

ASSESSMENT OF NUTRITIONAL PARAMETERS OF NATIVE APPLE CULTIVARS AS NEW GENE SOURCES

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Abstract

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Although there are tens of different apple varieties in Europe, only some of them were purposefully bred and selected in the past. In spite of the fact that they can have outstanding nutritional and technological properties, the majority of them are of only a local importance. The objective of this study was to show and popularize altogether 35 local apple varieties which are typical of the conditions of Central Europe. However, their genetic uniqueness represents an irreplaceable ecological wealth and for that reason these local varieties could become a new and outstanding source of nutrients and food. Today, they can be used not only for direct consumption and in food industry but also as a potential material for further breeding and selection. It was found out in our experiments that the highest content of total acids was shown by the variety 'Citronové zimní' (6.1 g.kg⁻¹ of fresh matter). As far as the content of pectins was concerned, the highest levels were found out in the variety 'Strymka' (3.26% in fresh matter). Of minerals, potassium showed the highest levels in fruit; for example, the variety 'Boikovo' contained 9.70 ppm of this element in dry matter. Peels showed approximately 7 times higher antioxidant capacity than the flesh. For example, peels of the variety 'Bernské růžové' showed antioxidant capacity of as much as 56.65 mmol of trolox per kg of fresh matter. This paper should contribute to efforts focused on saving of genetic variability of apples and their further application both in human nutrition and a further breeding and selection under conditions of pomological and alimentary practice.

apples, local varieties, titrable acidity, pectins, minerals, antioxidant capacity

Today, apple trees are the most popular and the most grown core fruit species in Europe. Due to their nutritional properties, apples are rather valued as fruit species (Gallus *et al.*, 2005). Thanks to the content of minerals and polyphenolic compounds the consumption of apples is recommended to prevent cardiovascular or oncogenic diseases (Wojdylo *et al.*, 2008).

In association with the process of intensification of agricultural production, the last century was characterised by extensive growing and breeding of only several selected and nowadays commercially successful apple varieties. Tens of others are only on the margin of general interest. A further propagation of local (native) cultivars is prevented above all by the

fact that their sensory and technological properties are not as good as those of purposefully bred and selected ones although their local importance may be rather considerable (Goland and Bauer, 2004). Nevertheless, many of these native varieties show a significant tolerance to pathogens and pests, a high adaptability to less favourable climatic and soil conditions, good resistance to stress (Tetera, 2003) and the uniqueness of their relationship to nutritional properties (Toth *et al.*, 2004).

In the Czech Republic, apple trees are the most frequent fruit species. The main objective of this paper is to emphasize some nutritional parameters of 35 typical Czech local apple varieties. During the process of landscape cultivation and care,

many of the recommended apple varieties were spreading in Bohemia and Moravia in the past. This process was also accompanied with the selection of local apple varieties (Hričovský *et al.*, 2003). The described varieties, however, could partly find a wider application in human nutrition (Monschein *et al.*, 2006) and it is also necessary to mention the possibility of their application in the breeding work and selection (Laurens, 1996).

MATERIAL AND METHODS

The main hypothesis of this paper is not to prove the dependence existing between model factors on the one hand and nutritional parameters on the other. Its main objective is to emphasize the abundance of genetic diversity as related to growing and utilisation of apple trees above all due to the fact that the Czech Republic represents historically one of the richest breeding potentials in the world. For experiments, altogether 35 apple varieties were used; some of them, however, originated not only from Bohemia and Moravia but also from some other countries. In spite of this, the majority of them are typical just of the territory of Central Europe and it is not possible to neglect or ignore their, often hundred-year-old, use for nutritional purposes (Tetera, 2006). This paper compares nutritional parameters of individual varieties, tries to point out their prospects and to contribute to the preservation of their originality for the contemporary pomicultural practice. Its most important objective is to save the genetic variability of apple trees and to enable their further use in the fields of human nutrition and pomicultural practice.

Sample collection and their preparation for chemical analyses

Apples were harvested from five trees of each variety under study in the stage of consume ripeness. Each of these samples involved 3 replications from each tree (i.e. altogether 15). The samples were stored in a controlled environment at the temperature of +2 °C and under conditions of 85% of relative humidity (Kyzlink, 1990). For analyses all fruit without core were used (i.e. peel and flesh together). The samples were obtained from 35 apple tree varieties, 29 of which originated from the Tišnov region. The other samples were harvested in the White Carpathians in the cadastre of Valašské Klobouky. In the past the White Carpathians were declared as a protected landscape area and the described varieties are quite typical of this region (Tetera, 2006).

Description of locality Tišnov

Fruits were harvested in experimental orchards of Mendel University in Brno. These orchards are situated in the Tišnov vicinity, the Czech Republic. The average altitude is 435 m above sea level, and the mean annual temperature and precipitation are 7.5 °C and 696 mm, respectively. The soil type was classified as the Mesotrophic Cambisol.

Description of locality Valašské Klobouky

Fruits were harvested in experimental orchards of Tomas Bata University in Zlín. These orchards are situated in the south-western part of the White Carpathians near Zlín, the Czech Republic. The average altitude is 340 m above sea level, and the mean annual temperature and precipitation are 7.9 °C and 760 mm, respectively. The soil type was classified as the Mesotrophic Cambisol.

Chemical analyses

With the exception of the determination of pectin substances, vitamin C and antioxidant capacity, all other chemical analyses were performed using the standard methods described by Novotný (2000).

Dry matter content was measured after drying off to a constant weight at the standard temperature of $105 \text{ }^{\circ}\text{C} \pm 2 \text{ }^{\circ}\text{C}$ – the apparatus VENTICELL 111 (BMT, Brno, Czech Republic). Soluble solid content (SSC) was estimated by means of polarimetric measurements in juice obtained after squeezing the fruit using a digital instrument HI 96801 (Hanna Instruments, Woonsocket, RI, USA). The content of total acids was measured by potentiometric titration; 20 g of homogenised sample were extracted for 30 minutes in a shaker in 200 ml of re-distilled water at the temperature of 80 °C. The obtained extract was filtered and titrated with sodium hydroxide to the pH value of 8.1 by using the apparatus pH211 (Hanna Instruments, Woonsocket, RI, USA). The obtained result was converted to the content of acids in $\text{g}\cdot\text{kg}^{-1}$ of fresh matter (FM).

Mineral content assay

The sample was dried off to a constant weight – the apparatus VENTICELL 111 (BMT, Brno, Czech Republic) – in a drier at the temperature of $105 \text{ }^{\circ}\text{C} \pm 2 \text{ }^{\circ}\text{C}$. A portion of 1 g of homogenised dry matter (DM) (the size of particles up to 1 mm) was thereafter mineralized in a mixture of concentrated sulphuric acid and 30% hydrogen peroxide. Mineralized samples were quantitatively transferred into a 250 ml volumetric flask and its volume was refilled to the volume with re-distilled water. The mineralizate was measured in an atomic absorption spectrometer PHILIPS PU 9200X (Philips, Amsterdam, the Netherlands). The content of total nitrogen was measured according to Kjeldahl using the apparatus KJELTEC TM 2300 (Foss, Hillerod, Denmark). The amount of minerals was expressed as ppm (respectively ppb) in DM.

Pectin substances content assay

The content of pectins was measured by means of a modified method described by Rop *et al.* (2008). A pulp sample (10 g) was extracted at the temperature of 80 °C in a shaker with hydrochloric acid $c = 1 \text{ mol}\cdot\text{dm}^{-3}$ for a period of 90 minutes. The obtained hydrolyzate was quantitatively transferred into a 250 ml volumetric flask and refilled to the volume with water. Pectins

were thereafter measured photometrically as a coloured complex consisting of the product of thermal decomposition of galacturonic acid with *m*-hydroxybiphenyl in concentrated H_2SO_4 . The samples of 5 ml were gradually taken off and put into 50-ml flasks; thereafter, they were mixed with 6 ml of sodium tetraborate ($c = 0.013 \text{ mol.dm}^{-3}$) dissolved in concentrated sulphuric acid, filled up to the volume with distilled water and boiled for 5 minutes. Boiled samples were let to stand for 20 minutes and thereafter they were measured (at 520 nm) together with standards in the apparatus LIBRA S6 (Biochrom Ltd., Cambridge, UK). The content of pectins was expressed in percents of fresh matter.

Determination of ascorbic acid

The determination of ascorbic acid content was carried out by a modified method of Wagner *et al.* (1979) and Miki (1981). 5 g of the sample were weighed in Erleymayer flask by adding 25 ml of extractant methanol: $H_2O:H_3PO_4$ in the ratio 99:0.5:0.5. The flask with the samples was placed into a water bath with the temperature of 25 °C where the samples were extracted for 15 minutes. To keep out the samples of daylight, the flask was covered with aluminium foil during the preparation. After the extraction the content of the bank was filtrated through paper Filtrapak No. 390. The filtrate prepared in this way before injection was diluted in ration of extractant and filtrated again through a membrane filter Nylon (0.45 μm Nylon filter disk). The instrument used for ascorbic acid analysis consisted of a solvent delivery pump (ESA Inc., Chelmsford, USA) – Model 582, guard cell (ESA Inc., Chelmsford, USA) – Model 5010A, working electrode potential $K1 = 600 \text{ mV}$, $K2 = 650 \text{ mV}$, chromatographic column – Model Supelcosil LC8 (150.0 x 4.6 mm), 5 μm particle size and an electrochemical detector (Coulchem III). Chromatographic conditions were constant: 30 °C, as a mobile phase methanol was used: $H_2O:H_3PO_4 = 99:0.5:0.5$, (filtrated through a filter Nylon, 0.2 μm), type of elution was isocratic, the flow rate of the mobile phase was 1.1 ml.min^{-1} , retention time 1.9–2.0 min. The content of ascorbic acid was calculated as $\text{mg.}100 \text{ g}^{-1}$ of fresh matter.

Antioxidant capacity assay

The peel was separated from three parts of the fruit with the scalpel and cut to pieces. The flesh was cut out from all the apple length in a shape of 3 cylinders with a diameter of 2 mm. The weight of 0.5 g was separated from the homogenised samples and immediately 3 ml of 50% methanol were added. After 15 minutes of extraction centrifugation at 3,000 rpm was performed.

The antioxidant capacity was determined by photochemiluminescence method (PCL) using KIT ACL (400.803) and the instrument Photochem (Analytik Jena AG, Germany). Free radicals (superoxide anion radicals) were produced by optical excitation (irradiation) of a photosensitiser

(dye). These radicals were partially eliminated from the sample by reaction with the antioxidants present in the sample. The remaining radicals cause the luminescence in the measuring cell, thereby allowing determination of the antioxidant capacity of the extract sample. The samples were diluted to give signals lying within the range of the calibration curve and within the linear range of the instrument. The total antioxidant capacity (TAC) of the fresh apple flesh or fresh apple peel was quantified by comparison with the Trolox standard (Balík *et al.*, 2008).

Statistical evaluation

All results were evaluated using the ANOVA variation statistics programme. Statistical data were calculated according to Snedecor and Cochran (1967) when using the statistical package Unistat, v. 5.1 and Office Excel® Microsoft.

RESULTS

When evaluating the overall average values with regard to individual apples, the highest weights of one fruit were recorded in the varieties 'Sikulské' (on average 236.3 g) and 'Lebelovo' from the locality near Tišnov (200.7 g). Also in the other locality there were relatively high average weights of 'Lebelovo' apples. Higher weights were for example recorded also in the varieties 'Limburské', 'Krasokvět' or 'Croncelské' (Tab. I). The variety 'Sikulské' showed also the highest content of dry matter (16.51%). More than 16% of dry matter was recorded also in the varieties 'Starkrimson', 'James Grieve' and 'Hvězdnatá reneta'. The variety 'Starkrimson' showed a high content of soluble solid content (16.10% FM). In the variety 'Strýmka' this value was 15.68%. More than 14% of soluble solid content in FM was shown also in the varieties 'Panenské české' and 'Citronové zimní' (Tab. I).

The titration acidity and the content of pectin substances were other important technological parameters estimated in altogether 35 samples of varieties under study. In this case there were considerable differences among individual varieties. As far as the total content of acids was concerned, the measured values ranged from 1.3 g.kg^{-1} FM ('Coxova reneta') to 6.1 g.kg^{-1} FM ('Citronové zimní'). Differences were also found out in the contents of pectins. The lowest levels were found out in the varieties 'Lebelovo' from the Tišnov region (1.11% FM) and 'Boikovo' (1.14% FM). The varieties 'Croncelské' and 'Jeptiška' contained both 1.15% FM while the highest one was found out in the variety 'Strýmka' (3.26% FM).

Of mineral elements, the highest contents in dry matter were those of potassium and the variety 'Boikovo' contained as much as 9.70 ppm. High contents of potassium were also found in the varieties 'Jeptiška', 'Gustavovo', 'Grávštýnské' or 'Albrechtovo'. In these varieties there were also high contents of other macroelements, above all of

I: Selected quality parameters of apple cultivars (n = 15)

Cultivar	Fruit weight (g)	Dry matter (%)	Soluble solid content (%)	Titrateable acidity (g.kg ⁻¹)	Pectins (%)
Albrechtovo/VK*	99.2 ± 7.6**	11.14 ± 0.03	13.50 ± 0.12	3.80 ± 0.27	2.01 ± 0.04
Baumannova reneta/Ti	142.6 ± 6.4	12.81 ± 0.02	13.85 ± 0.01	4.28 ± 0.28	2.90 ± 0.04
Bernské růžové/VK	80.5 ± 5.1	11.23 ± 0.15	11.70 ± 0.18	2.64 ± 0.12	2.19 ± 0.01
Bláhovo oranžové/Ti	89.7 ± 4.8	15.04 ± 0.05	12.96 ± 0.02	2.10 ± 0.52	1.78 ± 0.09
Boikovo/Ti	110.4 ± 10.3	17.23 ± 0.03	13.22 ± 0.02	1.93 ± 0.13	1.14 ± 0.03
Boskoopské/Ti	136.5 ± 9.7	13.67 ± 0.03	12.51 ± 0.01	1.90 ± 0.18	2.45 ± 0.08
Citronové zimní/Ti	154.1 ± 8.2	15.97 ± 0.06	11.14 ± 0.01	6.10 ± 0.48	1.50 ± 0.05
Coxova reneta /Ti	90.7 ± 7.6	10.62 ± 0.17	14.35 ± 0.02	1.30 ± 0.29	2.12 ± 0.16
Croncelské/Ti	168.3 ± 10.4	15.24 ± 0.28	14.22 ± 0.02	2.50 ± 0.24	1.15 ± 0.04
Gdánský hranáč/Ti	75.0 ± 3.9	13.44 ± 0.05	11.16 ± 0.01	4.30 ± 0.36	2.87 ± 0.51
Grávštynské/Ti	126.8 ± 7.1	10.83 ± 0.05	13.87 ± 0.02	2.35 ± 0.13	1.44 ± 0.02
Gustavovo/Ti	99.3 ± 8.8	15.66 ± 0.03	12.54 ± 0.02	2.50 ± 0.22	1.90 ± 0.17
Hájkova muš. reneta/Ti	124.2 ± 14.5	14.20 ± 0.04	11.00 ± 0.01	2.90 ± 0.14	1.93 ± 0.08
Hvězdnatá reneta/VK	119.0 ± 4.1	16.35 ± 0.03	11.60 ± 0.18	3.60 ± 0.29	1.33 ± 0.02
Jadernička moravská/VK	88.2 ± 4.0	7.57 ± 0.13	13.30 ± 0.22	1.50 ± 0.27	2.84 ± 0.14
James Grieve/Ti	147.5 ± 8.4	16.22 ± 0.02	14.05 ± 0.01	1.68 ± 0.15	2.02 ± 0.07
Jeptiška/Ti	155.7 ± 7.4	12.37 ± 0.04	11.20 ± 0.01	5.40 ± 0.57	1.15 ± 0.05
Kalvil bílý podzimní/Ti	161.4 ± 10.1	12.32 ± 0.02	12.01 ± 0.01	5.00 ± 0.50	1.92 ± 0.04
Krasokvět/Ti	170.1 ± 18.8	14.57 ± 0.06	13.89 ± 0.02	3.10 ± 0.29	1.85 ± 0.11
Krátkostopka králov./Ti	169.1 ± 7.0	11.84 ± 0.06	11.80 ± 0.22	3.20 ± 0.24	2.80 ± 0.09
Lebelovo/VK	165.0 ± 17.1	12.87 ± 0.10	11.60 ± 0.08	4.90 ± 0.54	1.59 ± 0.12
Lebelovo/Ti	200.7 ± 44.7	13.10 ± 0.03	11.75 ± 0.02	3.30 ± 0.36	1.11 ± 0.10
Lecar/Ti	100.5 ± 6.2	12.30 ± 0.03	13.61 ± 0.01	5.20 ± 0.08	2.56 ± 0.03
Limburské/Ti	198.8 ± 9.3	10.39 ± 0.02	13.14 ± 0.01	1.50 ± 0.29	2.09 ± 0.13
Matčino/VK	135.1 ± 11.6	12.42 ± 1.00	12.00 ± 0.14	1.60 ± 0.20	1.88 ± 0.06
Matčino/Ti	115.4 ± 5.8	14.21 ± 0.07	12.15 ± 0.01	1.90 ± 0.39	2.01 ± 0.11
Ontario/Ti	125.8 ± 8.9	14.89 ± 0.03	13.57 ± 0.01	1.80 ± 0.08	1.88 ± 0.05
Panenské české/Ti	111.2 ± 10.8	11.84 ± 0.03	14.86 ± 0.02	3.10 ± 0.14	1.18 ± 0.07
Parména zlatá/Ti	91.1 ± 5.4	16.13 ± 0.02	12.17 ± 0.01	3.00 ± 0.28	1.18 ± 0.05
Sikulské/Ti	236.3 ± 39.0	16.51 ± 0.02	13.84 ± 0.01	2.20 ± 0.23	1.63 ± 0.11
Sláva světa/Ti	153.0 ± 8.4	13.64 ± 0.08	11.05 ± 0.01	3.10 ± 0.47	1.87 ± 0.05
Spartan/Ti	82.8 ± 6.8	13.95 ± 0.01	13.90 ± 0.01	2.28 ± 0.32	2.40 ± 0.04
Starkrimson/VK	54.1 ± 2.4	16.35 ± 0.01	16.10 ± 0.41	1.70 ± 0.24	1.52 ± 0.12
Strýmka/Ti	111.3 ± 7.5	11.58 ± 0.08	15.68 ± 0.01	1.80 ± 0.29	3.26 ± 0.17
Šarlatka boračská/Ti	82.9 ± 5.2	14.51 ± 0.03	12.88 ± 0.02	1.90 ± 0.24	1.86 ± 0.02
Ušlechtilé žluté/Ti	95.5 ± 5.9	15.33 ± 0.02	11.85 ± 0.02	4.00 ± 0.37	1.58 ± 0.06
Vilémovo/VK	134.7 ± 5.7	11.84 ± 0.05	11.40 ± 0.08	2.60 ± 0.14	2.02 ± 0.10
Vilémovo/Ti	123.5 ± 6.9	15.64 ± 0.04	12.15 ± 0.02	3.50 ± 0.32	2.55 ± 0.05

*VK = Valašské Klobouky, Ti = Tišnov; **mean ± standard deviation (n = 15)

nitrogen (Tab. II). So, for example, a high content of nitrogen was found out in the variety 'Boskoopské' (4.50 ppm). The highest levels of phosphorus (1.07 ppm) were found out in the varieties 'Bláhovo oranžové' and 'Jadernička moravská'. As far as the other elements were concerned, the content e.g. of calcium ranged from 0.35 ppm (the variety 'Vilémovo') to 0.82 ppm (the varieties 'Boikovo' and 'Gustavovo'). In case of magnesium this range had limits of 0.23 ppm (the variety 'Bernské růžové') and

0.41 ppm (the varieties 'Croncelské' and 'Jeptiška') while in case of sodium the values ranged from 48 ppb (the variety 'Sláva světa') to 190 ppb (the variety 'Krátkostopka královská').

In the varieties harvested in the locality Valašské Klobouky the contents of vitamin C and of total antioxidant capacity were measured as well. While in the flesh the values of total antioxidant capacity ranged from 4.02 (the variety 'Vilémovo') to 6.59 mmol of trolox.kg⁻¹ FM (the variety 'Bernské

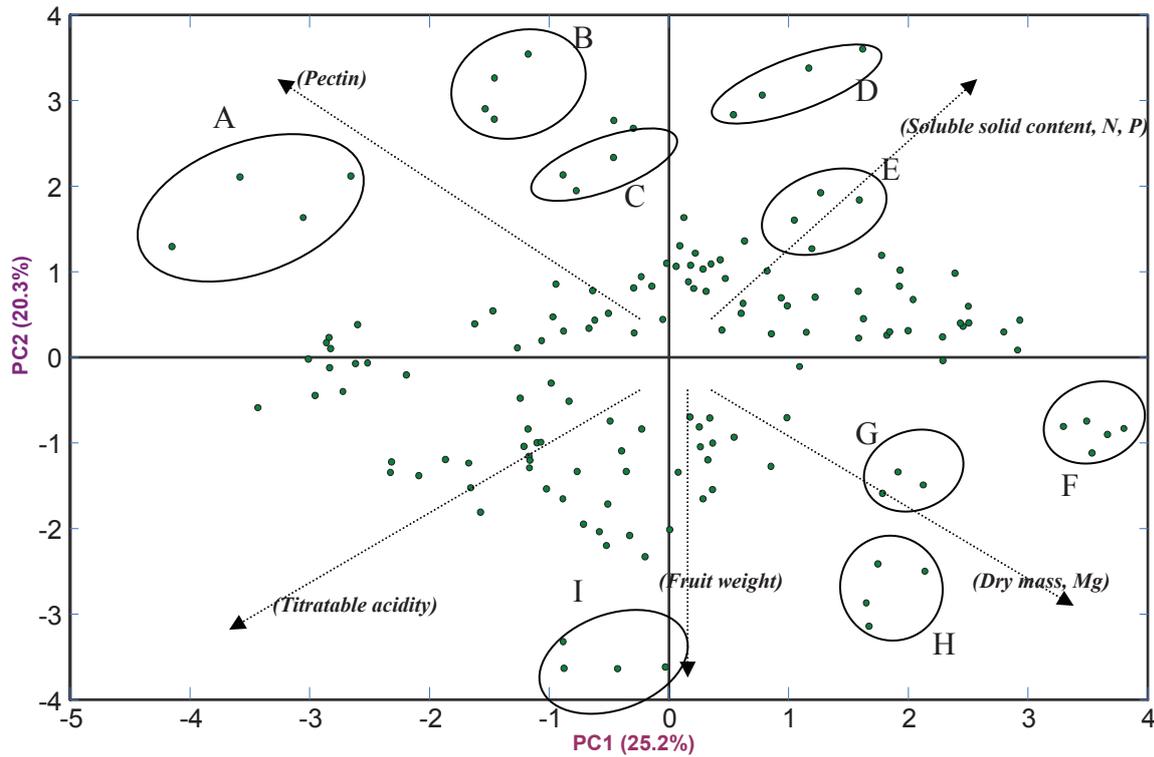
II: Content of elements in apple cultivars (n = 15)

Cultivar	N	P	K	Ca	Mg	Na
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppb)
Albrechtovo/VK*	3.68 ± 0.15	1.05 ± 0.06	9.10 ± 0.14	0.52 ± 0.01	0.34 ± 0.04	65 ± 17
Baumannova reneta/Ti	3.90 ± 0.14	1.05 ± 0.03	7.10 ± 0.22	0.69 ± 0.05	0.34 ± 0.01	70 ± 8
Bernské růžové/VK	3.08 ± 0.10	0.87 ± 0.08	6.30 ± 0.29	0.50 ± 0.01	0.23 ± 0.03	60 ± 8
Bláhovo oranžové/Ti	3.83 ± 0.22	1.07 ± 0.04	7.70 ± 0.35	0.70 ± 0.04	0.39 ± 0.03	100 ± 8
Boikovo/Ti	4.00 ± 0.08	0.97 ± 0.02	9.70 ± 0.22	0.82 ± 0.01	0.40 ± 0.01	103 ± 10
Boskoopské/Ti	4.50 ± 0.12	0.99 ± 0.06	8.40 ± 0.27	0.58 ± 0.03	0.37 ± 0.01	90 ± 12
Citronové zimní/Ti	3.20 ± 0.18	0.81 ± 0.02	7.10 ± 0.29	0.55 ± 0.01	0.39 ± 0.03	88 ± 10
Coxova reneta/Ti	3.40 ± 0.08	1.04 ± 0.04	6.53 ± 0.05	0.51 ± 0.04	0.32 ± 0.01	70 ± 8
Croncelské/Ti	3.73 ± 0.54	0.88 ± 0.05	8.50 ± 0.18	0.70 ± 0.12	0.41 ± 0.02	98 ± 10
Gdánský hranáč/Ti	2.90 ± 0.24	0.85 ± 0.04	6.70 ± 0.22	0.39 ± 0.01	0.29 ± 0.02	80 ± 8
Grávštýnské/Ti	4.00 ± 0.08	0.86 ± 0.08	9.20 ± 0.18	0.40 ± 0.03	0.28 ± 0.01	60 ± 8
Gustavovo/Ti	3.28 ± 0.21	0.81 ± 0.04	9.00 ± 0.43	0.82 ± 0.02	0.32 ± 0.01	60 ± 8
Hájkova muš. reneta/Ti	2.90 ± 0.34	0.93 ± 0.08	6.90 ± 0.14	0.59 ± 0.05	0.32 ± 0.01	90 ± 8
Hvězdnatá reneta/VK	3.10 ± 0.08	0.87 ± 0.02	8.50 ± 0.36	0.48 ± 0.02	0.36 ± 0.01	68 ± 10
Jadernička moravská/VK	3.20 ± 0.14	1.07 ± 0.04	7.80 ± 0.29	0.48 ± 0.03	0.30 ± 0.01	58 ± 10
James Grieve/Ti	3.93 ± 0.10	1.04 ± 0.04	8.10 ± 0.18	0.64 ± 0.05	0.40 ± 0.02	135 ± 13
Jeptiška/Ti	3.80 ± 0.18	0.86 ± 0.02	9.50 ± 0.32	0.80 ± 0.08	0.41 ± 0.01	90 ± 8
Kalvil bílý podzimní/Ti	3.00 ± 0.16	0.88 ± 0.05	9.00 ± 0.18	0.51 ± 0.03	0.30 ± 0.02	60 ± 8
Krasokvět/Ti	3.10 ± 0.14	1.00 ± 0.04	5.80 ± 0.32	0.46 ± 0.01	0.27 ± 0.02	138 ± 5
Krátkostopka králov./Ti	4.10 ± 0.20	0.95 ± 0.04	7.20 ± 0.38	0.39 ± 0.01	0.33 ± 0.02	190 ± 14
Lebelovo/VK	3.30 ± 0.14	1.02 ± 0.03	8.10 ± 0.22	0.41 ± 0.02	0.35 ± 0.02	188 ± 5
Lebelovo/Ti	3.50 ± 0.22	0.95 ± 0.07	7.80 ± 0.29	0.41 ± 0.01	0.34 ± 0.01	140 ± 14
Lecar/Ti	2.80 ± 0.18	0.89 ± 0.03	5.83 ± 0.05	0.48 ± 0.02	0.30 ± 0.02	60 ± 8
Limburské/Ti	4.20 ± 0.24	0.90 ± 0.03	7.50 ± 0.33	0.53 ± 0.05	0.30 ± 0.02	90 ± 8
Matčino/VK	3.30 ± 0.14	1.01 ± 0.05	7.80 ± 0.32	0.67 ± 0.01	0.34 ± 0.03	188 ± 10
Matčino/Ti	3.50 ± 0.41	0.98 ± 0.03	8.20 ± 0.18	0.75 ± 0.02	0.32 ± 0.02	150 ± 8
Ontario/Ti	3.70 ± 0.08	0.98 ± 0.03	8.80 ± 0.36	0.68 ± 0.02	0.36 ± 0.03	170 ± 12
Panenské české/Ti	4.00 ± 0.26	0.88 ± 0.03	8.10 ± 0.48	0.75 ± 0.04	0.35 ± 0.03	170 ± 16
Parména zlatá/Ti	3.00 ± 0.14	0.94 ± 0.03	6.50 ± 0.18	0.47 ± 0.03	0.33 ± 0.02	68 ± 13
Sikulské/Ti	3.00 ± 0.08	0.95 ± 0.04	6.10 ± 0.29	0.59 ± 0.01	0.33 ± 0.01	70 ± 8
Sláva světa/Ti	2.80 ± 0.24	0.89 ± 0.05	6.00 ± 0.32	0.51 ± 0.04	0.32 ± 0.02	48 ± 5
Spartan/Ti	3.90 ± 0.14	1.01 ± 0.06	8.80 ± 0.53	0.66 ± 0.05	0.31 ± 0.01	118 ± 10
Starkrimson/VK	3.30 ± 0.32	0.98 ± 0.05	6.30 ± 0.14	0.54 ± 0.05	0.29 ± 0.06	90 ± 8
Strýmka/Ti	3.70 ± 0.59	1.02 ± 0.06	9.20 ± 0.32	0.63 ± 0.03	0.30 ± 0.02	120 ± 8
Šarlatka boračská/Ti	3.40 ± 0.16	0.90 ± 0.04	6.70 ± 0.36	0.58 ± 0.01	0.28 ± 0.03	70 ± 8
Ušlechtilé zluté/Ti	3.00 ± 0.32	0.81 ± 0.03	7.20 ± 0.92	0.60 ± 0.03	0.33 ± 0.02	80 ± 8
Vilémovo/VK	3.30 ± 0.12	0.87 ± 0.05	6.30 ± 0.14	0.35 ± 0.01	0.27 ± 0.02	65 ± 13
Vilémovo/Ti	3.50 ± 0.18	0.90 ± 0.12	7.20 ± 0.42	0.45 ± 0.02	0.33 ± 0.01	70 ± 8

*VK = Valašské Klobouky, Ti = Tišnov; ***mean ± standard deviation (n = 15)

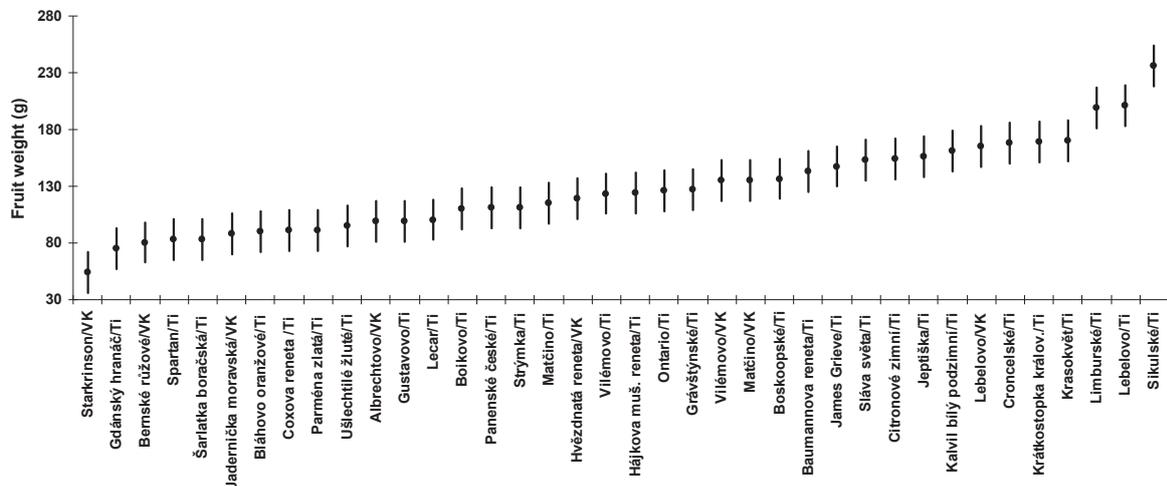
růžové'), in peels these values ranged from 19.11 (again the variety 'Vilémovo') to 56.65 mmol of trolox.kg⁻¹ FM (again the variety 'Bernské růžové'); the obtained results were statistically significant (Tab. III). Statistically significant minimum contents of vitamin C were found out in apples of the varieties 'Jadernička moravská' and 'Starkrimson' (Tab. V). On the other hand, statistically significant maximum

contents of vitamin C were found out in apples of the variety 'Albrechtovo' (13.55 mg.kg⁻¹ FM). When estimating correlations existing between the content of ascorbic acid and the total antioxidant capacity, the calculated correlation coefficients for the flesh and peel were $r = 0.7806$ and $r = 0.4995$, respectively (Fig. 6).



1: Principal component analysis of all observed analytic data

(A = Bernské růžové, B = Jaderňička moravská, C = Coxova reneta, D = Strýmka, E = Spartan, F = Boikovo, G = Croncelské, H = Jeptiška, I = Citronové zimní)

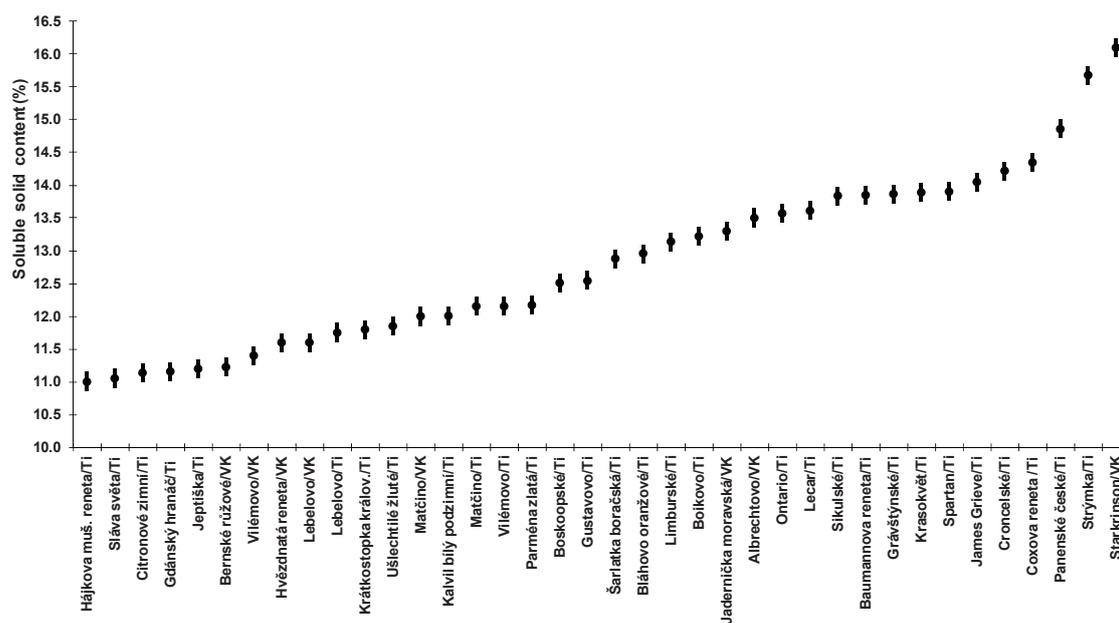


2: Mean of fruit weight and Tukey HSD intervals ($P=0.95$; $n=15$) depending on apple cultivars

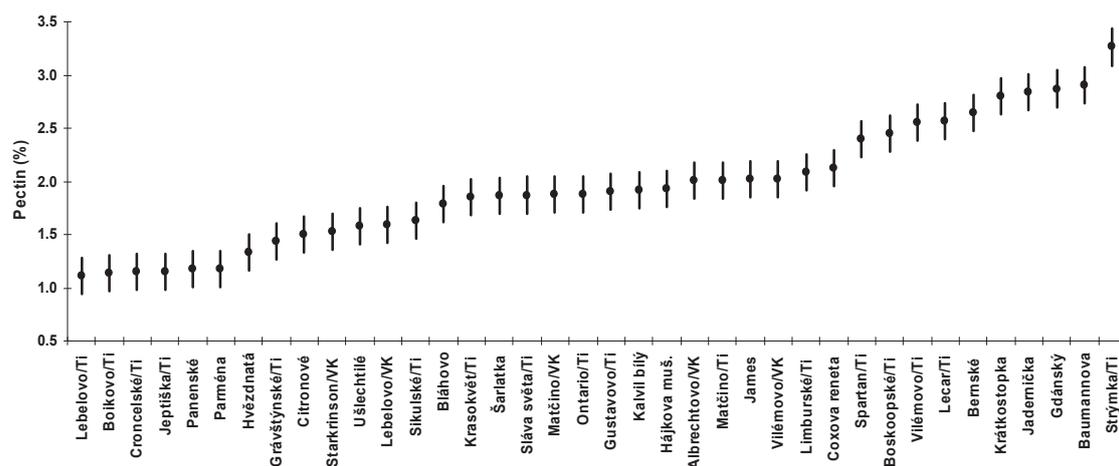
DISCUSSION

Today, apple trees are the most popular and the most grown core fruit species in Europe. As far as apples as fruit are concerned, their taste and their possible utilization for nutritional purposes represent the most valued characteristics. However, all properties of fruit which influence marketability of apples are of importance as well. What is also important is their capability to tolerate transport and storage conditions (Goland and Bauer, 2004).

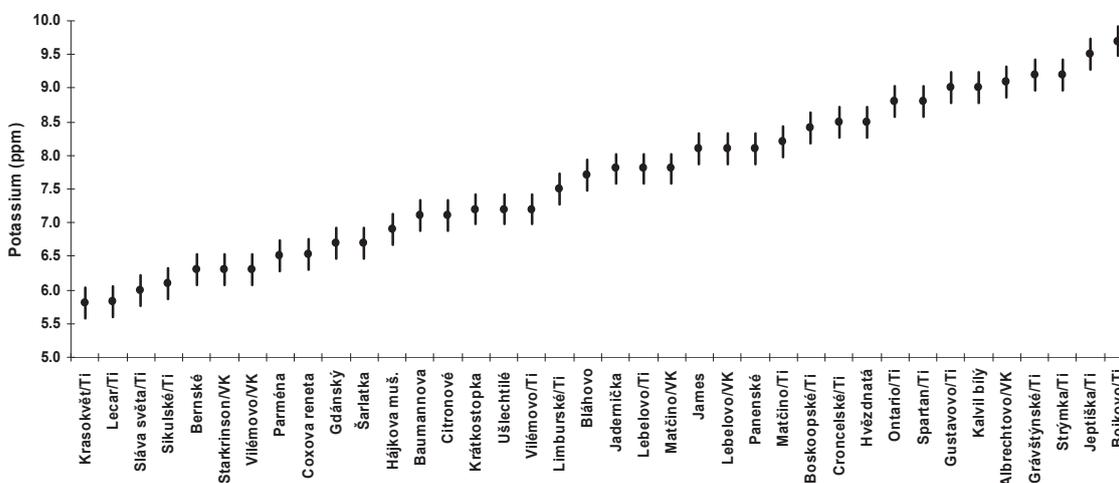
Although it is possible to find out tens of various apple tree varieties in Europe, only some of them were purposefully bred and selected in the past (Radicato *et al.*, 1995) and the same concerns also for example pears (Benitez, 1998). A further propagation of local varieties is prevented above all by the fact that their sensory and technological properties are not as good as those of purposefully bred and selected ones (Kuhn *et al.*, 2003) although their local importance may be rather considerable



3: Mean of soluble solid content and Tukey HSD intervals ($P=0.95$; $n=15$) depending on apple cultivars



4: Mean of pectin content and Tukey HSD intervals ($P=0.95$; $n=15$) depending on apple cultivars



5: Mean of potassium content and Tukey HSD intervals ($P=0.95$; $n=15$) depending on apple cultivars

III: Antioxidant capacity in peel of selected apple cultivars

Cultivar	Mean	*HSD interval	Homogeneous groups
	(mmol trolox.kg ⁻¹ FM)		
Jadernička moravská	19.11	10.16–28.03	A
Lebelovo	25.45	13.50–37.41	AB
Vilémovo	27.55	15.59–39.50	AB
Starkrimson	33.44	21.49–45.39	ABC
Hvězdnatá reneta	40.10	28.15–52.06	BC
Albrechtovo	41.73	29.78–53.69	BC
Matčino	46.55	34.60–58.51	BC
Bernské růžové	56.65	44.69–68.60	C
Total mean	36.32		

*high standard deviation (Tukey, P = 0.95, n = 5)

IV: Antioxidant capacity in flesh of selected apple cultivars

Cultivar	Mean	*HSD interval	Homogeneous groups
	(mmol trolox.kg ⁻¹ FM)		
Vilémovo	4.02	0.70–7.33	A
Matčino	4.20	0.88–7.51	A
Starkrimson	4.49	1.18–7.81	A
Jadernička moravská	4.82	1.51–8.13	A
Hvězdnatá reneta	5.73	2.42–9.05	A
Albrechtovo	6.00	2.68–9.31	A
Lebelovo	6.12	2.81–9.44	A
Bernské růžové	6.59	3.27–9.90	A
Total mean	5.25		

*high standard deviation (Tukey, P = 0.95, n = 5)

V: L-ascorbic acid content in selected apple cultivars (mg.100 g⁻¹)

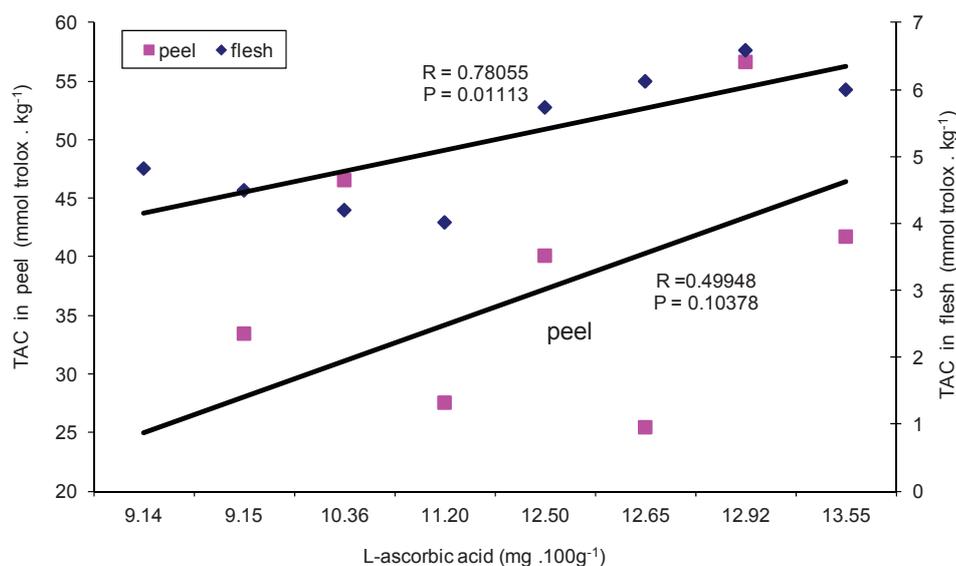
Cultivar	Mean	*HSD interval	Homogeneous groups
	(mg.100 g ⁻¹ FM)		
Jadernička moravská	9.14	8.83–9.45	A
Starkrimson	9.15	8.84–9.46	A
Matčino	10.36	10.05–10.67	B
Vilémovo	11.20	10.89–11.51	C
Hvězdnatá reneta	12.50	12.19–12.81	D
Lebelovo	12.65	12.34–12.96	D
Bernské růžové	12.92	12.61–13.23	D
Albrechtovo	13.55	13.24–13.86	E
Total mean	11.43		

*high standard deviation (Tukey, P = 0.95, n = 15)

(Goland and Bauer, 2004). Local varieties represent a rich source of genetically conditioned properties, i.e. not only their resistance to diseases but also some – until now – unknown and not described possibilities of a unique technological utilisation and specific taste and other sensory properties (Monschein *et al.*, 2006). Although it is necessary to consider some differences in their chemical composition, resulting from the year of harvest and influenced by the locality (Little and Taylor, 1981), it can be said that local varieties are well adapted to

local climatic conditions (Melounová *et al.*, 2004). It is also known that there are only slight differences in the contents of individual chemical compounds when comparing individual varieties and that they are determined by the genetic uniqueness of each of them (Goland and Bauer, 2004).

In individual apple tree varieties the values of measured chemical characteristics ranged within the limits mentioned in tables used in alimentary industry (Kováčiková *et al.*, 1997; Kopec, 1998). Nevertheless, individual varieties showed variability,



6: Correlation analysis between antioxidant capacity in peel (flesh) of apple cultivar and L-ascorbic content

which is presented in Tabs. I–V and Figs. 1–6. The similarity of chemical characteristics of individual apple varieties and their general affinity in the stage of consume ripeness is expressed by means of cluster analysis. When evaluating individual clusters it is obvious that the most marked characteristic is the kinship based on the stage of consume ripeness (Tetera, 2006).

Of chemical parameters under study, the most important are the following: the soluble solid content, the content of acids and the content of pectins (Rop *et al.*, 2010a). In apples, the content of organic acids is represented mainly (90%) by malic acid (Kyzlink, 1990). However, the presence of some macroelements (e.g. nitrogen) is manifested by an increase in the content of citric acid and a decrease in the malic acid (Jakopic *et al.*, 2007). Among other organic acids it is possible to find out malonic, shikimic, and fumaric acids, some amino acids (with predominating aspartic acid) and polyphenolic chlorogenic acid (Stampar *et al.*, 2002). So, for example, it was found out, similarly as Suni *et al.* (2000) noticed, that the content of acids in the variety 'Boskoopské' was low (1.9 g.kg⁻¹ FM). On the other hand, the variety 'Citronové zimní' contained 6.1 g.kg⁻¹ FM of organic acids. In the variety 'Boskoopské', the content of nitrogen in dry matter was also high (4.50 ppm of DM). Wolf *et al.* (2007) mentioned similar contents of nitrogen in apples (up to 5.00 ppm).

Apples are important above all due to their content of pectins, which predetermine them for the processing to fruit spreads thanks to their capability of gelification in presence of saccharose under conditions of low pH (Kyzlink, 1990). Of other core fruit species a high content of pectins can be found for example in quinces (Baker, 1997), which may contain as much as 3% of pectins in FM (Kováčiková *et al.*, 1997). In apples, however, the average content

of pectins is about 1.1% FM (Kopec, 1998). In our experiments, this value was found out in varieties with the lowest contents of pectin compounds (Tab. I). The variety 'Strýmka', which contained as much as 3.26% of pectins in FM, was an interesting exception. This variety is frequently used in the region of the White Carpathians (Tetera, 2006). However, this does not have to be an extreme value because Bailoni *et al.* (2005) mentioned that some local varieties may contain as much as 5% of pectins in FM.

As compared with other species of core fruit, apples show relatively high contents of mineral substances (Kovacs and Meresz, 2004). In core fruit, potassium is the most abundant macroelement (Kováčiková *et al.*, 1997). In our experiments, the variety 'Boikovo' contained as much as 9.70 ppm of this element in dry matter. Although some commercial varieties (e.g. 'Ontario' or 'Spartan') showed also high contents of macroelements, some typically local varieties contained more than 9.00 ppm of potassium. Also the contents of other elements (phosphorus, magnesium, sodium) were relatively high in local varieties, even when compared with tabular values (Kováčiková *et al.*, 1997; Kopec, 1998). Health benefits resulting from the consumption of apples due to their high content of minerals was emphasized also by several authors, e.g. by Biedrzycka (2008). It is well known that local varieties show very often higher contents of minerals than the commercial ones (Iwane, 1991).

The content of vitamin C in crops is most influenced by variety and year of cultivation (Valšíková *et al.*, 2010). The contents of vitamin C and antioxidant capacity were measured in apples showing the consume ripeness and originating from the locality Valašské Klobouky. As one can see in Tabs. III and IV, antioxidant capacity of peels was explicitly higher than of the flesh. This fact was

mentioned also by Drogoudi *et al.* (2008) who found out that the peel can show as much as 9 times higher antioxidant capacity (in our experiments this was 7 times more). Authors Rop *et al.* (2010b) emphasized high values of antioxidant capacity of local varieties, which – as compared with commercial varieties – contained considerable amounts of phenolic substances. It was also found out that there were high correlations between antioxidant capacity and the content of phenolic substances (Gil *et al.*, 2002). It was also found out that the correlation between antioxidant capacity and the content of ascorbic acid was also high (Schmitz-Eiberger *et al.*, 2003). So, for example, for apples Thaipong *et al.* (2006) mentioned correlation coefficients ranging from $r = 0.81$ to 0.97 . In our experiments the value of correlation coefficient was for the flesh and peel were $r = 0.78$ and $r = 0.49$, respectively (as compared with antioxidant capacity) (Fig. 6). In our measurement there was also a considerable variability of the contents of vitamin C in individual

varieties (Tab. V) and it could be said that this was typical of apple trees (Tetera, 2006).

By analysis of main components original variables of observed parameters of fruit were substituted by main components (Fig. 1). The first two main components represented as axes in Fig. 1 explain on the whole 45.5% of all variability of original variables and divide apple cultivars to several clearly distinguishable groups (A, B, C, D, E, F, G, H and I). With the first main component parameters SSC, the contents of nitrogen, phosphorus, magnesium and dry matter correlated positively, but especially the contents of pectins and acids negatively. In particular the fruit weight correlated negatively with the second main component. Therefore, it is possible to, for example, claim that the fruit of the cultivar 'Jadernička moravská' belongs to the fruit with a lower weight and a significantly higher content of pectins, on the contrary, the fruits of the cultivar 'Citronové zimní' are representatives of the varieties with larger fruits and with higher contents of acids.

SUMMARY

This paper presents chemical characteristics of 35 local varieties of apple trees, which originated from two localities situated in the territory of the Czech Republic. All varieties were characterised by variability in the content of basic chemical components. From the technological and nutritional points of view some of them (e.g. pectins) are rather important and their highest content was found out in the variety 'Strýmka'. On the other hand, the variety 'Boikovo' showed a high content of mineral substances especially potassium (9.70 ppm in dry matter). It was found out in our experiments that the highest content of total acids was shown by the variety 'Citronové zimní' (6.1 g.kg⁻¹ of fresh matter). Thanks to their antioxidant capacity, these local varieties can be used for prevention of many diseases. The antioxidant capacity of peels was as much as 7 times higher than that of the flesh. For example, peels of the variety 'Bernské růžové' showed antioxidant capacity of as much as 56.65 mmol of trolox per kg of fresh matter. Many of the cultivars described in this study are not well known; practically, they were not described in literature and the research results presented here are unique, especially as far as their chemical composition is concerned. This paper should contribute to efforts focused on saving of genetic variability of apples and their further application both in human nutrition and a further breeding and selection under conditions of pomological and alimentary practice.

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