

Preliminary studies of bioactive compounds and color in Mexican red wines from Baja California region

Estudios preliminares de los compuestos bioactivos y color de vinos rojos mexicanos de la región de Baja California

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Recibido: 09/07/2021 Aceptado: 20/10/2021

Resumen Se analizaron los compuestos fenólicos totales, el contenido total de antocianinas y las propiedades antioxidantes de diez vinos comercialmente basados en diferentes cultivares de uva de Baja California, México. Los resultados mostraron que el contenido de compuestos fenólicos de *Vitis vinifera* cv., Petit Verdot y Petit Syrah, presentaron los valores más altos de contenido fenólico total (1188,26 y 1148,13 mg GAE/L, respectivamente), con respecto a los otros vinos. Sin embargo, los vinos elaborados con tres cultivares diferentes (Cabernet Sauvignon, Petit Verdot, Merlot), y el vino del cultivar Petit Verdot presentaron el mayor contenido total de flavonoides (161,06 mg QE/L y 182.64 mg QE/L, respectivamente) y contenido total de antocianinas (286,38 mg ME/L y 2548,56 mg ME/L, respectivamente). En contraste, solo el vino de tres variedades de uva (Cabernet Sauvignon, Petit Verdot, Merlot) y el vino de la variedad Gamay exhiben la mayor actividad antioxidante entre los probados. Finalmente, estos resultados sugieren que el vino elaborado con diferentes cultivares (Cabernet Sauvignon, Petit Verdot, Merlot) es más beneficioso para la salud que otros vinos tintos en cuanto a su mayor actividad antioxidante, contenido total de antocianinas y contenido total de flavonoides.

Palabras clave: compuestos fenólicos; actividad antioxidante; vinos rojos; Baja California, flavonoides.

Abstract The total phenolic compounds, total anthocyanin content, and antioxidant properties of ten commercially wines based on different grape cultivars from Baja California, Mexico were analyzed. The results showed that the content of phenolic compounds of *Vitis vinifera* cv. Petit Verdot and Petit Syrah wines had the highest values of total phenolic content (1188.26 and 1148.13 mg GAE/L, respectively), compared to other wines. However, wines elaborated with three different cultivars (Cabernet Sauvignon, Petit Verdot, Merlot), and wine from cultivar Petit Verdot presented the highest total flavonoids content (161.06 mg QE/L and 182.64 mg QE/L, respectively) and total anthocyanin content (286.38 mg ME/L and 2548.56 mg ME/L, respectively). In contrast, only wine from three grape cultivars (Cabernet Sauvignon/Petit Verdot/Merlot), and wine from cultivar Gamay, exhibits the highest antioxidant activity among tested wines. Finally, these results suggest that wine elaborated with different cultivars (Cabernet Sauvignon, Petit Verdot, Merlot) is more beneficial to health than other red wines in terms of its higher antioxidant activity, total anthocyanin content, and total flavonoid content.

Keywords: phenolics compounds; antioxidant activity; red wines; Baja California; flavonoids.

Introduction

The tradition of wine production in Mexico dates back more than 1500 years and is the oldest wine-growing region in North America (Covarrubias & Thach, 2015). The production of Mexican wines is carried out within the states of Baja California, Chihuahua, Coahuila, Durango, Guanajuato, Nuevo Leon, Queretaro, Sonora, San Luis Potosi, Zacatecas, and Aguascalientes. Baja California, specifically in the municipality of Ensenada, the valleys of Guadalupe, San Vicente, Ojos Negros, Santo Tomás, and San Antonio de las Minas, are considered as a region with important viticulture traditions (90% of the national production of wine is produced in this region). These areas, privileged to have excellent edaphoclimatic conditions, are turned to advantage for vineyard culture, which corresponds to 2790 ha. This makes Baja California the Mexican capital of wine (Gonzalez, 2015). In recent years, the oenological industry of Baja California has based its market strategy in the exploitation of characteristics and particularities of different varieties of grapes used such as Syrah, Tempranillo, Cabernet Sauvignon, Sauvignon Blanc, Chenin Blanc, and the use of Petit Verdot, and Grenache grapes, among others (Arévalo, 2018; Meraz, 2017). The red wine includes different levels of polyphenols such as flavonoids, anthocyanins, phenolic acids, and polymeric tannins that contribute to the color, flavor, astringency, and bitterness of wine. These compounds also can help human health due to their antioxidant properties that serve to prevent various chronic diseases. In this sense, the polyphenols composition and antioxidant activity in different wines are particularly bound up with grape varieties used in their manufacture (Lachman; Šulc; Faitová; Pivec, 2009).

Recent studies have showed that grapes varieties have an impact in the antioxidant activity and bioactive compounds in red wines in different countries as France, Italy, Spain, and Brazil (Mulero; Zafrilla; Cayuela; Martínez-

Cachá; Pardo, 2011; Jäntschi; Sestraş; Bolboacă, 2013; Padilha; Telles; Corrêa; dos Santos-Lima; Elias-Pereira, 2017). In Mexico, red wine production is a traditional practice based in *Vitis vinifera* L. grapes and the variation of their physicochemical and biochemical properties is of great interest for the oenological industry of Baja California. Therefore, this study aimed to evaluate the total phenolic compound content, anthocyanin, total flavonoid content, and antioxidant activity of commercial red wines originating from Baja California, Mexico.

Materials and methods

Red wine samples

A total of 10 commercial red wines produced in Baja California, Mexico with *Vitis vinifera* red grape varieties (Grenache, Cabernet Sauvignon, Malbec-Ruby, Merlot, Petit Verdot, Petit Syrah, Pinot Noir, Tempranillo, Cariñena, and Gamay) were studied (Table 1). Wines were brought to the laboratory and stored at 5 °C until their analysis.

Table 1. Baja California commercial red wines evaluated in the present study

Sample code	Grave variety %	Alcohol %	Graphe	Vintage
Wine 01	Cabernet Sauvignon/ Grenache	13.3	100	2018
Wine 02	Malbec/Ruby Cabernet	12.5	70:30	2018
Wine 03	Petite Sirah	13.6	100	2015
Wine 04	Grenache/Cariñena/ Tempranillo	13.5	40:30:30	2017
Wine 05	Cabernet Sauvignon/ Petit Verdot/Merlot	12.5	40:30:30	2017
Wine 06	Cariñena/Tempranillo	13.2	50:50	2016
Wine 07	Cabernet/Malbec	12.5	50:50	2018
Wine 08	Cabernet Sauvignon	13.5	100	2016
Wine 09	Petit Verdot	13.5	100	2015
Wine 10	Gamay	13.5	100	2016

Source: own elaboration.

Determination of chromatic properties of red wine

To determine the chromatic parameters, a sample of 1 mL was collected from each bottle after, and color intensity ($A_{420} + A_{520} + A_{620}$), color hue (A_{420}/A_{520}), and brilliance of red wines [$100 \times [1 - (A_{420} + A_{620})/2A_{520}]$] were calculated according to Mira de Orduna (2010), using a DR 6000-Hach spectrophotometer. The total phenolic index (I_{280}) of samples was determined by the spectrophotometric absorbance of each wine at 280 nm according to Cetó *et al.* (2012).

Analysis of total phenolics content and total flavonoids content

To evaluate the total phenolic content of each red wine, the Folin-Ciocalteu method was used (Cervantes-García *et al.*, 2016). Briefly, 500 μ L of wine, previously diluted with distilled water (1:20) were mixed with 1.5 mL of Folin-Ciocalteu reagent (0.20 M) for 3 min, and then 1.5 mL of 20% (w/v) sodium carbonate were added. The mixtures were incubated in the dark at 25 °C for 60 min. The absorbance of each mixture was measured using a spectrophotometer (DR6000™ UV-VIS Spectrophotometers, Hach., USA) at the wavelength of 725 nm. All measurements were made in triplicates and the results were expressed as mg of gallic acid equivalents per liter (mg GAE/L). On the other hand, the total flavonoid content of the red wines was determined using aluminum chloride colorimetric according to Hosu, Cristea, and Cimpoi (2014). Briefly, 500 μ L of diluted wine samples were mixed with 500 μ L of 10% $AlCl_3$ solution and 500 μ L of 1M CH_3COONa solution in 4 mL distilled water. After incubation for 30 min, the absorbance was measured at 430 nm using a spectrophotometer (DR6000™ UV-VIS Spectrophotometers, Hach., USA). The total flavonoid content in each wine was determined in triplicates and the results were expressed as quercetin equivalents in mg per liter (mg QE/L).

Analysis of the total anthocyanins content

To evaluate the TA, each sample of wine (200 μ L) was mixed with 2.8 mL of a solution consisting of ethanol/water/HCl (70/30/1) (Di Stefano; Cravero; Gentilini, 1989). The absorbance of the solution was measured at 540 nm using a spectrophotometer (DR6000™ UV-VIS Spectrophotometers, Hach., USA). TA were measured in triplicate and expressed as malvidin-3-glucoside equivalents (mg ME/L) calculated according to Di Stefano *et al.* (1989): $TA_{540 \text{ nm}} \text{ (mg/L)} = (A_{540 \text{ nm}}) (16.7) (D)$. Where, $A_{540 \text{ nm}}$ is the absorbance at 540 nm and D is the dilution.

Antioxidant activity of wines

The antioxidant activity of each wine sample is presented according to Hosu *et al.* (2014). An aliquot of 1 mL of DPPH (1,1-diphenyl-2-picrylhydrazyl radical) in methanol (0.025 mg/100 mL) was mixed with 500 μ L of wine. The mixture was incubated under dark for 30 min at 25 °C and the absorbance was measured at 517 nm in a spectrophotometer (DR6000™ UV-VIS Spectrophotometers, Hach., USA). The antioxidant activity was report as DPPH radical inhibition (%) = $[(A_{\text{Control}} - A_{\text{Sample}})/A_{\text{Control}}] \times 100$. Where A_{Control} is the absorbance of the DPPH reaction and A_{Sample} is the absorbance in the presence of wine (Nile; Kim; Ko; Park, 2013). DPPH solution without wine served as a negative control. Ascorbic acid was used as standard positive.

Statistical analysis

The data obtained from biochemical variables were subjected to a one-way Analysis of Variance (ANOVA). When a significant ANOVA result was obtained (at $p < 0.05$) the Tukey's test was applied to the wines. In all cases, a P value of < 0.05 was considered statistically significant. the statistical analysis was performed using the Statistica package (version 9.0). All experiments were performed in triplicate; each being repeated at least three times.

Results and discussion

Determination of chromatic properties of red wine

The results obtained from the analysis of color intensity, hue, brilliance, and the total phenolic index are shown in Table 2.

Table 2. Color variables of Baja California commercial red wines

Sample code	Color Intensity	Color Hue	Brilliance %	I ₂₈₀
Wine 01	5.20	0.991	77.70	44.16
Wine 02	7.8	0.755	67.24	34.6
Wine 03	11.48	0.760	66.32	39.1
Wine 04	7.38	0.794	74.13	36.43
Wine 05	5.54	0.772	79.78	48.9
Wine 06	5.78	1.071	76.05	40.03
Wine 07	7.8	0.756	79.23	47.03
Wine 08	7.0	0.884	74.38	54.26
Wine 09	34.3	1.814	69.91	72.56
Wine 10	3.46	1.28	78.98	49.76

Source: own elaboration.

The results showed that the color intensity of wine-9 (Petit Verdot) and 3 (Petit Syrah) have the highest values (34.3 and 11.48, respectively) compared to other wines. The values of color intensity in the wines 07, 02, 08, 04 were in the range of 7.8 to 7, while in wines 06, 05, and 01 were 5.78, 5.54, and 5.20, respectively. In contrast, the wine-10 (Gamay) shows the lower values of color intensity (3.46). These variations could be the result of a natural qualitative difference in the varieties and winemaking techniques (Cliff; King; Schlosser, 2007). In this sense, the studies demonstrated that variation in color intensity may be due to factors such as anthocyanin content, temperature, maceration, or fermentation in red wines from other countries (Coradini; Madoşă; Petrescu; Coradini, 2014; Pérez-Navarro; García-Romero; Gómez-Alonso; Izquierdo-Cañas, 2018). On the other hand, Miljić *et al.* (2017) mention that the

color hue in the young red wines is in the range 0.5–0.7, while aging leads to an increase of this parameter (1.2–1.3). In this sense, all wines evaluated in this study were characterized by the highest values of hue (0.75 to 1.81), where the wines 06 (Carineña/Tempranillo), 09 (Petit Verdot), and 10 (Gamay) showed the highest value hue (1.071, 1.814 and 1.28, respectively). Among all the wine samples analyzed, this increase may be related to a low percentage of yellow color as a result of processes of wine aging (Babincev; Guresic; Simonovic, 2016). Regarding the brilliance, all wines have values between 66.91 and 79.78, which confirms the dominance of red color in the wines evaluated (Miljić; Puškaš; Hogervorst; Torovic, 2017).

The total phenolic index is one of the most important parameters of wine which determines some organoleptic and sensorial properties like color and astringency (Cetó *et al.*, 2012). As shown in Table 2, the total phenolic index showed values between 34.6 to 72.56, that can be compared to those reported in studies in different Merlot and Shiraz/Richter wines in two regions of Brazil and South Africa, ranging between 31–8 to 67.0 (Daudt & de Oliveira, 2013; Hunter *et al.*, 2014).

Analysis of total phenolics content and total flavonoids content

Figure 1 shows the total phenolic content and total flavonoid content in the samples of red wines. Among them, the highest total phenolic content (Fig. a) was found in wine 07 (Cabernet/Malbec) and wine 08 (Cabernet Sauvignon), with 1188.26 and 1148.13 mg GAE/L, respectively, followed by wine 02 (Malbec/Ruby Cabernet), 891.63 mg GAE/L, wine 03 (Petit Syrah), 932.53 mg GAE/L, wine 04 (Grenache/Carineña/Tempranillo), 583.33 mg GAE/L, wine 05 (Cabernet Sauvignon/Petit Verdot/Merlot), 608.4 mg GAE/L, wine 06 (Carineña/Tempranillo), 702.7 mg GAE/L, wine 09 (Petit Verdot), 682.2 mg GAE/L, wine 10 (Gamy), 688.33 mg GAE/L, and wine 01 (Cabernet Sauvignon/Grenache), with 298.53 mg GAE/L.

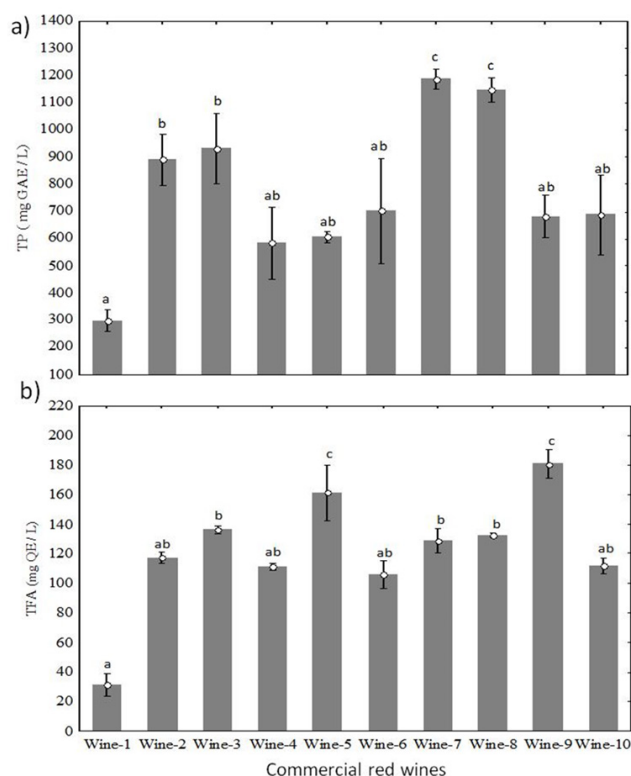


Figure 1. Total phenolics contents (a) and total flavonoid contents (b) from commercial red wine of Baja California, Mexico. Means with the same letter are not significantly different ($p < 0.05$). Error lines represent \pm S.D. of the mean for three separate experiments.

Source: own elaboration.

These results are partially in agreement with Granato, Katayama, and Castro (2011), who reported values of the total phenolic content of 1041 to 1958.78 mg GAE/L, for Brazilian red wines Pinot Noir, Malbec, Syrah, Cabernet Sauvignon, and Merlot grapes. Vrcek, Bojic, Zuntar, Mendaša, and Medić-Šarićb (2011) reported values of 554–2669 mg GAE/L in Croatian red wines from Plavac Mali and Zweigelt grapes. In contrast, Garaguso and Nardini (2015) reported values of 3043–5775 mg GAE/L in Italian red wines from Cabernet-Sauvignon, Barbera, Merlot, Monferrato, Refosco and Teroldego grapes.

On the other hand, as shown in Figure 1b, the wines 05 (Cabernet Sauvignon/Petit Verdot/Merlot) and wine 09 (Petit Verdot) presented the highest total flavonoids content (161.06 and 182.64 mg QE/L, respectively) followed by the wines 03 (136.10 mg QE/L), 07 (128.8 mg QE/L)

and 08 (132.77 mg QE/L). The wines 02, 04, 06 and 10 showed values of 117.16, 111.34, 105.89, and 112.05 mg QE/L, respectively.

Finally, wine 01 (Cabernet Sauvignon/Grenache) showed the lowest content of total flavonoids (31 mg QE/L) among all wine samples analyzed. Sartor, Malinovski, Caliar, Lima-da Silva, and Bordignon-Luiz (2017), and Kekelidze, Ebelashvili, Japaridze, Chankvetadze, and Chankvetadze (2018) found levels ranging from 5.23 and 53.62 mg QE/L for wine prepared from Saperavi and Syrah grapes, respectively. These differences in total phenolic and total flavonoids content between evaluated red wines and red wines from different countries can be attributed to variations among cultivar, vineyard location, different wine processing techniques and climate conditions. For example, variations among species of grapes of the same color, different wine processing techniques and conditions of grapevine cultivation such as heat, drought, and light intensity can have an impact on the phenolic metabolism (Franco-Bañuelos; Contreras-Martínez; Carranza-Téllez; Carranza-Concha, 2017).

Determination of TA

TA in wines is shown in Figure 2. Wine 05 (Cabernet Sauvignon/Petit Verdot/Merlot) showed the highest TA at 286.38 mg ME/L, followed by wine 09 (Petit Verdot), 2548.56 mg ME/L, and wine 07 (Cabernet/Malbec), 2471.42 mg ME/L, respectively. A high TA content was also found in wine 08 (Cabernet Sauvignon), with 2359.16 mg ME/L, and wine 03 (Petit Syrah), with 2155.92 mg ME/L. The TA contents from the other five regional wines decreased in the following order: wine 10 > wine 02 > wine 04 > wine 06 > wine 01. The wines 01 (Cabernet Sauvignon/Grenache) and 06 (Carineña/Tempranillo) showed the lowest values (896.71 and 974.25 mg ME/L, respectively) among analyzed wines. Ivanova-Pretopulos *et al.* (2015) found levels ranging from 260 to 1296 mg TA/L of varietal red wines (Merlot, Cabernet Sauvignon, and Syrah) from

different Macedonian wine regions. In this sense, Galindo-Tovar *et al.* (2019) mention that fruits of typical *V. tiliifolia* used to make the alcoholic beverages showed significantly lower levels of this anthocyanin compared to the wines evaluated in the present study.

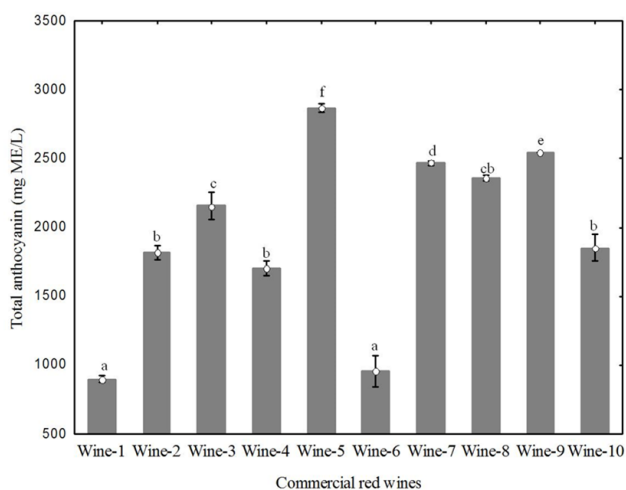


Figure 2. Total anthocyanins in commercial red wines of Baja California, Mexico. Means with the same letter are not significantly different from each other ($p > 0.05$). Error lines represent \pm S.D. of the mean for three separate experiments.

Source: own elaboration.

Mezey, Czako, Mezeyová, Bajčan, and Kobolkaet (2016) reported that the TA in their study ranged from 562.82 mg/L (Cabernet Sauvignon) to 1520 mg/L (cv. Alibernet). In this sense, Ivanova, Vojnoski, and Stefova (2012), and Ivanova-Pretopulos *et al.* (2015) mention that that process of maceration and the use of locally isolated yeasts in red wines produced from Vranec *Vitis vinifera* L. grape has influenced the content of anthocyanins. On the other hand, variations in the proportion of TA may be found in the wines, depending on the age of the wine. For example, old red wines obtained from three grape varieties, Vranec, Cabernet Sauvignon, and Merlot contained significantly lower levels of this anthocyanin, which indicated its degradation or transformation during the processes of wines aging (Dimitrovska; Tomovska; Bocevska, 2013).

Antioxidant activity of wines

Furthermore, the results obtained from DPPH radical scavenging activities of commercial red wines also show differences (Figure 3). Wine 09 (Peit Verdot), and wine 10 (Gamay) exhibit the highest antioxidant activity among tested wines, while wine 03 (Petit Syrah) and wine 04 (Grenache/Carineña/Tempranillo) showed lower radical activity.

Wines from grapes, Malbec/Ruby Cabernet (wine 02), Carineña/Tempranillo (wine 06), Cabernet/Malbec (wine 07), Cabernet Sauvignon/Grenache (wine 01), and Cabernet Sauvignon (wine 08) showed values of 74.46%, 74.47%, 71.76%, 69.41% and 65.23%, respectively. Some authors mention that total phenolic content determined according to the Folin-Ciocalteu method is not an absolute measurement of the number of phenolic compounds (Mahboudi; Kamalinejad; Ayatollahi; Babaeian, 2014; Amzad & Shah, 2015). In this sense, the wines analyzed possibly contain different types of phenolic and flavonoids compounds, which have different antioxidant capacities according to their structure, for example flavonoids, possess weak to moderate antioxidant activities (Csepregi; Neugart, Schreiner; Hideg, 2016).

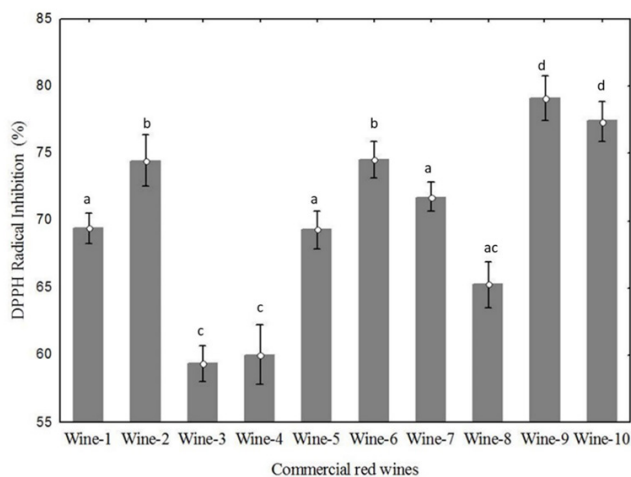


Figure 3. Scavenging effect of commercial red wines on DPPH. Results are represented as percentages of control, and the data represent mean \pm S.D. for three separate experiments

Source: own elaboration.

These studies are in agreement with Lima *et al.* (2011) and Galindo-Tovar *et al.* (2019), who reported lower values of total phenolic compounds but higher antioxidant activity in samples of red wine from *Vitis labrusca* grapes var. Bordô (Ives) and semi-sweet Lambrusco Italian wine. Majo, Guardia, Giammanco, la Neve, and Giammanco (2008) mention that the antioxidant properties of several samples of Sicilian red wines appear to be unequally influenced by the vintages for the different cultivars and that the correlation between antioxidant capacity and the total phenolic contents is weak. In this sense, authors like Mezey *et al.* (2016) mention that changes in total polyphenol content and antioxidant activity in Alibernet, Cabernet Sauvignon, and Torysa wines were found depending on the aging, according to the used statistical analyses. Another possibility is that the antioxidant capacity observed in the wines was not solely from the phenolic compounds such as anthocyanins and flavonoids evaluated, but could possibly be due to the presence of some other phytochemicals which also contribute to the total antioxidant capacity.

Conclusions

Finally, our results present some preliminary studies concerning the content of total phenolic compounds, anthocyanin, total flavonoid content and antioxidant activity in red wines produced in Baja California, Mexico and these are comparable to wines produced in other regions of Europe or South America. These results could be used in the optimization process of wine and allow producers to time the optimal date of wine release onto the market, depending on the desired content of total phenolic compound content, anthocyanin, total flavonoid content, and antioxidant activity.

Acknowledgements

The research (200/2461) was funded by the Universidad Autónoma de Baja California, Mexico.

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