Nutraceutical content of berries and minor fruits

Giancarlo Bounous, Gabriele Loris Beccaro, Maria Gabriella Mellano, Vittorino Novello
Dept. Colture Arboree, University of Turin
Via Leonardo da Vinci, 44 – I
10095 GRUGLIASCO TO, Italy

Keywords: berry fruit, nutraceutical properties, antioxidant activity, functional food, vitamin C, phenols.

Abstract:

Berry fruit and minor fruit represent a small portion of the total Italian fruit production, however they play a role of considerable interest in relation to the content of nutraceuticals. Among these substances can be listed vitamins, minerals, polyphenols, flavonoids and anthocyanins. The nutraceutical properties of these compounds are mainly concerned with the antioxidant activity that neutralizes the effects of free radicals, which contribute to cause oxidative damage to various cellular components. Numerous studies have shown that antioxidants reduce the occurrence of many diseases, including certain types of cancer. Consumers are increasingly concerned to the choice of their food, supporting both the search of organoleptic properties and quality, in the nutrition healthy sense too. These consumers are known as "conscious consumers" because their choices are focused on all aspects of quality, considering every sense of the term (organoleptic, nutritional, healthy and environmental).

INTRODUCTION

The role of phenols have been studied since long time on fruit and on wine; in the latter tannins, resveratrols and anthocyanins are considered as very active in contrasting *in vitro* and *in vivo* lipidic oxidation (Tamura, Yamagami, 1994; Castino, 1996; Teissedre *et al*., 1996). The polyphenolic activity assessed on wine is higher than that given by the sum of the single compound activity (Frankel *et al*., 1995). The amount of total polyphenol content in fruit are reportet in table 1.

Anthocyanins, which are photoprotectants and allelopatic compounds, have nutritional properties, including antioxidant, anti-inflammatory, estrogenic and cardiovascular properties, atherogenesis adjuvants and anti-tumor activities. They are mainly found in tegumental tissues, such as in epidermal cells and foliar hairs (Harborne, Williams, 2000). At cellular level, however, these pigments are mainly localized in the vacuole (Winkel-Shirley, 2001), or translocated towards the cell wall (Markham *et al.*, 2000, 2001). It has been suggested that anthocyanin transport into the vacuole occurs by means of three distinct ways: a H+-driven antiport (Klein *et al*., 1996), dependent on the electrochemical proton gradient generated by H+-ATPase and H+-PPiase activity; a conformational change, after protonation and vacuole accumulation (Matern *et al.,* 1983); an ATP-dependent transport, mediated by an ATP-binding cassette (ABC) transporter, of the glutathione-conjugated form, after glutathionation by glutathione S-transferase activity (Rea *et al*., 1998). In addition, it has been suggested by Debeaujon and coworkers (2001) the occurrence of another process, based on the presence of a proanthocyanidin precursor transporter in epidermal tissues of Arabidopsis seeds.

The anthocyanin uptake has also been investigated as concerns the human metabolism at the gastric level (Passamonti *et al*., 2002). It has been shown that bilitranslocase (BLT), a plasma membrane organic anion carrier localized at liver and gastric mucosa cells (Sottocasa *et al*., 1989), is competitively inhibited by anthocyanins, either as aglycons or mono- and di-glycosyde derivatives. Evidences corroborates the hypothesis that this protein may be involved in gastric uptake of anthocyanins (Passamonti *et al*., 2003). This carrier is expressed also in the epithelium of the gastric mucosa (Battiston *et al*., 1999; Passamonti *et al*., 2000), thus it could be involved in transport of nutritionally relevant substrates. Indeed, various classes of plant polyphenols turned out to be bilitranslocase substrates (Passamonti *et al*., 2002). The possibility that absorption of micronutrients (such as nicotinic acid) (Passamonti *et al*., 2000) and plant polyphenols (Passamonti *et al*., 2003) takes place at the stomach level has been tested. The gastric pathway of plant polyphenols is interesting, since it would enable these compounds to enter the circulation and be distributed to the liver before the absorption of other components of a meal.

It has been hypothesized that a transporter similar to BLT may be present also in plant cells, where it may catalyze the membrane transport of anthocyanins. Kinetic analysis has shown that there is an analogy between BLT and the plant carrier, although this indicates a different affinity for distinct substrates. In particular, there

have been recognized almost two binding sites between cyanidin-3-glucoside and the carrier: the first one with a low affinity at the level of pore; the other one with high affinity, localized on the external surface of the protein, where it is probably involved during the substrate recognition phase.
The positive influence of polyphenols on the human health resides in its already demonstrated activities as anti-oxidant, chemopreventic, antitumoral, antiaggregant, regulatory of the immune response, and preventive of DNA damage (Fauconneau, Waffo-Teguo, 1997).
The anti oxidant activity could be measured by the ORAC (*Oxigen Radical Absorbance Capacity*), which vary among fruit species (Wang *et al*., 1996)(tab. 2).
The presence of antioxidants in food is important for the health-conscious consumers aware of the healthy nutrition, and the food industry is becoming more and more interested in preparing 'functional foods', those containing various factors to ensure or enhance health (Finley *et al*., 2011). An healthy diet should take into account 5000 ORAC units per day (Cao *et al*., 1993).
Moreover, many other components such as vitamins (especially vitamin C, tab. 3) are responsible for the healthiness of the fruits.
The Italian agricultural production is relevant: in the year 2010 the total value reached 10 billion Euros, and the fruit production accounted the 13 %. The 85 % of the fruit arrives at the fresh market, and 15 % at the industry. The berry fruit represents only 1.2 % of the total (INEA, 2011) but its importance is increasing.
In the last years the Italian consumers have increased the knowledge of the importance of the fruit in the daily diet in order to reduce the risk of various pathologies. An analysis of the daily polyphenol intake from fruit and vegetables, in the nearby France, has been published by Brat and coauthors (2006).

BERRIES AND MINOR FRUITS

Temperate climates

Cornelian cherry (*Cornus mas* L.). It is spontaneous in Central and South Europe, in sun exposed areas. It is a deciduous bush or small tree, 2-6 m height. Fruit is rich in Vitamin C, fructose, minerals and tannins; it is used to prepare beverages, jams, jellies and cakes. The juice is useful against fever and cold, atherosclerosis and hypercholesterolemia (Rafieian-Kopaei *et al.,* 2010). The nutraceutical activity depends on the culture environment, the level of fruit maturity, and it is related to the high amount of flavonoids (especially quercitin) and antioxidant activity (Pawlowska *et al*., 2010).

Red Raspberry (*Rubus idaeus* L.). It is a shrub 1-2 m high, and could be cultivated till 1700 m a.s.l. The drupes have high antioxidant activity and are rich in phenols, flavonols such as kaempferol, myricetin and quercitin: in the cv Willamette the content reached 2.40, 0.26 and 0.71 μg/g FW respectively (Milivojević *et al.,* 2011).

Bilberry (*Vaccinium myrtillus* L.). This is a perennial shrub 0.10 -0.40 m high, spontaneous in mountain forests, in acidic soils. Berries are rich in fiber, minerals (calcium and iron), vitamin C, and some antioxidant compounds such as anthocyans and proanthocyanidins (Beccaro, Mellano, 2006; Beccaro *et al*., 2006). The flavonoid constituents and their contribution to antioxidant activity of the *Vaccinium* genus, have been found by Shiow and coauthors (2011). Fruits are consumed fresh, but processing is very important (jam, liquor, …). The nutraceutical value of the processed berries is related to the fruit selection criteria and the different techniques of processing (Mellano *et al*., 2010). Thanks to the high antioxidant activity, the derivatives of this species are very useful in the treatments of the circulatory disorders, especially in capillary fragility (retina and vein); it is also useful for treatment of abdominal colics, diarrhea and cystitis (Prior *et al*., 1998).

Buckthorn (*Hippophae rhamnoides* L.). It belongs to the *Eleagnaceae* family, and it is widely cultivated in Germany and North Europe, since it is adapted to low temperatures. The bush may reach 3-4 m of height. The berries are rich in flavonols (Mellano *et al*., 2008), vitamins (A, C, E, F, 13, K and B group), and mineral elements such as iron, calcium, magnesium and copper. A specific study on different cultivars have been done in Hungary, showing that the selected cultivars had bigger fruits, with no difference in the content of vitamin C (Bernath, Foldesi, 1992). Some preparations of Buckthorn are recommended for body external applications such as skin burns, X ray and radiotherapy treatments. For its nutraceutical peculiarities, the juice is used as diet integrator of the astronauts during the space flights.

Black currant (*Ribes nigrum* L.). This shrub, belonging to the *Saxifragaceae* family, can reach the height of 2 m,; it grows in the Euro-Asian mountains. It could be found spontaneous in the mountains of Northern Italy, but more frequently is cultivated. The extracts from different part of the plant show high antioxidant activity (Tabart *et al*., 2011). The floral bud has more phenol content than berry, and also the leaves have high phenol content. The content of ascorbic acid, phenols and anthocyans in black currant berries has been found higher than in *Rubus ulmifolius*, *Rubus idaeus*, *Ribes rubrum* and *Sambucus nigra* (Wu *et al.*, 2004). Leaves and shoots are commercialized as food integrators. The leaf extract has an anti inflammatory effect.

Wild rose (*Rosa canina* L.). It is a wild thorny shrub, that may reach the height of 2 m, thriving along the countryside roads and low mountain areas. The main nutraceutical components are located in the rosehip: essential oil (citronellol), flavonols, proanthocyanidins, vitamin C, but also the fruits are rich on polyphenols and present an high antioxidant activity (Mellano *et al*., 2008). The rosehip extracts are very effective for the blood vases and ocular apparatus (Lieutaghi, 1981). The rosehip extracts can act as antioxidant or prooxidant, depending on their concentration (Altiner *et al.,* 2010).

Elderberry (*Sambucus nigra* L.). The elderberry is a small tree living in humid forests and neutral or basic soils. The berry contains vitamins A and C; in the epicarp and endocarp are located the anthocyans, while the seeds are rich in cyanogenetic glucosides. All the parts of the plant are used in traditional medicine and pharmacopoeia. The berries are processed in jam, with laxative and diurectic effects.

Experimental data of anthocyanin and polyphenol content and antioxidant activity in different genera and cultivars of berry fruit species found in Piedmont, North West of Italy, are reported in tab. 4 and 5.

Tropical and subtropical climates

Barbados Cherry (*Malpighia glabra* L.). Called also Acerola, belongs to the *Malpighiaceae* family. Native of South America, it may be found in tropical and subtropical environments, but it can tolerate temperature no lower than -2 °C; it prefers calcareous and dry soils. It appears as a bush or small tree, till 6 m high. The berry is rich in vitamins (C, A, B1, B6), flavonoids and mineral elements such as calcium, phosphorus, iron, potassium and magnesium. The berry has the highest content in Vitamin C: from 1500 to 4500 mg for one edible portion, that means 90 times that of an orange, and 35 times that of a lemon. This vitamin C is more quickly absorbed by the organism than the synthetic one. The fruit is astringent, with antioxidant and anti-fungal activity, due to the high polyphenols content. Unripe fruit contains more vitamin C and has more antioxidant activity than the ripe one (Vendramini, Trugo, 2000; Assis *et al*., 2001), moreover unripe fruit presents also an antigenotoxic (protection of DNA) effect (Nunes *et al.,* 2011). Among the main utilization by processing, the extracts are used to produce anti-aging cosmetics.

Guava (*Psidium guajava* L.). Native of Central America, belongs to the *Mirtaceae* family, and it is grown in several tropical areas. It is an evergreen shrub, 4-6 m high. Fruits are rich in Vitamin C: from 350 to 450 mg per ripe fruit, 5 times more than that of an orange fruit. Fruits are also rich in tannins, polyphenols, terpens, flavonoids, essential oils, fibers, vitamins, fatty acids and minerals (calcium, phosphorus, iron and manganese) (Jimenez-Escrig *et al*., 2001). Leaf extracts have antiseptic activity, especially against *Staphilococcus* spp, particularly against *Staphilococcus aureus* (Gnan, Demello, 1999). Antitumor and antibiotic activities are due to the presence of high amount of quercitin. An anti-hyperglycemic effect of the fruit extracts has been found by Roman-Ramos and coauthors (1995).

Pomegranate (*Punica granatum* L.). This very old fruit tree species (1-4 m high) belongs to the *Punicaceae* family and is native of Iran, Northern India, Caucasus spread from ancient times in the Mediterranean basin. It played (and continues to play) an important role in the traditions and religions of Europe and Asia. It is drought and cold resistant. All the fruit parts are very rich in polyphenols, particularly ellagitannins, with antioxidant activity, higher than some teas and wines. Pomegranate extracts are used to treat arteriosclerosis. It is traditional the use of pomegranate juice as a adjuvant to prostate cancer therapy; this could be supported by the presence of brevifolin carboxylic acid in the fruit which has demonstrated a strong cytotoxic activity against human tumors. Moreover brevifolin carboxylic acid has been suggested as potential hepatoprotective agent and proposed for prevention and treatment of diseases caused by retrovirus, such as HIV (Fischer *et al*., 2011). The antimicrobial activity of the fruit juice could elongate the meat shelf-life (Vaithiyanathan *et al.*, 2011).

Tamarind (*Tamarindus indica* L.). This tree, native of tropical Africa, belongs to the *Leguminosae* family, and it is spread in all the tropical boundary, and also in Eastern India, Mexico, Brazil, Antilles. The total phenolic content and the antioxidative properties of raw and dry heated seed coat was found very high, especially against fatty acids with values higher than ascorbic acid (Siddhuraju *et al.,* 2007), and this could contribute to increase the food self-life.

CONCLUSIONS

Berry and minor fruit represent an interesting expression of past and modern fruit culture. Their cultivation and marketing is increasing worldwide due to an always greater interest related to the nutritional and nutraceutic properties of fruits, leaves and other parts of the plants. These species play an important dietetic role: they represent a valuable source of active compounds useful to prevent diseases and physiological disorders. The amount of active principles is related to genotype/environment interaction and agrothecniques adopted, and this variability can be a valuable element to distinguish the productions, and a tool of differentiation to obtain label certifications and to promote their use. In addition, berry and minor fruit are useful to restore marginal and abandoned areas: they reduce raindrop erosion of steep soils, value the ecosystems and increase their biodiversity.

Literature Cited

Altiner, D., Kilicgun, H. 2010. Correlation between antioxidant effect mechanisms and polyphenol content of *Rosa canina*. Journal of Medicinal Plant Research, 6 (23): 238-241.

Assis, S., Demerval, C., Oliveira, D. (2001. Activity of pectinmethylesterase, pectin content and vitamin C in acerola fruit at various stages of fruit development. Food Chemistry, 74 (2): 133-137.

Battiston, L., Macagno, A., Passamonti, S., Micali, F., Sottocasa, G.L. 1998. Specific sequence-directed anti-bilitranslocase antibodies as a tool to detect potentially bilirubin-binding proteins in different tissues of the rat. FEBS Lett., 453: 351-5.

Beccaro, G., Mellano,M.G. 2006. I piccoli frutti come *functional food*: variazione cultivarietale del contenuto in sostanze di interesse nutraceutico. In: Accademia dei Georgofili. I Georgofili: Atti della Accademia dei Georgofili. vol. Serie VIII, Vol. 2, tomo II, p. 485-491, FI:Accademia dei Georgofili.

Beccaro, G.L., Mellano, M.G., Botta, R., Chiabrando, V., Bounous, G., 2006. Phenolic and anthocyanin content and antioxidant activity in fruits of bilberry (*Vaccinium myrtillus* L.) and of highbush blueberry (*V.corymbosum* L.) cultivars in North Western Italy. Acta Hort., 715:553-557, ISSN: 0567-7572.

Bernath, J., Foldesi, D. 1992. *Sea buckthorn a promissing new medicinal and food crop*. J. of herbs, spieces and Medicinal Plants, 1 (2): 27-35.

Brat, P., George, S., Bellamy, A., Du Chaffaut, L., Scalbert, A., Mennen, L., Arnault, N., Amiot, M.J. 2006. Daily Polyphenol Intake in France from Fruit and Vegetables. J. Nutr. 136: 2368–2373.

Bounous, G., Beccaro, G.L., Mellano, M.G., Botta, R. 2009. Nutritional value and antioxidant activity of minor fruits grown in Piemonte (Italy). Acta Hort., 818:249-252, ISSN: 0567-7572.

Cao, G., Alessio, H., Cutler, R. 1993. *"Oxygen-radical absorbance capacity assay for antioxidants".* Free Radic Biol Med, 14 (3): 303–11.

Castino, M., 1996. Il complesso polifenolico dei vini quale fattore di protezione nelle alterazioni cardiovascolari. Quad. Vitic. Enol. Univ. Torino, 20: 79-88.

Debeaujon, I., Peeters, A.J.M., Léon-Kloosterziel, K.M., Koornneef, M., 2001. The TRANSPARENT TESTA12 gene of *Arabidopsis* encodes a multidrug secondary transporter-like protein required for flavonoid sequestration of the seed coat endothelium. Plant Cell, 13: 853-871.

Finley, J.W., Kong, AN., Hintze, K.J., Jeffery, E.H., Ji, L.L., Lei, X.G. 2011. Antioxidants in food: state of the science important to the food industry. J.Agric. Food Chem., 59: 6837-6846.

Fauconneau, B., Waffo-Teguo, R., Huguet, F., Barrier, L., Decendit, A., Mèrillon, J.M. 1997. Comparative study of radical scavenger and antioxidant properties of phenolic compounds from *Vitis vinifera* cell cultures using in vitro tests. Life Sciences, 61: 2103-2110.

Fischer, U.A., Carle, R., Kammerer, R. 2011. Identification and quantification of phenolic compounds from pomegranate (*Punica granatum* L.) peel, mesocarp, aril and differently produced juices by HPLC-DAD–ESI/MSn. Food Chemistry, 127: 807-821.

Gnan, S.O., Demello, M.T. 1999. Inhibition of *Staphylococcus aureus* by aqueous *Psidium guajava* extracts*.* J. Ethnopharm., 68: 103-108.

Harborne, J.B., Williams, C.A. 2000. Advances in flavonoid research since 1992. Phytochem., 55: 481-504.

Jimenez-Escrig, A., Rincón, M., Pulido, R., Saura-Calixto, F. 2001. Guava fruit as a new source of antioxidant dietary fiber. J. Agric. Food Chem., 49 (11): 5489-93.

Klein, M., Weissenbock, G., Dufaud, A., Gaillard, C., Kreuz, K., Martinoia, E. 1996. Different energization mechanisms drive the vacuolar uptake of a flavonoid glucoside and a herbicide glucoside. J. Biol. Chem., 271: 29666-71.

Lieutaghi, P. 1981. *Il libro degli alberi e degli arbusti*, Rizzoli Ed., pp 874.

Markham, K.R., Ryan, K.G., Gould, K.S., Rickards, G.K. 2000. Cell wall sited flavonoids in lisianthus flower petals. Phytochem. 54, 681-687.

Markham, K.R., Gould, K.S., Ryan, K.G. 2001. Cytoplasmic accumulation of flavonoids in flower petals and its relevance to yellow flower colouration. Phytochem., 58: 403-413.

Matern, U., Heller, W., Himmelspach, K. 1983. Conformational changes of apigenin 7-O-(6-O-malonylglucoside), a vacuolar pigment from parsley, with solvent composition and proton concentration. Eur. J. Biochem., 133: 439-448.

Mellano, M.G., Beccaro, G.L., Bounous, G. 2008. Nutraceutical value of local fruit species germplasm in agroecosystems of the Alps. In: First Symposium on Horticulture in Europe. Wien, 17-21 Feb, p. 292-293, LEUVEN:ISHS.

Mellano, M.G., Cavanna, M., Beccaro, G.L., Bounous, G. 2010. Valore nutraceutico di frutti e confetture di mirtillo di bosco. Food and trade, 2,4:11-16.

Milivojević, J., Maksimović, V., Nikolic, M., Bogdanović, J., Maletić, R., Milatović, D. 2011. Chemical and antioxidant properties of cultivated and wild *fragaria* and *rubus* berries. Journal of Food Quality, 34 (1): 1-9.

Nunes, Rda S., Kahl, V.F., Sarmento, Mda S., Richter, M.F., Costa-Lotufo, L.V., Rodrigues, F.A., Abin-Carriquiry, J.A., Martinez, M.M., Ferronatto, S., Ferraz, Ade B., da Silva, J. 2011. Antigenotoxicity and antioxidant activity of Acerola fruit (*Malpighia glabra* L.) at two stages of ripeness. Plant Foods Hum Nutr., 66(2):129-35.

Passamonti, S., Battiston, L., Sottocasa, G.L. 2000. Gastric uptake of nicotinic acid by bilitranslocase. FEBS Lett, 482: 167-8.

Passamonti, S., Vrhovsek, U., Mattivi, F. 2002. The interaction of anthocyanins with bilitranslocase. Biochem. Biophys. Res. Commun., 296: 631-636.

Passamonti, S., Vrhovsek, U., Vanzo, A., Mattivi, F. 2003. The stomach as a site for anthocyanins absorption from food. FEBS Letters, 544: 210-213.

Pawlowska, A.M., Camangi, F., Braca, A. 2010. Quali-quantitative analysis of flavonoids of *Cornus mas* L. (*Cornaceae*) fruits. Food Chemistry, 119: 1257–1261.

Prior, R.L., Cao, G., Martin, A., Sofic, E., O'Brien, C., Lischner, N., Ehlenfeldt, M., Kalt, W., Krewer, G., Mainland, M. 1998. Antioxidant capacity as influence by total phenolic and anthocyanin contenent, maturity and variety of *Vaccinium* species. J. Agric. Food Chem, 46 (7): 2686-2693.

Rafieian-Kopaei, M., Asgary, S., Adelnia, A., Setorki, M., Khazaei, M., Kazemi, S., Shamsi, F. 2011. The effects of cornelian cherry on atherosclerosis and atherogenic factors in hypercholesterolemic rabbits. J. Med. Plant. Res., 5(13): 2670-2676.

Roman-Ramos, R., Flores-Saenz, J.L., Alarcon-Aguilar, F.J. 1995. Anti-hyperglycemic effect of some edible plants. J. Ethnopharmacol, 48:25-32.

Rea, P.A., Li, Z-S., Lu, Y-P., Drozdowicz, Y.M., Martinoia, E. 1998. From vacuolar gs-x pumps to multispecific abc transporters. Annu. Rev. Plant Physiol. Plant Mol. Biol., 49: 727-760.

Shiow, Y. Wang, Hangjun Chen Mary J. Camp, Mark K. Ehlenfeldt 2011. Flavonoid constituents and their contribution to antioxidant activity in cultivars and hybrids of rabbiteye blueberry (*Vaccinium ashei* Reade). Food Chemistry, 129: 13-20.

Siddhuraju, P. 2007. Antioxidant activity of polyphenolic compounds extracted from defatted raw and dry heated *Tamarindus indica* seed coat. LWT, 40: 982-990.

Sottocasa, G.L., Lunazzi, G.C., Tiribelli, C. 1989. Isolation of bilitranslocase, the anion transporter from liver plasma membrane for bilirubin and other organic anions. Methods Enzymol., 174: 50-57.

Tabart, J., Kevers, C., Evers, D., Dommes, J. 2011. Ascorbic Acid, Phenolic Acid, Flavonoid, and Carotenoid Profiles of Selected Extracts from Ribes nigrum. Agric. Food Chem., 59 (9): 4763–4770.

Tamura, H., Yamagami, A. 1994. Antiossidative activity of monoacylated anthocyanins isolated from Muscat Bailey A grape. J. Agric. Food Chem., 44: 37-41.

Teissedre, P.L., Waterhouse, A.L., Walzem, R.L., German, J.B., Frankel, E.N., Ebeler S.E., Clifford, A.J. 1996. Composés phénoliques du rasins et du vin et santé. Bull. OIV, 781-782: 251-277.

Vaithiyanathan, S., Naveena, B.M., Muthukumar, M., Girish, P.S. and Kondaiah, N. 2011. Effect of dipping in pomegranate (*Punica granatum*) fruit juice phenolic solution on the shelf life of chicken meat under refrigerated storage (4 °C). Meat Science, 88 (3): 409-414.

Vendramini, A.L., Trugo, L.C. 2000. Chemical composition of acerola fruit (*Malpighia punicifolia* L.) at three stages of maturity. Food Chemistry 71:195-198.
Wang, H., Cao, G., Prior, R.L. 1966. Total Antioxidant Capacity of Fruits. J. Agric. Food Chem., 44: 701-705
Winkel-Shirley, B. 2001. Flavonoid biosynthesis. A colorful model for genetics, biochemistry, cell biology, and biotechnology. Plant Physiol., 126: 485-493.
Wu, X., Gu L., Prior, R.L., McKay, S. 2004. Characterization of Anthocyanins and Proanthocyanidins in Some Cultivars of *Ribes*, *Aronia*, and *Sambucus* and Their Antioxidant Capacity. J. Agric. Food Chem., 52 (26):7846–7856.
http://www.inea.it/

Tables

Table 1 – Total Phenol content (TPC) of fresh fruit, expressed as gallic acid equivalent (GAE) (Modified from Brat *et al.,* 2006)

Rank	Common name	Fruit lot	Mean TPC	Min	Max
		mg of GAE/100 g FEP			
1	Strawberry	1	263.8	–	–
2	Lychee	1	222.3	–	–
3	Grape	3	195.5	134.1	275.5
4	Apricot	4	179.8	103.1	318.3
5	Apple	9	179.1	90.2	300.0
6	Date	1	99.3	–	–
7	Cherry	1	94.3	–	–
8	Fig	1	92.5	–	–
9	Pear	4	69.2	40.7	148
10	White nectarine	1	72.7	–	–
11	Passion fruit	1	71.8	–	–
12	Mango	1	68.1	–	–
13	Yellow peach	1	59.3	–	–
14	Banana	1	51.5	–	–
15	Pineapple	2	47.2	32.7	61.6
16	Lemon	2	45.0	34.6	55.3
17	Yellow nectarine	1	44.2	–	–
18	Grapefruit	2	43.5	39.3	47.7
19	Orange	5	31.0	27.0	36.5
20	Clementine	3	30.6	22.7	38.7
21	Lime	1	30.6	–	–
22	Kiwi	2	28.1	26.1	30.0
23	Watermelon	1	11.6	–	–
24	Melon	1	7.8	–	–

Tab. 2 – ORAC content in some fruits (Modified from several sources).

Fruit	Serving size	Units
Apricot	3 fruits	172
Melon	3 slices	197
Pear	1 fruit	222
Banana	1 fruit	223
Peach	1 fruit	248
Apple	1 fruit	301
White grape	1 cluster	357
Kiwi	1 fruit	458
Black grape	1 cluster	569
Avocado	1 fruit	571
Plum	1 fruit	626
Orange	1 fruit	983
Orange juice	1 glass	1142
Strawberry	1 cup	1170
Pink grapefruit	1 fruit	1188
Grapefruit juice	1 glass	1274
Black currant	1 cup	1466
Blueberry	1 cup	3480

Tab. 3 – Content in vitamin C of fresh fruit (modified from **www.naturalhub.com)**

Fruit	Latin name	mg vitamin C/ 100 grams	mg vitamin C per average size fruit/slice
Acerola	*Malpighia glabra*	1.677	80
Apple	*Malus sylvestris*	6	8
Apricot	*Prunus armeniaca*	10	4
Banana	*Musa X paradisiaca*	9	11
Barbados Cherry	*Malpighia glabra*	1.678	112
Bilberry	*Vaccinium myrtillus*	1	0.01(estim)
Blackberry	*Rubus sp.*	6	0.6(estim)
Blackcurrant	*Ribes nigrum*	155 to 215	1.5 to 2(estim.)
Blueberry	*Vaccinium sp*	1.3 to 16.4	no data
Fig	*Ficus carica*	2	1
Grape, slip skin	*Vitis spp*	4	.01
Grape, european	*Vitis vinifera*	11	.60
Grapefruit	*Citrus paradisi*	34	44*
Guava, Cattley	*Psidium cattleianum*	37	2
Guava, tropical	*Psidium guajava*	183	165
Java plum	*Syzgium cumini*	14	.42
Jujube	*Ziziphus jujuba*	500	no data
Kiwifruit, green	*Actinidia deliciosa*	98	74
Kiwifruit, yellow	*Actinidia chinensis*	120 to 180	108 to 162
Lemon juice	*Citrus limon*	46	3
Lime juice	*Citrus aurantifolia*	29	1
Loquat	*Eriobotrya japonica*	1	.5
Lychee	*Litchi chinensis*	72	7
Mango	*Mangifera indica*	28	57
Medlar	*Mespilus germanica*	0.3	0.15(estim)
Melon, cantaloupe	*Cucumis melo*	42	29
Melon, honeydew	*Cucumis melo*	25	20
Orange	*Citrus sinensis*	53	70
Opuntia cactus	*Opuntia* spp.	23	no data
Papaya	*Carica papaya*	62	47

Pawpaw/Asimina	*Asimina triloba*	14	28(estim)
Passionfruit, purple	*Passiflora edulis*	30	5
Peach	*Prunus persica*	7	6
Peach, canned	*Prunus persica*	3	3
Pear	*Pyrus communis*	4	7
Persimmon, American	*Diospyros virginiana*	66	13(estim.)
Persimmon, Oriental	*Diospyros kaki*	40	40(estim.)
Pineapple	*Ananus comosus*	15	13
Plum	*Prunus sp*	10	6
Quince	*Cydonia oblonga*	15	15
Raspberry	*Rubus spp.*	25	.5
Raspberry	*Rubus spp.*	23 to 32	0.7 to 1
Redcurrant	*Ribes sativum*	58 to 81	0.58 to 0.81(estim)
Rosehip	*Rosa pomifera* cv.'Karpatia'	1.500	45(estim.)
Rosehip	*Rosa sp.* cv.'Pi Ro 3'	1.150	34(estim.)
Rosehip	*Rosa sp.* cv.'Vitaminnyj-VNIVI'	2.000 to 2.500	60 to 75(estim.)
Strawberry	*Fragaria x ananassa*	57	7
Tangerine/Mandarin	*Citrus reticulata*	31	26
Tamarillo, red	*Cyphomandra betaceae*	40	40
Tamarillo, red	*Cyphomandra betaceae*	31	22
Tamarillo, yellow	*Cyphomandra betaceae*	33	30
Tamarillo, yellow	*Cyphomandra betaceae*	31	22
Watermelon	*Citrullus lanatus*	10	27

Tab. 4 – Antioxidant activity (FRAP), antocyanin and total phenolic content in berry fruit species of genera *Rubus* and *Vaccinium* in Piedmont, North West Italy.

Species	Cultivar	Antocyanins			Polyphenols			FRAP		
		mg/100 g (cianidine 3-gluc)		*rank*	*mg/100 g (GAE)*		*rank*	*mmoli* Fe^{2+} */kg*		*rank*
Rubus idaeus L.	Tulameen	25	ghil	17	316	cdefgh	8	51.13	efghi	15
Rubus idaeus L.	wild	100	cdefghi	10	478	bcdefg	2	63.37	cdef	11
Rubus ulmifolius Schott.	Chester	101	cdefgh	9	355	bcdefgh	6	76.96	cd	9
Rubus ulmifolius Schott.	Lockness	110	cdefg	8	318	cdefgh	7	77.99	cd	7
Rubus ulmifolius Schott.	wild	300	ab	2	818	a	1	218.39	a	1
Vaccinium corymbosum L.	Darrow	30	fghil	15	212	fgh	13	20.16	m	25
Vaccinium corymbosum L.	Toro	83	fghil	12	257	defgh	11	27.17	lm	24
Vaccinium corymbosum L.	Berkeley	30	fghil	15	198	gh	15	31.26	hilm	22
Vaccinium corymbosum L.	Duke	79	fghil	13	199	gh	14	32.81	hilm	21
Vaccinium corymbosum L.	Coville	71	fghil	14	198	gh	15	33.54	hilm	20
Vaccinium corymbosum L.	Bluejay	113	cdef	7	166	h	17	35.17	ghilm	19
Vaccinium corymbosum L.	Earlyblue	123	cdefg	6	316	cdefgh	8	40.81	fghilm	18
Vaccinium corymbosum L.	Bluetta	142	bcde	5	294	defgh	10	42.30	fghilm	17
Vaccinium corymbosum L.	Brigitta	96	cdefghi	11	245	defgh	12	45.17	fghil	16
Vaccinium corymbosum L.	Elisabeth	174	bcd	4	359	bcdefgh	5	54.30	defgh	14
Vaccinium corymbosum L.	Elliott	231	b	3	459	bcdefgh	4	78.92	cd	5
Vaccinium myrtillus L.	wild	327	a	1	473	bcdef	3	147.81	b	2

The same letter indicates means not significantly different for p ≤0.05 (Tukey test).

Tab. 5 – Anthocyanin content in some species and cultivars in Piedmont, North West Italy.

	mg(cyanidine 3-gluc)/100 g
Hippophae rhamnoides L.	0 d
Rosa canina L. CM2	1.65 d
Rubus idaeus L.	45.47 d
Rubus nigrum L. PC 106	132.73 bc
Rubus nigrum L. PC 96	158.19 bc
Rubus nigrum L. Titania	191.18 b
Rubus nigrum L. Ben omond	218.91 ab
Rubus nigrum L. Tiben	271.34 a

The same letter indicates means not significantly different for p ≤0.05 (Tukey test).