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Antioxidant characterization of apricot (*Prunus armeniaca* L.) cultivars and hybrids

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Summary: This report forms a part in our long-term study dedicated to reveal the antioxidant properties of apricot fruits through several years. Nineteen apricot cultivars and 8 hybrids were comparatively analysed. Total phenol content and antioxidant activity showed a good correlation. The tested cultivars and hybrids could be arranged in three groups representing different antioxidant activities, 12 entries were involved in the group with relatively low antioxidant capacity (FRAP value < 1500 mmol/L); 10 accessions were classified in the group with medium antioxidant capacity (1500 mmol/L < FRAP value < 3000 mmol/L); and 5 genotypes were grouped to the category of high antioxidant value (FRAP > 3000 mmol/L). 'Morden 604' produced a surpassingly outstanding antioxidant character. H-donating ability has further supported our results. Phenolic substances were accumulated and ferric reducing ability was increased in the ripe fruits compared to the unripe ones. High levels of variations in the total phenol content and antioxidant capacity in of apricot fruits were revealed in this study. Environment, year or rootstocks may also influence the antioxidant properties of fruits, however it seems to be convincing that crossing parents with outstanding antioxidant character can produce hybrids with higher antioxidant capacity. Hungarian apricots are widely appreciated for their premium flavour and – as it was evidenced in this study – for their relatively good antioxidant properties. However, delicious fruits should be made functional foods having beneficial health effects through accumulating large amounts of antioxidant molecules in the fruit flesh.

Key words: antioxidant capacity, apricot, FRAP, phenol, *Prunus armeniaca*

Introduction

Although Mediterranean areas represent the majority of apricot (*Prunus armeniaca* L.) production in Europe, the Central and Eastern European regions account for nearly a 30% of the continent's production. In Hungary, a 15,000 Mt production yield was recorded last year (*Faostat*, 2004). Cultivar assortment at this area ranges from local cultivars (e.g. Hungarian Best or Hungarian Giant) to the worldwide well-known cultivars ('Bergeron', 'Hargrand' etc.).

Molecular biological studies have just started to revolutionize the horticultural production all over the world. The research institutions supply more and more valuable data; however, many abiotic and biotic factors provoke serious problems that remain to be solved. In countries lying on the northern edge of the profitable cultivation range, winter and spring frosts can seriously injure flowering buds (*Pedryc* et al., 1997; *Pedryc*, 2003). However, in some years frost-hampered yields are also recorded in Spain. Plum pox potyvirus, also known as sharka, is the most devastating viral disease worldwide of stone fruits including apricots. The disease significantly limits stone fruit production in areas where it is established; therefore considerable genetic and breeding efforts are being carried out to alleviate the negative consequences (*Salava* et al., 2002; *Krška* et al., 2002; *Zhebentyayeva* et al., 2002).

Successful breeding programs require germplasm collections of surveyed genetic diversity to design new crosses. Molecular markers, especially SSR markers are intensively used for this purpose (*Pedryc* et al., 1996; *Pedryc* et al., 2002; *Romero* et al., 2003; *Sánchez-Pérez* et al., 2005). In many breeding pograms in the USA or Europe, Asian resistant genotypes are intensively used, which raises a further problem: self-incompatibility of the Asian genotypes may also be inherited in the offsprings. It must be eliminated by careful cross design based on an accurate *S*-genotyping procedure (*Halász* et al., 2004; 2005).

As it can be seen from the above-described trends, new cultivars must meet more and more requirements. Furthermore, fruit quality remains to be the most important parameter. Among others, fruits must be delicious, appealing, and due to the recent changes in consumers' preference the popularity of health promoting foods are continuously increasing. Antioxidant properties are very important from this aspect as increased consumption of antioxidants has been found to be convincing in prevention of coronary heart disease, hypertension or cancer (*Van Duyn & Pivonka*, 2000). Berries are known to possess high polyphenol content and antioxidant activity, but similar analyses in stone fruits have only been initialised and until now restricted mainly to sour cherries (*Veres* et al.; 2003, 2004, 2005abc) and plums (*Lombardi-Boccia* et al., 2004).

Material and method

Plant material

Nineteen apricot cultivars and 8 hybrids were used in the experiments *(Table 1)*. All cultivars and hybrids were obtained from the apricot germplasm collection of the Corvinus University of Budapest, Department of Genetics and Plant Breeding in Szigetcsép.

Extraction methods

About 100 g of fresh apricot fruits (flesh and skin) was properly homogenized and the purée was centrifuged (13500 rpm, 25 min, –4 °C). Supernatant was used for the further analyses.

Determination of total antioxidant capacity and total phenol content

Total antioxidant power was assessed by the FRAP method (Ferric Reducing Ability of Plasma) and measured by spectrophotometric way at $\lambda = 593$ nm (*Benzie & Strain*, 1996). Total phenol content was determined by using Folin-Ciocalteau reagent and measured by spectrophotometer at $\lambda = 760$ nm (*Singleton & Rossi*, 1965). Calibration curves obtained by ascorbic acid (in case of FRAP) and gallic acid (phenol content) were used for the quantitative analyses.

H-donating activity

H-donating activity was determined by the method of Blois (1958) modified by Hatano *et al.* (1988) in the presence of a 1,1-diphenyl-2-picryl-hydrasyl radical (DPPH). Absorbance of the methanolic DPPH-dye was assessed spectrophotometrically at 517 nm. For characterization of the activity, inhibition% was given to the DPPH degradation.

Results and discussion

This report forms a part in our long-term study dedicated to reveal the antioxidant properties of apricot fruits through several years. In the first set of experiments, many apricot

Table 1. Apricot cultivars and hybrids analysed in the experiments

Genotype	Origin	Pedigree	Total phenol content (mmol/L)	FRAP value (mmol/L)
Cultivars				
Asian seedling	ASI	unknown	4.14	772.5
Aurora	USA	RR17-62 × NJA-13	2.50	493.5
Bergeron	FRA	Chance seedling	7.49	3737.1
Ceglédi arany	HUN	Rózsabarack C.1668 × Ceglédi óriás	7.91	2045.6
Ceglédi óriás	HUN	Local selection, Izsák	5.74	2156.1
Ceglédi Piroska	HUN	Ceglédi óriás × Magyar kajszi C.1789	5.01	1735.1
Dionys	ASI×ARM	Shalah × Kok-pshar	1.87	450.6
Goldrich	USA	Sunglo × Perfection	2.65	2200.0
Gönci magyar kajszi	HUN	Selected clone of Hungarian Best	5.10	2184.7
Harcot	CAN	((Geneva × Narmata) × Morden 604) × NJA1	13.39	4307.2
Harmat	HUN	open pollination from Shalah	1.34	555.2
Hybrid 8 (T-8)	HUN	open pollination from Shalah	1.24	451.7
Korai zamatos	HUN	open pollination from Jubilar	2.66	1044.5
Krimskyi Medunec	Ukr	Stepniak (Oranshevo krasnij × Krasnoshchekyi) × Shalah	7.59	2074.1
Mandulakajszi	HUN	unknown	2.13	1629.5
Morden 604	CAN	*P. mandshurica* (Scout × McClure)	32.32	13997.2
NJA-1	USA	Phelps × Perfection	8.78	3031.7
Shalah (syn. Yerevani)	ARM	unknown	2.78	941.4
Samarkandskyi rannii	ASI	unknown	2.48	715.0
Hybrids[a]				
15/1	HUN	NJA-1 × Asian seedling	1.87	752.6
6/11	HUN	Bergeron × Baneasa 4/11	3.76	1504.0
6/7	HUN	Bergeron × Baneasa 4/11	4.29	2712.5
6/62	HUN	Bergeron × Baneasa 4/11	9.1	4696.0
18/52	HUN	Aurora open pollinated	2.91	867.0
18/61	HUN	Aurora open pollinated	1.59	244.6
18/79	HUN	Aurora open pollinated	6.78	2494.1
18/91	HUN	Aurora open pollinated	1.33	390.0

[a]All tested hybrids originate from a breeding program conducted by Dr. A. Pedryc at the Department of Plant Genetics, Corvinus University of Budapest

cultivars and hybrids obtained from an apricot breeding program (*Pedryc* et al., 2005) were comparatively evaluated for total phenol content and their antioxidant activity was characterized by the ferric reducing ability, the FRAP value (*Benzie & Strain*, 1996) (*Table 1*). Total phenol content and antioxidant activity showed a good correlation: samples with higher phenol content possessed elevated FRAP values suggesting that besides the well-known great carotenoid content of apricot fruits, phenolic compounds may also contribute materially to the antioxidant capacity. Similarly, positive correlations were obtained between phenolic compounds and antioxidant activity in peach and plum (*Cevallos-Casals* et al., 2006). By arranging the tested cultivars and hybrids to three artificially established groups according to their antioxidant activity, 11 entries will be involved in the group with relatively low antioxidant capacity (FRAP value < 1500 mmol/L); 10 accessions will be classified in the group with medium antioxidant capacity (1500 mmol/L < FRAP value < 3000 mmol/L); and 5 genotypes will be grouped to the category of high antioxidant value (FRAP > 3000 mmol/L).

The first group contains principally apricots of Armenian ('Shalah', 'Harmat', 'Hyrid 8' etc.) or Central Asian ('Samarkandskyi rannii', Asian seedling etc.) origins. Most of them are characterized by early ripening time (*Pedryc*, 1996; *Romero* et al., 2002), which is likely to be in connection with their low antioxidant capacity. 'Aurora' derives from the New Jersey breeding programme during which many Asian genotypes were used. Some hybrids having Asian genotypes or 'Aurora' in their pedigree have also been characterized by low antioxidant capacity.

The second group with medium antioxidant activity contains all Hungarian cultivars, although these belong to different cultivar groups, the giant-fruited 'Hungarian Óriás', 'Mandulakajszi', as well as 'Hungarian Best'. Most of them are characterized by unknown origin as they were mainly selected at different regions of Hungary. A breeding programme was initialised in Ceglédi Research Center to combine large fruit sizes of 'Ceglédi óriás' with self-compatibility and/or other valuable properties of the 'Hungarian Best' cultivar group (*Surányi*, 1999). New cultivars 'Ceglédi arany' and 'Ceglédi Piroska' show very similar antioxidant activity of the fruit flesh to that of their ancestors. 'Goldrich' and 'Krimskyi Medunec', cultivars from the USA and Ukraine, respectively, are also included in this category.

Among fruits with the highest antioxidant capacity we can also find apricots of different origin: 'Bergeron', a late ripening French cultivar that is very popular in many cultivation areas; 'NJA-1' from the USA and 'Harcot' from Canada. However, the accession producing a surpassingly outstanding antioxidant character is 'Morden 604', which is a *Prunus mandshurica* hybrid (*Table 1*). It possessed nearly 2.5-times higher total phenol content than 'Harcot' the cultivar with the second highest phenol content. Antioxidant capacity in the fruits of 'Morden 604' is more than 3-times higher compared to 'Harcot'. Anyway, we must mention that 'Harcot' with the second highest antioxidant capacity has 'Morden 604' in its pedigree as a grandparent.

The hybrid family (18/52, 61, 79, 91) resulting from the open pollinated 'Aurora' shows antioxidant parameters within the range of 250–2500 mmol AA/L, which indicates that among several factors characters of the pollen parent may also significantly contribute to the antioxidant value of the progenies' fruits. However, the inheritance itself seems to be more complicated as reflected from the values of the Bergeron × Baneasa 4/11 hybrid family, in which considerable differences occur in both phenol content and total antioxidant activity. Nevertheless, it seems convincing that by crossing parents with outstanding antioxidant capacity, high antioxidant value of the descendants can be ensured.

H-donating ability represents the chain-breaking property of fruit juices, a feature that how efficiently an antioxidant agent can serve H to free radicals and neutralize them (*Blázovics* et al., 2003). H-donating activity of the tested 8 cultivars showed a close correlation with the phenol content and the FRAP value (*Figure 1*). Fruit juices of 'Morden 604' and 'Harcot' had the most considerable effect on DPPH stable free radical. Our previous classification according to the 3 groups of low, medium and high antioxidant capacities were also retrieved from this analysis.

We have measured how antioxidant properties of fruits are changing during the ripening process (*Figure 2*). Most of the results indicated that phenolic substances are accumulated and ferric reducing ability is increased in the ripe fruits compared to the unripe ones. H-donating ability has further confirmed these results, especially in 'Goldrich' and 'Ceglédi arany', where change directions of phenol contents and FRAP values were not fully consistent.

Breeding for higher levels of a trait requires that there be substantial variation in the plant breeding population and a sufficiantly high heritability to make recognizable improvement in the trait in successive generations, as it was envisaged in a red raspberry-breeding programme (*Connor* et al., 2005). High levels of variations in the total phenol

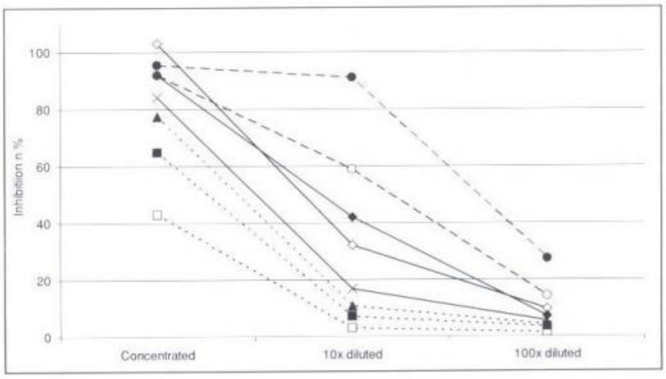

Figure 1. H-donating activity of apricot fruits of cultivars characterized by different antioxidant capacities. □ 'Harmat'; ■ 'Samarkandskyi rannii'; ▲ 'Korai zamatos'; × 'Mandulakajszi'; ◇ 'Gönci magyar kajszi'; ♦ 'Ceglédi óriás'; ○ 'Harcot'; and ● 'Morden 604'. Different line styles represent cultivars from the group with the lowest (– – –), medium (—) or highest (¯ ¯ ¯) antioxidant capacities.

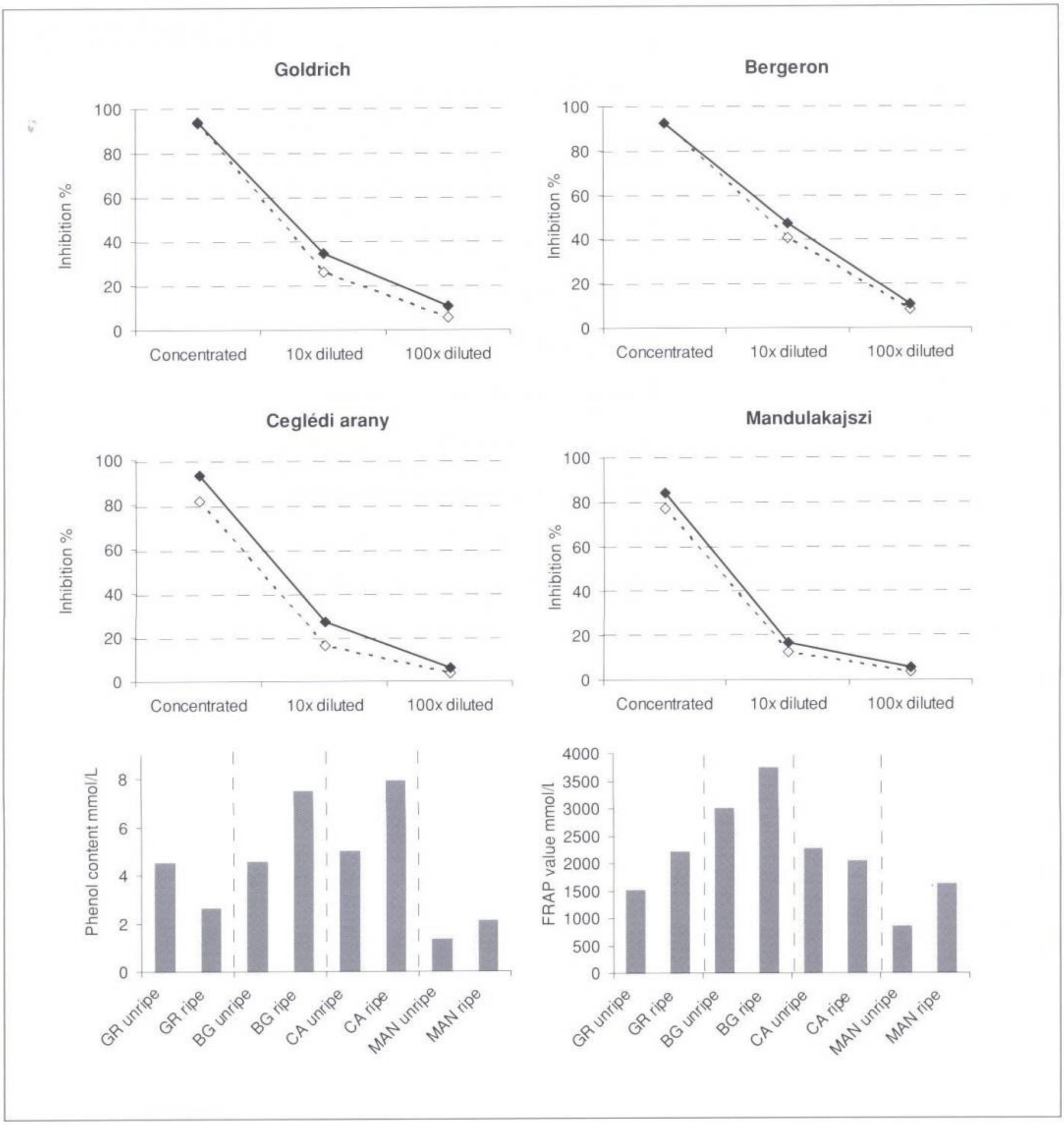

Figure 2. H-donating activity as well as phenol content and FRAP value of ripe (◆) and unripe (◇) apricot fruits. GR 'Goldrich'; BG 'Bergeron'; CA 'Ceglédi arany'; MAN 'Mandulakajszi'.

content and antioxidant capacity of apricot fruits were revealed in this study, similarly to other properties of apricot trees (*Pedryc*, 1992). However, the environment, year or rootstocks may also influence the antioxidant properties of fruits (*Connor* et al., 2005; *Scalzo* et al., 2005), hybrids with higher antioxidant capacity can be produced by crossing parents with outstanding antioxidant character. Such genotypes can be found in the tested breeding programme, which may open many possibilities. Hungarian apricots are widely appreciated for their premium flavour and – as it can be seen from this study – for their relatively good antioxidant properties. However, it can be further enhanced by coupling delicious fruits with the concept of functional food having beneficial health effects through accumulating large amounts and assortments of antioxidant molecules in fruits.

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