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EFFECT OF PHENOLIC COMPOUNDS ON ANTIOXIDANT ACTIVITY IN 8 BLUEBERRY (*VACCINUM SPP.*) JUICES

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ABSTRACT

Phenolic compounds of juices from 8 blueberry cultivars, Baldwin, Gardenblue, Anna, O'Neal, Misty, Bluecrop, Elliott and Brigitta, were evaluated. Antioxidant capacity (by DPPH, FRAP, and reducing power assays) of 8 juices were also investigated. Eight blueberry juices contained phenolics levels of 597.23–1417.45 mg gallic acid equivalents/L $_{juice}$, flavonoids levels of 102.80–546.25 mg rutin equivalents/L $_{juice}$ and anthocyanins levels of 138.60–492.62 mg cyanidin-3-glucoside equivalents/L $_{juice}$, respectively. Among these juices, the juice from 'Gardenblue' cultivar possessed the highest content of phenolics, flavonoids, and anthocyanins. Variance analysis showed significant differences ($P < 0.05$) in phenolic compounds (phenolics, flavonoids, anthocyanins) and antioxidant activities among 8 blueberry juices. Correlation analyses revealed phenolics, flavonoids, and anthocyanins were distinctly responsible for antioxidant capacity. A strong correlations was found between flavonoids and antioxidant capacity of 8 cultivars (DPPH, $r = 0.95$; FRAP, $r = 0.97$; reducing power, $r = 0.89$).

1.Introduction

Blueberry (genus Vaccinium, family Ericaceae) originates from North America and Europe (Rimando et al., 2004). Blueberries not only contain essential nutrients but also possess abundant phenolic compounds, such as anthocyanins, flavonoids and chlorogenicacids (Prior et al., 1998; Manach et al., 2005; Giovanelli et al., 2013). The phenolic compounds can protect organisms against oxidative stress induced by free radicals (Manach et al., 2005) and exhibit a wide range of biological properties, including cardioprotective, anti-inflammatory, and anticarcinogenic properties (Nohynek et al., 2006; Tsuda, 2012).

Blueberry fruits are commonly consumed in fresh or processed food, such as juice, wine, jam and so on (Anna and Grzegorz, 2015; Nindo et al., 2005). Processed blueberry juice not only increases the berries' commercial life but also allows wider consumer access to this diet-enriching food. Blueberry juice with higher amounts of phenolic compounds and stronger antioxidant capacity has increased nutritional and health benefits for the consumer (Nindo et al., 2005; Rossi et al., 2003). However, processing method and blueberry cultivars vary greatly in their phenolic compound content as well as antioxidant capacity (Prior et al., 1998; Sapers et al., 1984; Rodrigues et al., 2011;

Wang et al., 2012a; Wang et al., 2012b; Xin et al., 2015). Previous researches mainly focused on phenolic compound content and antioxidant capacity of different varieties blueberry fruits (Giovanelli and Buratti (2009); You et al., 2011; Howard et al., 2003), only a few data concern the differences of bioactive compounds from bluberry juices.

Because of blueberry's unique nutrition, blueberry species have been successfully propagated and cultivated in China since 1989. With the increase in production, growers require additional options, and processing into blueberry juice is an effective way to maximize usage and markets. The aim of this work was to investigate the bioactive compositions of juices from 8 blueberry (*Vaccinium spp.*) cultivars and further study the effect of bioactive composition on antioxidant activity

2.Materials and methods

2.1.Preparation of blueberry juices

Blueberries of uniform size and at physiological maturity were handpicked in the morning from a commercial blueberry plantation located in Hefei (31˚52'N, 117˚ 17'E) in central-eastern China. Eight cultivars, namely Baldwin, Gardenblue, Anna, O'Neal, Misty, Bluecrop, Elliott, and Brigitta, were harvested from June 11, 2014 to August 15, 2014, respectively. All fruits were collected and stored at -20 ºC until used.

Frozen blueberries were thawed and crushed into mashes, respectively. The mash was macerated with pectinase (Laffort, Sydney, Austrilia) at a concentration of 0.07 g/kg $_{fruit}$ for 2 h at room temperature, then squeezed with 200 mesh of silk cloth and centrifuged at 3100 × g for 15 min to obtain blueberry juice.

2.2.Chemicals

Folin–Ciocalteu reagent and gallic acid were obtained from Sinopharm Chemical Reagent (Shanghai, China). 2, 2-diphenyl-1-picrylhydrazyl (DPPH) and 2, 4, 6-Tris (2-pyridyl)-1, 3, 5-triazine (TPTZ) were purchased from Sigma–Aldrich (St. Louis, MO, USA). Other general chemicals with analytical grade were obtained from local suppliers.

2.3.Chemical analyses

Total soluble solids (expressed as °Brix) were measured on a digital refractometer (TD-45, TOP Instrument Co., Ltd., Zhejiang, China) at 25± 1℃ and results were expressed in °Brix. The titratable acidity and total sugars were also determined AOAC methods (1980).

2.4.Total phenolic content (TPC)

The TPC was determined according to Folin–Ciocalteu method (Sanchez-Patan et al., 2015). The absorbance of the sample was determined at 765 nm. The results were expressed as mg gallic acid equivalents (GAE) per one liter of juice (mg GAE/L $_{juice}$).

2.5.Total flavonoid content (TFC)

The TFC were measured using a colorimetric assay adapted from Mahmood et al. (2012).The absorbance was measured at 510 nm. The results were expressed as mg rutin equivalent (RE) per one liter of juice (mg RE/L $_{juice}$).

2.6.Total anthocyanin content (TAC)

The TAC was estimated using the pH differential method. Aliquots of each sample were diluted with pH 1.0 or pH 4.5 buffers to the same dilution. The absorbance was measured at 510 nm and 700 nm in both pH 1.0 and pH 4.5 buffers. The TAC was calculated by using Eq. (1).

$$TAC = \frac{(A \times MW \times DF \times V_e \times 1000)}{\varepsilon \times 1 \times M} \quad (1)$$

Where *A* is the difference in absorbance between pH 1.0 and 4.5, MW is the molecular weight of cyanidin-3-glucoside (449 g/mol); *DF* is the dilution factor; *Ve* is the extract volume, ε is the molar extinction coefficient of cyanidin-3-glucoside (29,600), and *M* is the mass of the blueberry extracted.

The results were expressed as mg cyanidin-3-glucoside (C3G) equivalents per one liter of juice (mg C3G/L $_{juice}$).

2.7.Free radical scavenging capacity (DPPH)

The DPPH free radical-scavenging capacity was estimated by adding 2.95 microliters of 0.1 mM DPPH methanolic solution to 50 μL of the sample extracts. The solution was thoroughly mixed and in dark for 30 min. The absorbance was measured at 517 nm. The results were expressed in mg VC equivalent antioxidative capacity per one liter of juice (mg VC/L $_{juice}$).

2.8. Ferric reducing antioxidant power (FRAP) assay

FRAP reagent was prepared fresh daily in acetate buffer (adjusted pH to 3.6 by acetic acid) by mixing TPTZ solution (10 mM in 40 mM HCl) and 20 mM iron chloride solution in the proportion of 10:1:1, respectively. Each sample (90 μL) was mixed with 3.0 mL of the FRAP reagent and incubated for 10 min at 37 °C. The absorbance was read at 593 nm. The results were expressed as mmol ferrous ion per one liter of juice (mmol Fe^{2+}/ L $_{juice}$).

2.9. Reducing power assay (RP)

The RP was determined by adding diluted samples (1 mL) into phosphate buffer (2.5 mL 0.2 M, pH 6.6) and potassium ferricyanide (2.5 mL, 1%). The mixture was incubated (50 °C, 20 min). Five mL of 10 % trichloroacetic acid was added to the mixture before centrifugation for 10 min at 2400 × g. A 2.5 mL aliquot of the supernatant was mixed with ultrapure water (2.5 mL) and 0.5 mL of 0.1% $FeCl_3$. The absorbance was read at 700 nm after standing for 2 min; the final result was expressed as mg VC equivalent per one liter of juice (mg VC/L $_{juice}$).

2.10.Statistical analysis

Data were expressed as the means ± the standard deviation (SD) of triplicate determinations. Mean differences were determined by one-way ANOVA followed by Duncan's range test using Prism™ v6.0 software. The differences were considered significant when $P < 0.05$ and are denoted by different letters. Linear regression plots were generated and correlations between antioxidant activities and phenolic, flavonoid and anthocyanin contents were computed as Pearson's correlation coefficient (*r*) using Prism™ v6.0 software.

3.Results and discussions

3.1.Quality attribute of blueberry juices

The quality and acceptability of juice are related to its total soluble solids (TSS) content, acidity and ratio of total soluble solids to acidity. Six quality attributes of juices from 8 common blueberry cultivars, namely pH, titratable acidity (TA), total soluble solids (TSS), total sugars (TS), and the ratio of total soluble solids / titratable acidity (TSS/TA), were measured (Table 1).

As shown in Table 1, eight blueberry juices contained TSS levels of 10.1 °Brix (Bluecrop)–14.8 °Brix (Anna), TA levels of 2.45 (Anna)–18.58 g/L $_{juice}$ (Elliott) and TSS/TA levels of 0.66 (Elliott)–6.04(Anna),

respectively (Table 1). TS varied from 86.33 (Bluecrop) to 137.66 g/ L $_{juice}$ (Anna). The pH values ranged from 2.59 (Elliott) to 3.60 (Anna).

Table 1. Titratable acidity (TA), pH, total soluble solids (TSS), total sugars (TS), and the ratio of total soluble solids / titratable acidity (TSS/TA) in the juices pressed from eight blueberry cultivars of *Vaccinium* species

Cultivars	Quality attributes				
	pH	TA (g/L $_{juice}$)	TSS (°Brix)	TS (g/L $_{juice}$)	TSS/TA
Anna	3.60±0.06^{h}	2.45±0.12^{a}	14.8±0.2^{e}	137.66±0.43^{g}	6.04
O'Neal	3.46±0.13^{gh}	3.61±0.18^{b}	10.8±0.4^{ab}	107.14±0.18^{c}	2.99
Misty	3.07±0.12^{ef}	6.72±0.31^{cd}	10.7±0.5^{ab}	102.04±0.45^{b}	1.50
Bluecrop	2.74±0.10^{abc}	12.22±0.56^{e}	10.1±0.2^{a}	86.33±0.74^{a}	0.83
Elliott	2.59±0.12^{a}	18.58±0.21^{g}	12.3±0.3^{d}	117.56±0.29^{e}	0.66
Brigitta	2.60±0.13^{ab}	14.21±0.71^{f}	11.4±0.5^{bc}	107.14±0.35^{c}	0.80
Baldwin	2.87±0.13^{cd}	7.03±0.33^{d}	12.0±0.6^{cd}	117.10±0.33^{d}	1.71
Gardenblue	2.96±0.06^{de}	6.57±0.32^{cd}	14.6±0.3^{e}	136.36±0.87^{f}	2.22

Significance testing among the different samples was performed by one-way ANOVA followed by Duncan's range test. Different superscripts between rows represent significant differences between samples ($P < 0.05$).

Table 2. The phenolic content (TPC), flavonoid content (TFC), and anthocyanin content (TAC), the antioxidant capacity (DPPH, FRAP, and RP), in the juices pressed from eight blueberry cultivars of *Vaccinium* species.

Cultivars	Phenolics				Antioxidants		
	TPC (mg/L $_{juice}$)	TFC (mg/L $_{juice}$)	TAC (mg/L $_{juice}$)		DPPH (mg/L $_{juice}$)	FRAP (mmol/L $_{juice}$)	RP (mg/L $_{juice}$)
Anna	1180.21±6.88^{f}	199.75±1.23^{f}	138.60±0.12^{a}		49.72±0.31^{e}	20.41±0.70^{c}	6.37±0.08^{f}
O'Neal	647.87±4.12^{b}	131.72±0.27^{d}	269.27±2.08^{f}		34.74±1.62^{c}	12.13±0.16^{a}	3.74±0.05^{d}
Misty	852.55±6.89^{d}	267.28±0.97^{g}	197.88±1.02^{e}		44.24±0.90^{d}	20.21±0.75^{c}	5.49±0.06^{e}
Bluecrop	645.11±3.43^{b}	102.80±0.72^{a}	166.15±1.16^{b}		26.68±0.57^{b}	11.61±0.48^{a}	3.19±0.01^{c}
Elliott	738.72±5.74^{c}	113.16±0.89^{b}	193.90±3.79^{d}		24.04±0.12^{a}	12.06±0.15^{a}	2.72±0.04^{a}
Brigitta	597.23±5.02^{a}	138.23±1.02^{e}	180.77±2.33^{c}		26.48±1.17^{b}	11.72±0.57^{a}	2.92±0.04^{b}
Baldwin	975.96±6.82^{e}	115.28±0.67^{c}	330.64±0.83^{g}		33.22±0.45^{c}	15.48±0.56^{b}	2.73±0.03^{a}
Gardenblue	1417.45±10.11^{g}	546.25±2.37^{h}	492.62±3.33^{i}		76.59±1.49^{f}	33.97±0.23^{d}	8.02±0.10^{g}

Significance testing among the different samples was performed by one-way ANOVA followed by Duncan's range test. Different superscripts between rows represent significant differences between samples ($P < 0.05$).

Sweet taste positively correlated with TSS and TS, sour correlated with titratable acidity (TA), and negatively correlated with pH and TSS/TA ratio (Bett-Garber et al., 2015). 'Anna' was less acidic (TA: 2.45 g/L $_{juice}$) and sweeter taste (TSS:14.8%;TS:137.66g/L$_{juice}$), consequently, 'Anna' cultivar had more advantageous TSS/TA ratio (6.04). While 'Elliott' was more acidic with a TA value of 18.58 g/L $_{juice}$ and had lower TSS/TA ratio (0.66). Sapers et al. (1984) also noted that 'Elliott' had the higher TA and lower TSS/TA of 11 highbush cultivars.

3.2.Phenolic compounds and antioxidant capacity

Phenolic compounds (phenolics, flavonoids, anthocyanins) and antioxidant capacity were shown in Table 2. Eight blueberry juices contained total phenolic content (TPC) of 597.23–1417.45 mg GAE /L $_{juice}$, total flavonoid content (TFC) of 102.80–546.25 mg RE/L $_{juice}$ and total anthocyanin content (TAC) of 138.60–492.62 mg C3G/L $_{juice}$, respectively (Table 2). TPC in 8 blueberry juices varies widely. TFC and TAC had significant differences ($P < 0.05$) among 8 cultivars. 'Gardenblue' possessed all the highest content of TPC, TFC and TAC in these cultivars.The free radical scavenging capacity (DPPH), ferric reducing antioxidant power (FRAP) and reducing power (RP) were also investigated. DPPH, FRAP and RP were 24.04–76.59 mg VC/L $_{juice}$, 11.61–33.97 mmol Fe^{2+}/L $_{juice}$ and 2.72–8.02 mg VC/L $_{juice}$, respectively (Table 2). There were obvious differences in DPPH among 8 cultivars (P <0.05). 'Gardenblue' displayed the highest scavenging effect (76.59 mg VC/L $_{juice}$) in these cultivars, followed by 'Anna' and 'Misty', respectively. Similar to the DPPH value, the highest FRAP (33.97 mmol Fe^{2+}/L) and the highest RP (8.02 mg/L) were found in 'Gardenblue' cultivar, followed by the 'Anna' and 'Misty' cultivars. Jessica *et al.* (2013) research showed that anthocyanin contents of blueberry fruits were primarily influenced by cultivar. Connor *et al.* (2002) and Rodrigues *et al.* (2011) reported total phenolic and anthocyanin contents presented significant differences among blueberry cultivars. Lee *et al. (*2004) and Gunduz *et al.,* (2015) stated the variability in total phenolic content, total anthocyanin content and antioxidant activity in various *Vaccinium* species. Wang *et al.* (2012b) found considerable variation was in flavonoid content and antioxidant activity among 42 blueberry (*Vaccinium spp.*) cultivars. Cultivars play a more important role in influencing total phenolics, total anthocyanins, total flavonols and oxygen radical-absorbing capacity in blueberries (Howard *et al.,* 2003). Koca and Karadeniz (2009) also reported that FRAP values varied from 7.41 to 57.92 μmol/g for six lowbush and four highbush blueberry fruits. It has been argued that the antioxidant activity of a product cannot be reasonably validated by a single method due to the complex nature of phytochemicals and their interactions, so it was important to use multiple assay systems measuring different indices (Pérez-Jiménez *et al.,* 2008).

3.3.Correlations between phenolic compounds and antioxidant activity in blueberries

Blueberry phenolics were reported as constituents, which are responsible for their high radical scavenging capacity (Giovanelli *et al.,* 2009; Wang *et al.,* 2008). In order to evaulate the antioxidant potential of 8 blueberry juices in terms of their polyphenol contents, linear regression plots were generated and the Pearson correlation coefficients were calculated (Figure 1).A very good correlation was noted between the RP values and the TPC (r = 0.84). Nevertheless, DPPH assay and FRAP assay showed striking correlations with TPC (DPPH, r = 0.90; FRAP, r = 0.92). Ramful *et al.* (2011) reported that TPC of the pulp extracts also correlated strongly with the antioxidant activities using the FRAP assays. TFC showed strong correlations with DPPH values (r = 0.95), with FRAP values (r = 0.97) and with RP values (r = 0.89). Considerable variation was found in flavonoid content, antioxidant activity, and their contribution to total antioxidant activity among 42 blueberry cultivars reported by Wang *et al.* (2012b).

A good correlation was obtained between FRAP assay values and TAC (r = 0.71). However, a moderate correlation was noted between TAC and antioxidant capacity of the cultivars (DPPH, r = 0.69; RP, r = 0.46).

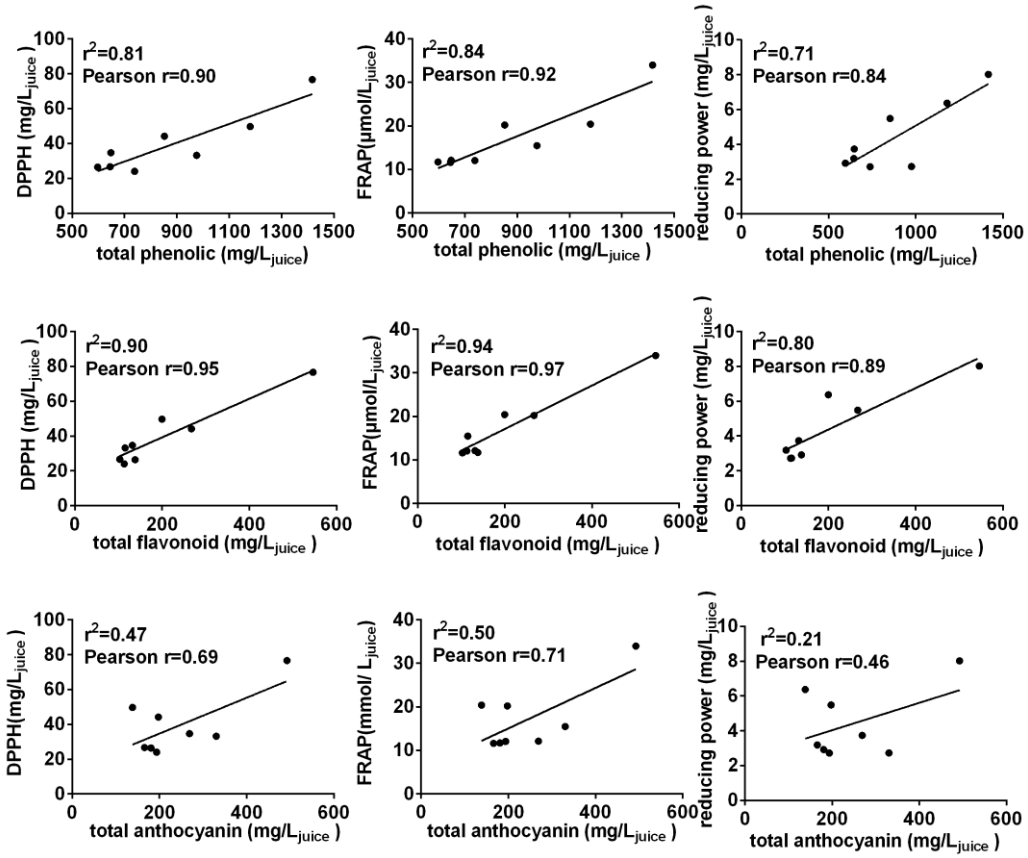

Figure 1. Linear regression plots and Pearson 's correlation coefficients of DPPH, FRAP, and reducing power values with respect to phenolics, flavonoids, and anthocyanins, of the juices pressed from eight blueberry cultivars of *Vaccinium* species

In our work, total phenolic and flavonoid had higher antioxidant potential than total anthocyanin (Figure 1). Vanessa *et al.* (2014) found the total flavonoid content was highly and positively correlated to the total monomeric anthocyanin content in berry fruits. Castrejon *et al.* (2008) reported anthocyanins in mature blueberries have lower antioxidant potential than other phenolic compounds. Giovanelli and Buratti (2009) pointed out the antioxidant activity was more related to the total phenolic rather than to the anthocyanin. The same type of linear correlation between antioxidant activities and phenolic contents had been found in fruit juices (Gardner *et al.*, 2000).

4.Conclusions

The present study demonstrated that the juices from 8 blueberry cultivars possessed significantly different phenolic contents and antioxidant activities. Correlation analyses revealed that the phenolics and flavonoids were distinctly responsible for the antioxidant capacity, and total flavonoids showed strong correlations with DPPH, FRAP and reducing power assays (DPPH, r = 0.95; FRAP, r = 0.97; reducing power r = 0.89). Among 8

blueberry juices, the cultivar 'Gardenblue' possessed the highest content of phenolic compounds (phenolics, flavonoids, and anthocyanins), corresponding to the highest value of antioxidant activity (DPPH, FRAP and Reducing power).

5.References

Anna, M., and Grzegorz, L. (2015). Bioactive Compounds of Blueberries: Post-Harvest Factors Influencing the Nutritional Value of Products. *International journal of molecular sciences*, 16 (8), 18642-18663.

Association of Official Analytical Chemists (1980). Official methods of analysis of the Association of Official Analytical Chemists (13th ed.) Washington, DC.

Bett-Garber, K.L., Lea, J.M., Watson, M.A., Grimm, C.C., Lloyd, S.W., Beaulieu, J.C., Stein-Chisholm, R.E., Andrzejewski, B.P., and Marshall, D.A. (2015). Flavor of Fresh Blueberry Juice and the Comparison to Amount of Sugars, Acids, Anthocyanidins, and Physicochemical Measurements. *Journal of Food Science,* 80 (4), S818-S827.

Castrejon, A.D.R., Elchholz, I., Rohn, S., Kroh, L.W., and Huyskens-Keil, S. (2008) .Phenolic profile and antioxidant activity of highbush blueberry (*Vaccinium corymbosum L.*) during fruit maturation and ripening. *Food Chemistry.*, 109 (3), 564-572.

Connor, A.M., Luby, J.J., Tong, C.B.S., Finn, C.E., and Hancock, J.F. (2002). Genotypic and environmental variation in antioxidant activity, total phenolic content, and anthocyanin content among blueberry cultivars. *Journal of the American Society for Horticultural Science*, 127 (1), 89–97.

Gardner, P.T., White, T.A.C., McPhail, D.B., and Duthie,G.G. (2000). The relative contributions of vitamin C, carotenoids and phenolics to the antioxidant potential of fruit juices. *Food Chemistry,* 68 (4), 471-474.

Giovanelli, G., and Buratti, S. (2009). Comparison of polyphenolic composition and antioxidant activity of wild Italian blueberries and some cultivated varieties. *Food Chemistry,* 112 (4), 903-908.

Giovanelli, G., Brambilla, A., and Sinelli, N. (2013). Effects of osmo-air dehydration treatments on chemical, antioxidant and morphological characteristics of blueberries. *LWT – Food Science and Technology,* 54 (2), 577-584.

Gunduz, K., Serce, S., and Hancock, J.F. (2015). Variation among highbush and rabbiteye cultivars of blueberry for fruit quality and phytochemical characteristics. *Journal of Food Composition and Analysis*, 38, 69-79.

Howard, L.R., Clark, J.R., and Brownmiller, C. (2003). Antioxidant capacity and phenolic content in blueberries as affected by genotype and growing season. *Journal of the Science of Food and Agriculture*, 83 (12), 1238–1247.

Jessica, S., David, S., and Duncan, H. (2013). Blueberry estimated harvest from seven new cultivars: Fruit and anthocyanins. *Food Chemistry,* 139 (1-4), 44–50.

Koca, I., and Karadeniz, B. (2009). Antioxidant properties of blackberry and blueberry fruits grown in the Black Sea Region of Turkey. *Scientia Horticulturae*, 121 (4), 447-450.

Lee, J., Finn, C.E., and Wrolstad, R.E. (2004b). Comparison of anthocyanin pigment and other phenolic compounds of Vaccinium membranaceum and Vaccinium ovatum native to the Pacific Northwest of North America. *Journal of Agricultural and Food Chemistry,* 52, 7039–7044.

Mahmood, T., Anwar, F., Abbas, M., and Saari, N. (2012). Effect of Maturity on Phenolics (Phenolic Acids and Flavonoids) Profile of Strawberry Cultivars and Mulberry Species from Pakistan. *International Journal of Molecular Sciences*, 13 (4), 4591-4607.

Manach, C., Williamson, G., Morand, C., Scalbert, A., and Remesy, C. (2005). Bioavailability and bioefficacy of polyphenols in humans. I. Review of 97 bioavailability studies. *The American Journal of Clinical Nutrition*, 81(1), 230S-242S.

Nindo, C. I., Tang, J., Powers, J. R., and Singh, P. (2005). Viscosity of blueberry and raspberry juices for processing applications. *Journal of Food Engineering*, 69 (3), 343–350.

Nohynek, L. J., Alakomi, H. L., Kahkonen, M. P., Heinonen, M., Helander, K.M., Oksman-Caldentey, K.M., and Puupponen-Pimia, R.H. (2006). Berry phenolics: Antimicrobial properties and mechanisms of action against severe human pathogens. *Nutrition and Cancer*, 54 (1), 18-32.

Pérez-Jiménez, J., Arranz, S., Tabernero, M., Díaz- Rubio, M., Serrano, J., Goñi, I., and Saura-Calixto, F. (2008). Updated methodology to determine antioxidant capacity in plant foods, oils and beverages: Extraction, measurement and expression of results. *Food research international*, 41 (3), 274-285.

Prior, R.L., Cao, G.H., Martin, A., Sofic, E., McEwen, J., O'Brien, C., Lischner, N., Ehlenfeldt, M., Kalt, W., and Krewer, G. (1998). Antioxidant Capacity As Influenced by Total Phenolic and Anthocyanin Content, Maturity, and Variety of *Vaccinium* Species. *Journalof Agriculturaland Food Chemistry*, 46 (7), 2686-2693.

Ramful, D., Tarnus, E., Aruoma, O.I., Bourdon, E., and Bahorun, T. (2011). Polyphenol composition, vitamin C content and antioxidant capacity of Mauritian citrus fruit pulps. *Food research international*, 44 (7), 2088-2099.

Rimando, A.M., Kalt, W., Magee, J.B., Dewey, J., and Balling, J.R. (2004). Resveratrol, pterostilbene, and piceatannol in vaccinium berries. *Journal of Agricultural and Food Chemistry*, 52 (15), 4713-4719.

Rodrigues, E., Poerner, N., Rockenbach, I.I., Gonzaga, L.V., Mendes, C.R., and Fett, R. (2011). Phenolic compounds and antioxidant activity of blueberry cultivars grown in Brazil. *Ciencia e Tecnologia de Alimentos*, 31 (4), 911-917.

Rossi, M., Giussani, E., Morelli, R., Lo Scalzo, R., Nani, R. C., and Torreggiani, D. (2003). Effect of fruit blanching on phenolics and radical scavenging activity of highbush blueberry juice. *Food research international*, 36 (9-10), 999–1005.

Sanchez-Patan, F., Barroso, E., van de Wiele, T., Jimenez-Giron, A., Martin-Alvarez, P.J., Moreno-Arribas, M.V., Martinez-Cuesta, M.C., Pelaez, C., Requena, T., and Bartolome, B. (2015) .Comparative in vitro fermentations of cranberry and grape seed polyphenols with colonic microbiota. *Food Chemistry*, 183, 273-282.

Sapers, G.M., Burgher, A.M., Phillips, J.G., Jones, S.B., and Stone, E.G. (1984). Color and composition of highbush blueberry cultivars. Journal of the American Society for Horticultural Science, 109 (1), 105–111.

Tsuda, T. (2012). Dietary anthocyanin-rich plants: Biochemical basis and recent progress in health benefits studies.

Molecular Nutrition and Food Research, 56 (1), 159-170.

Vanessa, R.D.S., Patrícia, A.P.P., Thais, L.T.D.S., Luiz, C.d.O.L., and Rafael, P.F.Q. (2014). Determination of the bioactive compounds, antioxidant activity and chemical composition of Brazilian blackberry, red raspberry, strawberry, blueberry and sweet cherry fruits. *Food Chemistry*, 156, 362–368.

Wang, S.Y., Chen, C.T., Sciarappa, W., Wang, C.Y., and Camp, M.J. (2008). Fruit quality, antioxidant capacity, and flavonoid content of organically and conventionally grown blueberries. *Journal of Agricultural and Food Chemistry*, 56 (14), 5788–5794.

Wang, S.Y., Chen, H.J., Camp, M.J., and Ehlenfeldt, M.K. (2012a). Genotype and growing season influence blueberry antioxidant capacity and other quality attributes. *International Journal of Food Science and Technology*, 47 (7), 1540-1549.

Wang, S.Y., Chen, H.J., Camp, M.J., and Ehlenfeldt, M.K. (2012b). Flavonoid constituents and their contribution to antioxidant activity in cultivars and hybrids of rabbiteye blueberry (*Vaccinium ashei Reade*). *Food Chemistry*, 132 (2), 855-864.

Xin, Y., Zhang, M., Xu, B.G., Adhikari, B., and Sun, J.C. (2015). Research trends in selected blanching pretreatments and quick freezing technologies as applied in fruits and vegetables: A review. *International Journal of Refrigeration*, 57, 11-25.

You, Q., Wang, B., Chen, F., Huang, Z., Wang, X., and Luo, P. G. (2011). Comparison of anthocyanins and phenolics in organically and conventionally grown blueberries in selected cultivars. *Food Chemistry*, 125 (1), 201–208.

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