Polyphenol content and antiradical activity in different apple varieties

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ABSTRACT: Polyphenols are important antioxidant constituents of apples and they contribute positively to human health because they possess an antiradical activity. Fifteen apple varieties were analysed for their total polyphenol content (TP) by two methods – by Folin-Ciocalteau reagent (FC) and by EBC method with carboxylmethylcellulose/sodium ethylendiamintetraacetate (CMC/EDTA) and their antiradical activity (ARA) by DPPH method using stable free radical 1,1-diphenyl-2-picrylhydrazyl (DPPH·). TP and ARA were determined in freshly expressed apple juice and apples and obtained results were statistically evaluated. The differences between varieties were significant. The correlation between TP content determined by FC method determining all free aromatic hydroxyls and EBC method determining mainly ortho-aromatic hydroxyls was found with $r = 0.73$. The highest differences among analysed varieties were found for ARA values in both, juice and apples and for TP content determined by FC in apples. High polyphenol content was found in Jonagold, Jonalord, Melodie and Melrose varieties both, in apples and juices; on the contrary low TP contents were estimated in Gloster and Rosana varieties. The highest ARA levels were found in Rajka, Bohemia and Melrose varieties, compared to low ARA levels found in apple fruits of Šampion and Topaz varieties.

Keywords: apple varieties; apple juice; polyphenols; antiradical activity

Consumption of fruits or vegetables has been shown to be effective in the prevention of heart and cardiovascular diseases and atherosclerosis (Stangl et al. 2005). These benefits are often attributed to the high antioxidant content of some plant resources. Besides size, shape, colour and taste of the fruit, a new quality parameter is becoming more and more popular – a bioactivity of the fruit and its health-promoting effect for the consumer (Schirrmacher, Schempp 2003). Apples are commonly eaten and are large contributors of phenolic compounds in European and North American diets (Wolfe et al. 2003). Apples are commonly eaten in Middle Europe during the whole growth period and are large contributors of secondary plant metabolites in human diets (Schmitz-Eiberger et al. 2003). Though the antioxidant activity is caused both, by phenolic compounds and ascorbic acid, it was demonstrated by Gliszczynska-Swiglo and Tyrakowska (2003) that Trolox® equivalent antioxidant capacity (TEAC) value depends mainly on their polyphenol content. Apples are a major source of flavonoids in Western diet (Lachman et al. 2000a) and they may help to protect against chronic diseases with their antioxidant mechanisms (Lotito, Frei 2004). Correlation studies showed that total phenolic compounds contribute strongest to the TEAC antioxidant value of apple while the contribution of ascorbic acid seemed to be low. Flavonols, flavanols, procyanidins, dihydrochalcones, and hydroxycinnamates were the identified phenolic classes in peel tissue, and the most abundant compounds are epicatechin, procyanidin 132, and phloridzin (Chinnici et al. 2004). The major phenolics in pulps were procyanidins and hydroxycinnamates and flavonols in amounts < 20 mg/kg fresh weight (FW). Some of them serve as substrates to enzymic browning of apple tissue by the effect of polyphenol oxidases (Lachman et al. 2000b). The antioxidant activities comprised contributions from polyphenols,

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phenolic acids, and flavonoids and correlated well with polyphenols and flavonoids (0.9207) (Leontowicz et al. 2003). Also Lee et al. (2003) confirm that flavonoids such as quercetin, epicatechin, and procyanidin B-2 rather than vitamin C contribute significantly to the total antioxidant activity of apples. A highly linear relationship (R^2 > 0.97) was attained between concentrations and total antioxidant capacity of phenolics and vitamin C. Among individual compounds the estimated contribution of major phenolics and vitamin C to the total antioxidant capacity of 100 g of fresh apples expressed in vitamin C equivalent antioxidant capacity (VCEAC) was: quercetin (40.39) > epicatechin (23.10) > procyanidin B-2 (22.07) > vitamin C (12.80) > phloretin (9.11) > chlorogenic acid (8.75). In apples five major polyphenolic groups with the total of sixteen individual compounds were found, among which the dihydroxycinnamic acid esters, phloretin glycosides, and flavan-3-ols were found in both flesh and peel, whereas quercetin glycosides were almost exclusively found in the peel (Tsao et al. 2003). In both apple peel and flesh, the predominant group of polyphenolics was the procyanidins, followed by quercetin glycosides in the peel and hydroxycinnamic acid esters in the flesh. Compared to the pulp of the apples, skin-extracts show a higher antioxidant potential (Schirrmacher, Schempp 2003). Wolfe et al. (2003) confirmed that within each variety, the total phenolic and flavonoid contents were significantly the highest in the peels, followed by the flesh. As Chinnici et al. (2004) discovered, among the single classes of compounds, procyanidins (in peels and pulps) and flavonols (in peels) statistically correlated to the total antioxidant capacity.

Content of polyphenolic antioxidants is affected by many factors, mainly by apple variety (Davey, Keulemans 2004; Wolfe et al. 2003; Schmitz-Eiberger et al. 2003), fruit development (Kondo et al. 2002), conditions during long-term storage (Leja et al. 2003), superficial scald development in apple fruit (Fernandez-Trujillo et al. 2003), and solar radiation (Colavita et al. 2004). The aim of this study was to compare the content of total phenolics and antioxidant activity of fifteen apple varieties.

MATERIAL AND METHODS

Plant material and its preparation: Fruits from 15 apple varieties (Table 1) were obtained from apple trees growing on Experimental Station of Czech University of Agriculture in Prague in Troja, on Research and Breeding Institute of Pomology in Holovousy and on Research Institute of Plant Production in Prague-Ruzyně from the harvest in 2004. The apples were harvested in proper harvest maturity of the given variety and analysed in consumer maturity 50 to 60 days after the harvest. One portion of fresh

Table 1. Total antiradical activity ARA (%) and polyphenol content TP in apple juice (mg/l) and apples (mg/kg FW) of 15 apple varieties (average ± STD)

Sample*	Varieties of apples	TP-FC apples	TP-EBC apples	ARA apples	TP-FC juice	TP-EBC juice	ARA juice
(1)	Bohemia	939.11 ± 12.69	168 ± 5.22	13.71 ± 0.77	419.89 ± 35.19	90 ± 13.92	7.49 ± 0.38
(2)	Gloster	805.92 ± 0.00	134 ± 2.32	10.17 ± 1.28	360.91 ± 8.87	90 ± 32.47	5.83 ± 0.99
(3)	Goldstar	995.69 ± 6.03	113 ± 8.12	9.03 ± 0.75	352.06 ± 84.83	78 ± 4.06	7.49 ± 0.54
(4)	Jonagold	1,216.43 ± 12.64	148 ± 0.00	9.53 ± 0.83	423.76 ± 24.86	107 ± 51.03	9.66 ± 0.74
(5)	Jonalord	939.06 ± 8.03	116 ± 1.16	13.80 ± 1.34	518.05 ± 24.89	151 ± 8.70	9.71 ± 1.19
(6)	Melodie	1,116.62 ± 11.31	185 ± 5.80	7.50 ± 1.03	697.41 ± 12.71	149 ± 10.44	7.97 ± 0.76
(7)	Melrose	1,343.06 ± 16.91	203 ± 21.10	13.69 ± 1.64	336.47 ± 51.37	98 ± 19.71	6.70 ± 1.91
(8)	Otava	895.37 ± 29.41	128 ± 1.16	12.59 ± 2.01	367.22 ± 100.71	104 ± 4.06	4.32 ± 1.20
(9)	Rajka	986.33 ± 36.69	155 ± 2.90	17.52 ± 1.94	355.32 ± 50.33	90 ± 0.58	7.84 ± 0.85
(10)	Rosana	760.03 ± 33.84	103 ± 0.58	12.48 ± 1.09	434.09 ± 30.10	90 ± 22.03	2.74 ± 1.03
(11)	Rubín	1,059.37 ± 0.55	159 ± 2.32	8.09 ± 2.41	372.90 ± 37.31	95 ± 15.08	7.13 ± 1.11
(12)	Rubinola	904.42 ± 23.01	118 ± 5.80	13.29 ± 1.36	418.69 ± 110.26	136 ± 3.47	8.40 ± 1.76
(13)	Selena	1,134.15 ± 29.52	161 ± 2.32	11.83 ± 0.57	331.11 ± 85.50	85 ± 16.82	13.50 ± 1.32
(14)	Šampion	1,290.52 ± 5.43	161 ± 1.16	7.16 ± 1.88	407.27 ± 29.64	94 ± 3.48	11.53 ± 0.53
(15)	Topaz	1,055.23 ± 9.86	162 ± 6.96	7.04 ± 0.54	393.47 ± 85.09	105 ± 8.12	5.87 ± 1.93
Average		1,029.42 ± 15.73	148 ± 4.46	11.16 ± 1.30	412.57 ± 51.44	104 ± 14.26	7.75 ± 1.10

*Five apple fruits of each variety were sampled for the analyses

apples (five apple fruits of each variety) was liquidised and apple juice obtained by pressing through gauze was percolated with N_2 for 5 min and left stand in the 20 ml test tubes sealed with paraffin in the refrigerator in the dark for ca. 1 hour before analysis. Other portion of fresh samples (obtained from five apple fruits of each variety) was after liquidising extracted with 80% water ethanol in darkness and left at laboratory temperature for seven days. The weight of samples represented 10 g. Obtained extracts were converted into 100 ml volumetric flask and adjusted with 80% water ethanolic solution to the mark. 0.5 ml aliquots were pipetted for the determination.

Determination of total phenolics (TP) by Folin-Ciocalteau (FC) method: For the determination of total polyphenols the adjusted method (Lachman et al. 2000c) with Folin-Ciocalteau reagent was used. Sample (0.5 ml) was pipetted into 50 ml volumetric flask and diluted with distilled water. Then 2.5 ml of Folin-Ciocalteau reagent was added and after agitation 7.5 ml of 20% sodium carbonate solution was added. After 2 hours standing at laboratory temperature absorbance of samples was measured on the spectrophotometer Helios γ (Spectronic Unicam, GB) at wavelength λ = 765 nm against blank. Results were expressed as gallic acid equivalents (in mg/kg fresh matter – FM in the case of fresh material and mg/l in the case of apple juice, gallic acid Merck, D). Average results were obtained from three parallel determinations.

Determination of total phenolics (TP) by EBC method by Basařová et al. (1993): Into 25 ml volumetric flask to 10 ml of apple sample, 8 ml of carboxylmethylcellulose/sodium ethylendiamintetraacetate (CMC/EDTA) and 0.5 ml ammonium ferric citrate solutions were added. After thorough agitation 0.5 ml dilute ammonia solution was added and after agitation the flasks were adjusted with distilled water till the mark. After 10 minutes standing at laboratory temperature absorbance of samples was measured on the spectrophotometer Helios γ (Spectronic Unicam, GB) at wavelength λ = 600 nm against blank. Blank: Into 25 ml volumetric flask to 10 ml of apple sample 8 ml of CMC/EDTA and 0.5 ml diluted ammonia solutions were added and then the volume was adjusted with water to the mark. CMC/EDTA solution: 10 g CMC and 2 g EDTA was diluted in water (ca. 1.5 hrs) in a 1,000 ml volumetric flask and filtered. CMC with low viscosity (Merck, Germany) was used. Ammonium ferric citrate solution: 3.5 g ammonium ferric citrate (green powder) was diluted in water in 100 ml volumetric flask. Ammonia solution: 1 part of concentrated ammonia solution was diluted in 2 parts of distilled water. TP was calculated as $TP = A_{600} \times 820$, where TP are total phenolics (mg/l) and A_{600} is measured absorbance. Average results were obtained from three parallel determinations.

Determination of antiradical activity (ARA) by DPPH· method: ARA was measured after the reaction with free stable radical 1,1-diphenyl-2-picrylhydrazyl (DPPH·) according to Molyneux (2004). Fresh solution of DPPH in the concentration of 25 mg DPPH in 1 l of methanol should be prepared before the determination. 3 ml of violet DPPH solution is pipetted into plastic cuvettes of 10 mm length and absorbance is measured (t_0) at wavelength λ = 515 nm on the spectrophotometer Helios γ (Spectronic Unicam, GB). Then 5 µl of sample is added and after stir with the hand stirrer in cuvettes the reaction mixture is left to stand for 5 min. The absorbance is measured again (t_5) and ARA is calculated from the decrease of absorbance in % according to relation: % of inactivation = $100 - [(A_{t5}/A_{t0}) \times 100]$. Average results were obtained from seven parallel determinations and expressed as % of inactivation. It is also possible to

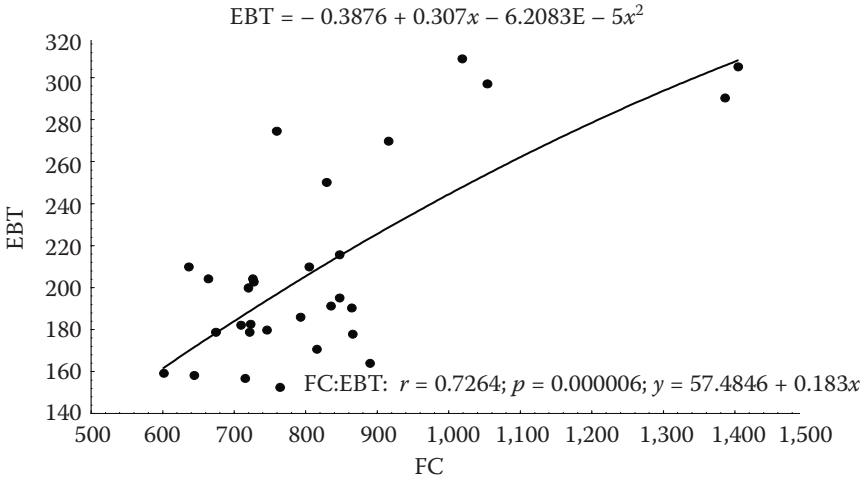

Fig. 1. Regression between TP content determined by EBT and FC in apples

Table 2. Scheffé variance analysis between varieties for ARA in apples

Sample**	(1) 13.707	(2) 10.166	(3) 9.0298	(4) 9.5318	(5) 13.804	(6) 7.5005	(7) 13.690	(8) 12.586	(9) 17.518	(10) 12.478	(11) 8.0857	(12) 13.292	(13) 11.832	(14) 7.1596	(15) 7.0352
(1)		0.098260	0.001591*	0.012210*	1.000000	0.000001*	1.000000	0.999880	0.043485*	0.999620	0.000017*	1.000000	0.963361	0.000000*	0.000000*
(2)	0.098260		0.999857	1.000000	0.074282	0.580862	0.102941	0.747256	0.000000*	0.810114	0.911514	0.270825	0.988143	0.342730	0.268230
(3)	0.001591*	0.999857		1.000000	0.001037*	0.995202	0.001710*	0.094075	0.000000*	0.126556	0.999987	0.008776*	0.481674	0.964072	0.937050
(4)	0.012210*	1.000000	1.000000		0.008430*	0.926826	0.012997*	0.312595	0.000000*	0.381976	0.997415	0.051261	0.816252	0.776372	0.698473
(5)	1.000000	0.074282	0.001037*	0.008430*		0.000000*	1.000000	0.999661	0.059083	0.999050	0.000010*	1.000000	0.942929	0.000000*	0.000000*
(6)	0.000001*	0.580862	0.995202	0.926826	0.000000*		0.000001*	0.000247*	0.000000*	0.000411*	1.000000	0.000007	0.006672*	1.000000	1.000000
(7)	1.000000	0.102941	0.001710*	0.012997*	1.000000	0.000001*		0.999901	0.041192*	0.999679	0.000019*	1.000000	0.966224	0.000000*	0.000000*
(8)	0.999880	0.747256	0.094075	0.312595	0.999661	0.000247*	0.999901		0.000508*	1.000000	0.003366*	1.000000	0.999999	0.000046*	0.000025*
(9)	0.043485*	0.000000*	0.000000*	0.000000*	0.059083	0.000000*	0.041192*	0.000508*		0.000306*	0.000000*	0.010046*	0.000012*	0.000000*	0.000000*
(10)	0.999620	0.810114	0.126556	0.381976	0.999050	0.000411*	0.999679	1.000000	0.000306*		0.005246*	0.999998	1.000000	0.000080*	0.000043*
(11)	0.000017*	0.911514	0.999987	0.997415	0.000010*	1.000000	0.000019*	0.003366*	0.000000*	0.005246*		0.000139*	0.053389	0.999990	0.999948
(12)	1.000000	0.270825	0.008776*	0.051261	1.000000	0.000007*	1.000000	1.000000	0.010046*	0.999998	0.000139*		0.997143	0.000001*	0.000001*
(13)	0.963361	0.988143	0.481674	0.816252	0.942929	0.006672*	0.966224	0.999999	0.000012*	1.000000	0.053389	0.997143		0.001619*	0.000935*
(14)	0.000000*	0.342730	0.964072	0.776372	0.000000*	1.000000	0.000000*	0.000046*	0.000000*	0.000080*	0.999990	0.000001*	0.001619*		1.000000
(15)	0.000000*	0.268230	0.937050	0.698473	0.000000*	1.000000	0.000000*	0.000025*	0.000000*	0.000043*	0.999948	0.000001*	0.000935*	1.000000	

* Significant difference at $P < 0.05$

** (1) Bohemia, (2) Gloster, (3) Goldstar, (4) Jonagold, (5) Jonalord, (6) Melodie, (7) Melrose, (8) Otava, (9) Rajka, (10) Rosana, (11) Rubín, (12) Rubinola, (13) Selena, (14) Šampion, (15) Topaz

make the calibration curve of ascorbic acid (Sigma). R^2 for ascorbic acid is 0.9991.

Statistical evaluation: The results [three parallel determinations from three (TP/EBC) and seven parallel determinations (ARA)] were statistically evaluated with Statistica 7.0 programme by the analysis of variance with multiple grouping. More detailed evaluation was performed by Scheffé test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

Summary results are given in Table 1. Total polyphenol content determined with Folin-Ciocalteau assay ranged from 760 mg/kg FW in cv. Rosana to 1,343 mg/kg FW in cv. Melrose. It corresponds to values obtained by Vrhovsek et al. (2004), who estimated total polyphenols expressed as (+/–) catechin in eight apple varieties in range 662 to 2,119 mg/kg FW depending on the variety and the results of Thielen et al. (2004), where mash concentrations ranged from 170 up to 1,004 mg/kg fresh weight. Content of total phenols in apple juice was lesser ranging from 331 mg/l in Selena variety up to 697 mg/l in Melodie variety. Lichtenhäler and Marx (2005) evaluated total oxidant scavenging capacity of apple juices in comparison with common European fruit and vegetable juices as average for hydroxyl radicals and apple, tomato, carrot, and sauerkraut juices were classified into the group with even lower antioxidant capacities against peroxyl radicals and peroxynitrite. Thielen et al. (2004) also confirmed a huge variation of polyphenol amounts (89–437 mg/l) and Kahle et al. (2005) estimated 154–178 mg/l for dessert apple juices, whereas for "old" German cider apple va-

Table 3. Scheffé variance analysis between varieties for ARA in apple juice

Sample**	(1) 7.4884	(2) 5.8321	(3) 7.4853	(4) 9.6591	(5) 9.7114	(6) 7.9732	(7) 6.6951	(8) 4.3152	(9) 7.8403	(10) 2.7376	(11) 7.1255	(12) 8.4024	(13) 13.491	(14) 11.534	(15) 5.8695
(1)		0.945259	1.000000	0.647751	0.603919	1.000000	0.999988	0.051435	1.000000	0.000017*	1.000000	0.999923	0.000000*	0.000959*	0.955101
(2)	0.945259		0.946148	0.002943*	0.002264*	0.671839	0.999963	0.975215	0.772638	0.068508	0.995110	0.318772	0.000000*	0.000000*	1.000000
(3)	1.000000	0.946148		0.645135	0.601237	1.000000	0.999989	0.052045	1.000000	0.000017*	1.000000	0.999919	0.000000*	0.000943*	0.955868
(4)	0.647751	0.002943*	0.645135		1.000000	0.936470	0.106858	0.000000*	0.884233	0.000000*	0.346053	0.996433	0.002873*	0.855771	0.003540*
(5)	0.603919	0.002264*	0.601237	1.000000		0.918428	0.089825	0.000000*	0.857698	0.000000*	0.307484	0.994432	0.003719*	0.882538	0.002732*
(6)	1.000000	0.671839	1.000000	0.936470	0.918428		0.995701	0.006646*	1.000000	0.000001*	0.999971	1.000000	0.000000*	0.010402*	0.701667
(7)	0.999988	0.999963	0.999989	0.106858	0.089825	0.995701		0.470028	0.998761	0.001519*	1.000000	0.929444	0.000000*	0.000010*	0.999980
(8)	0.051435	0.975215	0.052045	0.000000*	0.000000*	0.006646*	0.470028		0.012189*	0.964350	0.171319	0.000767*	0.000000*	0.000000*	0.968877
(9)	1.000000	0.772638	1.000000	0.884233	0.857698	1.000000	0.998761	0.012189*		0.000002*	0.999997	1.000000	0.000000*	0.005624*	0.798017
(10)	0.000017*	0.068508	0.000017*	0.000000*	0.000000*	0.000001*	0.001519*	0.964350	0.000002*		0.000144*	0.000000*	0.000000*	0.000000*	0.059879
(11)	1.000000	0.995110	1.000000	0.346053	0.307484	0.999971	1.000000	0.171319	0.999997	0.000144*		0.995749	0.000000*	0.000128*	0.996456
(12)	0.999923	0.318772	0.999919	0.996433	0.994432	1.000000	0.929444	0.000767*	1.000000	0.000000*	0.995749		0.000002*	0.060007	0.346601
(13)	0.000000*	0.000000*	0.000000*	0.002873*	0.003719*	0.000000*	0.000000*	0.000000*	0.000000*	0.000000*	0.000000*	0.000002*		0.806902	0.000000*
(14)	0.000959*	0.000000*	0.000943*	0.855771	0.882538	0.010402*	0.000010*	0.000000*	0.005624*	0.000000*	0.000128*	0.060007	0.806902		0.000000*
(15)	0.955101	1.000000	0.955868	0.003540*	0.002732*	0.701667	0.999980	0.968877	0.798017	0.059879	0.996456	0.346601	0.000000*	0.000000*	

rieties 261–970 mg/l were determined. High polyphenol content was found in apples and juices of Jonagold, Jonalord, Melodie and Melrose varieties. On the contrary low TP contents was estimated in apple fruits of Rosana and Gloster varieties, which corresponds to low TP content in juices. The highest ARA levels were found in Rajka, Bohemia and Melrose varieties contrary to low ARA levels found in Šampion and Topas varieties, which does not unambiguously correspond to their low antioxidant antiradical activities in juices (Table 1).

We agree with the results obtained by Schmitz-Eiberger et al. (2003) and Schirrmacher and Schempp (2003) that the high content of total polyphenols was demonstrated in Jonagold and Jonalord varieties with high antiradical activity in apples and juices. Leja et al. (2003) estimated relatively high total polyphenols in Jonagold and Šampion varieties, but in their results Jonagold variety showed total phenols higher in comparison with Šampion, while the contents of anthocyanins were comparable. In their work the increase of the antioxidant activity during storage correlated with an increase of the concentration of catechin and phloridzin and this ascertainment was also confirmed by Napolitano et al. (2004). Thus the loss of L-ascorbic acid during storage among the early varieties could be balanced by the increase of total polyphenols (Davey, Keulemans 2004).

A relatively good correlation between TP content determined by FC method and EBC method was found with $r = 0.73$ (Fig. 1) despite the fact, that contrariwise to FC method EBC method determines only free ortho-dihydroxy groups (Basařová et al. 1993). The highest differences among analysed varieties were found for ARA values in both, juice and apples and for TP content determined by FC in apples (Tables 2 to 4). The differences between varieties were significant. Like Arnous et al. (2001) in red wines, we found only a non-significant link between the antiradical activity and the total phenolics suggesting that flavanols, esp. proanthocyanidins could be the class of polyphenols that account for hydroxyl free radical scavenging efficacy at a great deal (Vanzani et al. 2005). This could be caused by different amounts of individual phenolics

Table 4. Scheffé variance analysis between varieties for TP FC in apples

Sample**	(1) 469.56	(2) 400.76	(3) 497.85	(4) 608.21	(5) 469.53	(6) 558.31	(7) 671.53	(8) 447.69	(9) 493.17	(10) 380.01	(11) 529.68	(12) 452.21	(13) 567.08	(14) 645.26	(15) 527.62
(1)		0.625163	0.999633	0.012174*	1.000000	0.263254	0.000235*	0.999982	0.999954	0.252650	0.793189	0.999999	0.162723	0.001141*	0.827948
(2)	0.625163		0.166874	0.000172*	0.625677	0.003584*	0.000006*	0.956536	0.216744	0.999999	0.022966*	0.916919	0.002053*	0.000023*	0.026272*
(3)	0.999633	0.166874		0.075219	0.999629	0.787302	0.001293*	0.929915	1.000000	0.046979*	0.998691	0.964792	0.616120	0.006887*	0.999358
(4)	0.012174*	0.000172*	0.075219		0.012154*	0.932326	0.734707	0.002962*	0.056063	0.000054*	0.430224	0.003956*	0.984891	0.994122	0.392360
(5)	1.000000	0.625677	0.999629	0.012154*		0.262911	0.000235*	0.999982	0.999953	0.252982	0.792752	0.999999	0.162489	0.001139*	0.827546
(6)	0.263254	0.003584*	0.787302	0.932326	0.262911		0.062930	0.074034	0.699002	0.000972*	0.999582	0.097854	1.000000	0.288873	0.999110
(7)	0.000235*	0.000006*	0.001293*	0.734707	0.000235*	0.062930		0.000068*	0.000968*	0.000002*	0.009892*	0.000088*	0.108122	0.999840	0.008645*
(8)	0.999982	0.956536	0.929915	0.002962*	0.999982	0.074034	0.000068*		0.965706	0.648103	0.367831	1.000000	0.042518*	0.000305*	0.404415
(9)	0.999954	0.216744	1.000000	0.056063	0.999953	0.699002	0.000968*	0.965706		0.063207	0.994864	0.985466	0.520356	0.005088*	0.997085
(10)	0.252650	0.999999	0.046979*	0.000054*	0.252982	0.000972*	0.000002*	0.648103	0.063207		0.005951*	0.555194	0.000570*	0.000008*	0.006805*
(11)	0.793189	0.022966*	0.998691	0.430224	0.792752	0.999582	0.009892*	0.367831	0.994864	0.005951*		0.450189	0.993589	0.054229	1.000000
(12)	0.999999	0.916919	0.964792	0.003956*	0.999999	0.097854	0.000088*	1.000000	0.985466	0.555194	0.450189		0.056724	0.000398*	0.490486
(13)	0.162723	0.002053*	0.616120	0.984891	0.162489	1.000000	0.108122	0.042518*	0.520356	0.000570*	0.993589	0.056724		0.436706	0.989514
(14)	0.001141*	0.000023*	0.006887*	0.994122	0.001139*	0.288873	0.999840	0.000305*	0.005088*	0.000008*	0.054229	0.000398*	0.436706		0.047537*
(15)	0.827948	0.026272*	0.999358	0.392360	0.827546	0.999110	0.008645*	0.404415	0.997085	0.006805*	1.000000	0.490486	0.989514	0.047537*	

constituting apple phenolic complexes of varieties with different antioxidant and antiradical efficiency. Vanzani et al. (2005) estimated that polyphenols contributed from 47% (Granny Smith) to 78% (Braeburn), with an average value of 54% to the total antioxidant efficiency experimentally measured in the apple extracts. However, Tsao et al. (2005) found significant correlations between polyphenol content and the Trolox equivalent antioxidant capacity value (TEAC) and Gliszczynska-Swiglo and Tyrakowska (2003) between total phenolic content and the ferric reducing/antioxidant power. No correlations for vitamin C indicated that the TEAC value of apple juices and apples depends mainly on their polyphenol content (Vanzani et al. 2005). In agreement with the results obtained by Wang et al. (1996) who estimated the total antioxidant activity of twelve fruits and five commercial fruit juices using automated oxygen radical absorbance capacity (ORAC) assay and apples classified as average antioxidant sources among fruits. Interesting fact was that the contribution of the fruit pulp fraction to the total ORAC activity of fruit was less than 10%. DPPH does react neither with flavonoids that contain no OH-groups in B-ring (Yokozawa et al. 1998) nor with aromatic acids containing only one OH-group (Roginsky, Lissi 2005; von Gadov et al. 1997). It is interesting that TP contents in apple juices or apples determined by EBC are comparable to those found for beers (Basařová et al. 1993).

Some novel production methods (Van der Sluis et al. 2004) use selected apple varieties (Jonagold, Elstar, Golden Delicious) for the production of enriched juice by applying an alcoholic extraction either on the pulp or on the pomace with the antioxidant activity 5 times higher than in conventional apple juice. The high content of polyphenolic antioxidants in some varieties, especially in Jonagold, Jonalord, Melodie, and Melrose

and the related antiradical activity indicates that breeding could enhance the content of these bioactive components. The fruits with high contents of phenolic substances may impart health benefits when consumed and should be regarded as a valuable source of antioxidants.

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Obsah polyfenolů a antiradikálová aktivita v různých odrůdách jablek

ABSTRAKT: Polyfenoly jsou důležité antioxidační obsahové látky jablek a pozitivně přispívají ke zdraví lidí, protože vykazují antiradikálovou aktivitu. Byl stanoven obsah celkových polyfenolů (TP) dvěma metodami – Folin-Ciocalteauovým reagens (FC) a EBC metodou s karboxymethylcelulosou/natrium-ethylendiamintetraacetátem (CMC/EDTA) a antiradikálová aktivita (ARA) za použití DPPH· metody pomocí stabilního volného radikálu 1,1-difenyl-2-pikrylhydrazylu u 15 odrůd jablek. TP a ARA byly stanoveny v čerstvých jablkách a ve vylisované jablečné šťávě a získané výsledky byly statisticky vyhodnoceny. Byla nalezena korelace mezi obsahem TP stanoveným metodou FC, která stanovuje především všechny volné aromatické hydroxylové skupiny, a EBC metodou stanovující zejména orto-aromatické hydroxylové skupiny s korelačním koeficientem r = 0,73. Největší rozdíly mezi analyzovanými odrůdami byly nalezeny u hodnot ARA v jablkách i v jablečné šťávě a u obsahu TP stanoveném FC v jablkách. Vysoké obsahy polyfenolů byly nalezeny v jablkách a jablečné šťávě odrůd Jonagold, Jonalord, Melodie a Melrose a naopak nízké obsahy polyfenolů u odrůd Gloster a Rosana. Nejvyšší antiradikálovou antioxidační aktivitu vykazovaly odrůdy Rajka, Bohemia a Melrose, zatímco nízké hodnoty byly stanoveny u odrůd Šampion a Topaz.

Klíčová slova: odrůdy jablek; jablečná šťáva; polyfenoly; antiradikálová aktivita

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