	38.11±0.86 ^{f}	54.92±1.07 ^{c}	51.40±1.55 ^{d}	44.12±0.42 ^{e}	94.38±1.27 ^{b}	100.99±0.73 ^{a}
p-coumaric acid	2.54±0.11 ^{e}	14.11±0.56 ^{b}	8.37±0.77 ^{c}	5.37±0.12 ^{d}	29.16±1.06 ^{a}	29.28±0.91 ^{a}
Trans-ferulic acid	3.11±0.02 ^{e}	5.58±0.13 ^{b}	3.03±0.00 ^{e}	3.42±0.00 ^{d}	5.91±0.11^{a}	4.14±0.03 ^{c}
Stilbene						
t- resveratrol	0.05±0.00 ^{a}	0.05±0.00 ^{a}	0.05±0.00 ^{a}	0.05±0.00 ^{a}	0.05±0.00 ^{a}	0.05±0.00 ^{a}
Flavones						
Luteolin	1.17±0.12 ^{b}	1.15±0.03 ^{b}	1.37±0.06 ^{b}	1.50±0.08 ^{b}	5.15±0.54 ^{a}	5.12 a
Flavan-3-ol						
Catechin	46.96±7.66e	64.77±3.08 d	99.54±2.40 ^{c}	47.57±2.88 ^{e}	124.98±8.92 ^{b}	162.15±5.19 ^{a}
Total anthocyanins	74.39	436.77	63.92	64.31	115.94	112.78
Total flavonols	21.62	30.09	28.47	26.07	46.64	39.05
Total phenolic acids	85.29	177.21	131.62	93.54	191.89	212.63
Stilbene	0.05	0.05	0.05	0.05	0.05	0.05
Flavones	1.17	1.15	1.37	1.5	5.15	5.12
Flavan-3-ol	46.96	64.77	99.54	47.57	124.98	162.15
Total phenolic compounds	229.48	719.05	324.92	233.04	484.65	531.74
Total phenol (GAE mg/L)	109.42±13.45 ^{c}	300.83±22.37 ^{a}	201.47±2.17 ^{b}	111.79±13.17 ^{c}	268.85±23.40 ^{a}	277.63±21.17 ^{a}

Note. Values represent the average of three replications±standard deviation. Different letters in the same row represent statistical different results according to Tukey test, ($p < 0.05$).

3.4 Phenolic Compounds Profile in Wines

The phenolic compounds contents in wines vary between 411.45 (YW2) and 548.32 mg/L (YW1). These results reflect the data found by the spectrophotometric method (Table 5). From the twenty compounds analyzed, all of them were detected, except pelargonidin 3-O-glucoside in wines YW1 and YW2, possibly due to the absence of this anthocyanin in wines elaborated with Isabel (Nixdorf et al., 2010). In the four samples, the phenolic acids were the most representatives, corresponding to around 40% of the total value for each wine. The gallic acid was the compound that contributed the most to this result. In this study, we observed higher contents in wines made from *V. labrusca* (YW1-123.20 mg/L and YW2-83.46 mg/L). Other phenolic acids as the chlorogneic, p-cummaric, trans-ferulic and caffeic acid also showed high levels in the wines elaborated with *V. labrusca* and *V. vinifera* grapes. These compounds are also present in high concentrations in Merlot, Cabernet Sauvignon, Isabel, Bordo and Concord grapes (Burin et al., 2014; Natividade et al., 2013). The catechin content was higher in the four analyzed samples when compared to the other analyzed compounds. However, this result was not

observed in the YW2 wine (101.38 mg/L), but was the highest if compared to other Brazilian wines (22-90 mg/L) (Belmiro et al., 2017).

The anthocyanins occur in high contents in wines YW1 and YW2. Among the anthocyanins, malvidin 3,5-diglucoside and cyanidin 3,5-diglucoside are normally found in hybrid grapes (Burns et al., 2002). These diglycosylated molecules were the most representative and showed superior values ($p < 0.05$) compared to the CSW and MW. The highest contents of cyanidin 3,5-diglucoside and delphinidin 3-O-glucoside were obtained in the wines elaborated from *V. vinifera*. CSW contains higher malvidin 3-O-glucoside (12.50 mg/L) content compared to the other samples and presented similar values to the Brazilian wines (15.3-3.3 mg/L) (Dias et al., 2013). *t*-resveratrol was detected in all of the analyzed wines, showing no variation.

The phenolic compounds profile in wines can be affected by different previously known variables, such as vinification procedure, grape quality, climatic conditions, aging, among others, which produce wines with different characteristics and functional quality (Belmiro et al., 2017; Moreno-Arribas, 2009). In addition, the analysis of the *V. labrusca* wines demonstrates that both (YW1 and YW2) have interesting profiles of phenolic compounds and with antioxidant activity (Nixdorf et al., 2010). Thus, these beverages mean opportunities for winemaking in the regions where these varieties are well established and where the *V. vinifera* grapes cultivation is difficult due to the climatic conditions.

It is important to point out that the aging process can affect the polyphenol content in wines. In wines from wine grapes, the differences in the content can be attributed to the conditions of elaboration and to the aging time, while in the young wines (hybrid grapes), we found compounds, as the anthocyanins 3-glucosides, which are unstable pigments and are affected during the different stages of the processing (Moreno-Arribas & Polo, 2009). These factors lead to losses of antioxidant compounds, resulting in lower content of bioactive compounds for the consumer.

3.5 Multivariate Data Analysis

The principal components analyses (PCA) was developed with the 10 samples derived from grape (juice and wine) and 29 variables, considering only the BAs, phenolic compounds and pH. After autoscaling, two principal components were identified (PC1 and PC2), corresponding to 29% and 27%, respectively, accounting for 55.40% of the total variability (Figure 1A). The variables that showed a strong positive correlation were putrescine, spermidine, serotonin, total polyphenols, quercetin, catechin, gallic acid and pH, which show dominant positive characteristics in the first principal component, explaining the higher variability and they all presented factor loading greater than 0.80. The second principal component is positively correlated to 3-O-methylquercetin, chlorogenic acid, *p*-coumaric acid, luteolin and histamine, with factor loading greater than 0.70 (Figure 1B). The score plot obtained from quantitative data of samples (juice and wine) show a discrimination of beverages. According to the PCA results, there was a separation along the second component, where the whole juices (WJ1 and WJ2) and wines elaborated with hybrid grapes (YW1 and YW2) were separate groups from the other samples. In the positive part of first component, we can observe the separation of the wines elaborated with *V. vinifera* (Merlot and Cabernet Sauvignon), while in the negative part of the first component there is the separation of the nectars and of the juices elaborated in our laboratory.

Table 5. Phenolic compounds profile (mg/L) in red wines

Compound	Young wine 1	Young wine 2	Cabernet Sauvignon wine	Merlot wine
Anthocyanins				
Cyanidin 3,5-diglucoside	36.37±0.01 ^{b}	37.77±0.20 ^{a}	34.87±0.26 ^{c}	34.94±0.12 ^{c}
Delphinidin 3-O-glucoside	24.22±0.42 ^{a}	24.63±0.12 ^{a}	24.65±0.03 ^{a}	23.59±0.06 ^{b}
Cyanidin 3-O-glucoside	0.58±0.06 ^{a}	0.59±0.08 ^{a}	0.22±0.11 ^{b}	0.23±0.02 ^{b}
Pelargonidin 3-O-glucoside	0.00±0.00 ^{b}	0.00±0.00 ^{b}	0.25±0.13 ^{a}	0.29±0.07 ^{a}
Malvidin 3,5-diglucoside	57.73±1.68 ^{a}	44.61±2.04 ^{b}	4.41±0.49 ^{c}	1.94±0.30 ^{c}
Peonidin 3-O-glucoside	0.35±0.05 ^{c}	0.69±0.08 ^{b}	1.42±0.23 ^{a}	0.65±0.06 ^{bc}
Malvidin 3-O-glucoside	5.12±0.12 ^{c}	7.05±0.08 ^{b}	12.50±0.52 ^{a}	7.00±0.12 ^{b}
Flavonols				
Rutin	13.40±0.13 ^{b}	11.48±0.30 ^{c}	30.71±0.39 ^{a}	13.54±0.07 ^{b}
Quercetin	3.54±0.15 ^{b}	3.08±0.11 ^{b}	7.41±0.99 ^{a}	8.33±1.35 ^{a}
3-O-Methylquercetin	2.13±0.29 ^{a}	1.17±0.14 ^{b}	1.97±0.05 ^{a}	2.05±0.10 ^{a}
Kaempferol	5.07±0.10 ^{a}	1.50±0.24 ^{c}	3.95±0.15 ^{b}	4.14±0.22 ^{b}
Phenolic acids				
Gallic acid	123.20±3.00 ^{b}	83.46±0.57 ^{c}	144.01±22.31 ^{ab}	167.95±8.70 ^{a}
Trans-cinnamic acid	0.11±0.01 ^{d}	0.62±0.03 ^{b}	2.68±0.06 ^{a}	0.43±0.01 ^{c}
Caffeic acid	10.34±0.34 ^{c}	12.39±0.26 ^{b}	6.40±0.22 ^{d}	16.19±0.57 ^{a}
Chlorogenic acid	57.61±061 ^{a}	59.06±1.32 ^{a}	40.92±0.32 ^{d}	42.94±0.37 ^{c}
p-coumaric acid	11.82±0.20 ^{b}	13.41±1.01 ^{a}	6.33±0.27 ^{a}	11.38±0.29 ^{b}
Trans-ferulic acid	5.23±0.06 ^{a}	4.68±0.05 ^{b}	3.79±0.06 ^{c}	3.53±0.06 ^{d}
Stilbene				
t-resveratrol	0.05 ^{a}	0.05 ^{a}	0.05 ^{a}	0.05 ^{a}
Flavones				
Luteolin	4.99±0.06 ^{a}	3.87±0.30 ^{ab}	3.43±0.47 ^{ab}	3.16±1.09 ^{b}
Flavan-3-ol				
Catechin	186.53±20.99 ^{a}	101.38±14.26 ^{b}	190.35±13.88 ^{a}	189.74±8.52 ^{a}
Total anthocyanins	124.37	115.34	78.31	68.65
Total flavonols	24.13	17.23	44.04	28.06
Total phenolic acids	208.3	173.63	204.13	242.43
Stilbene	0.05	0.05	0.05	0.05
Flavones	4.99	3.87	3.43	3.16
Flavan-3-ol	186.53	101.38	190.35	189.74
Total phenolic compounds	548.37	411.5	520.31	532.09
Total phenol (GAE mg/L)	293.24±46.26 ^{b}	235.11±7.41 ^{b}	478.29±24.91 ^{a}	509.14±36.35 ^{a}

Note. Values represent the average of three replications±standard deviation. Different letters in the same row represent statistical different results according to Tukey test, ($p < 0.05$).

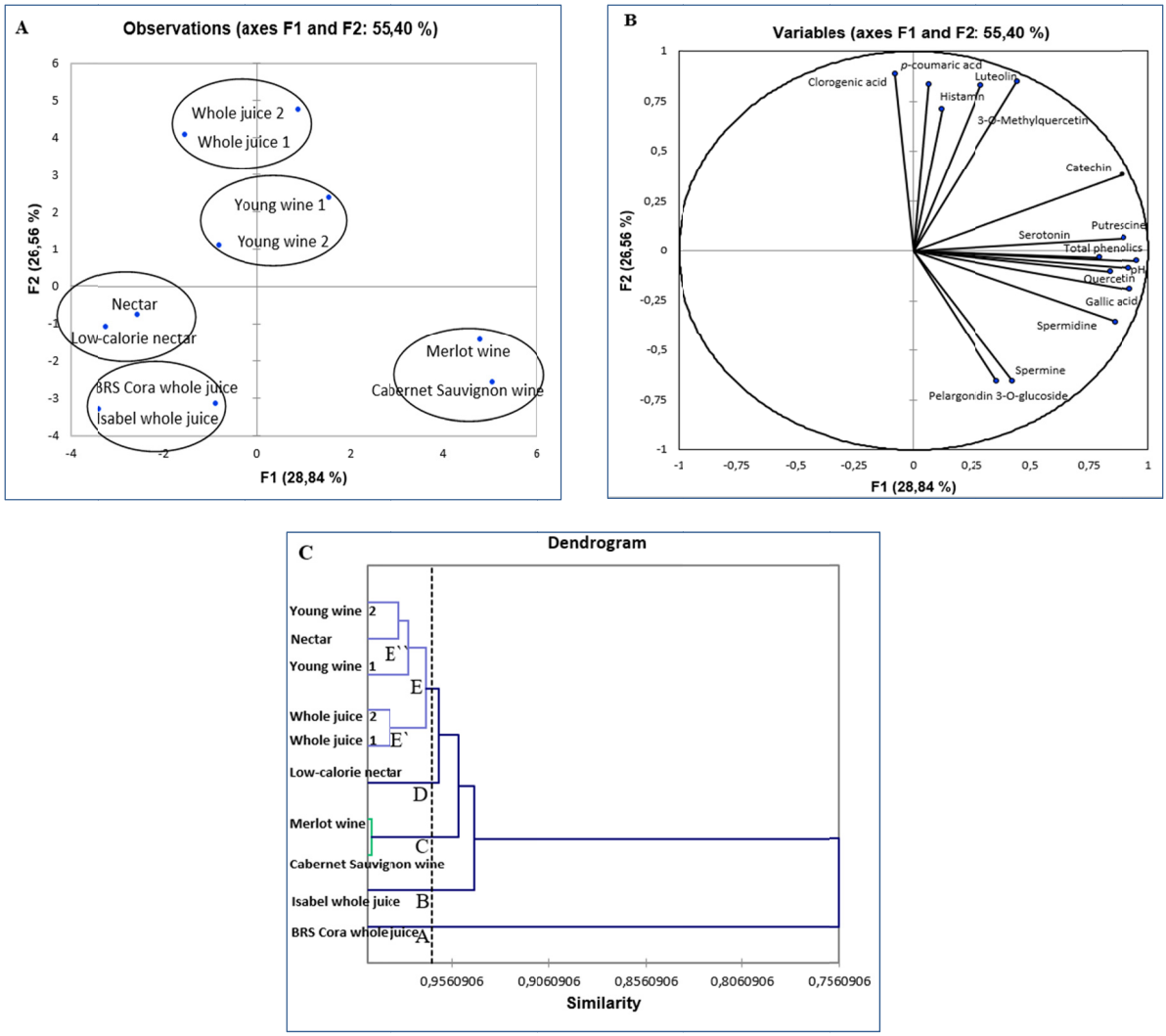

Figure 1. Plots of the principal component analysis (PCA): (A) score plot; (B) loading plot; and dendrogram of cluster analysis (C) of biogenic amines and phenolic compounds on grape beverages

Cluster analysis was based on BAs, phenolic compounds and pH. The dendrogram was built through the cluster analysis from the similarity matrix (Pearson correlation coefficient) showing five main groups (A-E) with 0.95 of similarity (Figure 1C). The clusters A, B and D are formed only by grape juices (BRS Cora whole juice, Isabel whole juice, and low-calorie nectar, respectively). The cluster C is formed by the CSW and MW wines, both elaborated with wine grapes and the last cluster (E) concentrates the highest number of samples, formed by two subgroups, E' (two commercial whole juices-WJ1 and WJ2) and E'' (YW1, YW2 and N). The results show that there was a separation among the groups formed by the wines from *V. labrusca* (lower quality) and Nectar (E''), meaning that the presence of carbohydrate (sugarcane addition) influences the composition. In addition, other factors, such as chemical composition, different cultivars or regions, or processing methods, can promote alterations in the bioactive contents. In opposition, E' formed by whole juices (WJ1 and WJ2), contain only grapes, and consequently, higher content of bioactive compounds. However, even being elaborated with different types of carbohydrates there is a similarity among the samples, composing the E cluster, what may happen due to the presence of Isabel grape (*V. labrusca*). Isabel juice was also elaborated with the same grape, but it is separated in another cluster (B). This result happens due to the absence of other grapes in the composition, while the beverages that compose the cluster E contain a blending of Isabel grape with other grapes (Table 1). The anthocyanins content, mainly delphinidin 3-O-glucoside, phenolic acids and some BAs, as spermine and serotonin, contribute to the separation of this juice in one cluster (A).

The results obtained from the Pearson correlation (data not shown) mean that a higher BA content could be related to the higher phenolic compounds content. The obtained correlation also demonstrates that high pH values are related to the increasing activity of some bacteria that synthesize BA. Low pH inhibits the metabolism of some microorganisms and as consequence there is no formation of BA (Landete et al., 2005). In addition, edaphoclimatic conditions from cultive region and hygienic conditions of the grape before the processing can collaborate with alterations in the BA synthetic pathway and with pH variations, influencing the phenolic compounds levels.

Isotopic analysis demonstrated the presence of sugar from C4 plants in some samples, which can induce a change in quality. Authenticity of wines and the real fruit percentage of juices are important factors to establish the health benefits of grape derived beverages. Functional properties of beverages derived from grapes, both alcoholic and non-alcoholic, were confirmed by the high phenolic compounds and BAs levels. All the evaluated beverages presented a distinct profile of phenolic compounds and BAs. *V. vinifera* wines (CSW and MW), which contain mainly carbon from plants from the C3 photosynthetic cycle, showed the highest concentrations of total phenolic compounds and total BAs. Serotonin, spermine and putrescine were the most representative amines, while the contents of histamine, tyramine and cadaverine were low, demonstrating the low contamination, with levels below of what was reported as harmful to the human health. The *V. labrusca* wines, with more than 20% of C4 carbon present, contains lower total BAs contents. Putrescine was the predominant BA and undesirable values of histamine and cadaverine were observed, while tyramine occurs only in YW1. The wines YW1 and YW2, the two commercial whole juices and the juice elaborated with BRS Cora grapes contains the highest anthocyanins contents. In nectar, there is the highest percentage of C4 plants carbon, with low levels of BA and anthocyanins, even though they present a SS content similar to the whole juices, result attributed to the addition of sucrose from sugarcane. Thus, anthocyanin profile, BA levels and isotopic analyses can be applied as tools to detect antioxidant levels and functional quality of grape-derived beverages.

References

Asci, H., Ozmen, O., Ellidag, H. Y., Aydin, B., Bas, E., & Yilmaz, N. (2017). The impact of gallic acid on the methotrexate-induced kidney damage in rats. *Journal of Food and Drug Analysis,* 1-8. https://doi.org/10.1016/j.jfda.2017.05.001

Belmiro, T. M. C., Pereira, C. F., & Paim, A. P. S. (2017). Red wines from South America: Content of phenolic compounds and chemometric distinction by origin. *Microchemical Journal, 133*, 114-120. https://doi.org/10.1016/j.microc.2017.03.018

Burin, V. M., Falcão, L. D., Gonzaga, L. V., Fett, R., Rosier, J. P., & Bordignon-Luiz, M. T. (2010). Colour, phenolic content and antioxidant activity of grape juice. *Ciencia e Tecnologia de Alimentos, 30*(4), 1027-1032. https://doi.org/10.1590/S0101-20612010000400030

Burns, J., Mullen, W., Landrault, N., Teissedre, P. L., Lean, M. E. J., & Crozier, A. (2002). Variations in the profile and content of anthocyanins in wines made from Cabernet Sauvignon and hybrid grapes. *Journal of Agricultural and Food Chemistry, 50*(14), 4096-4102. https://doi.org/10.1021/jf011233s

Calderone, G., & Guillou, C. (2008). Analysis of isotopic ratios for the detection of illegal watering of beverages. *Food Chemistry, 106*(4S), 1399-1405. https://doi.org/10.1016/j.foodchem.2007.01.080

Cecchini, F., & Morassut, M. (2010). Effect of grape storage time on biogenic amines content in must. *Food Chemistry, 123*(2), 263-268. https://doi.org/10.1016/j.foodchem.2010.04.026

Dadáková, E., Křížek, M., & Pelikánová, T. (2009). Determination of biogenic amines in foods using ultra-performance liquid chromatography (UPLC). *Food Chemistry, 116*(1), 365-370. https://doi.org/10.1016/j.foodchem.2009.02.018

Dias, F. D. S., Silva, M. F., & David, J. M. (2013). Determination of Quercetin, Gallic Acid, Resveratrol, Catechin and Malvidin in Brazilian Wines Elaborated in the Vale do São Francisco Using Liquid-Liquid Extraction Assisted by Ultrasound and GC-MS. *Food Analytical Methods, 6*(3), 963-968. https://doi.org/10.1007/s12161-012-9507-2

Flores, H. E., & Galston, A. W. (1982). Analysis of polyamines in higher plants by high performance liquid chromatography. *Plant Physiology, 69*(3), 701-706. https://doi.org/10.1104/pp.69.3.701

Granato, D., Koot, A., Schnitzler, E., & van Ruth, S. M. (2015). Authentication of geographical origin and crop system of grape juices by phenolic compounds and antioxidant activity using chemometrics. *Journal of Food Science, 80*(3), C584-C593. https://doi.org/10.1111/1750-3841.12794

Koziet, J., Rossmann, A., Martin, G. J., & Ashurts, P. R. (1993). Determination of carbon-13 content of sugars of fruit and vegetable juices. A European inter-laboratory comparison. *Analytica Chimica Acta, 271*(1), 31-38. https://doi.org/10.1016/0003-2670(93)80548-Y

Landete, J. M., Ferrer, S., & Pardo, I. (2005). Which lactic acid bacteria are responsible for histamine production in wine? *Journal of Applied Microbiology, 99*(3), 580-586. https://doi.org/10.1111/j.1365-2672.2005.02633.x

Lima, G. P. P., Da Rocha, S. A., Takaki, M., Ramos, P. R. R., & Ono, E. O. (2008). Comparison of polyamine, phenol and flavonoid contents in plants grown under conventional and organic methods. *International Journal of Food Science and Technology, 43*(10), 1838-1843. https://doi.org/10.1111/j.1365-2621.2008.01725.x

Linares, D. M., del Rio, B., Redruello, B., Ladero, V., Martin, M. C., Fernandez, M., … Alvarez, M. A. (2016). Comparative analysis of the in vitro cytotoxicity of the dietary biogenic amines tyramine and histamine. *Food Chemistry, 197*, 658-663. https://doi.org/10.1016/j.foodchem.2015.11.013

MAPA (Ministério da Agricultura, Pecuária e Abastecimento). (2017). *Legislação de bebidas, vinhos e derivados da uva e do vinho*. MAPA, Brasil. Retrieved from http://www.agricultura.gov.br/assuntos/vigilancia-agropecuaria/ivegetal/bebidas

Minussi, R. C., Rossi, M., Bologna, L., Cordi, L., Rotilio, D., Pastore, G. M., & Durán, N. (2003). Phenolic compounds and total antioxidant potential of commercial wines. *Food Chemistry, 82*(3), 409-416. https://doi.org/10.1016/S0308-8146(02)00590-3

Moreno-Arribas, M. V., & Polo, M. C. (2009). *Wine Chemistry and Biochemistry*. Springer, New York, NY. https://doi.org/10.1007/978-0-387-74118-5

Natividade, M. M. P., Corrêa, L. C., Souza, S. V. C. de, Pereira, G. E., & Lima, L. C. de O. (2013). Simultaneous analysis of 25 phenolic compounds in grape juice for HPLC: Method validation and characterization of São Francisco Valley samples. *Microchemical Journal, 110*, 665-674. https://doi.org/10.1016/j.microc.2013.08.010

Nixdorf, S. L., & Hermosín-Gutiérrez, I. (2010). Brazilian red wines made from the hybrid grape cultivar Isabel: Phenolic composition and antioxidant capacity. *Analytica Chimica Acta, 659*(1-2), 208-215. https://doi.org/10.1016/j.aca.2009.11.058

OIV. (2016). Compendium of international Methods of Wine and must Analysis. *International Organisation of vine and wine* (Volume 1). Retrieved from http://www.oiv.int/public/medias/5772/compendium-2018-en-vol1.pdf

Preti, R., Bernacchia, R., & Vinci, G. (2016). Chemometric evaluation of biogenic amines in commercial fruit juices. *European Food Research and Technology*. https://doi.org/10.1007/s00217-016-2701-5

Preti, R., Vieri, S., & Vinci, G. (2016). Biogenic amine profiles and antioxidant properties of Italian red wines from different price categories. *Journal of Food Composition and Analysis, 46*, 7-14. https://doi.org/10.1016/j.jfca.2015.09.014

Rodriguez-Naranjo, M. I., Ordóñez, J. L., Callejón, R. M., Cantos-Villar, E., & Garcia-Parrilla, M. C. (2013). Melatonin is formed during winemaking at safe levels of biogenic amines. *Food and Chemical Toxicology, 57*, 140-146. https://doi.org/10.1016/j.fct.2013.03.014

Souza, S. C., Theodoro, K. H., Souza, É. R., Da Motta, S., & Glória, M. B. A. (2005). Bioactive amines in Brazilian wines: Types, levels and correlation with physico-chemical parameters. *Brazilian Archives of Biology and Technology, 48*(1), 53-62. https://doi.org/10.1590/S1516-89132005000100009

ten Brink, B., Damink, C., Joosten, H. M. L. J., & Huis in't Veld, J. H. J. (1990). Occurrence and formation of biologically active amines in foods. *International Journal of Food Microbiology, 11*(1), 73-84. https://doi.org/10.1016/0168-1605(90)90040-C

Tofalo, R., Perpetuini, G., Schirone, M., & Suzzi, G. (2016). Biogenic Amines: Toxicology and Health Effect. *Encyclopedia of Food and Health* (1st ed.). Elsevier Ltd. https://doi.org/10.1016/B978-0-12-384947-2.00071-4