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ORIGINAL RESEARCH PAPER

PHYSICOCHEMICAL CHARACTERISATION OF TWO JAPANESE PLUM (*PRUNUS SALICINA* LINDL.) CULTIVARS GROWN IN SOUTH-WESTERN ROMANIA

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Abstract

In the present study, two Japanese plum (*Prunus salicina* Lindl.) cultivars grown in a collection orchard in Oltenia (South-Western Romania), namely Eldorado and Methley, were evaluated for their geometrical, physical, nutritional and antioxidant properties. In addition, phenolic compounds, organic acids and vitamin C contents were determined by high-performance liquid chromatography in fruit flesh and peel. Methley had larger fruits with higher pulp ratio as compared with Eldorado, however Methley plums had lower dry matter, soluble solids content and titratable acidity. Total phenolic content was higher in Eldorado plums as compared with Methley plums, both in fruit flesh (143.82 mg/100 g and 129.27 mg/100 g, respectively) and peel (572.14 mg/100 g and 536.44 mg/100 g, respectively). The analysis of phenolic compounds indicated that rutin was the dominant flavonoid in the peel of both cultivars (76.10 mg/100 g in Methley and 51.63 mg/100 g in Eldorado), followed by epicatechin or catechin hydrate, depending on cultivar. Chlorogenic acid was the major phenolic acid in flesh, its content was higher in the flesh of Methley plums (2.31 mg/100 g) as compared with Eldorado (1.79 mg/100 g). In terms of organic acids content, malic acid was predominant, followed by citric or tartaric acids, depending on cultivar. The nutritional and bioactive properties of Eldorado and Methley Japanese plum cultivars make them suitable to be grown in the agroecological conditions of South-Western Romania.

Keywords: Japanese plum cultivars, phenolic acids, flavonoids, organic acids, antioxidant activity

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Introduction

Plums are one of the most popular fruits with great commercial interest and wide distribution, mainly attributed to the high number of plum species originating from different climatic and geographical regions (Celik *et al.*, 2017). *Prunus domestica* L., *Prunus cerasifera* Ehrh., *Prunus spinosa* L., *Prunus cerasus* L. and *Prunus persica* L. are the most distributed plum species in the spontaneous and cultivated flora of the Sub-Carpathian area of Oltenia (South-West Romania) (Cosmulescu *et al.*, 2018). Originating in China, the Japanese plum (*Prunus salicina* Lindl.) is largely grown for fresh consumption, mostly in temperate and subtropical zones. The Japanese plum (*Prunus salicina* Lindl.) dominates in the world of plum commercial cultivation (Basanta *et al.*, 2016; Głowacka *et al.*, 2021), the globally Japanese plum production being larger than that of European plum (*Prunus domestica* L.) (Fanning *et al.*, 2014). The *Prunus salicina* fruits are distinguished by size, aroma, color of the flesh and skin, and fruit storage capacity (Blazek, 2007; Topp *et al.*, 2012). Japanese plum cultivars present a large variability in both flesh and peel color, with black, purple, red, green or yellow color of the peel and yellow or red color of the flesh, some cultivars showing a combination of yellow and red flesh. Other cultivars, the so-called blood plums, have red/black peel and red flesh. They differ from European plums (*Prunus domestica* L.) in various aspects such as size and composition of volatile compounds, sugars, organic acids and phenolic compounds (Lozano *et al.*, 2009; Venter *et al.*, 2014). However, similar to the European plum, the Japanese plum is a valuable source of fibre (mean values around 1.5%) and phytochemicals, including hydroxycinnamic acid derivatives, anthocyanins, flavonols, carotenoids, and proanthocyanidins, more highly concentrated in the peel than in the flesh (Butac *et al.*, 2019; Stacewicz-Sapuntzakis *et al.*, 2001; Lozano *et al.*, 2009). In association with the red color intensity of peel and flesh, the anthocyanin content varies considerably between cultivars, the darker-colored blood plums having an extremely high content of anthocyanins (54-272 mg/100 g as compared with 30 mg/100 g in the whole fruit of yellow-fleshed varieties) (Fanning *et al.*, 2014). Cyanidin-3-glucoside and cyanidin-3-rutinoside are the main anthocyanins in Japanese plums (Milatović *et al.*, 2013, 2019) followed by other cyanidin and peonidin derivatives (Butac *et al.*, 2019). A small carotenoid content was found in Japanese plums, ranging from 0.09 to 1.9 mg/100 g fresh weight, consisting mostly of β-carotene and small amounts of β-cryptoxanthin (Gil *et al.*, 2002). Large variations in the content of bioactive compounds have been reported depending on cultivar and maturity stage, as well as on other pre- and post-harvest factors including environment, climate, storage temperature and period (Gil *et al.*, 2002; Singh *et al.*, 2009). Interest in the nutraceutical value of foods has determined plant breeders to select cultivars for further evaluation based on phenolic content and antioxidant activity (Vizzoto *et al.*, 2007).

The aim of this study was to compare the nutraceutical value (total polyphenol content, antioxidant activity, phenolic and organic acid composition from the fruit flesh and peel) of two Japanese plum cultivars (Eldorado and Methley) grown in a collection orchard from Dolj county, Oltenia region, South-West Romania. Other

fruit attributes (geometrical properties, fruit weight, pulp ratio, dry matter, soluble solids, titratable acidity) were also evaluated to characterize these plum cultivars.

Materials and methods

Plant materials

Fruits from two Japanese plum (*Prunus salicina* Lindl.) cultivars (Eldorado and Methley) were harvested at commercial maturity from an experimental plum collection orchard established in 2016 in Orodel, Cornu village (44°13'N 23°16'E), Dolj county (South-Western Romania). The area has a temperate climate, with an average precipitation of 600 mm and a mean monthly temperature of 14…21 °C in summer and -1°C...-6°C in winter (annual average temperature = 11 °C). The collection orchard was planted in 2016 on a reddish preluvosol soil within the framework of the project PN-II-PT-PCCA-2013-2014 (project no. 168/2014, GERMPLUM). Standard growing techniques have been applied since the establishment of the orchard. The trees were on their own roots and the planting density was 5 m ×4 m. Winter pruning was performed yearly while no fruit thinning was applied. The fruits were harvested from different sides of five trees for each cultivar (about 20 randomly selected fruits from each tree) and transported to the laboratory for analysis.

Chemicals

Gallic acid, Folin–Ciocalteu's reagent, 2,2-diphenyl-1-picrylhydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), potassium dihydrogen phosphate, and phosphoric acid were purchased from Sigma-Aldrich (Steinheim, Germany), while anhydrous sodium carbonate, sodium hydroxide, methanol (HPLC grade), acetic acid (analytical grade), malic, citric, tartaric, ascorbic, and oxalic acids were purchased from Merck (Darmstadt, Germany). The standards of phenolic acids (vanillic, caffeic, chlorogenic, *trans*-cinnamic, *p*-coumaric, ferulic, gallic, syringic) and flavonoids (quercetin, rutin, catechin hydrate, epicatechin) were purchased from Sigma (Sigma-Aldrich GmbH, Steinheim, Germany).

Geometrical and physical properties

Fruit length (L), fruit width (W) and fruit thickness (T) of twenty randomly selected fruits were measured by a digital caliper and expressed in mm. Based on the results, the geometric mean diameter (D_g) was calculated following equation 1 (Ertekin *et al.*, 2006). The sphericity index (S_p) was then calculated using equation 2.

$$D_g = (LWT)^{1/3} \quad (1)$$

$$S_p = \frac{D_g}{L} \times 100 \quad (2)$$

The aspect ratio (R_a) and the surface area (S, cm^2) of the fruits were calculated using equations 3 and 4.

$$R_a = W/L \quad (3)$$

$$S = \pi\left(D_g^2\right) \quad (4)$$

Fruit weight and stone weight were measured on twenty randomly selected fruits using an electronic balance with 0.1 mg precision, and pulp ratio (%) was calculated by average weight of the pulp divided by average weight of the fruit. The fruit volume (V), expressed in cm^3, was determined using the liquid displacement method and it was used to calculate fruit density (g/cm^3).

Moisture content, soluble solids content and titratable acidity

The dry matter content (%) was determined gravimetrically by measuring the weight loss of 5 g fresh fruit after drying at 103 °C until reaching a constant weight (AOAC method 934.01, 1990). The total soluble solids content (SCC) (%) was measured in freshly prepared juice using a Hanna digital refractometer (Hanna Instruments, Woonsocket, USA) according to AOAC Method 932.12 (AOAC, 1995). The reported average values were obtained after triplicate analysis. The titratable acidity (TA) was determined by titration of 10 ml fruit extract with 0.1 N NaOH up to pH 8.1 according to AOAC Method 942.15 (AOAC, 1995). The fruit extract was made from 10 g homogenate of three blended fruits diluted to 100 g with distilled water. The results were expressed as g malic acid per 100 g fresh weight. Two independent extracts were prepared and each one was titrated in duplicate.

Extraction Procedure

After stone removal and peel separation, the flesh and peel samples were cut into small pieces and crushed in a mortar with pestle. One gram of fruit flesh or peel samples was mixed with 10 mL methanol in triplicate centrifuge tubes and sonicated for 60 min in an ultrasonic water bath (Bandelin Electronic GmbH, Berlin, Germany). After centrifugation at 6000 rpm for 5 min, the supernatants were collected, filtered and used in the total phenolic content and DPPH radical scavenging activity assays, as well as in the chromatographic analysis of individual phenolic compounds. Three extracts were prepared from each sample.

Total Phenolic Content

The total phenolic content was measured in the extracts of fruit flesh and peel by the spectrophotometric Folin–Ciocalteu method according to Singleton *et al.* (1999) and expressed as milligrams of gallic acid equivalents (GAE) per 100 g fresh weight (FW). Briefly, 100 µl of extract or standard gallic acid solution was diluted in 6 ml of distilled water and mixed with 0.5 mL of Folin–Ciocalteu reagent (1:1 with water). After 3 min, 1,5 mL of 20% (w/v) Na_2CO_3 solution was added and the volume was adjusted to 10 mL with distilled water. The mixture was incubated in the dark at 40 °C for 30 min, then the absorbance was measured at 765 nm on a Varian Cary 50 UV spectrophotometer (Varian Co., Cary, NC, USA). The total phenolic content of the extracts was calculated from the regression equation of calibration curve [y = (x+0.0272)/0.0011, R2 = 0.999] and expressed as mg gallic acid equivalents (GAE) per 100 g fresh weight (fw).

DPPH Radical Scavenging Activity

The antioxidant activity of the fruit flesh and peel was tested as the ability to scavenge the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical following Brand-Williams *et al.* (1995) with minor modifications. Aliquots of appropriate diluted

flesh or peel extract (50 µL) were combined with 3 mL of 0.004% DPPH solution in methanol. The mixture was homogenized and incubated in the dark for 30 min at room temperature, then the absorbance was read at 517 nm against methanol using a Varian Cary 50 UV spectrophotometer (Varian Co., USA). The control sample was prepared by adding 50 µL of methanol instead of the extract. The DPPH radical scavenging activity was calculated by using equation 5.

$$\text{DPPH radical inhibition (\%)} = [1 - A_{sample}/A_{control}] \times 100 \quad (5)$$

Trolox was used as a standard and the results were expressed as millimoles Trolox per 100 g of fresh weight (FW). The analysis was carried out in three replicates for each sample.

Phenolic compounds

Individual phenolic compounds were quantified in the fruit flesh and peel extracts by the HPLC-DAD method developed by Nour *et al.* (2017) on a Finningan Surveyor Plus HPLC system (Thermo Electron Corporation, San Jose, CA). The separation was performed on a Hypersil Gold C18 column (5 µm, 250 × 4.6 mm) at 20°C using a gradient mobile phase consisting of 1% aqueous acetic acid (eluent A) and methanol (eluent B). The detection was operated at 254, 278 and 300 nm. The following elution conditions were set: 0 to 20 min, linear gradient from 90% A to 80% A, 20–27 min, linear gradient from 80% A to 60% A, 27–52 min, 60% A, 52–57 min, linear gradient from 60% A to 80% A and 57–60 min, linear gradient from 80% A to 90% A. The flow rate was 1 mL/min and the injection volume was 5 µL. Before injection the extract was filtered through a 0.45 µm nylon syringe filter. The concentration of phenolic compounds was expressed as mg per 100 g of fresh weight (FW).

Organic acids

The extraction of organic acids was carried out by vortexing 1 g fruit flesh or peel homogenate with 15 ml of distilled water for 2 min, followed by centrifugation at 6000 rpm for 10 min. The supernatant was filtered through a 0.45 µm nylon syringe filter before injection. Individual organic acids were quantified in the extracts by the HPLC-DAD method developed by Nour *et al.* (2010) on a Finningan Surveyor Plus HPLC system (Thermo Electron Corporation, San Jose, CA). The separation was carried out in isocratic conditions on a Hypersil Gold aQ column (5 µm, 250 × 4.6 mm) at 10°C using a 50 mM KH_2PO_4 aqueous solution adjusted to pH 2.8 with ortho-phosphoric acid as the mobile phase. The DAD detection was performed 254 nm for ascorbic acid and 214 nm for the other organic acids. The injection volume was 5 µL and the flow rate of the mobile phase was 0.7 mL/min.

Statistical analysis

Means and standard deviations were calculated using Statgraphics Centurion software (version XVI.I) from StatPoint Technologies, Inc. (The Plains, VA, USA). The differences between means were evaluated using the one-way analysis of variance (ANOVA) followed by the Duncan's multiple range test and differences were considered significant at $p < 0.05$.

Results and discussion

Geometrical properties

The results on the biometric properties of Japanese plum fruits are presented in Table 1. All sizes, geometric mean diameter and surface area of the Methley fruits were significantly ($p < 0.05$) higher than those of the Eldorado fruits. The average values of the geometric mean diameter were calculated as 48.64 mm for Methley and 29.30 mm for Eldorado plums. The mean thickness and width of Methley plums exceeded 50 mm, while length exceeded 40 mm.

Table 1. Geometrical properties of plum cultivars

	Length (mm)	Width (mm)	Thickness (mm)	Geometric mean diameter (D_g, mm)	Sphericity index (S_p, %)	Aspect ratio (R_a)	Surface area (S, mm^2)
Eldorado	27.23 ± 1.40^b	32.16 ± 1.23^b	28.73 ± 1.19^b	29.30 ± 1.17^b	107.61 ± 1.50^b	1.18 ± 0.03^b	26.99 ± 2.12^b
Methley	41.97 ± 2.14^a	54.37 ± 2.95^a	50.46 ± 3.04^a	48.64 ± 2.58^a	115.89 ± 1.05^a	1.29 ± 0.04^a	74.49 ± 2.84^a

Different lowercase letters in a column indicate significant differences between cultivars ($p < 0.05$).

Son (2010) reported fruit height in the range 40.15-55.94 mm for 14 Japanese plum (*P. salicina* L.) cultivars grown in Mersin-Turkey. Sphericity is an indicator of the shape characteristics of the fruit relative to a sphere of the same volume (Ertekin *et al.*, 2006). The closer the sphericity index is to the value 1, the greater the tendency of the fruits to approach the spherical shape. Both cultivars recorded a mean sphericity index higher than 1, indicating the oblate shape of the plums. However, the differences between the fruits of the two cultivars were not statistically significant ($p > 0.05$) in terms of Sphericity index. The results demonstrated the flatter shape of the Methley plums as compared to the Eldorado plums, indicating a higher tendency of Eldorado fruits toward being spherical in shape. Głowacka *et al.* (2021), in a study on 36 Japanese plum cultivars (mostly hybrids of *Prunus salicina* with *Prunus cerasifera*), found that 18 cultivars had round fruits while the fruits of five cultivars were round, but flattened at the tops.

Physical properties

In terms of fruit weight, the two cultivars differed significantly ($p < 0.05$), the Methley plums had a much higher weight (74.28 g) as compared with Eldorado fruits (16.25 g) (Table 2).

Głowacka *et al.* (2021), in a study on 36 Japanese plum cultivars grown in the climatic conditions of central Poland, reported fruit weights between 21 and 87.7 g while Son (2010) found fruit weight in the range 46.71-91.26 g after analyzing 14 Japanese plum cultivars grown in Turkey. Higher average fruit weights, between 50.6 g and 111.3 g, have been reported by Venter *et al.* (2014) in a study on ten South African Japanese plum cultivars and selections.

Table 2. Physical properties of plum cultivars

	Weight (g)	Volume (cm^3)	Stone weight (g)	Pulp ratio (%)	Density (g/cm^3)
Eldorado	16.25 ± 1.53^b	14.81 ± 1.41^b	0.63 ± 0.09^b	96.12 ± 0.42^b	1.09 ± 0.01^a
Methley	74.28 ± 3.26^a	70.20 ± 3.45^a	1.76 ± 0.38^a	97.63 ± 0.37^a	1.06 ± 0.01^b

Different lowercase letters in a column indicate significant differences between cultivars ($p < 0.05$).

The stone weight is of interest, mostly in plum processing, as it influences the yield and pulp ratio. The average stone weight of Methley plums (1.76 g) was much higher than that of Eldorado plums (0.63 g), however the difference between the pulp ratio of the two cultivars, although statistically significant ($p < 0.5$), was not so big. Stone weights between 0.86 g ('Čačanska rodna') and 1.86 g ('Stanley') have been reported by Dimkova *et al.* (2018) in fruits of some *Prunus domestica* cultivars while Sümbül *et al.* (2024) reported stone weights in the range 0.37-1.05 g in 22 plum genotypes growing naturally in the Sivas province (Turkiye). The values of pulp ratio were high when compared with the *Prunus domestica* fruits. In the present study, pulp ratio of 97.63% and 96.12% have been calculated for Methley and Eldorado cultivars, respectively. For comparison, Dimkova *et al.* (2018) reported pulp ratio of 93.68% for 'Stanley' and 93.15% for 'Hanita' *Prunus domestica* cultivars. Mean bulk densities of 1.06 g/cm^3 and 1.09 g/cm^3 were found in the present study for the fruits of the two Japanese plum cultivars. Previously, Ertekin *et al.* (2006) reported 1.05 g/cm^3 and 1.03 g/cm^3 for 'Stanley' and 'Frenze 90' *Prunus domestica* cultivars. These differences could be attributed to the cultivar-specific characteristics, harvesting year, climate, geographical origin and method of cultivation.

Dry matter, soluble solids content and titratable acidity

The dry matter and soluble solid contents are important for obtaining a higher yield in plum drying or processing. A significantly higher soluble solids content was found in the plums of Eldorado cultivar (18.81%) as compared with Methley (15.17%) (Table 3). Głowacka *et al.* (2021) reported soluble solids content ranging from 9.6% to 17.8% in the fruits of 36 Japanese plum cultivars, Lozano *et al.* (2009) found between 12.3% and 17.8% in the fruits of six Japanese plum (*Prunus salicina* Lindl.) cultivars grown in Spain, while Venter *et al.* (2014) found soluble solids content between 11.45% and 21.0% after analyzing ten Japanese plum cultivars and selections from South Africa. Lower soluble solid contents have been reported by Ertekin *et al.* (2006) (12.8-14.8%) or by Usenik *et al.* (2008) (13.5-15.6%) in European (*Prunus domestica*) plum cultivars grown in Antalya (Turkey) and Slovenia, respectively. Differences could be attributed to cultivar as well as environmental conditions.

Eldorado plums presented a higher titratable acidity (1.54 g malic acid/100 g) as compared with Methley (1.32 g malic acid/100 g). SCC/TA plays a significant role in consumer acceptance and willingness to pay for plums. A lower titratable acidity along with a higher SCC/TA ratio may increase the acceptability of plums.

Table 3. Dry matter, soluble solids content and titratable acidity of the plum cultivars

	Dry matter (%)	Soluble solids content (%)	Titratable acidity (g malic acid/100 g)	SSC/TA
Eldorado	22.60 ± 0.18[a]	18.81 ± 0.47[a]	1.54 ± 0.04[a]	12.21 ± 0.24[a]
Methley	18.50 ± 0.09[b]	15.17 ± 0.38[b]	1.32 ± 0.05[b]	11.49 ± 0.26[b]

Different lowercase letters in a row indicate significant differences between cultivars ($p < 0.05$).

Significantly higher SCC/TA ratio was found for Eldorado as compared with Methley. Previously, other authors reported titratable acidities between 0.85 and 3.08 g malic acid/100 g and SCC/TA values ranging from 7.34 to 20.85 in the fruits of various Japanese plums (*Prunus salicina* Lindl.) cultivars grown in Spain (Lozano *et al.*, 2009; Venter *et al.*, 2014).

Total phenolic content and DPPH radical scavenging activity

Total phenolic content was significantly ($p < 0.05$) higher in Eldorado plums as compared with Methley plums, both in fruit flesh (143.82 mg/100 g and 129.27 mg/100 g, respectively) and peel (572.14 mg/100 g and 536.44 mg/100 g, respectively) (Figure 1). Lower values have been reported previously by Melgajero *et al.* (2012), who found 62.4 mg GAE/100 g in the flesh and 241 mg GAE/100 g in the peel of the Japanese plum (*Prunus salicina* L.) Red Beaut, genotype "606" cultivar. In the whole fruit, Lozano *et al.* (2009) reported total phenolic content between 94.54 mg/100 g and 202.46 mg/100 g in six Japanese plum (*Prunus salicina* Lindl.) cultivars grown in Spain, while Venter *et al.* (2014) reported between 225 mg GAE/100 g and 383 mg GAE/100 g in ten Japanese plum cultivars grown in South Africa. These differences could be attributed to the different cultivars tested, maturity stage, environmental factors and orchard management or even to the different extraction and analysis methods used.

In correlation with the results of total phenolic content, significantly ($p < 0.05$) higher DPPH antioxidant activity values were found in Eldorado plums as compared with Methley plums, both in the fruit flesh (0.84 mmol Trolox/100 g and 0.80 mmol Trolox/100 g, respectively) and in the peel (2.46 mmol Trolox/100 g and 2.28 mmol Trolox/100 g, respectively). In agreement with our results, Venter *et al.* (2014) reported DPPH radical scavenging activity between 1.24 and 2.79 mmol Trolox/100 g, while Basanta *et al.* (2016) found 1.51 mmol Trolox/100 g in the pulp and 2.22 mmol Trolox/100 g in the peel of a Japanese plum cultivar from Mendoza province (Argentina). Some of the bioactive and health promoting properties of Japanese plums, including antioxidant, anti-inflammatory, antidiabetic, antimicrobial and antimutagenic activities, have been attributed to their high phenolic content and antioxidant capacity (Fanning *et al.*, 2014; Igwe and Charlton, 2016; Liu *et al.*, 2020).

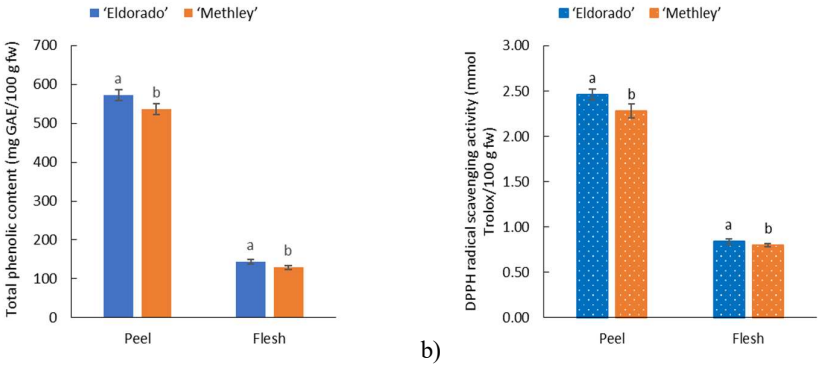

Figure 1. Total phenolic content (a) and DPPH radical scavenging activity (b) in the fruit flesh and peel of plum cultivars. Different lowercase letters indicate significant differences between cultivars ($p < 0.05$).

Phenolic compounds

Large differences were found between the phenolic profiles of the two Japanese plum cultivars. In flesh, of the individual phenolic acids detected, chlorogenic and ferulic acids were dominant, while among flavonoids, epicatechin and catechin hydrate predominated. The highest content of chlorogenic acid was found in Methley (1.28 mg/100 g), while the highest content of epicatechin was found in the fruits of Eldorado cultivar (10.17 mg/100 g) (Table 4).

Table 4. Content of phenolic compounds (mg/100 g) in the flesh of the plum cultivars

	Vanillic acid	Rutin	Quercetin	Gallic acid	Catechin hydrate	Syringic acid
Eldorado	nd	0.20 ± 0.01	nd	nd	2.20 ± 0.09^{a}	nd
Methley	nd	nd	nd	nd	2.21 ± 0.08^{a}	0.37 ± 0.01
	Epicatechin	*Trans*-cinnamic acid	Chlorogenic acid	Caffeic acid	*p*-Coumaric acid	Ferulic acid
Eldorado	10.17 ± 0.31^{a}	nd	0.29 ± 0.01^{b}	0.07 ± 0.01^{b}	0.17 ± 0.01^{b}	0.22 ± 0.01^{b}
Methley	1.79 ± 0.05^{b}	0.03 ± 0.01	1.28 ± 0.04^{a}	0.11 ± 0.01^{a}	0.27 ± 0.01^{a}	1.16 ± 0.04^{a}

Different lowercase letters indicate significant differences between cultivars ($p < 0.05$).

Chromatograms of the phenolic compounds at 254, 278 and 300 nm from Methley plum peel are shown in Figures 2, 3 and 4, respectively.

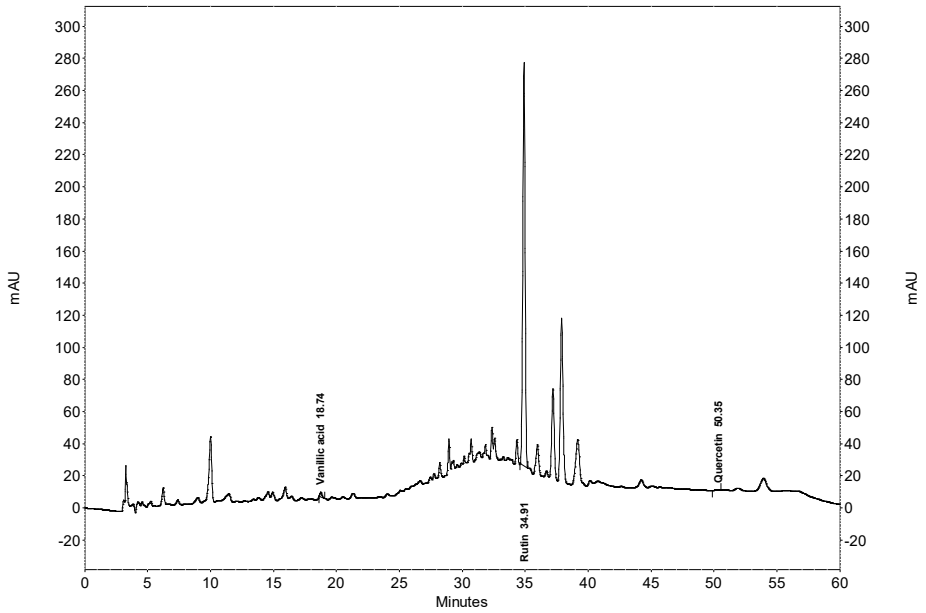

Figure 2. Chromatogram of the phenolic compounds at 254 nm from Methley plum peel

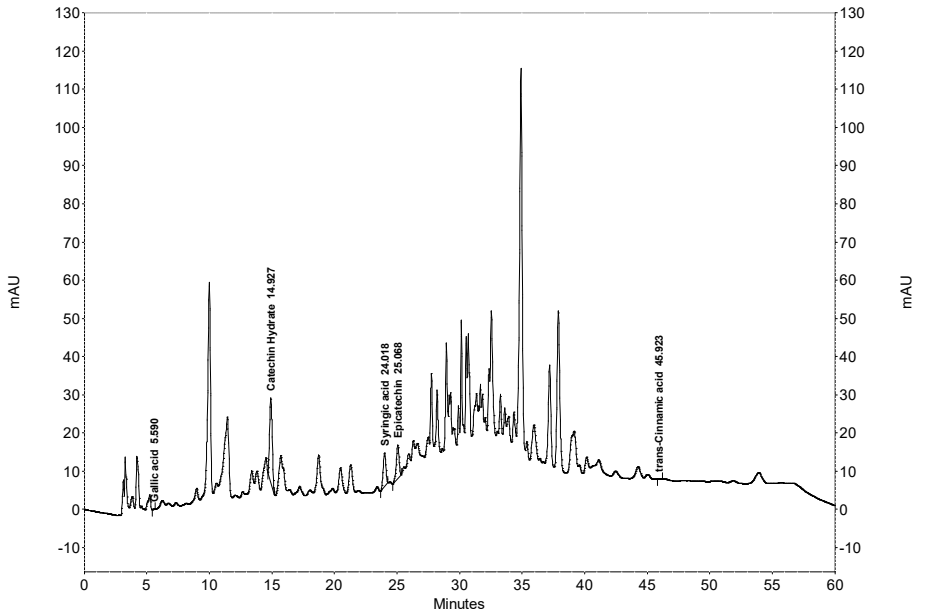

Figure 3. Chromatogram of the phenolic compounds at 278 nm from Methley plum peel

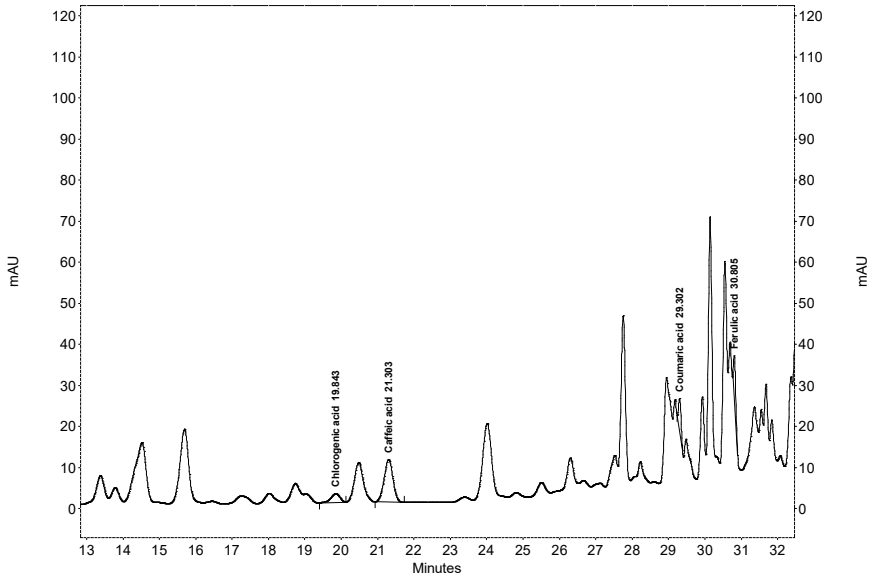

Figure 4. Chromatogram of the phenolic compounds at 300 nm from Methley plum peel

Rutin was the dominant flavonoid in the peel of both cultivars (76.10 mg/100 g in Methley and 51.63 mg/100 g in Eldorado) (Table 5). However, epicatechin ranks second in the phenolic profile of Eldorado peel (49.16 mg/100 g) while catechin hydrate ranks second in the peel of Methley plums (23.58 mg/100 g). Venter *et al.* (2014) found also epicatechin (0.50-11.31 mg/100 g) and catechin (4.99-18.93 mg/100 g) in the fruits of seven South African plum (*Prunus salicina* Lindl.) cultivars. Many previous studies reported rutin as the major flavonoid in the flesh and peel of *Prunus domestica* cultivars (Khallouki *et al.*, 2012; Tomić *et al.*, 2019; Liaudanskas *et al.*, 2020; Trendafilova *et al.*, 2022; Fotirić Akšic *et al.*, 2023).

Table 5. Content of phenolic compounds (mg/100 g) in the peel of the plum cultivars

	Vanillic acid	Rutin	Quercetin	Gallic acid	Catechin hydrate	Syringic acid
Eldorado	3.84 ± 0.12	51.63 ± 1.63^{b}	nd	1.88 ± 0.08	6.97 ± 0.22^{b}	nd
Methley	nd	76.10 ± 1.55^{a}	0.07 ± 0.01	nd	23.58 ± 0.78^{a}	2.19 ± 0.07
	Epicatechin	*Trans*-cinnamic acid	Chlorogenic acid	Caffeic acid	*p*-Coumaric acid	Ferulic acid
Eldorado	49.16 ± 1.45^{a}	nd	1.79 ± 0.06^{b}	nd	0.11 ± 0.01^{b}	0.04 ± 0.00^{b}
Methley	8.15 ± 0.21^{b}	0.03 ± 0.01	2.31 ± 0.08^{a}	1.58 ± 0.07	0.31 ± 0.02^{a}	1.28 ± 0.06^{a}

Different lowercase letters indicate significant differences between cultivars ($p < 0.05$).

There are also differences between Eldorado and Methley plums regarding the content of phenolic acids in the peel. Chlorogenic acid content was higher in Methley plums (2.31 mg/100 g) as compared with Eldorado (1.79 mg/100 g), vanillic acid

was not detected in Methley peel, while syringic and caffeic acids were not detected in Eldorado peel. In good agreement with our results, Venter *et al.* (2014) detected chlorogenic acid in the fruits of four of the seven South African plum (*Prunus salicina* Lindl.) cultivars, at levels ranging from 8.8 to 21.7 mg/100 g. Some studies indicated also chlorogenic acid as the predominant phenolic acid in *P. domestica* L. fruits (Lombardi-Boccia *et al.*, 2004; Treutter *et al.*, 2012; Celik *et al.*, 2017; Liaudanskas *et al.*, 2020), while others found neochlorogenic acid as the major hydroxycinnamic acid derivative in plums (Usenik *et al.*, 2008; Tomić *et al.*, 2019; Fotirić Akšic *et al.*, 2023).

Organic acids

Organic acids are major sour flavoring substances in plums and play a key role in pectin gelation (Tomić *et al.*, 2019; Xiao *et al.*, 2024). Chromatograms of the organic acids at 214 nm from Eldorado and Methley are shown in Figures 5 and 6, respectively.

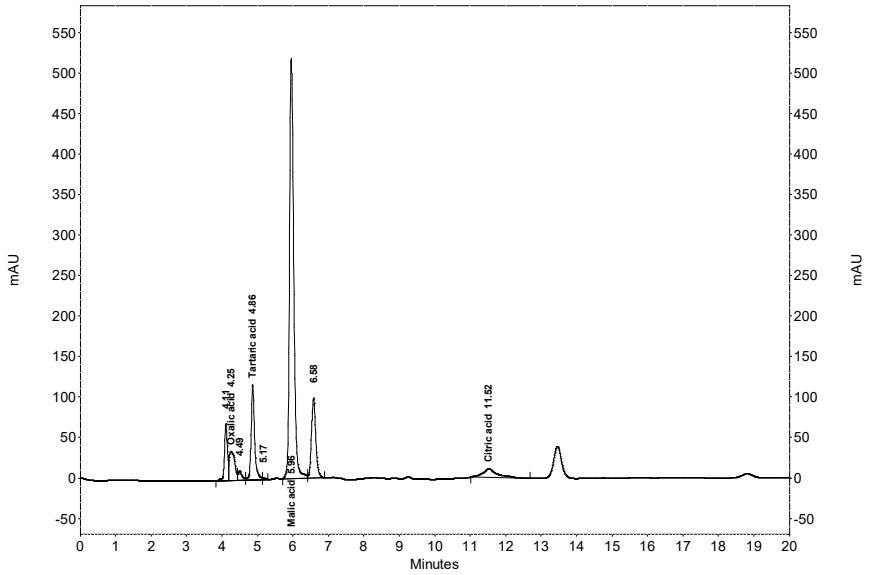

Figure 5. Chromatogram of the organic acids at 214 nm from Eldorado plum peel

As previously reported (Singh *et al.*, 2009; Yu *et al.*, 2021; Xiao *et al.*, 2024), the results showed that malic acid was the predominant organic acid, both in flesh and peel of the examined plum cultivars. Higher malic acid contents were found in the peel as compared with the flesh of both plum cultivars. Eldorado showed significantly higher malic acid content as compared with Methley, both in peel and flesh. Previously, Melgarejo *et al.* (2012) found 1970 mg malic acid/100 g in Japanese plums, while in some European (*Prunus domestica*) cultivars, Usenik *et al.* (2008) reported malic acid contents between 900 and 2180 mg/100 g, Lombardi-Boccia *et al.* (2004) found 1980 mg/100 g malic acid and Xiao *et al.* (2024) found

malic acid levels in the range 177.58–1568.43 mg/100 g FW and 327.68–2187.46 mg/100 g FW in flesh and peel, respectively.

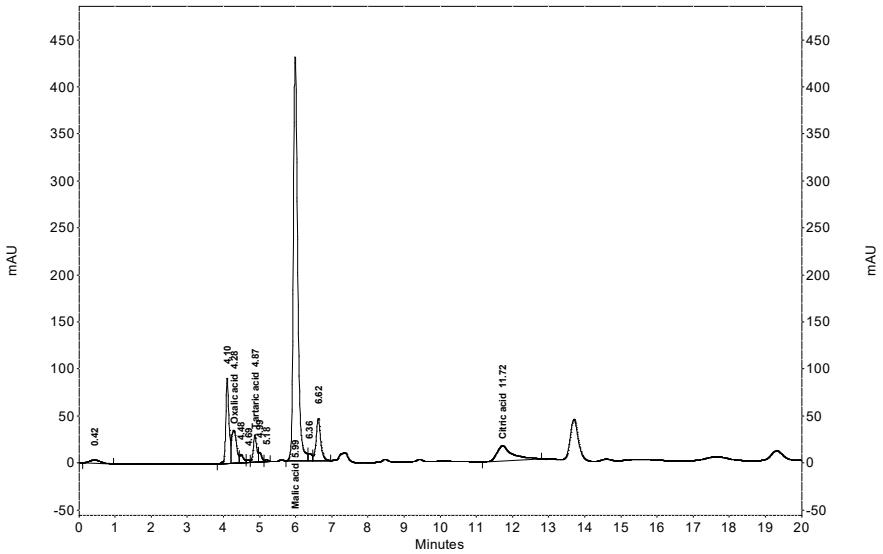

Figure 6. Chromatogram of the organic acids at 214 nm from Methley plum peel

Table 6. Content of organic acids (mg/100 g) in the fruit flesh of plum cultivars

	Malic acid	Tartaric acid	Citric acid	Oxalic acid	Ascorbic acid
Eldorado	1483.35±55.16^{a}	105.70±6.67^{a}	48.18±3.96^{b}	18.24±1.30^{a}	3.08±0.18^{a}
Methley	951.90±33.36^{b}	23.18±1.48^{b}	77.58±6.77^{a}	11.67±0.96^{b}	1.37±0.06^{b}

Different lowercase letters indicate significant differences between plum cultivars ($p < 0.05$).

Table 7. Content of organic acids (mg/100 g) in the peel of plum cultivars

	Malic acid	Tartaric acid	Citric acid	Oxalic acid	Ascorbic acid
Eldorado	1550.81±29.11^{a}	146.82 ± 4.18^{a}	147.79 ± 6.77^{b}	15.20 ± 0.43^{a}	5.23 ± 0.21^{a}
Methley	1311.56±22.45^{b}	37.24 ± 1.50^{b}	196.53 ± 7.45^{a}	13.15 ± 0.34^{b}	3.55 ± 0.09^{b}

Different lowercase letters indicate significant differences between plum cultivars ($p < 0.05$).

The levels of citric acid were 2.5-3 times higher in the peel as compared with the flesh, and significantly higher in the fruits of Methley cultivar as compared with Eldorado. In contrast, the levels of tartaric acid were around 5 times lower in Methley plums than in Eldorado. In good agreement with our results, Melgarejo *et al.* (2012) reported 62 mg citric acid/100 g in Japanese plums. In European plums, Tomić *et al.* (2019) found between 30 and 180 mg citric acid per 100 g, while Xiao *et al.* (2024) reported 2.70–71.96 and 9.03–79.14 mg citric acid/100 g FW in the flesh and peel, respectively. Xiao *et al.* (2024) detected also tartaric acid in plums (0.70–288.40 and

1.09–419.47 mg/100 g FW in flesh and peel, respectively). The levels of ascorbic acid were low in all plum samples, but in line with previously reported results (Lombardi-Boccia *et al.*, 2004).

Conclusions

The study provides a comparative analysis of two Japanese plum cultivars (Eldorado and Methley) grown in a collection orchard in Oltenia (South-Western Romania), in terms of geometrical, physical, nutritional, and phytochemical properties. Methley plums had higher sizes, geometric mean diameter, weight, volume, surface area and pulp ratio but lower dry matter, soluble solids content and titratable acidity as compared with Eldorado plums. Total phenolic content and DPPH radical scavenging activity were significantly ($p < 0.05$) higher in Eldorado plums as compared with Methley plums, both in fruit flesh and peel. Large differences were found between the phenolic profiles of the two Japanese plum cultivars. Chlorogenic and ferulic acids were dominant in the flesh while rutin was the predominant flavonoid both in fruit flesh and peel. Vanillic acid was found only in Eldorado peel, while syringic and caffeic acids were found only in Methley peel. Malic acid was the main organic acid, with higher levels in the peel as compared with the flesh. Eldorado plums showed significantly higher levels of malic, tartaric and ascorbic acids but lower citric acid content as compared with Methley, both in peel and flesh. The high content of soluble solids and titratable acidity, as well as the high phenolic content of the two Japanese plum cultivars recommend them for fresh consumption and make them suitable to be grown in South-Western Romania.

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