Prospecting Antioxidant Capacities and Health-Enhancing Phytonutrient Contents of Southern Highbush Blueberry Wine Compared to Grape Wines and Fruit Liquors

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Received: September 13, 2011 Accepted: October 12, 2011 Published: February 1, 2012

doi:10.5539/sar.v1n1p26 URL: http://dx.doi.org/10.5539/sar.v1n1p26

Abstract

Blueberry wines may have a multitude of health benefits, but few studies have quantified the health-enhancing antioxidants, total phenols, anthocyanins and flavonoids in blueberry wines, especially the Southern highbush blueberry wine, in comparison to grape wines and fruit liquors. This study was initiated to fill such a gap by measuring the antioxidant capacity and key phytonutrients of Southern highbush blueberry wine as compared to red, Rose and white wines and fruit liquors. The Oxygen Radical Absorbance Capacity (ORAC) of the Southern highbush blueberry wine tested in this study ranged from 18.54 to 25.48 mmol TE/L, with an average of 22.57 ± 2.92 mmol TE/L. This was higher than the ORAC values of over 80% of the red wines and 100% of the Rose and white wines reported in literature. A majority of the red wines were higher, but all the Rose and white wines and most fruit liquors were lower in total phenolic content than the Southern highbush blueberry wine. Anthocyanin contents of the blueberry wines were generally comparable to those of the red wines. Results show that blueberry wines could be more potent than most red, Rose and white wines in health enhancement and disease prevention from the antioxidant perspective.

Keywords: Blueberry, Wine, Antioxidant, Phenolic, Anthocyanin, Flavonoid, ORAC

1. Introduction

Blueberry (*Vaccinium spp*.) is a popular natural food product consumed worldwide. For centuries, native American tribes have used the leaves, roots, and fruits from the blueberry plant for medicinal purposes (Sanchez-Moreno *et al*., 2003), and blueberries continue to be used in many types of dietary health products as pharmaceutical or food supplements in modern society (Kalt & Dufour, 1997). In the U.S., blueberries rank only second to strawberries in terms of berry consumption, while in Canada, blueberry is the largest fruit crop grown nationally, accounting for over ½ of entire Canadian fruit acreage (Scrivener, 2008).

In North America, the most commonly cultivated species is the (Northern) highbush blueberry, but with adaption to the Southern U.S. climate, its hybrid like the Southern highbush blueberry, which was developed by crossing northern highbush varieties from Michigan and New Jersey with wild blueberries native in Florida and other southeastern states (Williamson & Lyrene, 2004), has been created and quickly spread to Florida, Georgia, California, and even the Mediterranean regions of Europe, Southern Hemisphere countries and China. According to the U.S. blueberry (cultivated and wild) production and utilization data (USDA, 2009), of the total utilized production of 204 million tons in 2009, 101 million tons were for fresh use, while 103 million tons were processed, including blueberry wine production.

Since blueberries are on the top of most everyday fruits grown or marketed in North America in terms of antioxidant capacities (USDA, 2010), blueberry wines also contain significant amounts of phenols and has significantly higher antioxidant activity compared to many other wine products (Saucier *et al*., 1999). Antioxidants are critical to health protection by their ability to combat the free radicals that can cause damages to cellular structures or DNA. Literature shows a multitude of health benefits of blueberries and blueberry wine.

Due to the presence of anthocyanin, blueberries can considerably improve cardiovascular health. The anthocyanin and resveratrol contents in blueberry, which have natural cardiovascular protective qualities, are comparable or higher than in red wine (Sanchez-morendo *et al*., 2003). Also, blueberry wine has marginally higher antioxidant ability than red wine and much higher antioxidant capacity than white wine (Sanchez-morendo *et al*., 2003), so blueberry wine may be more potent than red wine in preventing heart diseases.

Literature shows that blueberries have improved the learning capacity and motor skills in aging animals, thus reducing the chances of dementia or Alzheimer's (Robert *et al*., 1977; Joseph *et al*., 1999; Shukitt-Hale *et al*., 1999; Greenwell, 2000). Blueberries have also been found to offer protection from urinary tract infections caused by bacteria adhering to the mucosal lining of the bladder or urinary tract (Ofek *et al*., 1991; Jepson & Craig, 2007). Highly beneficial to the digestive and excretory system, antioxidants in blueberries help combat free radicals that can cause inflammation on the digestive pathways, and thus prevents occurrence of peptic ulcers **(**Watson, 2001**)**. Eating blueberries, drinking blueberry juice, or taking blueberry wine in an appropriate quantity may help heal the existing ulcer or hemorrhoid condition (Seeram *et al*., 2008).

In addition, blueberries can improve day or nighttime vision, reduce the restoration time after exposure to glare, and prevent weakness of eyes (macular degeneration) arising from aging. The various phytonutrients present in blueberries, such as anthocyanin, flavonoids and phenolics, part of which are carried forward to wine during fermentation, are known for their benefits to the eyes and canhelp protect against occurrences of "Cataracts" (Robert *et al*., 1977; Greenwell, 2000). Studies also show that some compounds, such as polyphenols (flavonoids, proanthocyanidins, ellagitannins, etc.), stilbenoids,lignans and triterpenoids, present in blueberries are capable of inhibiting cell proliferation in the human breast, colon and ovarian cancers (Damianaki *et al*., 2000; Seeram *et al*., 2008).

Blueberry wine is usually produced by fermentation through nontraditional methods. During blueberry wine processing, an initial press of the berries provides the juice used for fermentation along with its skin and seeds. Sulfur dioxide and pectin enzymes are usually added. After the primary fermentation, usually 2-3 weeks, wine is separated from the dregs on a free run basis and the residuals are lightly pressed to extract the remaining wine.

During fermentation, phenolic compounds including catechins and other components, flavonoids and anthocyanins are transferred from the juice, skins or seeds into the blueberry wine. Su and Chien (2007) reported that the blueberry wine making process did not really lower the anthocyanin content. There are only a few studies that have quantified the antioxidant capacity, anthocyanins and total phenols in blueberry wines, e.g., Sanchez-Moreno *et al*. (2003), Su and Chien (2007) and Johnson *et al*. (2011). However, no analytical quantification of the foregoing antioxidant activity and phytonutrients was found in literature for the Southern highbush blueberry wine. Therefore, the objective of this study was to prospect the antioxidant capacity and key phytonutrients of Southern highbush blueberry wine and systematically compare with grape wines and fruit liquors.

2. Materials and Methods

2.1 Southern Highbush Blueberry Wine Samples

Southern highbush blueberry wine was obtained from a local blueberry winery for two batches of experiments conducted at the University of Florida. The blueberries used to produce the wine were a mixture of several cultivars including Star, Windsor, Emerald, Primadonna and Jewel. In the first batch, three 750 mL bottles were obtained for each of the different processing conditions: low sulfite, unfiltered; sulfite, unfiltered; and sulfite, filtered. Low sulfite consisted of 30 ppm total sulfites, while normal levels of sulfite were 150 ppm total sulfites. Filtering was performed first with a crude filter (>1 μm) with subsequent filtration by a fine filter (>0.45 μm). Two 10 mL portions of wine from each bottle were sampled for analysis, making 6 total observations for each wine. In a second study, 12 liters of non-sulfite, filtered wine, which was eligible for labeling as "organic," were obtained from the same local winery.

2.2 Determination of Antioxidant Capacity

Antioxidant capacity of the Southern highbush blueberry wine was measured by the Oxygen Radical Absorbance Capacity (ORAC) method. The ORAC values were expressed as mmol Trolox equivalent (TE) per liter.

For the filtered blueberry wine with no sulfite added, the ORAC values were determined using a modified method per Huang *et al*. (2002). Briefly, 50μL ORAC Phosphate Buffer (75mM, ORAC-PB) and appropriately diluted samples were added to a 96-well black plate (Fisher Scientific, Pittsburg, PA). This was followed by addition of 100μL, 20nM fluorescein working solution to all filled wells. The mixture was incubated at 37^{o}C for

10 min before the addition of peroxyl radical generator 2,2'azobis (2-amidinopropane) dihydrochloride (140mM, AAPH). The rate of fluorescence decay was monitored over time by calculating the area under the fluorescent decay curve and quantified using a standard curve of TROLOX, using a Spectra Max Gemini XPS microplate reader (Molecular Devices, Sunnyvale, CA). The fluorescence was monitored at 485 nm excitation and 530 nm emissions for 40 min at 1 min intervals. The antioxidant capacities of the extracts were expressed as mmol TE/L of blueberry wine.

For the other wines, the ORAC procedure was basically the same as above, except for different dilutions as: 1:1000, 1:1500, 1:2000, and 1:3000.

2.3 Determination of Total Phenols

Total phenols were determined using a modification of Folin-Ciocalteu's method. To a 96 well clear plate (Fisher Scientific, Pittsburg, PA), 12.5µl of 2N Folin-Ciocalteu's phenol reagent was added to 50 µl of deionized distilled water (ddH_2O) and 12.5µl of wine sample. After 5 min, 7% sodium carbonate (Na_2CO_3) solution (125µl) was added to the mixture and incubated (90 min, 25°C). The absorbance of the sample was measured at 750 nm versus a reagent blank using a microplate reader. A standard curve for total phenolics was developed using gallic acid. The concentration was expressed as mg of gallic acid equivalents (GAE)/L of wine.

2.4 Determination of Total Flavonoids

A standard colorimetric assay (Kim *et al*., 2003) with slight modifications was used to quantify total flavonoid content. To a 96 well clear plate, 25µl of the wine sample was added to 125 µl of ddH_2O. Subsequently, 7.5µl of 5% sodium nitrate ($NaNO_2$) was added to the mixture and allowed to stand for 5 min. Fifteen microliters of 10% aluminum chloride ($AlCl_3$) was added to the mixture and incubated at ambient temperature for an additional 5 min. Following that, 50 µl of sodium hydroxide (1M, NaOH) were added to the mixture and immediately diluted by the addition of 27.5µl of ddH_2O. The absorbance of the mixture was measured at 510nm against a reagent blank and compared to a catechin standard using a microplate reader. The total flavonoids was expressed as mg of catechin equivalents (CE)/L of wine.

2.5 Determination of Total Anthocyanins

Total anthocyanins were determined by the pH differential method (Benvenuti *et al*., 2004). Two buffer systems, potassium chloride (KCl) (pH 1.0, 0.025 M) and sodium acetate ($NaC_2H_3O_2$) (pH 4.5, 0.4 M) were utilized. An aliquot of the blueberry extracts were diluted (1:10) and adjusted to pH 1.0 and pH 4.5 using the prepared buffers. Subsequently, the solutions were incubated at ambient temperature for 20 min. Absorbance was measured using a UV/VIS spectrophotometer (Beckman Coulter, Du 730, Life Sciences UV/VIS, Lawrence, KS) at 510nm and 700 nm at each pH, respectively. Results were calculated using equations 1 and 2 below and expressed as mg of cyanidin-3-glucoside/L of wine.

$$A = (A_{510nm} - A_{700nm})_{pH1.0} - (A_{510nm} - A_{700nm})_{pH4.5} \quad (1)$$

$$\text{Anthocyanins} = A \times MW \times DF \times 1000/(\varepsilon \times 1) \quad (2)$$

where A is absorbance, MW molecular weight [449.2]), DF dilution factor, ε molar absorptivity [26, 900] (Sellappan *et al*., 2002).

2.6 Statistical Analysis and Comparison

For the blueberry wine data obtained in this study, significant differences were analyzed using 1-way ANOVA, with means separated by the Tukey's Studentized Range test, using SAS version 9.0 at a 0.05 significance level. For the comparison among blueberry wines, grape wines and fruit liquors, a literature search was conducted to gather the reported data on ORAC, total phenols and anthocyanins and tabulate them together with the measured values from this study that were referenced as a benchmark value. A percentage was calculated for the wines or fruit liquors that were above or below the benchmark values of the blueberry wine.

3. Results and Discussion

3.1 Antioxidant Capacities, Total Phenols, Anthocyanins and Flavonoids of Southern Highbush Blueberry Wine

Similar to the USDA (2010) database for the ORAC values of selected foods, antioxidant capacity of the Southern highbush blueberry wine, with or without sulfite and filtration, was also determined by the ORAC method and expressed in the TROLOX equivalent (TE) values. The key phytonutrients (i.e., total phenols, total anthocyanins and total flavonoids) were measured for the filtered blueberry wine with no sulfite added to provide the benchmark information on the level of phytonutrients of the Southern highbush blueberry wine that is eligible for labeling as organic. The results are shown in Table 1.

The ORAC values of the Southern highbush blueberry wines ranged from 18.54 to 25.48 mmol TE/L. The ORAC values of low sulfite, unfiltered wine appeared to be significantly lower than those of the rest samples ($p \leq 0.05$). The average of the ORAC values shown in Table 1 was 22.57±2.92 mmol TE/L, which reflected the overall antioxidant capacity of the Southern highbush blueberry wine tested in this study. This ORAC value ranked high compared to most blueberry wines listed in Table 2.

According to the literature, addition of sulfite to non-organic wine has two major purposes: to inhibit microorganisms and to prevent non-enzymatic browning (mainly, Maillard reaction) (Fleet, 1993). Non-enzymatic browning is a problem in wines that leads to a reduction in phenols, such as catechins, which are the major polyphenolic antioxidants in wines (Saucier and Waterhouse, 1999). The rate of Maillard reaction is enhanced by increasing the amount of reducing sugars and/or increasing the temperature (Eriksson *et al*., 1981). Thus, if blueberry wine, which is rich in reducing sugars (10-12%) and in polyphenols, is exposed to an environment of raised temperature for an extended duration, the Maillard reaction is favorable. As mentioned earlier, sulfite addition can combat this reaction. However, in the event of improper amount of sulfite, or in the case of aforementioned low-sulfite/unfiltered wine, antioxidant capacity might diminish.

Although Table 1 shows the effect of higher sulfite concentration on stabilizing the antioxidant activity of the blueberry wine, sulfite cannot be added to any blueberry wine destined for "organic" labeling, for which the sulfite limit is 10 ppm to reflect the naturally occurring sulfite in wine. The non-sulfite, filtered blueberry wine tested in this study, which could be claimed as organic, had an ORAC value of 23.49 mmol TE/L.

Table 1 also shows the total phenolic, anthocyanin and flavonoid contents of the filtered, non-sulfite Southern highbush blueberry wine. Anthocyanins are the major water-soluble flavonoids in blueberries, giving the red, purple and blue color to many fruits and vegetables (Espín *et al*., 2007), and considered biologically active compounds exhibiting a wide range of health benefits, e.g., antioxidant (Cao *et al*., 1997), antifungal (Benkeblia, 2004), and anti-carcinogenic properties (Ames, 1983). Flavonoids are naturally occurring phenols that are present in many plants including blueberries. Flavonoids and phenolics in general are strong protector against heart disease and cancer (Yao *et al*., 2004). The total phenols andanthocyaninsof the Southern highbush blueberry wine tested in this study are compared with those of grape wines and fruit liquors in section 3.3.

3.2 ORAC Comparison between Blueberry Wines and Grape Wines

The data presented in Table 2 reflect the ORAC values of most blueberry and grape wines reported hitherto in the literature. A small number of wines had their antioxidant activities measured by a different method from ORAC, e.g., TRAP in Campos *et al*. (1996), which were not included in Table 2. Grape wines are divided into red, rose and white wine types. The blueberry wines listed came from highbush or Southern Highbush varieties. Besides the specific cultivar of Elliot and Weymouth, most blueberry wines were produced from mixed cultivars. For example, Johnson *et al*. (2011) used 15 cultivars including Berkley, Blue Chip and Blue Haven, while in this study, the mixed cultivars were, as mentioned earlier, Star, Windsor, Emerald, Primadonna and Jewel.

To facilitate the comparison, the average ORAC value of the Southern highbush blueberry wine tested in this study, i.e., 22.57 mmol TE/L, was chosen as a benchmark. For the 20 red wines listed in Table 2, the ORAC values ranged from 5.25 to 39.9 mmol TE/L. Four of the 20 red wines (i.e., 20%) had ORAC values higher than 22.57 mmol TE/L, while 16 of the 20 red wines (i.e., 80%) had lower ORAC values than the Southern highbush blueberry wine.

The ORAC values of the 6 Rose wines listed in Table 2 ranged from 1.52 to 11.2 mmol TE/L, which were all much lower than that the Southern highbush blueberry wine tested in this study.

For the 13 white wine types listed in Table 2, the ORAC values ranged from 0.6 to 5.35 mmol TE/L, which were far below that the Southern highbush blueberry wine. The much lower antioxidant potentials of white wines than red wines or blueberry wines were attributed to the fact that there is no skin or seed contact during the fermentation of white wine, while most antioxidants and phytonutrients are contained in the skins or seeds (Rigo *et al*., 2000; Yilmaz & Toledo, 2004).

The foregoing comparison suggests that blueberry wine could be more potent than red wine in health enhancement and disease prevention as far as the antioxidant capacity is concerned.

3.3 Comparison of Total Phenols and Anthocyanins among Blueberry Wines, Grape Wines and Fruit Liquors

Similar to the ORAC comparison, the total phenolicvalue of the Southern highbush blueberry wine tested in this study, i.e., 929 mg GAE/L, was used as a benchmark for comparison. For the 26 red wines listed in Table 3, the total phenolic values ranged from 700 to 4059 mg GAE/L. A majority of red wines (24/26) had total phenols higher than that of the Southern highbush blueberry wine, with only 2 of 26 falling below. The total phenolic

contents of the Rose and white wines were all lower than that of the Southern highbush blueberry wine. Of the 8 fruit liquors, two had a comparable total phenolic value to that the Southern highbush blueberry wine, while the other 6 all fell below.

A limited number of wine's anthocyanin data were reported in literature. Listed in Table 3 are only 10 red wine types for which the total anthocyanin contents were reported. Except for the highbush blueberry cultivar Elliot that had a much lower anthocyanin value (i.e., 14.7 mg C3GE/L), most anthocyanin contents of the blueberry wines and grape wines listed in Table 3 were comparable.

4. Conclusions

The Oxygen Radical Absorbance Capacity of the Southern highbush blueberry wine ranged from 18.54 to 25.48 mmol TE/L, averaging 22.57±2.92 mmol TE/L. About 80% of red wines and 100% of Rose and white wines reported in literature had lower ORAC values than 22.57 mmol TE/L, with only 20% of red wines above this ORAC value. From the perspective of antioxidant activities, blueberry wines could be more potent than most red wines and all Rose or white wines in health enhancement and disease prevention. For total phenolic contents, an overwhelming majority of the red wines was higher than that of the Southern highbush blueberry wine, but all the Rose and white wines were lower than it. Most fruit liquors reported in literature had lower total phenolic contents than the Southern highbush blueberry wine. The anthocyanin contents of blueberry wines were generally comparable to those of the red wines.

Acknowledgements

The authors thank Sandra Shriver, Mike Hubbard and Tim Van Burenfor their assistance in the antioxidant measurements and thank the Island Grove AG Products, Hawthorne, FL for providing blueberry wines for this study.

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Table 1. The ORAC values, total phenols (TP), anthocyanins and flavonoids of Southern highbush blueberry wine with and without sulfite addition or filtration

Southern Highbush Blueberry Wine	**ORAC** (mmol TE/L)	**TP** (mg GAE/L)	**Anthocyanins** (mg C3GE/L)	**Flavonoids** (mg CE/L)
No sulfite, filtered	$^{*}23.49\pm8.71^{a}$	929±52	60.62±3.51	1233±166
Low sulfite, unfiltered	$^{\Psi}18.54\pm3.67^{b}$			
Sulfite, unfiltered	$^{\Psi}22.77\pm0.46^{a}$	Average ORAC value = 22.57 ± 0.46 mmol TE/L		
Sulfite, filtered	$^{\Psi}25.48\pm5.35^{a}$			

* Values are mean of triplicate measurements.

$^{\Psi}$ Values are mean of six measurements.

Values with the same superscripted letters are not significantly different ($p \leq 0.05$).

Table 2. Comparison of the ORAC values among the red, Rose, white and blueberry wines

Wine	**ORAC** (mmol TE/L)	Source
Red Wine		
Graciano	39.9	Davalos et al. (2004)
Cabernet Sauvignon	34.7	Davalos et al. (2004)
Tempranillo	30.8	Davalos et al. (2004)
Aglianico	12.14	Pellegrini (2003)
Chianti	11.43	Pellegrini (2003)
Sauvignon	8.95	Pellegrini (2003)
Aglianico	10.4-12.8	Fogliano (1999)
Guardiolo	8.4	Fogliano (1999)
Solopaca	7.6	Fogliano (1999)
Gragnano	7.0	Fogliano (1999)
LacrimaChristi	6.4	Fogliano (1999)
Villard Noir	27.20	Sanchez-Moreno *et al*. (2003)
Cabernet Sauvignon	10.06-21.22	Sanchez-Moreno *et al*. (2003)
Tempranillo	18.94	Sanchez-Moreno *et al*. (2003)
MontepulcianoSangiovese	18.66	Sanchez-Moreno *et al*. (2003)
Merlot	17.08	Sanchez-Moreno *et al*. (2003)
Chambourcin	14.67-16.00	Sanchez-Moreno *et al*. (2003)
Mendocino	9.74	Sanchez-Moreno *et al*. (2003)
Pinot Noir	9.52	Sanchez-Moreno *et al*. (2003)
Red Table	5.25	Sanchez-Moreno *et al*. (2003)
Rose Wine		
Garnacha	11.2	Davalos *et al*. (2004)
Tempranillo	10.0	Davalos *et al*. (2004)
Cabernet	8.95	Davalos *et al*. (2004)
Villa Torre	2.42	Pellegrini (2003)
Tamerici	2.18	Pellegrini (2003)
Bardolino	1.52	Pellegrini (2003)
White Wine		
Albarino	4.84	Davalos *et al*. (2004)
Verdejo	3.18	Davalos *et al*. (2004)
Vernaccia	1.94	Pellegrini (2003)
Pinot	1.68	Pellegrini (2003)
Greco di Tufo	1.61	Pellegrini (2003)
Coda di volpe	0.9	Fogliano (1999)
Solpaca	0.8	Fogliano (1999)
Falanghina	0.8	Fogliano (1999)
Lacrima Christi	0.6	Fogliano (1999)
Chardonnay	3.38-5.35	Sanchez-Moreno *et al*. (2003)
Vidal Blanc	3.33	Sanchez-Moreno *et al*. (2003)
Sauvignon Blanc	2.59-2.68	Sanchez-Moreno *et al*. (2003)
Pinot Grigio	2.28	Sanchez-Moreno *et al*. (2003)
Blueberry Wine		
Southern Highbush, Mixed	22.57	This study
Highbush, Mixed	4.5-25.1	Johnson *et al*. (2011)
Highbush, Mixed	16.67-24.39	Sanchez-Moreno *et al*. (2003)
Highbush, Elliot	18.80	Sanchez-Moreno *et al*. (2003)
Highbush, Weymouth	9.18	Sanchez-Moreno *et al*. (2003)

Table 3. Total phenol and total anthocyanin comparison amongthe red, Rose, white and blueberry wines and fruit liquors

Wine or Liquor	Total Phenols (mg GAE/L)	Anthocyanins (mg C3GE/L)	Source
Red Wine			
Graciano	1468	-	Davalos *et al*. (2004)
Cabernet	1428	-	Davalos *et al*. (2004)
Tempranillo	1302	-	Davalos *et al*. (2004)
Villard Noir	1850	59.02	Sanchez-Moreno *et al*. (2003)
Cabernet Sauvignon	1593-1804	59.06-60.23	Sanchez-Moreno *et al*. (2003)
Tempranillo	1932	72.33	Sanchez-Moreno *et al*. (2003)
MontepulcianoSangiovese	1817	94.81	Sanchez-Moreno *et al*. (2003)
Merlot	1637	52.61	Sanchez-Moreno *et al*. (2003)
Chambourcin	1256-1267	111.70-170.10	Sanchez-Moreno *et al*. (2003)
Aglianico	1300-2300	-	Fogliano (1999)
Guardiolo	1400		Fogliano (1999)
Solopaca	1200	-	Fogliano (1999)
Gragnano	900	-	Fogliano (1999)
LacrimaChristi	700	-	Fogliano (1999)
Cabernet Sauvignon	2164-3340	-	Frankel *et al*. (1995)
Merlot	1800-2133	-	Frankel *et al*. (1995)
Zinfandel	2000	-	Frankel *et al*. (1995)
Petite Sirah	2020-4059	-	Frankel *et al*. (1995)
Pinot Noir	2816	-	Frankel *et al*. (1995)
Tempranillo	1455-2446	-	Sanchez-Moreno *et al*. (2000)
Garnacha	1277-1530	-	Sanchez-Moreno *et al*. (2000)
Cabernet Sauvignon	2358	-	Sanchez-Moreno *et al*. (2000)
Pinot Noir	1037-2529	57-117	Rigo *et al*. (2000)
Enanito	1963-2063	255-294	Rigo *et al*. (2000)
Teroldego	1663-2352	246-443	Rigo *et al*. (2000)
Cabernet Sauvignon	-	261	Nyman & Kumpulainen (2001)
Reference red wine	1390-1600	-	Heinonen *et al*. (1998)
Rose Wine			
Garnacha	432	-	Davalos *et al*. (2004)
Tempranillo	439	-	Davalos *et al*. (2004)
Cabernet	389	-	Davalos *et al*. (2004)
Garnacha	419-486	-	Sanchez-Moreno *et al*. (2000)
Tempranillo	330-373	-	Sanchez-Moreno *et al*. (2000)
White Wine			
Albarino	214		Davalos *et al*. (2004)
Verdejo	186		Davalos *et al*. (2004)
Chardonnay	280-306	-	Sanchez-Moreno *et al*. (2003)
Vidal Blanc	220	-	Sanchez-Moreno *et al*. (2003)
Sauvignon Blanc	191-270	-	Sanchez-Moreno *et al*. (2003)
Pinot Grigio	191	-	Sanchez-Moreno *et al*. (2003)
Coda di volpe	120	-	Fogliano (1999)
Solpaca	150	-	Fogliano (1999)
Falanghina	140	-	Fogliano (1999)
Lacrima Christi	110	-	Fogliano (1999)
Sauvignon Blanc	165-193	-	Frankel *et al*. (1995)
Chardonnay	240-259	-	Frankel *et al*. (1995)
White Zinfandel	243-331	-	Frankel *et al*. (1995)
Malvar	139-265	-	Sanchez-Moreno *et al*. (2000)
Verdejo	178	-	Sanchez-Moreno *et al*. (2000)
Albillo	293	-	Sanchez-Moreno *et al*. (2000)
Chardonnay	201	-	Sanchez-Moreno *et al*. (2000)
Reference white wine	265	-	Heinonen *et al*. (1998)
Blueberry Wine			

ISSN 1927-050X E-ISSN 1927-0518

Southern Highbush, Mixed	929	60.62	This study
Highbush, Mixed	375.4-657.1	-	Johnson *et al*. (2011)
Highbush, Mixed	1514-1860	80.56-162.20	Sanchez-Moreno *et al*. (2003)
Highbush, Elliot	1470	14.70	Sanchez-Moreno *et al*. (2003)
Highbush, Weymouth	600	74.69	Sanchez-Moreno *et al*. (2003)
Rabbiteye (V. ashei)	1150	99.6	Su and Chien (2007)
Fruit Liquor			
Cranberry	500	-	Heinonen *et al*. (1998)
Cherry	1080	-	Heinonen *et al*. (1998)
Arctic Bramble	555-610	-	Heinonen *et al*. (1998)
Strawberry	410-525	-	Heinonen *et al*. (1998)
Rowanberry	545	-	Heinonen *et al*. (1998)
Cloudberry	450-500	-	Heinonen *et al*. (1998)
Cloudberry+Red Raspberry	415	-	Heinonen *et al*. (1998)
Red Raspberry+Black Current	1050	-	Heinonen *et al*. (1998)