NOVA SCOTIA
Department of Economic and Rural Development and Tourism

Haskap: A New Berry Crop With High Antioxidant Capacity

Final Report

Submitted by:

H.P. Vasantha Rupasinghe, Ph.D

Associate Professor and Canada Research Chair in Fruit Bioactives & BioProducts
Department of Environmental Sciences,
Nova Scotia Agricultural College, Truro, Nova Scotia
(Contacts: vrupasinghe@nsac.ca; (902) 893 6623)

February 27, 2012

Summary

This study evaluated the antioxidant capacity and total phenolic content as well as total flavonoid content of three haskap cultivars, ‘Borealis’, ‘Indigo Gem 915’ and ‘Tundra’ grown in Saskatchewan with comparison to six other commercial fruits using ferric reducing antioxidant power (FRAP) assay, oxygen radical absorbance capacity (ORAC) assay, the 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging assay, the aluminum chloride colorimetric method and the Folin-Ciocalteu (FC) method, respectively. The results indicated that haskap berries, especially cv. ‘Borealis’ possessed the highest antioxidant capacities and total phenolic contents, specifically total flavonoid among the tested fruits and could be used as a promising fruit source of natural dietary antioxidants. The nutritional values of the fruits were also assessed using proximate analysis. Strawberry possessed the highest amount of most minerals and nutrients whereas the nutritional values for the three haskap cultivars were among the average. Further investigations can be recommended for understanding the specific heath promoting properties of haskap grown in Canada and potential for developing unique functional foods, value-added food ingredients and natural health products.

BACKGROUND

Haskap (*Lonicera caerulea)*, also called ‘blue honeysuckle’, ‘honeyberry’ and ‘sweet berry honeysuckles’, is a relatively new berry crop to Canada and possess potential to promote as a fruit with unique flavor, aroma and nutritional characteristics (Skupien et al., 2009; Lewis 2011). The edible berries of Genera *Lonicera* have been used widely in folk medicine in northern Russia, China and Japan since ancient times (Jurikova et al., 2012). In recent years, phenolic compounds present in fruit crops specially berries gained much attention due to the accumulating scientific evidence for their potential health benefits. Physiologically active phytochemicals in berries such as flavonoids and phenolic acids have been shown to contribute to the prevention of various chronic diseases such as cancer, cardiovascular and neurodegenerative diseases (Rupasinghe, 2008). The major classes of phenolics present in haskap are flavonols (quercetin glycosides), flavn-3-ols (catechin and proanthocyanindins), anthocyanins (cyanidin glucoside) and phenolic acids (salycil acid, coumaric acid, gentistic acid) (Skupien et al., 2009; Jurikova et al., 2012). Most of the chronic diseases are considered to be initiated by oxidative stress and antioxidant and other physiological properties of dietary phenolic compounds have been demonstarted to play a vital role in reducing the risk of chronic diseases (Karacabey and Mazza, 2010).

In Canada, there are three major haskap varieties selected based on growing performance include ‘Borealis’, ‘Indigo Gem 915’ and ‘Tundra’. However, to our knowledge, it has not been reported the total antioxidant capacities of haskap grown in Canada with comparison to other major berry crops. Therefore, the objective of this study was to compare the antioxidant capacity, total phenolic content, total flavonoid content and general basic value of haskap berries with selected six other berry crops.

RESULTS AND DISCUSSION

Antioxidant capacity

It has been suggested that at least two different in vitro assays be employed when assessing the effectiveness of antioxidants (Schlesier et al. 2002). Therefore, The FRAP, ORAC and DPPH assays, the three most commonly used in vitro assays for analysing the total antioxidant capacity of phenolics-rich fruit extracts, were used in this study.

The FRAP values were vary from 7.57 to 46.9 µmol TE/g fresh weight (FW) with the mean value of 21.54 µmol TE/g (FW) for the nine fruits (Table 1). It is interesting to observe that among the nine fruits compared, only the three Haskap cultivars, 'Borealis', 'Indigo Gem 915' and 'Tundra', had FRAP values above the average, with Haskap 'Borealis' and 'Indigo Gem 915' being equally the highest. More specifically, the FRAP value of these two fruits were about six times greater than red table grape, raspberry and strawberry, three times greater than partridgeberry, blueberry and blackberry.

The ORAC values for the nine fruits were ranged from 61.7 to 262.4 µmol TE/g FW with the mean value of 151.9 µmol TE/g FW (Table 1). It is also interesting to see that the three Haskap cultivars, 'Borealis', 'Indigo Gem 915' and 'Tundra' as well as partridgeberry, had ORAC values above the average, with Haskap 'Tuntra' being the highest. More specifically, the ORAC value of Haskap 'Tuntra' was about two times greater than partridgeberry, blueberry, blackberry and red table grape, and four times greater than strawberry and raspberry.

The IC_{50} values from $DPPH^{\bullet}$ assay for the nine fruits were varied from 3.23 to 37.7 mg FW /mL with the mean value of 13.4 mg FW /mL (Table 1). The three haskap berries together with partridgeberry, blackberry and strawberry had equally lower IC_{50} values, whereas red table grape, blueberry and raspberry had equally higher IC_{50} values. Lower IC_{50} value means higher antioxidant capacity. Therefore, the three haskap fruits possessed higher antioxidant capacity among others.

Total phenolic content

The total phenolic contents of nine fruits were analysed using the Folin–Ciocalteu method (Table 1). The total phenolic contents varied from 166.7 to 622.5 mg GAE/100 g

FW with the mean value of 340.3 mg GAE/100 g FW for nine fruits. It is interesting to notice that Haskap 'Borealis' had the highest total phenolic content. However, haskap 'Indigo Gem 915', haskap 'Tundra' and blackberry had equally second largest amount of total phenolic content (428.1 to 500.8 mg GAE/100 g FW, $p > 0.05$), followed by partridgeberry. The equally lowest total phenolic content belonged to blueberry, strawberry, raspberry and red table grape (166.7 to 265.2 mg GAE/100 g FW, $p > 0.05$).

The reported values of total phenolic compound for Haskap fruits (blue honeysuckles) were from 575 to 903 mg GAE/100 g FW (Rop et al. 2011), which were quite similar to our results (428.1 to 622.5 mg GAE/100g FW). For strawberry and blackberry, the reported values of total phenolic compound were 238 mg GAE/100g FW (Vasco et al. 2008) and 355.3 mg GAE/100g FW (Marinova et al. 2005), which were also similar to present data. However, for blueberry, the reported value (670.9 mg GAE/100g FW) was four times of our value (Marinova et al. 2005),

Total flavonoid content

The total flavonoid contents of nine fruits were analysed using the aluminum chloride colorimetric method (Table 1). The total flavonoid contents varied from 54.7 to 699.3 mg QE/100 g FW with the mean value of 359.6 mg QE/100 g FW for nine fruits. Similar as with the total phenolic content measured by the Folin–Ciocalteu method, Haskap 'Borealis' had the highest total flavonoid content. Haskap 'Indigo Gem 915' and haskap 'Tundra' had equally second largest amount of total flavonoid content (594.4 to 638.6 mg QE/100 g FW, $p > 0.05$), followed by Partridgeberry and blueberry (476.6 and 343.0 mg QE/100 g FW). And the equally lowest total flavonoid content belonged to strawberry and raspberry (54.7 and 63.5 mg QE/100 g FW, $p > 0.05$).

The reported values of total flavonoid for haskap fruit were from 301 to 401 mg QE/100 g FW (Rop et al. 2011), which were half the values of our results (594.4 to 699.3 mg QE/100 g FW). For strawberry, the reported value was 69.7 mg QE/100g FW (Marinova et al. 2005), which was similar to our data. However, for blueberry and blackberry, the reported values were 190.3 mg and 55.5 QE/100 g FW (Marinova et al. 2005), which were half or one third of our results (343.0 and 171.3 QE/100 g FW).

Correlation between antioxidant capacities, total flavonoid and total phenolic content

A highly positive correlation between the FRAP value and total phenolic content indicated that phenolic compounds could be one of the main components responsible for reducing ability of these fruits (Table 3). And a highly positive correlation between the total phenolic content and total flavonoid content indicated that total flavonoid could be the major polyphenols responsible for antioxidant ability of these fruits. Similarly, a highly positive correlation between the ORAC value, total phenolic content and total flavonoid suggested that phenolic compounds, specifically total flavonoid, could also be main components responsible for reducing peroxyl radical-induced oxidation of these fruits. A significant correlation between FRAP and ORAC assays is observed (Table 3). However, the correlation between FRAP and DPPH assays or ORAC and DPPH assays is very weak.

Three haskap cultivars, namely Haskap 'Borealis', 'Indigo Gem 915', 'Tundra' had the strongest antioxidant capacities among nine tested fruits based on a combinative consideration of the results obtained by FRAP and ORAC assays as well as the aluminum chloride colorimetric method and the Folin–Ciocalteu method. Especially, haskap 'Borealis' consistently gave the strongest antioxidant capacities, the highest total phenolic content and the highest total flavonoid content. It could therefore be expected that the new Haskap 'Borealis' could be considered as a cultivar for developing value-added food products and natural health products for preventing the chronic diseases caused by oxidative stress (Li et al. 2012).

Nutritional values

The nutritional values of the nine fruits including dry matter, crude protein, crude fat, total carbohydrate, ash and minerals including calcium, phosphorus, sodium, potassium, magnesium, manganese, copper and zinc contents are presented (Table 2). Interestingly, strawberry possessed the highest amount of most minerals and nutrients including ash, magnesium, potassium, sodium, phosphorous, copper, crude fat and crude protein among other fruits. However, red table grape showed the highest in carbohydrate and dry matter, followed by Haskap 'Borealis' and 'Indigo Gem 915'. Haskap 'Tundra', strawberry,

raspberry and blackberry had equally the highest crude protein value, followed by Haskap 'Borealis' and 'Indigo Gem 915'. Haskap 'Tundra' and strawberry possessed equally amount of ash, followed by Haskap 'Borealis', 'Indigo Gem 915' and raspberry. Haskap 'Tundra' showed the highest level of calcium. Strawberry and raspberry had equally the highest value of magnesium. Partridgeberry and blueberry gave the maximum value of manganese. There were no significant difference in the values of zinc and sodium among nine fruits ($p < 0.05$).

In conclusion, the haskap cultivars 'Borealis' possessed the highest antioxidant capacities and total phenolic content, specifically total flavonoid among the nine tested fruits. However, the nutritional values such as mineral contents of the three haskap fruits were among the average of the nine fruits. The results of this study suggest that this recently introduced berry crop in Canada could be considered as one of the fruits with highest antioxidant capacity in vitro. However, further investigations are warranted for understanding the heath promoting properties of haskap grown in Canada and potential for developing unique functional foods and natural health products.

EXPERIMENTAL PROCEDURES

Plant Materials and Chemicals

Fruits of three haskap cultivars 'Borealis', 'Indigo Gem 915' and 'Tundra' were obtained from the University of Saskatchewan, SK, Canada. A sample of partridgeberry was obtained from the Southern Labrador, Canada. Blueberry was purchased from Oxford Frozen Foods Ltd., Oxford, NS, Canada. Red table grape, strawberry, raspberry and blackberry were purchased from Sobeys Inc., Truro, NS, Canada.

Gallic acid, 2,4,6-tris (2-pyridyl)-S-triazine (TPTZ), Trolox, fluorescin, Folin-Ciocalteu reagent, quercetin, 1,1-diphenyl-2-picrylhydrazyl (DPPH), ferric chloride and phosphate buffer were obtained from Sigma-Aldrich (St. Louis, MO, USA). 2,2'-Azobis (2-amidinopropane) dihydrocholride (AAPH) was purchased from Walco Chemical Products Co Inc., (Buffalo, NY, USA). Hydrochloric acid, and 96-well microplates were purchased from Fisher Scientific (Ottawa, ON, Canada).

Sample Preparation

For antioxidant analyses, the fresh fruit samples were initially frozen at -20°C for 24 h. The frozen samples (50 g) were then ground and extracted with Methanol (250 mL) using a laboratory blender (Model HBB909, Hamilton Beach Brands, Inc. Glen Allen, VA, USA). The extract was filtered through six layers of cheese cloth and centrifuged at 6000 rpm for 10 min before further analysis.

Determination of Total Phenol Content by Folin-Ciocalteu Assay

The Folin-Ciocalteu assay was performed to estimate the total phenols present in fruit samples. The assay was modified for use with a 96-well, 200 mL high throughput microplate reader, the FLUOstar OPTIMA plate reader (Model FLUOstar OPTIMA, BMG Labtech, Durham, NC, USA) as described by Singleton and Rossi (1965) and modified by Rupasinghe et al. (2010). Briefly, 20 mL of the fruit extract was mixed with 100 mL of 0.2 N Folin-Ciocalteu reagent in the microplate wells of the clear 96-well microplates (COSTAR 9017, Fisher Scientific, Ottawa, ON, Canada) and left to stand. After 5 min, 80 mL of a 7.5% sodium carbonate solution was added and the microplate was covered for 2 h at ambient temperature before reading at 760 nm. The total phenol measure was calculated using gallic acid standards at the concentrations of 118.1, 235.2, 587.8 and 881.7 µM. The solutions were made fresh under reduced light conditions and the reaction was carried out under dark conditions.

Determination of Total Flavonoid Content by Aluminum Chloride Colorimetric Method

The aluminum chloride colorimetric method was modified from a procedure described by (Marinova et al 2005). The principle of aluminum chloride colorimetric (Total flavonoid assay) method is that aluminum chloride forms acid stable complexes with the C-4 keto group and either of the C-3 or C-5 hydroxyl group of flavones and flavonols. In addition, aluminum chloride also forms acid labile complexes with the orthodihydroxyl groups in the A- or B-ring of flavonoids. Quercetin was used to make the calibration curve. An aliquote (1 mL) of extracts or standard solution of quercetin (50, 100, 200, 300, and 500 µM) was mixed with 4 mL of distilled water and 0.3 mL of 5% $NaNO_2$. Five minutes later, 0.3 mL of 10% $AlCl_3$ was added. After another minute, 2 mL of 1 M NaOH was

added and the total volume was made up to 10 mL with distilled water. The absorbance was read at 510 nm. Total flavonoid content was expressed as both µmol quercetin equivalents (QE) per gram fresh weight and milligram quercetin equivalents (QE) per 100 gram fresh weight.

Ferric Reducing Antioxidant Power Assay

The ferric reducing antioxidant power (FRAP) assay was used to determine the electron donating potential of the fruit samples based on the assay described by Benzie and Strain (1996) and modified by Rupasinghe et al. (2010). The working reagent, consisting of 300 mM acetate buffer (pH 3.6), 1 mM 2,4,6-Tris(2-pyridyl)-s-triazine solution, and 20 mM ferric chloride, was combined in the ratio 10:1:1 directly before analysis and preheated to 37°C. Twenty microlitres of each sample or standard was placed in the wells of the 96-well clear polystyrene microplate and 180 mL of the working reagent was injected by the port of the FLUOstar OPTIMA plate reader. The absorbance was read at 593 nm after a 6 min reaction time and antioxidant capacity was calculated based on Trolox standards at the concentrations of 50, 75, 150, 300 and 500 mM.

Oxygen Radical Absorbance Capacity Assay

The hydrophilic oxygen radical absorbance capacity (ORAC) assay was performed based on Huang et al. (2002). The fluoresce in sodium salt (0.957 mM), as well as samples and standards, was diluted in 75 mM phosphate buffer (K_2HPO_4/NaH_2PO_4, pH 7). Thirty-five microlitres of the sample or Trolox standard and 130 mL of the fluorescein probe were combined in the wells of the black 96-well polystyrene microplate and the plate was warmed to 37°C for 5 min. The injection port was used to inject 35 mL of 150 mM pre-warmed (37°C) AAPH into the wells. The plate was maintained at 37°C for the duration of the analyses (approximately 45 min) with excitation and emission readings every 45 s for the first 2 min then at every 2 min for the remaining 43 min. Excitation of the reaction mixture was at 490 nm and the emission was read at 510 nm. The antioxidant capacity of the samples was calculated as Trolox equivalents using a quadratic relation developed from area under the fluorescence decay curves for standards made to 50, 75, 150, 300 µM concentrations. The dilution factors were 270 for the three haskap fruits, 260 for blackberry and 250 for rest of samples.

The Free Radical Scavenging Assay using DPPH$^{\bullet}$

The free radical scavenging activity of fruit polyphenols was measured using the method described by Brand-Williams et al. (1995) and modified by Lu and Foo (2000). A 0.2 mM solution of DPPH$^{\bullet}$ (1,1-diphenyl-2-picrylhydrazyl) in methanol was prepared and to 0.1 mL of this solution, 0.1 mL of an antioxidant solution in methanol was added at different concentrations. The decrease in absorbance at 517 nm was measured at 0, 5 and then every 15 min until the reaction reached a plateau. The percentage of DPPH$^{\bullet}$ remaining at the steady-state was calculated as a function of the molar ratio of antioxidant to DPPH$^{\bullet}$. The IC_{50} value, defined as the amount of the sample to scavenge 50% of the DPPH radicals, was calculated from the results.

Determination of Nutritional Value

Dry matter was tested by drying the samples at 65°C until constant weight was reached. Crude protein was measured using the Combustion Method (AOAC Method 990.03). Crude fat was determined by an Ankom XT10 Extraction System (AOCS Method Am 5-04). Ash was determined by dry combustion (AOAC Method 942.05, 15th edition). Total carbohydrate was calculated by subtracting the weight of crude protein, crude fat, moisture, and ash from the total weight (wet weight) of the sample. Minerals including calcium, phosphorus, sodium, potassium, magnesium, manganese, copper and zinc were determined by ICP Optical Emission Spectroscopy (AOAC Method 968.08, 15th edition).

Statistical Analysis

All measurements were conducted in triplicates and the means were reported. Statistical analysis was conducted on data using ANOVA, the general linear model, with SAS System version 9.2 for Windows. Mean separations were examined using Tukey's Student range test (t-test). Significant differences were compared using a *p*-value of 0.05. Correlation analyses were performed using MINITAB 15.1 for Windows with Pearson correlation coefficients recorded.

ACKNOWLEDGEMENTS

This research was funded by Nova Scotia Economic & Rural Development (NSERD) program. I would like to thank LaHave Forest, Inc., Nova Scotia and Dr. Bob Bors, University of Saskatchewan, for providing the haskap samples and Dr. Li Juan Yu and Khushwant Bhullar for their assistance in carry out the laboratory analysis, statistical analysis and writing this report.

REFERENCES

Benzie, I. and Strain, J. 1996. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. Anal. Biochem. **239**: 70-76.

Brand-Williams, W., Cuvelier, M. E. and Berset, C. 1995. Use of a free radical method to evaluate antioxidant activity. LWT-Food Sci Tech, **28:** 25-30.

Fu, L., Xu, B., Xu, X.., Gan, R., Zhang, Y. And Xia, E. 2011. Antioxidant capacities and total phenolic contents of 62 fruits. Food Chem. **129**: 345-350.

Huang, D., Ou, B., Hampsch-Woodil, M., Flanagan, J. and Prior, R. 2002. High-throughput assay of oxygen radical absorbance capacity (ORAC) using a multichannel liquid handling system coupled with a microplate fluorescence reader in 96-well format. J. Agric Food Chem. **50**: 4437-4444.

Jurikova, T., Rop, O., Mlcek, J., Sochor, J., Balla, S., Szekeres, L., Hegedusova, A., Hubalek, J., Adam, V., and Kizek, R. 2012. Phenolic profile of edible honeysuckle berries (Genus *Lonicera*) and their biological effects. Molecules. **17**:61-79.

Karacabey, E. and Mazza, G. 2010. Optimisation of antioxidant activity of grape cane extracts using response surface methodology. Food Chem. **119**: 343-348.

Lewis, J. 2011. Is Haskap for you? http://www.atlanticfarmfocus.ca [2012 Jan.13].

Li, H., Deng, Z., Wu, T., Liu, R., Loewen, S. and Tsao, R. 2012. Microwave-assisted extraction of phenolics with maximal antioxidant activities in tomatoes. Food Chem. **130**: 928-936.

Lu, Y. and Foo, L.Y. 2000. antioxidant and radical scavenging activities of polyphenols from apple pomace. Food Chem. **68**: 81-85.

Marinova, D., Ribarova, F. and Atanassova, M. 2005. Total phenolics and total flavonoids in Bulgarian fruits and vegetables. Journal of the University of Chemical Technology and Metallurgy, **40:** 255-260.

Rop, O., Reznicek, V., Mlcek, J., Jurikova, T., Balik, J. Sochor, J. and Kramarova, D. 2011. Antioxidant and radical oxygen species scavenging activities of 12 cultivars of blue honeysuckle fruit. Hort. Sci. **38:** 63-70.

Rupasinghe, H.P.V. 2008. The Role of Polyphenols in Quality, Postharvest Handling, and Processing of Fruits. Postharvest Biology and Technology of Fruits, Vegetables and Flowers (Ed.) Paliyath, G., Murr, D.P., Handa, A.K., and S. Lurie, S. Blackwell Publishing. pp. 260-281.

Rupasinghe, H. P. V., Huber, G. M., Embree, C. G. and Forsline, P. L. 2010. Red-fleshed apple as a source for functional beverages. Can J. Plant Sci. **90**: 95-100.

Schlesier, K., Harwat, M., Bohm, V. and Bitsch, R. 2002. Assessment of antioxidant activity by using different in vitro methods. Free Radical Res. **36**: 177-187.

Singleton, V. and Rossi, J. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am. J. Enol. Viticul. **16**: 144-158.

Skupien, K., Ochmian, I. and Grajkowski, J. 2009. Influence of ripening time on fruit chemical composition of two blue honeysuckle cultivars. J. Fruit Oranamental Plant Res. **17**: 101-111.

Vasco, C., Ruales, J. and Kamal-Eldin, A. 2008. Total phenolic compounds and antioxidant capacities of major fruits from ecuador. Food Chem. **111**: 816-823.

Wang, S. Y. and Lin, H. S. 2000. Antioxidant activity in fruits and leaves of blackberry, raspberry, and strawberry varies with cultivar and developmental stage. J. Agric Food Chem. **48**: 140-146.

Table 1. Antioxidant capacities and total phenolic contents for nine fruits

No.	Fruit name	ORAC (μmol TE/g FW)	DPPH (IC_{50}, mg FW/mL)	FRAP (μmol TE/g FW)	Folin-Ciocalteu mg GAE/100g FW)	Total Flavonoid (mg QE/100g FW)
1	Haskap 'Borealis'	237.19*b*	5.83*b*	46.38*a*	622.52*a*	699.29*a*
2	Haskap 'Indigo Gem'	237.77*b*	7.80*b*	46.90*a*	500.78*b*	638.55*b*
3	Haskap 'Tundra'	262.44*a*	6.45*b*	27.96*b*	428.14*b*	594.43*b*
4	Partridgeberry	110.89*e*	6.23*b*	17.71*bc*	278.42*c*	476.57*c*
5	Blueberry	160.66*c*	32.27*a*	16.24*bc*	166.77*c*	343.00*d*
6	Blackberry	105.97*e*	3.37*b*	15.03*bc*	429.81*b*	171.35*e*
7	Strawberry	61.73*f*	3.23*b*	8.00*c*	201.79*c*	63.46*f*
8	Raspberry	61.94*f*	18.10*ab*	7.57*c*	169.41*c*	54.70f
9	Red table grape	128.90*d*	37.67*a*	8.09*c*	265.22*c*	195.22*e*

TE, Trolox equivalents; GAE, gallic acid equivalents; QE, quercetin equivalents; FW: Fresh weight.

a-f Means followed by different letters within the same column represent significant differences ($p < 0.05$). Data are the average of triplicates.

Table 2. Nutritional Values for nine fruits

Fruit name	Dry matter (%)	Crude protein (%)	Crude Fat (%)	Carbohydrate (%)	Ash (%)	Calcium (%)	Phosphorus (%)	Sodium (%)	Potassium (%)	Magnesium (%)	Manganese (ppm)	Copper (ppm)	Zinc (ppm)
Haskap 'Borealis'	17.72*b*	5.11*b*	2.91*cd*	15.59*b*	4.00*b*	0.14*d*	0.21*c*	0.02*a*	1.47*b*	0.08*e*	10.45*f*	6.35*cd*	8.65*a*
Haskap 'Indigo Gem'	15.91*c*	4.60*bc*	2.18*de*	14.30*c*	3.27*c*	0.33*b*	0.17*d*	0.02*b*	1.13*c*	0.11*d*	10.59*f*	3.61*e*	8.33*a*
Haskap 'Tundra'	12.36*e*	8.41*a*	4.77*a*	10.19*f*	4.33*ab*	0.52*a*	0.24*b*	0.02*b*	1.39*b*	0.15*b*	12.30*f*	3.40*e*	11.89*a*
Partridgeberry	14.32*d*	3.57*cd*	3.74*bc*	13.07*de*	1.41*e*	0.08*e*	0.08*f*	0.02*a*	0.49*e*	0.04*f*	146.51*a*	4.78*de*	10.00*a*
Blueberry	14.34*d*	2.97*d*	2.27*de*	13.46*cd*	0.91*e*	0.08*e*	0.09*ef*	0.02*b*	0.39*e*	0.04*f*	114.87*b*	3.10*e*	7.50*a*
Blackberry	14.30*d*	7.67*a*	4.69*ab*	12.22*e*	2.18*d*	0.12*d*	0.16*d*	0.02*b*	0.83*d*	0.12*c*	58.05*c*	8.20*b*	13.92*a*
Strawberry	9.64*f*	8.97*a*	2.59*de*	8.06*g*	4.92*a*	0.25*c*	0.40*a*	0.02*a*	2.01*a*	0.16*a*	40.23*d*	18.19*a*	14.17*a*
Raspberry	12.79*e*	8.78*a*	4.89*a*	10.64*f*	3.15*c*	0.13*d*	0.24*b*	0.02*b*	1.27*bc*	0.16*ab*	24.89*e*	4.21*e*	18.58*a*
Red table grape	20.94*a*	2.33*d*	1.63*e*	19.65*a*	2.20*d*	0.09*e*	0.12*e*	0.02*b*	0.90*d*	0.04*f*	5.49*f*	7.90*bc*	3.75*a*

a-g Means followed by different letters within the same column represent significant differences ($p < 0.05$). Data are the average of triplicates.

Table 3. Pearson correlation coefficients to show linear relationship among the antioxidant capacity measures, Folin–Ciocalteu, FRAP, ORAC, DPPH and Total Flavonoid Content in nine fruits

No. Fruit name	Total Flavonoid mg QE/100g FW)	ORAC (µmol TE/g FW)	DPPH (mg/mL)	FRAP (µmol TE/g FW)	Folin-Ciocalteu (mg GAE/100g FW)
Total Flavonoid	1	-	-	-	-
ORAC	0.907*	1	-	-	-
DPPH	-0.284	-0.129	1	-	-
FRAP	0.904*	0.853*	-0.391	1	-
Folin-Ciocalteu	0.949*	0.789*	-0.493	0.928*	1

TE, Trolox equivalents; GAE, gallic acid equivalents; QE, quercetin equivalents; FW: Fresh weight.

*Significant correlations are shown ($p < 0.05$).

Table 3. Pearson correlation coefficients to show linear relationship among the antioxidant capacity measures, Folin–Ciocalteu, FRAP, ORAC, DPPH and Total Flavonoid Content in nine fruits

No. Fruit name	ORAC (µmol TE/g FW)	DPPH (mg/mL)	FRAP (µmol TE/g FW)	Folin-Ciocalteu (mg GAE/100g FW)	Total Flavonoid mg QE/100g FW)
ORAC	1	-	-	-	-
DPPH	-0.129	1	-	-	-
FRAP	0.853*	-0.391	1	-	-
Folin-Ciocalteu	0.789*	-0.493	0.928*	1	-
Total Flavonoid	0.907*	-0.284	0.904*	0.949*	1

TE, Trolox equivalents; GAE, gallic acid equivalents; QE, quercetin equivalents; FW: Fresh weight.

*Significant correlations are shown ($p < 0.05$).