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Determination of the pomological and nutritional properties of selected plum cultivars and minor fruit species

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Abstract: This study included twenty-three samples of minor fruit species and twenty-three plum cultivars. First of all, the pomological properties of the plum cultivars were assessed, where the cultivar 'Aphrodite' was determined as the cultivar with the biggest fruits (56.6 g). The selected nutritional properties were subsequently determined in all forty-six samples. The highest value of the total soluble solids in the plums was 27.3 % in 'Stanley' (*Prunus domestica*) and 26.1 % in 'Krasavica' (*Sorbus aucuparia*) in the minor fruits; the highest total content of ascorbic acid in the plums was 83.3 mg/100 g in 'Stanley' (*P. domestica*) and 622.9 mg/100 g in 'Krasavica' (*S. aucuparia*) in the minor fruits; the highest total phenolic content in the plums was 429.8 mg GAE/100 g in 'Fortune' (*Prunus salicina*) and 45.3 mg GAE/100 g in the minor fruits and 983.9 mg GAE/100 g in 'Vydubecký' (*Cornus mas*); the highest total flavonoid content in the plums was 291.5 mg CE/100 g in 'Fortune' (*P. salicina*) and 544.7 mg CE/100 g in 'Nero' (*Sorbus melanocarpa*) in the minor fruits, and the highest total antioxidant activity in the plums was 809.5 mg TE/100 g in the hybrid 'SLE2014/2' (*P. domestica* × *P. salicina*) and 849.8 mg TE/100 g in 'Amfora' (*Lonicera edulis*) in the minor fruits.

Keywords: vitamin C; antioxidant activity; Japanese plum; European plum; phenols

According to various authors, 19–40 botanical plum species grow in Asia, Europe and North America. Over 6 000 cultivars have been bred from these species (Hedrick 1911; Rehder 1986; Blažek 2007). Despite their high diversity, only two species dominate the modern commercial production, European (*Prunus domestica* L.) and Japanese plums (*Prunus salicina* Lindl.) (Topp et al. 2012). Other important and utilised species include *Prunus americana* Marsh. (American plum) and *Prunus cerasifera* Ehrh. (myrobalan) (Okie, Weinberger 1996). European and Japanese plums are taxonomically classified in the same section, but they differ in adaptability, in origin and in the method of domestication. Their fruit is also very different, along with their ripening periods and method of use (Topp et al. 2012). Asian plums are highly adaptive and are grown in subtropical and mild climates. Their adaptability to temperatures is so high that they are able to survive at temperatures as low as –40 °C. They are mainly used for direct consumption, but some varieties may be stored for various periods of time (Liu 2007).

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Japanese plums are derived from the botanical species *P. salicina*. They originated in China and were introduced to Japan over two thousand years ago. Most species, including fruit species from Asia, were introduced to Europe along the Silk Route, but this was not the case for Japanese plums. Japanese plums were initially introduced from Japan to the USA (California) in 1870 and then introduced to Europe at the turn of the 20th century. As a result, this species of fruit imported from Japan was given the name Japanese plum in the USA (Hedrick 1911). One of the biggest pioneers in breeding Asian plums was Luther Burbank, who brought 12 cultivars and 210 seedlings of the Japanese plum from Japan to the USA in 1884 (Okie, Weinberger 1996). The 'Burbank' cultivar originated from these seedlings. During the course of his life, Burbank produced hundreds and thousands of hybrids, which are still grown today. For instance, the 'Santa Rosa' cultivar remains one of the most frequently grown varieties in California (Howard 1945; Crow 2001).

Fruit has been considered as a method of prevention against various types of cancer, civilizational diseases and illnesses linked to natural ageing for many years (Prior Cao 2000; Wargovich 2000; Noratto et al. 2009; González-Flores et al. 2011). This has been confirmed, for example, in studies where the consumption of polyphenol-rich plum and peach juice led to the reduction of obesity, metabolic disorders and cardiovascular diseases in rats (Noratto et al. 2015). The high health benefits of dried plums and other plum products are referred to by Stacewicz-Sapuntzakis (2013). A complex and thorough study of the volatile compounds of the European plum (*P. domestica*) was published by Pino, Quijano (2012) and detailed composition of Japanese plums was published by Fanning et al. (2014). The fruit from the *Prunus* genus (particularly plums) contains a broad spectrum of phytochemical substances such as carotenoids, phenolic or polyphenolic compounds (resveratrol), anthocyanins and vitamin C, etc. (Gil et al. 2002; Byrne et al. 2009; Usenik et al. 2009; Sebastià et al. 2012; Milala et al. 2013; Dimkova et al. 2018; Vlaic et al. 2018). All these substances are distinguished by their high antioxidant activity. It is not generally known that some phenolic compounds and anthocyanins have a significantly higher antioxidant activity than the well-known vitamin C and carotenoids (Gil et al. 2002; Chun et al. 2003; Kim et al. 2003; Vizzotto 2005). The value of the antioxidant activity is closely linked to the overall content of the phenolic compounds. A high degree of correlation between the antioxidant activity and the total content of phenolic compounds has been described in plums (Gil et al. 2002; Vizzotto 2005, 2007; Cevallos-Casals et al. 2006). Some studies state that blueberries have the highest antioxidant activity of all fruit species, but the values of some plum varieties (mostly in the Asian varieties) exceed those of blueberries. However, the antioxidant activity differs in the individual genotypes (Wang et al. 1996; Prior et al. 1998; Cevallos-Casals et al. 2006). The evaluation of the antioxidant activity itself is not an easy task. There are currently several methods that can be used to determine the antioxidant activity, for instance, the FRAP (Ferric Reducing *Antioxidant* Power), DPPH (Diphenyl-1-picrylhydrazyl) and ORAC (Oxygen Radical Absorbance Capacity) methods (Frankel et al. 2000).

The goal of this work was to test the productivity and properties of Japanese plums in the Czech Republic. To compare some nutritionally important substances and properties, the obtained values for the plums were compared with the selected traditional varieties of a minor fruit species. In the case of the minor fruit species, it has already been reported that their values of the nutrients are among the highest between fruit species. Therefore, it was interesting to compare them together with the results obtained from the plums.

MATERIAL AND METHODS

This study included a total of twenty-three plum cultivars from which fifteen were Japanese plums: 'Fortune', 'Black Amber', 'Sorriso di Primavera', 'Shiro', 'Aphrodite', 'Fertility', 'Vanier', 'Golden Japan', 'Zurna', 'Wan Hong', 'Burbank', 'Santa Rosa', 'Kometa', 'Angeleno', 'Gavota', six were European plums: 'Ontario', 'Oulinská', 'Tichookenaskij', 'Cacak's Early', 'Stanley', 'Lavinia' and two were perspective hybrids of the Japanese plum type (SLE2014/1 and SLE2014/2). All the plum cultivars were grown in an experimental orchard, which is located on the land of the Faculty of Horticulture in Lednice, MENDELU, Czech Republic. In order to obtain the pomological data and the values of the content of the substances, fifty fruits from each tree were harvested at the optimum ripeness, which was defined when a significant proportion of fruits have attained the minimum % colour (every

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fruit must have the minimum percentage of its surface coloured) (Siddiq, Sultan 2012). The harvested fruits were transported to the laboratory of the Faculty of Horticulture in Lednice in plastic bags to prevent any loss of water during transport. The fruits were cleaned from dirt and dust.

Thirteen minor fruit varieties were also tested from the selected fruit species: *Sambucus nigra* L. cv. 'Dana', *Rubus fruticosus* L. cv. 'Thorn Free', *Rubus idaeus* L. cv. 'Sugana', *Vaccinium myrtillus* L., *Vaccinium corymbosum* L. cv. 'Nelson', *Sorbus melanocarpa* L. cv. 'Nero', *Sorbus aucuparia* L. cv. 'Krasavica', *Lonicera edulis* L. cv. 'Amfora', *Cornus mass* L., cv. 'Vydubecký', *Ribes nigrum* L. cv. 'Titania', *Ribes rubrum* L. cv. 'Red Lake', *Grossularia uva-crispa* L. red cultivar 'Hinnonmaki Red' and green cultivar 'Hinnonmaki Green'. All the minor fruit varieties were grown in the experimental orchard of the Faculty of Horticulture, MENDELU, with the exception of *Vaccinium corymbosum*, which was grown in the experimental orchard of the Research and Breeding Institute of Pomology at Holovousy and the wild growing *Vaccinium myrtillus*, whose fruits were picked in the forest in Vysočina region in the Czech Republic. The minor fruit varieties were harvested in quantities of 500 g at the optimal consumption ripeness defined by the overall colouring of the fruits.

Determination of pomological properties. Ten plums were chosen at random from the fifty harvested fruits and were gradually weighed on an analytical scale Kern PES 6200-2M (Kern & Sohn, Germany). The size of all the fruits was then measured by a vernier calliper (mm): length (*L*), width (*W*) and thickness (*T*). These parameters were then measured for the stones as well. The fruit firmness was measured using a digital fruit firmness tester (TR Truoni, Italy) with an 8 mm diameter plunger in kg and calculated to kg/cm^2. The pulp fraction (%), the weight fraction of the pulp of the fruit weight was calculated according to the formula:

(fruit mass (g)/stone mass (g) × 100) – 100.

Determination of nutritional properties. The total content of soluble solids (%) (TSS) was determined using a Kruss AR4D refractometer (Kruss, Germany) at room temperature.

The samples for determining the content of the ascorbic acid (mg/100 g) (vitamin C) were prepared using the method according to Wright, Kader (1997), the sample itself consisted of 80% flesh and 20% peel. For plums, a sample consisting of 100% flesh was prepared in addition. The total content of the ascorbic acid (TAA) was determined using High Performance Liquid Chromatography (HPLC) according to the method by Zapata and Dufour (1992).

For each plum cultivar, three methanol extracts were prepared from the fruits as follows: 5 g of fruit (MIX – 80% flesh and 20 % peel; FLESH – 100% flesh; PEEL – 100% peel) was homogenised in 20 ml of 75% methanol and left to extract for 24 hours. After 24 hours, the homogenate was filtered through filter paper. From the minor fruit varieties, the methanol extract was prepared using 80% flesh and 20% peel. The extracts were then used to determine the total antioxidant activity (TAC), the total content of phenolic compounds (TCP) and the total content of flavonoids (TCF).

The TCF (mg CE/100 g) was determined spectrophotometrically in a Specord 50 Plus (Analytik Jena, Germany) using aluminium chloride ($AlCl_3$) and sodium nitrite ($NaNO_2$). The results were expressed as the mg equivalent of catechin (CE) per 100 g of fresh mass.

The TCP (mg GAE/100 g) was measured using a spectrophotometer at a wavelength of 750 nm. Prior to the measurement, the samples were prepared by mixing 50 µl of the methanol extract with 1 ml of a Folin-Ciocalteu reagent and 1 ml of demineralised water.

The DPPH (mg TE/100 g) method was used to determine the total antioxidant activity (TAC). The DPPH method is based on scavenging the radical cation DPPH + (2.2-diphenyl-1-picrylhydrazyl). Under normal conditions, this cation has a purple colour and creates a yellow colour following the reduction. 200 µl of diluted methanol extract was added to 3.8 ml of the DPPH reactive solution. The absorbance was measured after 30 min using a spectrophotometer at a wavelength of 515 nm. A solution of Trolox was used as the standard.

Statistical assessment. The statistical evaluation was performed using software Statistica 12. All the pomological investigations were performed on ten pieces of fruit, the results were averaged, and the standard deviation was calculated. The nutritional parameters were determined in triplicate, the results were averaged, and the standard deviation was calculated. An analysis of variance (ANOVA) using Tukey's HSD test was performed on all the monitored parameters. The correlation between the content of the flavonoids and the phenolic compounds and between all the nutritional parameters and the antioxidant activity was also executed.

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RESULTS AND DISCUSION

Pomological properties

The plums were harvested during the period from July 25, 2018 to September 11, 2018. The other fruit varieties were harvested from May 23, 2018 to September 26, 2018 (Tables 1 and 2). In this study, all the plums were harvested when fully ripen. The principle that the earliest varieties generate the highest profit applies to all fruit species (Cao et al. 2000). The plum harvest period, particularly of Japanese plums, follows smoothly into the apricot harvest period (‘Velkopavlovická’, July 10, 2018) and slightly overlaps the harvest period of European plums (‘Stanley’, September 11, 2018). This, therefore, fills in the gap between the harvests of these two very important stone fruit species. Pirkhezri et al. (2014) published the ripening period of Japanese plums in Iran from the middle of June to the 3rd week of September, which is very similar to the harvesting period in the Czech Republic.

One of the most important properties of this fruit is its size. A large fruit is preferred for both direct consumption and for processing (Pirkhezri et al. 2014). In this study, the Japanese plums achieved a greater weight than the European plums, however, this study includes only six European plum cultivars. The cultivar ‘Aphrodite’ 56.6 g (*L*: 45.4 mm; *W*: 44.2 mm; *T*: 46.56 mm; see Table 1) had the largest fruits, which is a very attractive cultivar with a balanced ripening period and an oval fruit shape (data not shown). On the contrary, the cultivar ‘Shiro’, 12.9 g (*L*: 27.6 mm; *W*: 26.6 mm, *T*: 27.7 mm) had the smallest fruits, see Table 1. Compared to the reference cultivar ‘Angeleno’, 39.1 g (*L*: 36.5 mm; *W*: 41.2 mm; *T*: 41.7 mm) only ‘Aphrodite’ had significantly larger fruits. On the contrary, the ‘Shiro’, ‘Soriso di Primavera’, ‘Wan Hong’, ‘Burbank’, ‘Tichookeanskij’, ‘Golden Japan’, ‘SLE2014/1’, ‘SLE2014/2’, ‘Stanley’, ‘Black Amber’, ‘Ontario’ and ‘Oulinská’ cultivars had significantly smaller fruits.

In relation to the stone size, the average values ranged from 0.5 g in ‘Golden Japan’ (*L*: 16.1 mm; *W*: 11.3 mm; *T*: 5.9 mm) to 2.7 g in the ‘Fertility’ cultivar (*L*: 28.7 mm; *W*: 20.3 mm; *T*: 11.1 mm), see Table 1. ‘Fertility’ is an inter-species hybrid of *Prunus salicina* × *Prunus armeniaca*, which explains the larger size of its stone. Compared to the reference cultivar ‘Angeleno’, 0.88 g (*L*: 16.3 mm; *W*: 13.5 mm; *T*: 8.5 mm) the ‘Gavota’, ‘Soriso di Primavera’, ‘Lavinia’, ‘Santa Rosa’, ‘Stanley’, ‘Ontario’, ‘Aphrodite’, ‘SLE2014/2’, ‘Cacak’s Early’ and ‘Fertility’ cultivars had significantly larger stones, on the contrary ‘Golden Japan’ had significantly smaller stones.

An important parameter is the pulp fraction, which indicates the proportion of the edible part of the whole fruit. The highest pulp fraction was recorded in both the interspecific hybrids ‘SLE2014/2’ and ‘SLE2014/1’ (99.2% and 99.0%, respectively). Of the commercial varieties, the greengage ‘Oulinská’ (98.9%) and ‘Stanley’ (98.6%) had the highest pulp fraction. On the contrary, the lowest values were obtained with the Japanese plum variety ‘Shiro’ (91.0%) (Table 1).

The fruit firmness ranged from 0.7 kg/cm^2 ‘Kometa’ to 3.9 kg/cm^2 ‘Fortune’, see Table 1. None of the varieties had a significantly higher fruit firmness than the reference cultivar ‘Angeleno’ (3.6 kg/cm^2). With the exception of ‘Fortune’, ‘Black Amber’, ‘Burbank’ and ‘Santa Rosa’, all the other varieties had a significantly lower fruit firmness. The fruit firmness should be at least 2.65 kg/cm^2 to prevent damage during standard post-harvest operations (Gómez et al. 2006). Only four cultivars achieved this value in this study: ‘Fortune’ (3.9 kg/cm^2), ‘Black Amber’ (3.7 kg/cm^2), ‘Angeleno’ (3.6 kg/cm^2) and ‘Burbank’ (3.3 kg/cm^2). The fruits of these cultivars, therefore, can be manipulated even when fully ripe without any mechanical damage. Fruits achieving a value ranging between 1.32–2.65 kg/cm^2 are rated as “ready to buy” (Valero et al. 2007), where a total of eight cultivars fell within this range (Table 1). The fruits of the rest of the cultivars had lower values, which does not mean that they are not suitable for consumption, however, their manipulation could lead to some mechanical damage.

Nutritional properties

Total content of soluble solids (TSS). The TSS values of plum cultivars ranged from 14.4% ‘Ontario’ to 27.3% ‘Stanley’ (Table 3). Compared to ‘Angeleno’ (19.8%), a significantly higher TSS was measured only in the cultivars ‘Wan Hong’ and ‘Stanley’, on the contrary, a significantly lower TSS was measured in the cultivars ‘Ontario’, ‘Kometa’, ‘SLE2014/1’, ‘Vanier’, ‘Golden Japan’, ‘Fertility’, ‘Cacak’s Early’ and ‘Oulinská’. For plums, the TSS and firmness are two of the most important properties demonstrating the fruits’ quality (Crisosto 1994; Paz et al. 2008). Crisosto et al. (2004) state that 12% is a minimum acceptable TSS value for plums for direct consumption. All the tested cultivars achieved this value. Liverani et al. (2010) came to the conclusion

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Table 1. Pomological traits of the tested plum cultivars

Cultivar	Time of harvest	Fruit length (mm)[a]	Fruit width (mm)	Fruit thickness (mm)	Fruit mass (g)	Stone length (mm)	Stone width (mm)	Stone thickness (mm)	Stone mass (g)	Pulp fraction (%)	Fruit firmness (kg/cm^2)
Fortune	22-Aug	$42.82 \pm 0.6^{f-i}$	40.86 ± 1.0^{ghi}	43.68 ± 0.9^{ij}	45.58 ± 2.6^{g}	$20.06 \pm 0.4^{d-h}$	$14.24 \pm 0.4^{b-g}$	8.12 ± 0.3^{de}	1.02 ± 0.05^{cde}	97.74 ± 0.2^{ab}	3.92 ± 0.2^{h}
Black Amber	03-Aug	30.84 ± 0.8^{abc}	$37.26 \pm 1.6^{e-h}$	36.68 ± 0.9^{efgh}	$25.04 \pm 2.8^{b-e}$	17.62 ± 0.2^{bcd}	$13.38 \pm 0.2^{a-d}$	7.26 ± 0.1^{bcd}	0.64 ± 0.05^{abc}	$97.30 \pm 0.4^{a-d}$	3.71 ± 0.1^{gh}
Soriso di Primavera	03-Aug	$31.74 \pm 0.5^{a-d}$	28.42 ± 0.3^{ab}	29.30 ± 0.1^{ab}	17.52 ± 0.2^{ab}	22.78 ± 0.4^{hi}	$14.38 \pm 0.3^{c-g}$	6.41 ± 0.2^{ab}	$1.34 \pm 0.06^{e-h}$	92.33 ± 0.5^{ij}	1.01 ± 0.1^{abc}
Shiro	03-Aug	27.62 ± 0.8^{a}	26.62 ± 0.6^{a}	27.70 ± 0.5^{a}	13.92 ± 0.7^{a}	19.46 ± 0.8^{defg}	$13.94 \pm 0.3^{b-f}$	6.56 ± 0.2^{abc}	$1.26 \pm 0.07^{d-h}$	$90.95 \pm 0.2^{j}k$	0.95 ± 0.1^{ab}
Aphrodite	03-Aug	45.44 ± 1.0^{i}	44.20 ± 0.6^{i}	46.58 ± 0.6^{j}	56.60 ± 2.0^{h}	24.84 ± 0.4^{i}	17.96 ± 0.2^{h}	10.12 ± 0.1^{ij}	2.08 ± 0.08^{i}	$96.30 \pm 0.2^{b-e}$	$1.17 \pm 0.02^{a-d}$
Fertility	25-Jul	43.34 ± 0.6^{ghi}	$40.36 \pm 1.1^{f-i}$	45.51 ± 1.4^{j}	45.76 ± 2.7^{g}	28.71 ± 0.4^{j}	20.26 ± 0.4^{i}	11.12 ± 0.1^{j}	2.74 ± 0.05^{j}	93.93 ± 0.4^{fgh}	0.82 ± 0.1^{ab}
Vaniar	25-Jul	37.52 ± 1.3^{ef}	$37.42 \pm 1.5^{e-h}$	$36.64 \pm 1.5^{d-h}$	38.92 ± 2.2^{fg}	19.18 ± 0.5^{cdef}	$13.60 \pm 0.7^{b-e}$	8.48 ± 0.1^{def}	1.12 ± 0.04^{def}	$97.10 \pm 0.1^{a-d}$	0.79 ± 0.02^{ab}
Golden Japan	25-Jul	$34.26 \pm 0.8^{b-e}$	$33.62 \pm 1.3^{c-e}$	$33.02 \pm 1.1^{b-f}$	21.72 ± 2.2^{abc}	16.15 ± 0.3^{abc}	11.30 ± 0.1^{a}	5.94 ± 0.3^{a}	0.48 ± 0.08^{a}	97.67 ± 0.5^{ab}	0.97 ± 0.1^{abc}
Zurna	25-Jul	37.90 ± 1.0^{ef}	$36.20 \pm 0.8^{d-h}$	$34.78 \pm 0.6^{c-g}$	$28.84 \pm 1.7^{c-f}$	18.06 ± 0.3^{bcde}	12.16 ± 0.4^{ab}	7.44 ± 0.1^{bcd}	0.65 ± 0.09^{ab}	97.95 ± 0.3^{a}	0.85 ± 0.1^{ab}
Wan Hong	16-Aug	$33.68 \pm 0.8^{b-e}$	29.62 ± 0.5^{abc}	31.42 ± 0.5^{abc}	18.36 ± 0.9^{ab}	$18.84 \pm 0.7^{b-f}$	12.21 ± 0.2^{ab}	7.56 ± 0.1^{bcd}	0.72 ± 0.05^{abc}	96.09 ± 0.2^{cde}	$1.94 \pm 0.1^{b-e}$
Burbank	16-Aug	29.02 ± 1.5^{ab}	32.10 ± 0.8^{bcd}	31.06 ± 1.3^{abc}	20.20 ± 1.5^{abc}	15.92 ± 1.5^{ab}	12.22 ± 0.2^{abc}	7.58 ± 0.3^{bcd}	0.92 ± 0.07^{bcd}	95.43 ± 0.2^{ef}	3.29 ± 0.4^{fgh}
Santa Rosa	16-Aug	36.68 ± 1.1^{de}	$35.98 \pm 1.2^{d-g}$	$35.21 \pm 1.0^{c-g}$	29.44 ± 2.5^{cdef}	22.44 ± 0.5^{ghi}	15.68 ± 1.0^{efg}	$8.54 \pm 0.3^{d-g}$	1.44 ± 0.1^{fgh}	95.04 ± 0.4^{efg}	2.54 ± 0.4^{efg}
Kometa	25-Jul	$39.08 \pm 0.8^{e-h}$	$39.91 \pm 0.2^{f-i}$	37.92 ± 0.6^{fgh}	35.04 ± 1.7^{ef}	14.28 ± 0.4^{a}	20.54 ± 0.3^{i}	7.76 ± 0.1^{bcd}	0.91 ± 0.08^{bcd}	97.72 ± 0.2^{abc}	0.73 ± 0.1^{a}
Angelano	11-Sep	36.46 ± 1.2^{de}	41.20 ± 1.2^{hi}	41.66 ± 1.0^{hij}	39.11 ± 3.8^{fg}	16.36 ± 0.7^{abc}	13.48 ± 0.2^{bcd}	8.46 ± 0.3^{def}	0.88 ± 0.1^{bcd}	96.36 ± 0.2^{ab}	3.64 ± 0.1^{gh}
Gavota	25-Jul	35.86 ± 0.3^{cde}	$33.24 \pm 0.7^{b-e}$	30.78 ± 0.6^{abc}	32.65 ± 1.2^{def}	18.08 ± 0.4^{bcde}	16.14 ± 0.1^{fgh}	$9.42 \pm 0.2^{e-i}$	$1.32 \pm 0.04^{e-h}$	97.84 ± 0.2^{cde}	$2.16 \pm 0.1^{c-f}$
Ontario	03-Aug	38.52 ± 1.2^{efg}	33.92 ± 0.4^{cde}	$34.38 \pm 0.8^{b-g}$	$26.98 \pm 0.9^{b-e}$	$20.78 \pm 0.4^{e-h}$	$15.02 \pm 0.3^{d-g}$	$9.52 \pm 0.3^{f-i}$	1.62 ± 0.08^{h}	98.45 ± 0.3^{fgh}	$1.55 \pm 0.3^{a-e}$
Oulinská	16-Aug	35.50 ± 0.7^{cde}	31.76 ± 0.5^{bcd}	$34.26 \pm 0.8^{b-g}$	$25.22 \pm 1.6^{b-e}$	$19.86 \pm 0.4^{d-h}$	$15.04 \pm 0.3^{d-g}$	$9.48 \pm 0.2^{f-i}$	$1.24 \pm 0.06^{d-h}$	98.92 ± 0.1^{efg}	1.08 ± 0.2^{abc}
Tichookeanskij	03-Aug	35.08 ± 0.9^{cde}	30.20 ± 0.3^{abc}	$34.32 \pm 0.5^{b-g}$	20.84 ± 0.7^{abc}	19.68 ± 0.2^{defg}	13.48 ± 0.3^{bcd}	7.84 ± 0.1^{cd}	$1.25 \pm 0.04^{d-g}$	97.69 ± 0.2^{fgh}	2.31 ± 0.3^{def}
Cacak's Early	25-Jul	51.52 ± 0.6^{j}	33.64 ± 0.6^{cde}	38.82 ± 1.3^{ghi}	38.56 ± 2.5^{fg}	30.12 ± 0.5^{j}	16.33 ± 0.1^{gh}	9.92 ± 0.2^{hij}	2.38 ± 0.04^{ij}	97.72 ± 0.5^{ghi}	2.28 ± 0.1^{def}
Stanley	11-Sep	44.22 ± 0.8^{hi}	26.34 ± 0.6^{a}	$32.58 \pm 0.5^{a-e}$	$23.24 \pm 1.2^{a-d}$	28.28 ± 0.5^{j}	$14.06 \pm 0.1^{b-f}$	7.96 ± 0.1^{d}	1.58 ± 0.04^{gh}	98.56 ± 0.5^{hi}	$1.44 \pm 0.4^{a-e}$
Lavinia	25-Jul	$38.94 \pm 1.9^{e-h}$	35.43 ± 1.6^{def}	$32.24 \pm 1.6^{a-e}$	32.20 ± 1.3^{def}	$20.34 \pm 0.4^{d-h}$	$13.02 \pm 0.2^{a-d}$	$8.58 \pm 0.2^{d-h}$	$1.34 \pm 0.05^{e-h}$	98.44 ± 0.2^{de}	$1.56 \pm 0.1^{a-e}$
SLE2014/1	03-Aug	$33.90 \pm 0.9^{b-e}$	$32.51 \pm 0.8^{b-e}$	$33.56 \pm 1.0^{b-f}$	$22.52 \pm 1.3s^{bcd}$	$18.84 \pm 0.5^{b-f}$	$13.04 \pm 0.5^{a-d}$	8.24 ± 0.3^{def}	1.02 ± 0.09^{cde}	98.97 ± 0.4^{ef}	1.03 ± 0.2^{abc}
SLE2014/2	03-Aug	36.42 ± 0.7^{de}	32.00 ± 0.5^{bcd}	33.96 ± 0.6^{bcdefg}	24.96 ± 1.2^{bcde}	21.43 ± 0.5^{fgh}	14.74 ± 0.3^{defg}	9.88 ± 0.2^{ghij}	2.34 ± 0.09^{i}	$99.18 \pm 0.1k$	0.82 ± 0.1^{ab}

[a]Any two means within a row not followed by the same letter are significantly different at $P \leq 0.05$

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Table 2. Nutritional properties of the tested minor fruit species

Minor fruit species/cultivar	Time of harvest (date)	Total soluble solid (TSS) (%)[a]	Total ascorbic acid (TAA) in mix (mg/100 g)	Total flavonoids (TCF) in mix (mg CE/100 g)	Total phenolics (TCP) in mix (mg GAE/100 g)	Total antioxidant activity (TAC) DPPH mix (mg TE/100 g)
Sambucus nigra 'Dana'	22-Aug	8.35 ± 0.6^{abc}	122.06 ± 2.8^{f}	48.01 ± 0.9^{e}	323.63 ± 0.12^{i}	264.89 ± 3.31^{ef}
Rubus fruticosus 'Thorn Free'	11-Aug	7.40 ± 0.2^{ab}	115.14 ± 6.2^{ef}	32.59 ± 0.0^{d}	244.56 ± 8.2^{f}	155.67 ± 4.99^{c}
Rubus idaeus 'Sugana'	11-Aug	8.10 ± 0.1^{abc}	69.63 ± 0.9^{cd}	12.36 ± 0.8^{ab}	135.59 ± 0.08^{d}	94.45 ± 3.04^{a}
Vaccinium myrtillus – wild shrub	29-Jul	6.60 ± 0.1^{a}	14.34 ± 1.7^{a}	139.59 ± 6.1^{m}	567.19 ± 0.45^{m}	392.7 ± 5.37^{h}
Vaccinium corymbosum 'Nelson'	02-Aug	9.00 ± 0.5$^{a–d}$	14.13 ± 1.5^{a}	117.53 ± 0.0^{kl}	346.83 ± 0.08^{k}	270.24 ± 3.14^{f}
Sorbus melanocarpa 'Nero'	22-Aug	24.61 ± 1.0^{j}	61.25 ± 2.2^{cd}	544.67 ± 4.3^{p}	849.94 ± 0.23^{q}	435.82 ± 7.95^{i}
Sorbus aucuparia 'Krasavica'	26-Sep	26.11 ± 0.2^{j}	622.99 ± 1.6^{k}	112.05 ± 4.2^{ik}	335.8 ± 0.1^{j}	268.85 ± 9.7^{f}
Lonicera edulis 'Amfora'	23-May	11.80 ± 1.0$^{d–h}$	183.75 ± 2.2^{g}	257.78 ± 2.3^{o}	799.07 ± 2.17^{p}	849.76 ± 13.62^{j}
Cornus mass 'Vydubecký'	22-Sep	20.92 ± 0.3^{i}	331.45 ± 3.3^{h}	127.04 ± 0.9^{im}	983.88 ± 0.41^{r}	340.07 ± 3.6^{g}
Ribes nigrum 'Titania'	13-Jul	13.93 ± 0.4^{gh}	429.21 ± 8.7^{i}	74.51 ± 5.0^{fg}	539.32 ± 0.24^{l}	340.73 ± 2.88^{g}
Ribes rubrum 'Red Lake'	13-Jul	13.65 ± 0.7^{gh}	132.77 ± 10.1^{f}	24.5 ± 0.0^{bcd}	156.59 ± 0.05^{e}	118.95 ± 8.28^{ab}
Grossularia uva-crispa 'Hinnonmaki Red'	13-Jul	14.03 ± 0.5^{h}	64.18 ± 5.0^{cd}	31.11 ± 1.0^{d}	143.86 ± 1.45^{d}	225.04 ± 9.16^{d}
Grossularia uva-crispa 'Hinnonmaki Green'	13-Jul	14.04 ± 1.0^{h}	33.09 ± 1.0^{ab}	5.64 ± 0.0^{a}	45.25 ± 0.12^{a}	94.08 ± 3.24^{a}

[a]Any two means within a row not followed by the same letter are significantly different at $P \leq 0.05$

that European plums have a higher TSS than Japanese cultivars. However, only six European plum cultivars are included in the present work, which are also not typical representatives of this group. Therefore, were unable to confirm this statement with any accuracy from the present work. On the other hand, we proved a higher TSS at the European plums than at the Japanese plums in a previous work, when most of the European cultivars achieved TSS values of over 20% (Wolf et al. 2019).

The TSS values ranged between 6.6 % (*V. myrtillus*) to 26.1% 'Krasavica' (Table 2), in the minor fruit varieties. Only the varieties 'Vydubecký' (*C. mas*), 'Nero' and 'Krasavica' (*Sorbus*) had a higher TSS than the plum cultivars with the lowest TSS. The TSS values of the samples derived from the *Sorbus* genus are, however, significantly higher than those in a study of Kampus et al. (2009). The remaining samples had TSS values significantly lower than the plums.

Total content of ascorbic acid (TAA). The TAA in MIX in the plum cultivars ranged from 0.7 mg/100 g 'Kometa' to 8.4 mg/100 g 'Stanley'. Significantly higher TAA in MIX compared to 'Angeleno' (6.1 mg/100 g) was only measured at the cultivar 'Stanley'. On the contrary, all the cultivars, except for 'Wan Hong', had a significantly lower TAA in MIX compared to 'Angeleno' (Table 3). Gil et al. (2002) measured a TAA in the tested plum cultivars within the range of 3–10 mg/100 g. Our data reached slightly lower values.

The TAA in FLESH in the plum cultivars ranged from 0.6 mg/100 g 'Kometa' to 5.4 mg/100 g 'Stanley' (Table 3). A higher TAA in the FLESH content compared to 'Angeleno' (4.7 mg/100 g) was only found in the cultivar 'Wan Hong' and 'Stanley'. All the cultivars, with the exception of 'Stanley', 'Oulinská' and 'Burbank', had a significantly lower TAA in FLESH compared to the cultivar 'Angeleno'. Gil et al. (2002) state that the peel contains a higher TAA than the flesh. Unfortunately, the TAA was not measured in the peel in the present study. However, the TAA in MIX was higher than the TAA in FLESH in most cultivars with the exception of 'Black Amber', 'Zurna', 'Oulinská' and 'Cacak's Early'. This indicates that the TAA in the peel increases the TAA in MIX. Even on the basis of these results, we assume that the TAA in the peel will be several times higher than in FLESH.

The TAA contain in the minor fruit varieties in MIX ranged from 14.1 mg/100 g 'Nelson' to 622.9 mg/100 g 'Krasavica' (Table 2). The plum cultivars 'Kometa', 'Tichookeanskij', 'Ontario', 'Cacak's Early' and 'Zurna' had a non-significant lower TAA in MIX than the minor fruit varieties. However, the samples of 'Thorn Free', 'Dana', 'Red Lake',

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Table 3. Nutritional properties of the tested plum cultivars

Cultivar	Total soluble solid (TSS) (%)[a]	Total ascorbic acid (TAA) in mix (mg/100 g)	Total ascorbic acid (TAA) in flesh (mg/100 g)	Total flavonoids (TCF) in flesh (mg CE/100 g)	Total flavonoids (TCF) in peel (mg CE/100 g)	Total flavonoids (TCF) in mix (mg CE/100 g)
Fortune	20.61 ± 0.3^{hij}	16.77 ± 0.1^{cd}	15.53 ± 0.2$^{a–e}$	31.79 ± 1.4^{ab}	789.43 ± 12.1^{ij}	291.46 ± 3.0^{n}
Black Amber	17.71 ± 0.3$^{c–h}$	15.96 ± 0.1^{bcd}	18.81 ± 0.1$^{c–f}$	104.05 ± 0.0^{gh}	923.02 ± 12.1^{kl}	220.89 ± 0.0^{l}
Soriso di Primavera	19.14 ± 0.1^{fgh}	45.78 ± 0.2^{i}	8.54 ± 0.1^{ab}	56.36 ± 0.0^{cd}	400.78 ± 0.0$^{c–f}$	92.04 ± 0.0^{d}
Shiro	19.43 ± 0.2^{ghi}	48.46 ± 0.4^{i}	24.49 ± 0.1^{efg}	122.84 ± 1.4^{ijk}	291.48 ± 0.0^{bc}	101.24 ± 0.0^{de}
Aphrodite	19.66 ± 0.3^{ghi}	24.62 ± 0.1^{f}	18.84 ± 0.2$^{c–f}$	131.51 ± 1.4^{jk}	935.17 ± 24.2^{kl}	211.69 ± 0.0^{kl}
Fertility	16.35 ± 0.5$^{a–e}$	16.8 ± 2.1^{cd}	11.94 ± 0.9^{abc}	108.39 ± 0.0^{hi}	680.12 ± 12.1^{hi}	181.01 ± 3.0^{i}
Vaniar	15.77 ± 0.2$^{a–d}$	17.21 ± 0.1^{l}	17.94 ± 0.1$^{b–f}$	111.28 ± 1.4^{hi}	461.51 ± 32.1$^{d–g}$	125.78 ± 3.0^{f}
Golden Japan	16.11 ± 0.3$^{a–d}$	22.03 ± 0.4^{ef}	22.25 ± 0.7$^{d–g}$	34.68 ± 0.0^{ab}	194.32 ± 12.1^{ab}	64.42 ± 0.0^{c}
Zurna	17.96 ± 0.3$^{d–g}$	13.01 ± 0.2^{bc}	21.52 ± 0.3$^{c–g}$	73.71 ± 0.0^{e}	376.49 ± 12.1^{cde}	147.26 ± 0.0^{g}
Wan Hong	22.37 ± 0.3^{j}	63.5 ± 0.2^{j}	69.48 ± 0.6^{kl}	174.87 ± 2.9^{mn}	971.61 ± 12.1^{l}	147.26 ± 0.0^{g}
Burbank	21.65 ± 0.2^{ij}	46.9 ± 0.1^{i}	56.42 ± 0.2^{ij}	156.08 ± 0.0^{l}	789.43 ± 12.1^{ij}	202.49 ± 0.0^{jk}
Santa Rosa	18.53 ± 0.3$^{e–h}$	32.35 ± 0.6^{g}	29.06 ± 0.3^{gh}	108.39 ± 0.0^{hi}	388.64 ± 12.1$^{c–f}$	193.28 ± 0.0^{j}
Kometa	15.13 ± 0.5^{ab}	7.36 ± 0.1^{a}	7.83 ± 1.3^{a}	86.71 ± 0.0^{ef}	473.65 ± 0.0^{efg}	116.58 ± 3.0^{f}
Angelano	19.75 ± 0.4^{ghi}	61.38 ± 0.9^{j}	66.06 ± 0.3^{jkl}	186.43 ± 0.0^{n}	874.44 ± 0.0^{jkl}	162.61 ± 3.0^{h}
Gavota	18.98 ± 0.4^{fgh}	40.44 ± 0.1^{h}	55.66 ± 5.4^{i}	43.35 ± 0.0^{b}	340.06 ± 32.1^{cd}	73.63 ± 0.0^{c}
Ontario	14.45 ± 0.4^{a}	11.25 ± 0.1^{ab}	13.82 ± 0.1$^{a–d}$	91.04 ± 0.0^{gh}	376.49 ± 12.1^{cde}	119.65 ± 0.0^{f}
Oulinská	16.91 ± 0.5$^{b–f}$	37.63 ± 0.4^{h}	61.91 ± 0.2^{ijk}	274.59 ± 14.4^{o}	157.88 ± 12.1^{a}	33.74 ± 3.0^{a}
Tichookeanskij	19.36 ± 0.4^{fgh}	11.03 ± 0.1^{ab}	16.94 ± 0.1$^{a–f}$	115.61 ± 1.4^{hij}	838.01 ± 0.0^{jk}	242.37 ± 3.0^{m}
Cacak‘s Early	16.38 ± 0.4$^{a–e}$	12.51 ± 3.6^{bc}	35.66 ± 5.7^{h}	21.67 ± 0.0^{a}	145.74 ± 0.0^{a}	46.02 ± 0.0^{b}
Stanley	27.25 ± 0.8^{k}	83.27 ± 0.1^{k}	73.01 ± 0.9^{l}	169.09 ± 0.0^{lm}	364.35 ± 72.8^{cde}	119.65 ± 0.0^{f}
Lavinia	20.42 ± 0.4^{hij}	19.75 ± 0.4^{def}	17.61 ± 2.4$^{b–f}$	72.26 ± 1.4^{de}	510.09 ± 21.0^{fg}	104.31 ± 3.0^{e}
SLE2014/1	15.66 ± 0.4^{abc}	29.86 ± 0.1^{g}	37.72 ± 0.2^{h}	134.44 ± 0.0^{k}	570.81 ± 24.2^{gh}	174.87 ± 0.0^{i}
SLE2014/2	17.93 ± 0.7$^{d–g}$	30.04 ± 0.3^{g}	25.34 ± 0.1^{fg}	52.02 ± 0.0^{c}	485.81 ± 48.5^{efg}	208.62 ± 3.0^{k}

Cultivar	Total phenolics (TCP) in flesh (mg GAE/100 g)	Total phenolics (TCP) in peel (mgGAE/100 g)	Total phenolics (TCP) in mix (mg GAE/100 g)	Total antioxidant activity (TAC) DPPH flesh (mg TE/100 g)	Total antioxidant activity (TAC) DPPH peel (mg TE/100 g)	Total antioxidant activity (TAC) DPPH mix (mg TE/100 g)
Fortune	303.25 ± 0.38^{u}	560.85 ± 0.5^{s}	429.77 ± 0.4^{t}	560.76 ± 0.0^{m}	1 130.97 ± 0.0^{l}	745.99 ± 9.1^{i}
Black Amber	207.94 ± 0.31^{l}	646.07 ± 1.3^{u}	343.22 ± 0.0^{s}	504.68 ± 0.0^{l}	1 246.16 ± 10.4^{n}	777.74 ± 0.0^{ijk}
Soriso di Primavera	114.88 ± 0.44^{g}	210.75 ± 0.4^{f}	121.01 ± 0.1^{d}	119.62 ± 0.0^{cd}	753.98 ± 0.0^{h}	380.93 ± 0.0^{b}
Shiro	246.95 ± 0.34^{p}	156.66 ± 0.9^{d}	330.01 ± 0.2^{r}	373.84 ± 0.0^{i}	345.57 ± 0.0^{de}	534.36 ± 5.3^{ef}
Aphrodite	251.21 ± 0.42^{q}	710.48 ± 1.2w	310.04 ± 0.5^{p}	523.37 ± 0.0^{l}	1 507.96 ± 0.0^{o}	777.74 ± 9.1^{ijk}
Fertility	223.35 ± 0.13^{n}	530.92 ± 0.1^{r}	281.42 ± 0.2^{n}	342.68 ± 6.2^{h}	1 036.72 ± 18.1^{k}	745.99 ± 0.0^{i}
Vaniar	220.89 ± 0.11^{n}	375.46 ± 0.7^{k}	208.26 ± 0.3^{j}	342.68 ± 6.2^{h}	264.53 ± 5.2^{b}	560.82 ± 5.3^{f}
Golden Japan	69.34 ± 0.24^{c}	140.14 ± 0.7^{c}	94.79 ± 0.0^{c}	80.99 ± 1.2^{b}	230.38 ± 10.4^{b}	753.98 ± 18.1^{ij}
Zurna	134.07 ± 0.01^{g}	280.47 ± 0.9^{h}	213.55 ± 0.7^{k}	135.82 ± 1.2^{d}	471.23 ± 18.1^{f}	518.49 ± 5.3^{de}
Wan Hong	292.51 ± 0.29^{s}	655.54 ± 1.1^{v}	250.13 ± 0.1^{l}	654.22 ± 0.0^{n}	2 324.77 ± 0.0^{p}	788.32 ± 5.3^{jk}
Burbank	295.24 ± 0.18^{t}	471.39 ± 0.5^{o}	310.25 ± 2.4^{p}	685.37 ± 6.2^{o}	1 497.48 ± 10.4^{o}	772.45 ± 5.3^{ij}
Santa Rosa	185.48 ± 0.18^{k}	397.49 ± 0.5^{l}	311.54 ± 0.1^{p}	392.53 ± 0.0^{ij}	753.98 ± 0.0^{h}	661.34 ± 5.2^{gh}
Kometa	175.04 ± 0.13^{J}	305.02 ± 3.0^{j}	169.26 ± 0.1^{g}	280.38 ± 0.0^{g}	785.39 ± 0.0^{h}	486.74 ± 10.5^{d}
Angelano	313.14 ± 0.2^{v}	597.80 ± 0.3^{t}	257.92 ± 0.2^{m}	504.68 ± 0.0^{l}	1 288.04 ± 0.0^{n}	677.21 ± 5.2^{h}
Gavota	100.53 ± 0.18^{d}	246.15 ± 0.7^{g}	131.97 ± 0.1^{e}	110.96 ± 3.3^{c}	376.99 ± 0.0^{e}	407.38 ± 5.2^{b}
Ontario	153.21 ± 0.04^{i}	173.86 ± 0.4^{e}	162.07 ± 0.1^{f}	179.44 ± 0.0^{e}	303.68 ± 10.4^{c}	523.78 ± 0.0^{e}
Oulinská	37.73 ± 0.11^{a}	72.18 ± 0.6^{a}	51.46 ± 0.3^{a}	218.07 ± 12.4^{f}	62.83 ± 0.0^{a}	444.42 ± 9.1^{c}

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Table 3 to be continued. Nutritional properties of the tested plum cultivars

Cultivar	Total phenolics (TCP) in flesh (mg GAE/100 g)	Total phenolics (TCP) in peel (mg GAE/100 g)	Total phenolics (TCP) in mix (mg GAE/100 g)	Total antioxidant activity (TAC) DPPH flesh (mg TE/100 g)	Total antioxidant activity (TAC) DPPH peel (mg TE/100 g)	Total antioxidant activity (TAC) DPPH mix (mg TE/100 g)
Tichookeanskij	230.03 ± 0.21[o]	509.29 ± 1.6[q]	175.12 ± 0.2[hi]	411.22 ± 0.0[jk]	1 183.32 ± 10.4[m]	634.89 ± 0.0[g]
Cacak's Early	44.44 ± 0.28[b]	129.89 ± 0.4[b]	64.14 ± 0.1[b]	49.84 ± 1.2[a]	219.91 ± 0.0[b]	206.33 ± 0.0[a]
Stanley	69.16 ± 0.03[c]	323.11 ± 0.2[j]	178.82 ± 0.3[i]	61.06 ± 1.2[a]	607.37 ± 10.4[g]	444.42 ± 0.0[c]
Lavinia	138.32 ± 0.02[h]	455.78 ± 0.2[n]	172.12 ± 0.3[gh]	127.14 ± 0.0[cd]	848.22 ± 18.1[i]	449.71 ± 5.3[c]
SLE2014/1	289.36 ± 0.44[r]	432.64 ± 1.0[m]	325.69 ± 1.8[q]	429.91 ± 0.0[k]	1036.72 ± 0.0[k]	523.78 ± 0.0[e]
SLE2014/2	112.77 ± 0.14[e]	488.66 ± 1.6[q]	298.06 ± 0.1[o]	118.38 ± 1.2[cd]	963.41 ± 10.4[j]	809.48 ± 0.0[k]

[a]Any two means within a row not followed by the same letter are significantly different at $P \leq 0.05$

'Amfora', 'Vydubecký', 'Titania', and 'Krasavica' had a significantly higher TAA in MIX content than any plum cultivar.

If we compare the TAA content in the plums to the TAA content in the minor fruit varieties, the minor fruit varieties had a higher TAA, with the exception of blueberries (1.4–2.3 mg/100 g), which had TAA values similar to plums. The notional threshold of 10 mg/100 g, which none of the plums exceeded, was exceeded in ten samples of the minor fruit varieties. The samples with the highest content were representatives of *C. mas*, *S. aucuparia* and *R. nigrum*. 'Krasavica', 622.9 mg/100 g had the highest TAA content. The TAA values in the samples of the minor fruit varieties from this work usually corresponded to the data from other publications, Kampuss et al. (2009) 49–53 mg/100 g (*Sorbus*), Marková (2001) 20–170 mg/100 g (*Lonicera*) and Göttingerová (2018) 38.94 mg/100 g (*Cornus*).

Total content of phenolic compounds (TCP). The TCP in MIX in the plum cultivars ranged from 51.5 mg GAE/100 g 'Oulinská' to 429.8 mg GAE/100 g 'Fortune' (Table 3). Kim et al. (2003) measured values ranging from 174.0 to 375.0 mg GAE/100 g (only European plums), and Gil et al. (2002) measured values ranging from 42.0 to 109.2 mg GAE/100 g (only Japanese plums). These studies confirm the fact that the actual phenolic content and the content of the other substances differs depending on the cultivar, rootstock, nutrition and climatic phenomena (Blažek, Kneifl 2005). The cultivars 'Fertility', 'SLE2014/2', 'Aphrodite', 'Burbank', 'Santa Rosa', 'SLE2014/1', 'Shiro', 'Black Amber' and 'Fortune' had a significantly higher TCP compared to 'Angeleno' (257.9 mg GAE/100 g). The remaining cultivars had a significantly lower TCP compared to 'Angeleno'.

The TCP in FLESH in the plums ranged from 37.7 mg GAE/100 g 'Oulinská' to 313.1 mg GAE/100 g 'Angeleno' (Table 3). All the tested cultivars had a significantly lower TCP in FLESH compared to 'Angeleno'. The TCP in PEEL in the plums ranged between 72.2 mg GAE/100 g 'Oulinská' to 710.5 mg GAE/100 g in 'Aphrodite' (Table 3). The cultivars 'Black Amber', 'Wan Hong' and 'Aphrodite' had a significantly higher TCP in PEEL when compared to the cultivar 'Angeleno' (597.8 mg GAE/100 g). The remaining cultivars had a significantly lower TCP in PEEL. When comparing the TCP in PEEL and the TCP in FLESH, the TCP in PEEL was usually twice the value the TCP in FLESH in most plum samples. This result shows that the peel contains more phenolic compounds than the flesh (Figure 1). A higher TCP in FLESH than the TCP in PEEL was only measured in the 'Shiro' cultivar which has yellow fruits. A significant correlation ($R > 0.7$) was calculated between the TCP in PEEL and the TCP in FLESH (Table 4).

In the minor fruit varieties, the TCP in MIX ranged from 45.3 mg GAE/100 g 'Hinnonmaki Green' to 983.9 mg GAE/100 g 'Vydubecký' (Table 2).

Table 4. Correlation coefficients of the analysed components between the different fruit parts

Fruit	Part of fruit	MIX/FLESH	MIX/PEEL	FLESH/PEEL
Plum	TAA	0.78392	–	–
	TCF	–0.0471	0.76552	0.21413
	TCP	0.77856	0.6917	0.71413
	TAC	0.65067	0.64055	0.76364

TAA – total content of ascorbic acid; TCF – total content of flavonoids; TCP – total content of phenolic compounds; TAC – total antioxidant activity

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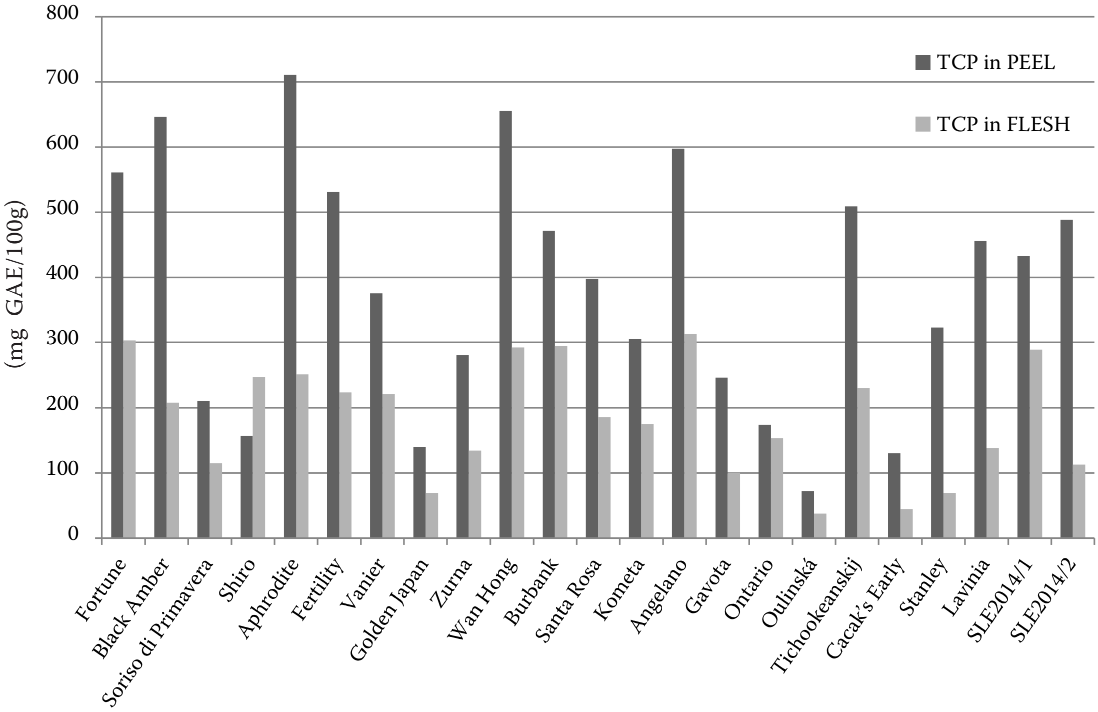

Figure 1. Comparison of the total content of phenolic compounds (TCP) in FLESH and PEEL at plum cultivars

The samples of 'Titania', wild *V. myrtillus*, 'Amfora', 'Nero' and 'Vydubecký' had a significantly higher TCP in MIX compared to the plums. Very high values (700.0–980.0 mg GAE/100 g) were measured in the samples of the 'Amfora', 'Nero' and 'Vydubecký' cultivars. In relation to blueberries, which have become very popular recently, their TCP is similar to the TCP in plums, with the exception of *V. myrtillus*, which had a higher TCP (567.2 mg GAE/100 g). The TCP of the *S. aucuparia* samples were very similar to those measured in the study by Kampuss et al. (2009). When focusing on currants and gooseberries, their TCP value did not exceed 200.0 mg GAE/100 g in any sample, with the exception of the cultivar 'Titania' which had a TCP value of 539.0 mg GAE/100 g, which, in addition, is actually higher than that published by Contessa et al. (2013).

Total content of flavonoids (TCF). The TCF in MIX in the plum cultivars ranged from 33.7 mg CE/100 g 'Oulinská' to 291.5 mg CE/100 g 'Fortune' (Table 3). Compared to the reference cultivar 'Angeleno' (162.6 mg CE/100 g), a significantly higher TCF in MIX was measured in the cultivars 'SLE2014/1', 'Fertility', 'Santa Rosa', 'SLE2014/2', 'Burbank', 'Aphrodite', 'Black Amber', 'Tichookeanskij' and 'Fortune', whereas the remaining cultivars had a significantly lower TCF in MIX.

The TCF in FLESH in the plums ranged from 21.7 mg CE/100 g 'Cacak's Early' to 274.6 mg CE/100 g 'Oulinská' (Table 3). Compared to the cultivar 'Angeleno' (186.4 mg CE/100 g), a significantly higher TCF in FLESH was only measured in the cultivar 'Oulinská'. On the contrary, a significantly lower content was measured in all the remaining cultivars, except for 'Wan Hong'. The TCF in PEEL in the plum cultivars ranged from 145.7 mg CE/100 g 'Cacak's Early' to 971.6 mg CE/100 g 'Wan Hong' (Table 3). In all the plum cultivars, except for 'Wan Hong', 'Aphrodite', 'Black Amber', 'Tichookeanskij', 'Fortune' and 'Burbank', a significantly lower content of the TCF in PEEL was measured compared to 'Angeleno' (874.4 mg CE/100 g). When comparing the TCF in PEEL and the TCF in FLESH, the TCF in PEEL was much higher than in the TCF in FLESH (Figure 2). This indicates that the flavonoids in the fruit are predominantly concentrated in the peel. No significant correlation was found between the TCF in PEEL and the TCF in FLESH.

When the TCF and TCP were compared in the different parts of the fruit, the TCF in MIX has around one-third of the value of the TCP (Figure 3), with a correlation coefficient of R = 0.826. Similar results were obtained by Kim et al. (2003), where the correlation reached R = 0.934. The TCF in FLESH had around one-half of the value of the TCP, with a non-

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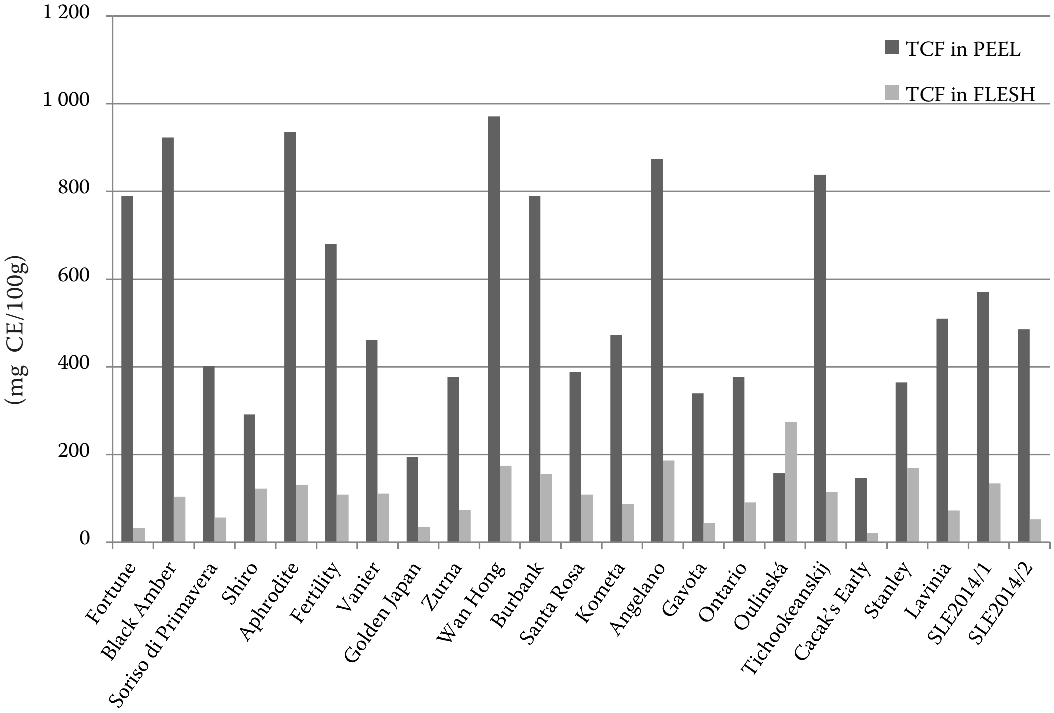

Figure 2. Comparison of the total content of flavonoids (TCF) in FLESH and PEEL in the plum cultivars

significant correlation of R = 0.220. When comparing the TCF and TCP in PEEL (Figure 4), the value of the TCF was one-quarter higher than that of the TCP, with a correlation coefficient of R = 0.931. Based on these results, the flavonoids are the major component of the phenolic compounds in PEEL, whereas in FLESH they only represent a small part of the phenolic compounds and are not significantly influencing the TCP as in PEEL.

In the minor fruit varieties, the TCF in MIX ranged from 5.6 mg CE/100 g 'Hinnonmaki Green' to 544.7 mg CE/100 g 'Nero' (Table 2). Compared to the plum cultivars, the cultivar 'Nero' had a significantly higher TCF in MIX while the cultivars 'Hinnonmaki Green' and 'Sugana' had a significantly lower TCF in MIX. When comparing the TCF and TCP in the minor fruit varieties, the same conclusion was made as at the plum cultivars, that the TCF content is many times lower than the TCP content in the majority of the samples. The cultivar 'Nero' is the exception to this, which had the highest TCF content among all the tested samples. The TCF of this sample was actually two-thirds of the TCP. The actual correlation coefficient between the TCF and TCP was determined as significant R > 0.7 (Table 4).

Total content of antioxidant activity (TAC). The TAC in MIX in the plum cultivars ranged from 206.3 mg TE/100 g 'Cacak's Early' to 809.5 mg TE/100 g 'SLE2014/2' (Table 3). Compared to 'Angeleno' (677.2 mg TE/100 g), a significantly higher TAC in MIX was measured in the cultivars 'Fertility', 'Fortune', 'Golden Japan', 'Burbank', 'Aphrodite', 'Black Amber', 'Wan Hong' and 'SLE2014/2'. Compared to the 'Angeleno' cultivar, a significantly lower TAC was measured in all the remaining cultivars, with the exception of 'Santa Rosa'.

The TAC in FLESH in the plum cultivars ranged from 49.8 mg TE/100 g 'Cacak's Early' to 685.4 mg TE/100 g 'Burbank' (Table 3). Compared to 'Angeleno' (504.7 mg TE/100 g), a significantly higher TAC in MIX was measured in the cultivars 'Fortune', 'Wan Hong' and 'Burbank'. On the contrary, a significantly lower TAC in MIX was measured in all the remaining cultivars when compared to 'Angeleno', with the exception of 'Black Amber' and 'Aphrodite'.

The TAC in PEEL in the plum cultivars ranged from 62.8 mg TE/100 g 'Oulinská' to 2 314.8 mg TE/100 g 'Wan Hong' (Table 3). Compared to 'Angeleno' (1 288.0 mg TE/100 g), a significantly higher TAC in MIX was measured in the cultivars 'Burbank', 'Aphrodite' and 'Wan Hong'. On the contrary, significantly lower TAC in MIX was measured in all the remaining cultivars when compared to 'Angeleno', with the exception of 'Black Amber'. The TAC in PEEL was higher than the TAC in FLESH, with the exception of the cultivars 'Vanier', 'Oulinská'

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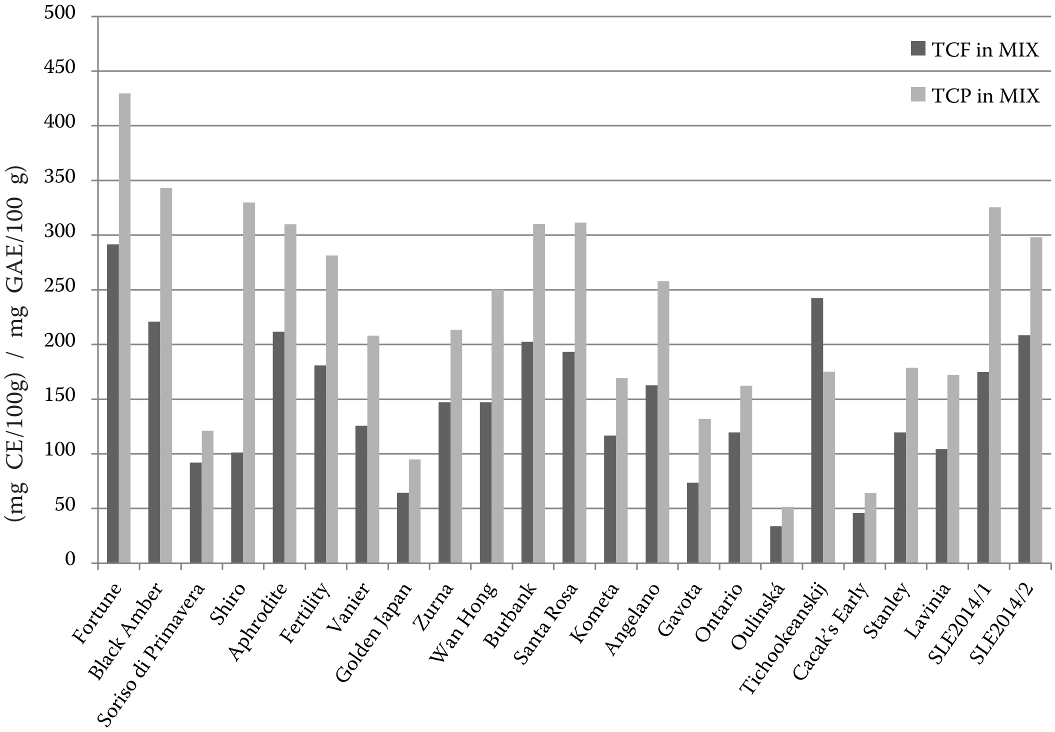

Figure 3. Comparison of the total content of flavonoids (TCF) and the total content of phenolic compounds (TCP) in MIX (peel+flesh) in the plum cultivars

and 'Shiro'. The higher TAC in PEEL correlates with the TCP in PEEL (R = 0.870). The same positive impact of the TCP on the TAC was observed in several other studies (Velioglu et al. 1998; Kalt et al. 1999; Proteggente et al. 2002).

The TAC in MIX in the minor fruit varieties ranged from 94.1 mg TE/100 g 'Hinnonmaki Green' to 849.8 mg TE/100 g 'Amfora' (Table 2). Compared to the plums, a significantly higher TAC was measured only in 'Amfora'. Compared to the plums, a significantly lower TAC was measured in the samples of 'Hinnonmaki Green', 'Sugana', 'Red Lake' and 'Thorn Free'.

The TAC in all the samples ranged from 94.1 to 849.78 mg TE/100 g. Of the minor fruit varieties, only the samples of *V. myrtillus*, 'Nero' and 'Amfora' came close to the TAC of the plums. The remaining minor fruit samples had a significantly lower TAC (the TAC of 'Cacak's Early' was not included in the TAC of the plums, as its value was significantly lower than that of the rest of the plum cultivars). The fact that plums have one of the highest antioxidant activities has already been published in several publications (Prior et al. 1998; Gil et al. 2002; Kim et al. 2003; Cevallos-Casals et al. 2006). The theory that blueberries have a higher TAC than plums was not confirmed in the present study. Garden blueberries (*V. corymbosum*) had a much lower TAC than Japanese plums, only *V. myrtillus* equalled the plums in the TAC value.

However, the sample of 'Amfora' (*L. edulis*) must be highlighted. Under the conditions in the Czech Republic, it is the earliest fruit to ripen and it reached very interesting values with regard to the nutritional substances, not just the TAC, but also the TCF, TCP, TAA and TSS. Compared to *C. mas* or *S. nigra*, which also had very interesting values of the abovementioned substances, *L. edulis* fruits have higher organoleptic properties.

Correlation between individual fruit components and antioxidant activity

A correlation matrix was executed, thanks to which the correlation coefficients between the quantities of the substances in the individual parts of the fruit were calculated (Table 4). The correlation coefficients between the content of the various substances and the TAC in the individual parts of the fruit were subsequently calculated (Table 5). There was no significant correlation between the TAA and the TAC. Highly significant correlations were calculated between the TCP and the TAC and a significant correlation was calculated between the TCF and the TAC in FLESH.

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Table 5. Correlation coefficients between the TAC (total antioxidant activity), TCP (total content of phenolic compounds), TAA (total content of ascorbic acid) and TCF (total content of flavonoids)

Fruit	Part of fruit	TCP/TCF	TAA/TAC	TCP/TAC	TCF/TAC
	MIX	0.8267	0.0124	0.66531	0.70658
Plum	FLESH	0.22027	0.14508	0.90332	0.40128
	PEEL	0.93132	–	0.87093	0.89919
Minor fruits	MIX	0.72466	0.2043	0.78798	0.66583

For abbreviations see Table 4

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