International Journal of Horticultural Science 2008, 14 (1–2): 59–64
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Antioxidant capacity, total phenolics and mineral element contents in fruits of Hungarian sour cherry cultivars

Papp, N.[1], Szilvássy, B.[1], Szabó, Z.[2], Nyéki, J.[2], Stefanovits-Bányai, É.[1] & Hegedűs, A.[1]

[1]*Corvinus University of Budapest, Faculty of Food Science, Department of Applied Chemistry, 1118 Budapest, Villányi út 29., Hungary; E-mail: hegedus.attila@uni-corvinus.hu*
[2]*University of Debrecen, Centre of Agricultural Sciences, Institute for Extension and Development, Böszörményi út 138, Debrecen, H-4032, Hungary*

Summary: Several epidemiological studies revealed that the consumption of antioxidant compounds and the risk of atherosclerosis, increased blood pressure or cancer are inversely proportional. Fruits of sour cherry contain a wide range of antioxidant compounds including melatonin, perillyl alcohol, ellagic acid, several flavonoids, polyphenolics, and anthocyanins. This study was carried out to survey the antioxidant power and mineral element content of seven commercial sour cherry cultivars and three cultivar candidates and to assess the influence of some external conditions on fruits' functional properties. Our analysis revealed nearly 5- and 2-fold differences between the lowest and highest antioxidant capacities and total phenolics content, respectively. Some cultivars ('Kántorjánosi' and 'Újfehértói fürtös') and cultivar candidates (D, 'Petri' and 'Éva') showed outstanding antioxidant capacity and total phenolic content; in addition, mineral element content in fruits of the 'Újfehértói fürtös' cultivar was also favourable. Redox parameters of fruits were influenced by the cultivation plot or fruit positions within the canopy in about half of the cultivars tested. Genetic background of cultivars forms the decisive factor in determining fruits' antioxidant capacity, although external factors may have also sizeable modifying effects. Enhanced functional properties of the fruit may also be further increased through breeding programs since considerable variation exists within the tested germplasm.

Key words: antioxidant, mineral elements, *Prunus cerasus*, sour cherry, total phenolics

Introduction

The evaluation of the antioxidant properties of stone fruits gains more and more importance. These studies are fuelled by the realization that fruits contribute considerably to human health and prevention of several degenerative diseases. In Hungary and in other parts of the civilised world, heart and vascular diseases as well as different types of cancer are among the main causes of mortality. The role of free radicals in the aetiology and pathogenesis of such diseases is a well-understood physiological process. This knowledge has drawn attention to the applicability of food antioxidants in disease prevention. In some parts of the world, mainly in the USA, systematic and detailed analyses have been initiated to size up the therapeutic possibility supplied by plant food sources (fruits and vegetables). In this field, Hungary should spare no effort to conduct similar experiments since genetic potential and variability of Hungarian fruit cultivars may permit to find genotypes to be used as functional food (*Pedryc* et al., 2005; *Stefanovits-Bányai* et al., 2005; *Veres* et al., 2005a). Therefore, the estimation of antioxidant power of fruits must be added to the standard cultivar description protocols. Although, berry fruits are generally reputed to contain exceptional levels of antioxidants, stone fruits are less known and hence underutilized from this aspect, which offers further possibilities. Sour cherry (*Prunus cerasus* L.) is the most studied stone fruit species in terms of its antioxidant potential and health promoting effects.

Several epidemiological studies revealed that the consumption of antioxidant compounds and the risk of atherosclerosis, increased blood pressure or cancer are inversely proportional (*Halliwell*, 2000; *Southon*, 2000; *Van Duyn & Pivonka*, 2000; *He* et al., 2006). Among fruits, berry species were shown first to accumulate high amounts of polyphenolic compounds and great antioxidant power (*Moyer* et al., 2002; *Hannum*, 2004; *Connor* et al., 2005). Recently, several similar studies were also published aimed at stone fruits, involving plums (*Gil* et al., 2002; *Lombardi-Boccia* et al., 2004; *Vasantha Rupasinghe* et al., 2006), peaches and nectarines (*Tomás-Barberán* et al., 2001; *Gil* et al., 2002; *Scalzo* et al., 2005; *Dalla Valle* et al., 2007) or apricot (*Ruiz* et al., 2005; *Stefanovits-Bányai* et al., 2005; *Betul Akin* et al., 2008).

Fruits of sour cherry contain a wide range of antioxidant compounds including melatonin (*Burkhardt* et al., 2001; *Reiter & Tan*, 2002), perillyl alcohol, ellagic acid, several flavonoids and other polyphenolics (*Wang* et al., 1999), and anthocyanins (*Seeram* et al., 2001; *Kang* et al., 2002; *Chaovanalikit & Wrolstad*, 2004; *Bonerz* et al., 2006; *Jakobek* et al., 2007). Flavonoids and quinic acid derivatives were found to be the more antioxidative substances in native Italian sour cherries (*Piccolella* et al., 2008).

Total antioxidant capacity of fresh and processed sour cherry fruits was studied with several different assays (FRAP, TEAC, ORAC, TBARS etc.) (*Karakaya* et al., 2001; *Blando* et al., 2004; *García-Alonso* et al., 2004). Water- and Lipid-soluble antioxidant capacity of the Hungarian cultivars and several Bosnian types were carried out by *Veres* et al. (2005b). Among cultivars, the 'Csengődi' and 'Kántorjánosi' were characterized by outstanding antioxidant capacity. The anthocyanin content of the cultivar 'Csengődi' was also shown to be extraordinary (*Sass-Kiss* et al., 2005).

It is also a very important field of research to estimate how the way of processing effects the antioxidant capacity (*Dietrich* et al., 2003; *Kim & Padilla-Zakour*, 2004; *Bonerz* et al., 2006) and phenolics constitution of the end-products (Chaovanalikit & Wrolstad, 2004). Ferric reducing ability (FRAP) and scavenging effect against the 2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) radical (ABTS) were measured in desserts made from sour cherry (*García-Alonso* et al., 2003).

Sour cherry anthocyanin demonstrated considerable cyclooxygenase inhibitory activities (*Seeram* et al., 2001; 2003), which was later clarified to efficiently suppress inflammation-induced pain behaviour in rats (*Tall* et al., 2003). Efficacy for cherry juice in decreasing some of the symptoms of exercise-induced muscle damage was also shown in human intervention studies (*Conolly* et al., 2006). Anthocyanins from sour cherry have been shown to inhibit tumor development in Apc^{Min} mice and the growth of human colon cancer cell lines (*Kang* et al., 2002).

Dr. Amy Iezzoni of Michigan State University introduced the Hungarian cultivar 'Újfehértói fürtös' under the new name 'Balaton' in the U.S. in 1984. This cultivar turned out to be the most favourable cultivar in the U.S. in terms of its fruits' phytochemical contents. Several publications and patents have been based on this cultivar.

This study was carried out to survey the antioxidant power and mineral content of sour cherry commercial cultivars and cultivar candidates and assess the influence of some external conditions on fruits' functional properties.

Materials and methods

Cultivars tested

The analyses were carried out by using the most important Hungarian sour cherry cultivars (*Table 1*). In several cases, the same cultivar was harvested at several cultivation regions (Siófok and Újfehértó) or from different positions within the canopy (inside or outside) to test how external factors may affect the fruits' antioxidant value.

Extraction and sample preparation

For the extraction of antioxidants, a 100 g of halved and seeded fruits were homogenized and centrifuged with a Hettich Zentrifugen (Mikro 22 R; Tuttlingen, Germany) device (4 °C, 35-min, 18,750 g_n); supernatants were used for redox assays.

Antioxidant capacity

Antioxidant power was measured with the FRAP (ferric reducing ability of plasma) method (*Benzie & Strain*, 1996). The antioxidant power was calculated from a standard curve obtained by different concentrations of ascorbic acid.

Total phenolic content (TPC)

Total amount of soluble phenols were determined using Folin-Ciocalteu's reagent according to the method of *Singleton & Rossi* (1965). The content of soluble phenols was calculated from a standard curve obtained by different concentrations of gallic acid.

Table 1 Cultivars used in the analyses

Cultivars	Ripening time	Fruit colour	Average fruit weight (g)	Cultivation plot	Sampling time
D (LPP4/ID)	End of June	Dark red	5.5±0.6	Újfehértó	2007. VI. 29.
Debreceni bőt.	End of June – Beginning of July	Dark red	5.4±0.9	Siófok	2007. VI. 20.
Debreceni bőt.	End of June – Beginning of July	Dark red	5.1±0.5	Újfehértó	2007. VI. 29.
Érdi bőtermő	Middle of June	Dark carmine	6.0±0.6	Siófok	2007. VI. 14.
Érdi bőtermő	Middle of June	Dark carmine	6.6±0.5	Újfehértó	2007. VI. 18.
Kántorjánosi 3	End of June	Light claret	6.4±0.5	Siófok	2007. VI. 20.
Kántorjánosi 3	End of June	Light claret	5.8±0.8	Újfehértó	2007. VI. 29.
Korai pipacs	Middle of June	Light red	4.7±0.4	Újfehértó	2007. VI. 29.
R (Petri)	Beginning of July	Dark red	5.9±0.5	Újfehértó	2007. VII. 1.
T (Éva)	Beginning of July	Dark red	5.5±0.4	Újfehértó	2007. VII. 1.
Újfehértói fürtös	Beginning of July	Claret	5.5±0.5	Siófok	2007. VI. 27.
Újfehértói fürtös	Beginning of July	Claret	4.6±0.5	Újfehértó	2007. VII. 1.

Determination of element concentration

Dried fruit samples (0.2 g) were digested in a mixture of 2 ml HNO_3 and 2 ml H_2O_2 in teflon bomb (PTFE) for ICP analysis (*Stefanovits-Bányai* et al., 2006). The digested samples were filled up with deionised water to 10 ml. The following elements were determined by ICP-OES (Thermo Jarrell Ash Co, ICAP 61): Al, As, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Na, P, Pb, and Zn.

Results and discussion

Our analysis revealed a nearly 5-fold difference between the lowest and highest antioxidant capacities when testing 10 cultivars or cultivar candidates (*Figure 1*). 'Korai pipacs', an early ripening cultivar showed the lowest FRAP value, which points to the association between the ripening time and the antioxidant value of fruits as it was shown previously in case of apricot (*Stefanovits-Bányai* et al., 2005). The highest FRAP values were measured in fruits of 'Újfehértói fürtös' and the cultivar candidate T. The order of the FRAP values of cultivars increased as follows 'Érdi bőtermő' < 'Debreceni bőtermő' < 'Kántorjánosi', similarly to the results of *Veres* et al. (2005b) who established the same order of these cultivars when assessing water-soluble antioxidant capacity of fruits by the Photochem chemiluminometer.

Total phenolics content showed smaller differences (slightly more than two-fold variance) between the lowest and the highest values showed again by the accessions 'Korai pipacs' and 'Éva', respectively (*Figure 2*). FRAP and TPC results showed close correlations (r=0.788) indicating that a crucial part of the sour cherry antioxidant capacity is attributable to a wide range of polyphenolics present in the fruit skin and flesh.

Variations due to the different cultivation plots were studied in case of the cultivars 'Újfehértói fürtös', 'Debreceni bőtermő', 'Érdi bőtermő' and 'Kántorjánosi'. Fruits of the 'Újfehértói fürtös' grown at Újfehértó possessed 40% higher antioxidant capacity as compared to fruits harvested at Siófok (*Figure 3A*). This cultivar is grown in several parts of the world, e.g. in the USA, because of its high adaptive capacity. However, our results indicate that the fruit antioxidant properties of 'Újfehértói fürtös' may be more valuable in places where this cultivar is native. The fruits of the cultivar 'Debreceni bőtermő' showed no variations in their antioxidant capacity according to the different cultivation plots. In general, fruits of the cultivars grown at Újfehértó were characterized by higher antioxidant capacity than those harvested at Siófok.

Total phenolic content of fruits changed very similarly to the FRAP values (*Figure 3B*) with two exceptions. One of those is that fruits of 'Érdi bőtermő' harvested at Siófok and Újfehértó were not different in their TPC; and that TPC values in 'Kántorjánosi' fruits originated from Újfehértó exceeded those grown at Siófok.

There were no significant differences in the antioxidant capacity and total phenolics content in fruits ripened outside or inside of the tree canopy in half of the cultivars (*Figure 4*). Other cultivars possessed increased levels of antioxidant capacity in their fruits ripened in the outer regions of the canopy than those harvested from the inside of the canopy. This might be due to the fact that higher light intensity and UV irradiation enhance the levels of various stress pigments, e.g. anthocyanins (*Kataoka* et al., 2005; *Ubi*, 2004).

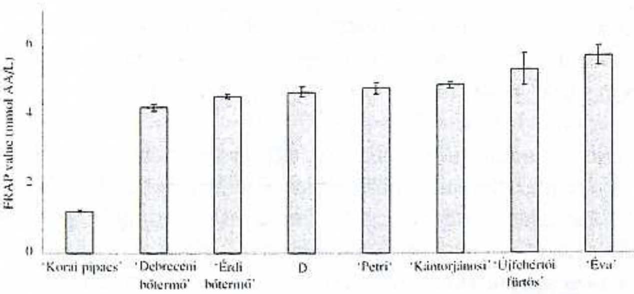

Figure 1 Antioxidant capacity of sour cherry cultivars and cultivar candidates

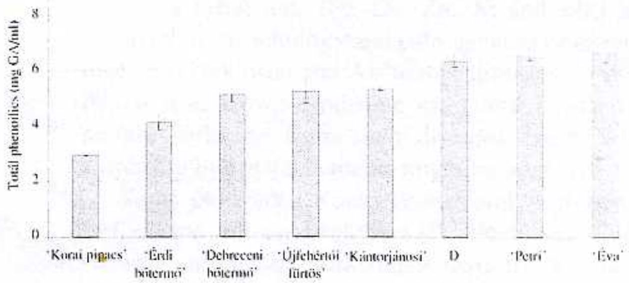

Figure 2 Total phenolics content of sour cherry cultivars and cultivar candidates.

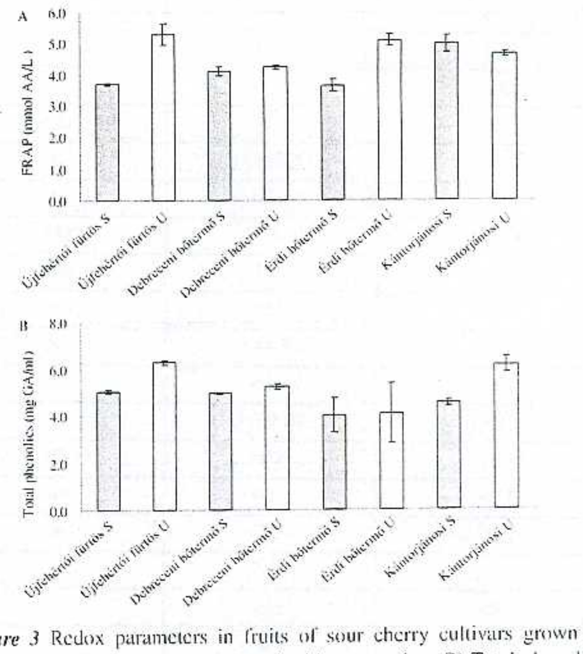

Figure 3 Redox parameters in fruits of sour cherry cultivars grown in different cultivation regions. (A) Antioxidant capacity, (B) Total phenolics content. S: Siófok, U: Újfehértó

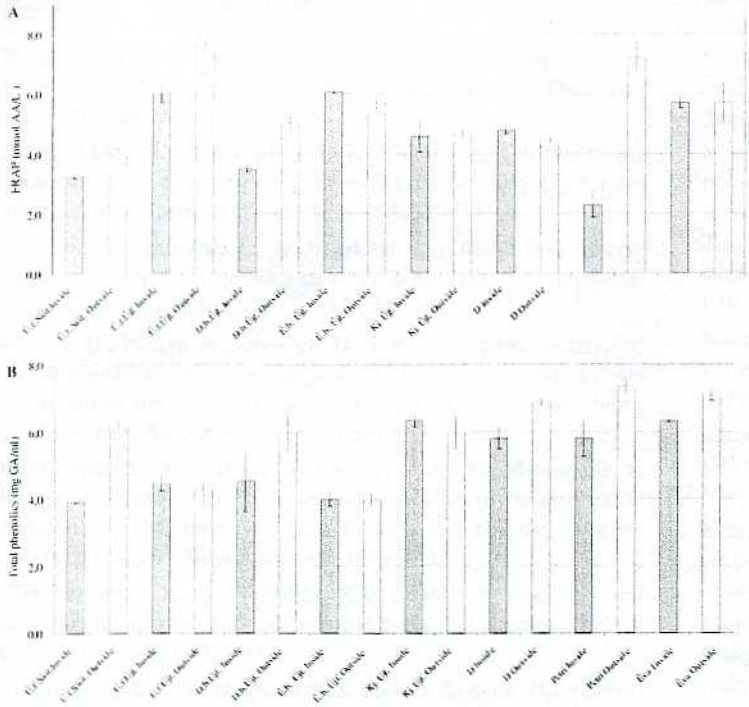

Figure 4 Redox parameters in fruits harvested from different positions (inside or outside) within the canopy of sour cherry cultivars and cultivar candidates grown in Hungary. (A) Antioxidant capacity, (B) Total phenolics content. Abbreviations for cultivar names: Ú.f. 'Újfehértói fürtös', D.b. 'Debreceni bőtermő', É.b. 'Érdi bőtermő', Kj. 'Kántorjánosi'; abbreviations for cultivation plot: Sióf. Siófok, Újf. Újfehértó.

Mineral element content in fruits of the cultivar 'Újfehértói fürtös' was also determined (*Table 2*). Mineral element content calculated on a fresh weight basis can be used to estimate the nutrient intake from daily fruit consumption, while values calculated on a dry weight basis might be helpful to compare the mineral element contents in fruits of different species grown at the same plot. No toxic heavy metals (As, Cd, Cr, Mo, Ni or Pb) could be detected in the fruits. Al content of sour cherry equals with the lowest values of the wide concentration range detected for Japanese plum cultivars (60-290 g/g dry weight) (*Hegedűs*, 2007). In average, sour cherry contains 3-times higher amounts from calcium than Japanese plum fruits, 2.5-times higher amounts from Cu, while levels of Fe, K, Mn and Na were approximately identical in these two species of fruits. Sour cherry accumulated nearly half the quantity found in Japanese plum fruits.

Cultivar-averaged FRAP values of sour cherries were approximately two-times higher than those of Japanese plums, while sour cherries' total phenolics content was only slightly higher than plums' TPC values. Some of the nutrient elements are redox active metals that might influence fruits' antioxidant capacity. Their health aspects mainly depend on the physiological requirements of human body since under iron deficiency high Fe-content of fruits can be beneficial while supraoptimal concentrations of iron may induce severe oxidative damage *via* catalization of the Fenton type reactions.

Some metal ions (Fe, Cu, Zn, Al and Mn) are involved in the aetiology and pathogenesis of several diseases (Parkinson and Alzheimer diseases, tardive dyskinesia, Down-syndrome etc.) and hence for people suffering from such diseases fruits with extremely low metal contents might be proposed.

Some cultivars ('Kántorjánosi' and 'Újfehértói fürtös') and cultivar candidates (D, 'Petri' and 'Évi') showed outstanding antioxidant capacity and total phenolic content; in addition mineral element content in fruits of the 'Újfehértói fürtös' cultivar was also favourable. Genetic background of cultivars forms the decisive factor in determining fruits' antioxidant capacity, although external factors may have also sizeable modifying effects. A detailed qualitative and quantitative analysis of sour cherry fruits of different cultivars may lead to a specialised consumption of Hungarian sour cherry. Enhanced functional properties of the fruit may also be further increased through breeding programs since considerable variation exists within the tested germplasm.

Table 2 Mineral element composition of fruits of the cultivar 'Újfehértói fürtös'

Mineral element weight)	Quantity (g/g dry weight)	Quantity (g/g fresh
Al	69.28	12.57
As	<d.l.	<d.l.
B	37.33	6.78
Ba	2.99	0.54
Ca	2672.00	484.61
Cd	<d.l.	<d.l.
Co	<d.l.	<d.l.
Cr	<d.l.	<d.l.
Cu	9.66	1.75
Fe	15.60	2.83
Ga	1.01	<d.l.
K	12535.50	2270.98
Li	<d.l.	<d.l.
Mg	1030.90	187.00
Mn	7.29	1.32
Mo	<d.l.	<d.l.
Na	344.30	62.51
Ni	<d.l.	<d.l.
P	1159.00	210.01
Pb	<d.l.	<d.l.
Se	<d.l.	<d.l.
Si	12.21	2.22
Sr	7.26	1.32
Ti	<d.l.	<d.l.
V	<d.l.	<d.l.
Zn	3.87	0.70

References

Benzie, I.I.F. & Strain, J.J. (1996): The ferric reducing ability of plasma (FRAP) as a measuring of "antioxidant power": The FRAP assay. *Ann. Biochem.* 239: 70–76.

Betul Akin, E., Karabulut, I. & Topcu, A. (2008): Some compositional properties of main Malatya apricot (*Prunus armeniaca* L.) varieties. *Food Chem.* 107: 939–948.

Blando, F., Gerardi, C. & Nicoletti, I. (2004): Sour cherry (*Prunus cerasus* L.) anthocyanins as ingredients for functional foods. J. *Biomed. Biotechnol.* 5: 253–258.

Bonerz, D., Würth, K., Dietrich, H. & Will, F. (2006): Analytical characterization and the impact of ageing on anthocyanin composition and degradation in juices from five sour cherry cultivars. *Eur. Food Res. Technol.* 224 (3): 355–364.

Burkhardt, S., Tan, D.X., Manchester, L.C., Hardeland, R. & Reiter, R.J. (2001): Detection and quantification of the antioxidant melatonin in Montmorency and Balaton tart cherries (*Prunus cerasus*). J. *Agric. Food Chem.* 49: 4898–4902.

Chaovanalikit, A. & Wrolstad, R.E. (2004): Anthocyanin and polyphenolic composition of fresh and processed cherries. *J. Food Sci.* 69 (1): FCT73–FCT 83.

Connolly, D.A.J., McHugh, M.P. & Padilla-Zakour, O.I. (2006): Efficacy of a tart cherry juice blend in preventing the symptoms of muscle damage. *Brit. J. Sport Med.* 40: 679–683.

Connor, A.M., Stephens, M.J., Hall, H.K. & Alspach, P.A. (2005): Variation and heritabilities of antioxidant activity and total phenolic content estimated from a red raspberry factorial experiment. J. *Amer. Soc. Hort. Sci.* 130: 403–411.

Dalla Valle, A.Z., Mignani, I., Spinardi, A., Galvano, F. & Ciappellano, S. (2007): The antioxidant profile of three different peaches cultivars (*Prunus persica*) and their short-term effect on antioxidant status in human. *Eur. Food Res. Technol.* (in press)

Dietrich, H., Patz, C.D. & Rechner, A. (2003): Influence of processing method on the phenolic antioxidants of fruit juices. (Elderberry, blackberry, morello cherry, gooseberry). *Flüssiges Obst.* 70 (12): 714–721.

García-Alonso, F.J., Periago, M.J., Vidal-Guevara, M.L., Cantos, E., Ros, G., Ferreres, R. & Abellán, P. (2003): Assessment of the antioxidant properties during storage of a dessert made from grape, cherry, and berries. *J. Food Sci.* 68 (4): 1525–1530.

García-Alonso, M., Pascual-Teresa, de S., Santos-Buelga, C. & Rivas-Gonzalo, J.C. (2004): Evaluation of the antioxidant properties of fruits. *Food Chem.* 84: 13–18.

Gil, M.I., Tomás-Barberán, F.A., Hess-Pierce, B. & Kader, A.A. (2002): Antioxidant capacities, phenolic compounds, carotenoids, and vitamin C contents of nectarine, peach, and plum cultivars from California. J. *Agric. Food Chem.* 50: 4976–4982.

Halliwell, B. (2000): The antioxidant paradox. Lancet, 355: 1179–1180.

Hannum, S.M. (2004): Potential impact of strawberries on human health: A review of the science. *Crit. Rev. Food. Sci.* 44: 1–17.

He, F.J., Nowson, C.A. & MacGregor, G.A. (2006): Fruit and vegetable consumption and stroke: meta-analysis of cohort studies. *Lancet.* 367: 320–326.

Hegedűs, A. (2007): Gyümölcsfák nemesítését segítő biokémiai és molekuláris vizsgálatok. *Habilitation Thesis.* University of Debrecen.

Jacob, R.A., Spinozzi, G.M., Simon, V.A., Kelley, D.S., Prior, R.L., Hess-Pierce, B. & Kader, A.A. (2003): Consumption of cherries lowers plasma urate in healthy women. *J. Nutr.* 133: 1826–1829.

Jakobek, L., Seruga, M., Medvidovic-Kosanovic, M. & Novak, I. (2007): Anthocyanin content and antioxidant activity of various red fruit juices. *Dtsch. Lebensm.-Rundsch.* 103 (2): 58–64.

Kang, S.-Y., Seeram, N.P., Nair, M.G. & Bourquin, L.D. (2003): Tart cherry anthocyanins inhibit tumor development in ApcMin mice and reduce proliferation of human colon cancer cells. *Cancer Lett.* 194 (1): 13–19.

Karakaya, S., El, S.N. & Tas, A.A. (2001): Antioxidant activity of some foods containing phenolic compounds. *International Journal of Food Sciences and Nutrition.* 52: 501–508.

Kataoka, I., Sugiyama, A. & Beppu, K. (2005): Involvement of UV rays in sweet cherry fruit coloration during maturation. *Acta Hort.* 667: 461–466.

Kim, D.-O. & Padilla-Zakour, O.I. (2004): Jam processing effect on phenolics and antioxidant capacity in anthocyanin-rich fruits: cherry, plum, and raspberry. *J. Food Sci.* 69 (9): S395–S400.

Lombardi-Boccia, G., Lucarini, M., Lanzi, S., Aguzzi, A. & Cappelloni, M. (2004): Nutrients and antioxidant molecules in yellow plums (*Prunus domestica* L.) from conventional and organic productions: a comparative study. *J. Agric. Food Chem.* 52: 90–94.

Lugasi A. & Blázovics A. (2001): Az egészséges táplálkozás tudományos alapjai. 4. számú útmutató az egészség megőrzéséhez. Országos Élelmezés- és Táplálkozástudományi Intézet, Budapest.

Moyer, R.A., Hummer, K.E., Finn, C.E., Frei, B. & Wrolstad, R.E. (2002): Anthocyanins, phenolics, and antioxidant capacity in diverse small fruits: *Vaccinium, Rubus*, and *Ribes*. J. Agric. Food Chem., 50: 519–525.

Pedryc A., Hermán R. & Halász J. (2005): A Budapesti Corvinus Egyetem KTK Genetika és Növénynemesítés Tanszéken előállított új kajszibarackhibridek értékelése. XI. Növénynemesítési Tudományos Napok Összefoglalói (Szerk.: Kertész Z.), MTA, Budapest, 42.

Piccollella, S., Fiorentino, A., Pacifico, S., D'Abrosca, B., Uzzo, P. & Monaco, P. (2008): Antioxidant properties of sour cherries (*Prunus cerasus* L.): Role of colorless phytochemicals from the methanolic extract of ripe fruits. *J. Agric. Food Chem.* 56: 1928–1935.

Reiter, R.J. & Tan, D.-X. (2002): Melatonin: An Antioxidant in Edible Plants. *Ann. N.Y. Acad. Sci.* 957: 341–344.

Ruiz, D., Egea, J., Gil, M.I. & Tomás-Barberán, F.A. (2005): Characterization and quantitation of phenolic compounds in new apricot (*Prunus armeniaca* L.) varieties. *J. Agric. Food Chem.* 53: 9544–9552.

Sass-Kiss, Á., Kiss, J., Milotay, P., Kerek, M.M. & Toth-Markus, M. (2005): Differences in anthocyanin and carotenoid content of fruits and vegetables. *Food Res. Int.* 38: 1023–1029.

Scalzo, J., Politi, A., Pellegrini, N., Mezzetti, B. & Battino, M. (2005): Plant genotype affects total antioxidant capacity and phenolic contents in fruit. *Nutrition.* 21: 207–213.

Seeram, N.P., Momin, R.A., Nair, M.G. & Bourquin, L.D. (2001): Cyclooxygenase inhibitory and antioxidant cyanidin glycosides in cherries and berries. *Phytomedicine.* 8 (5): 362–369.

Seeram, N.P., Zhang, Y. & Nair, M.G. (2003): Inhibition of proliferation of human cancer cells and cyclooxygenase enzymes by anthocyanidins and catechins. *Nutr. Cancer.* 46 (1): 101–106.

Singleton, V.L. & Rossi J.A. (1965): Colorimetry of total phenolics with phosphomolybdic phosphotungstic acid „reagents". *Am. J. Enol. Vitic.* 16: 144–158.

Southon, S. (2000): Increased fruit and vegetable consumption within the EU: potential health benefits. *Food Res. Int.* 33: 211–217.

Stefanovits-Bányai, É., Engel, R., Hermán, R., Blázovics, A. & Hegedűs, A. (2005): Antioxidant characterization of apricot (*Prunus armeniaca* L.) cultivars and hybrids. *International Journal of Horticultural Science.* 11: 47–51.

Stefanovits-Bányai, É., Szentmihályi, K., Hegedűs, A., Koczka, N., Váli, L. Taba, G. & Blázovics, A. (2006): Metal ion and antioxidant alterations in leaves between different sexes of *Ginkgo biloba* L. Life Sci. 78 (10): 1049–1056.

Tall, J.M., Seeram, N.P., Zhao, C., Nair, M.G., Meyer, R.A. & Raja, S.N. (2004): Tart cherry anthocyanins suppress inflammation-induced pain behavior in rat. *Behav. Brain Res.* 153 (1): 181–188.

Tomás-Barberán, F.A., Gil, M.I., Cremin, P., Waterhouse, A.L., Hess-Pierce, B. & Kader, A.A. (2001): HPLC-DAD-ESIMS analysis of phenolic compounds in nectarines, peaches, and plums. *J. Agric. Food Chem.* 49: 4748–4760.

Ubi, B.E. (2004): External stimulation of anthocyanin biosynthesis in apple fruit. *Journal of Food Agriculture & Environment.* 2: 65–70.

Van Duyn, M.A.S. & Pivonka, E. (2000): Overview of the health benefits of fruit and vegetable consumption for the dietetics professional: Selected literature. *J. Am. Diet. Assoc.* 100: 1511–1521.

Vasantha Rupasinghe, H.P., Jayasankar, S. & Lay, W. (2006): Variation in total phenolics and antioxidant capacity among European plum genotypes. *Sci. Hortic.* 108: 243–246.

Veres, Zs., D. Holb, I., Nyéki, J., Szabó, Z. & Fári, M. (2005a): Total anthocyanine content and antioxidant density of some Hungarian sour cherry varieties. *International Journal of Horticultural Science.* 11 (2): 109–113.

Veres, Zs., Remenyik, J., Nyéki, J., Szabó, Z., Popovics, L., Holb. I. & Fári, M.G. (2005b): A meggy (*Prunus cerasus*) bioaktív anyagai (különös tekintettel az antioxidáns aktivitásra és antioxidáns sűrűségre). *Agrártudományi Közlemények.* 17: 83–87.

Wang, H., Nair, M.G., Strasburg, G.M., Booren, A.M. & Gray, J.I. (1999): Novel antioxidant compounds from tart cherries (*Prunus cerasus*). *J. Nat. Prod.* 62: 86–88.