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Bioactive compounds content and nutritional potential of different parsley parts (*Petroselinum crispum* Mill.)

Sadržaj bioaktivnih spojeva i nutritivni potencijal različitih dijelova peršina (Petroselinum crispum Mill.)

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ABSTRACT

Parsley highlights among other vegetables for high vitamin C content. It also contains minerals, essential oils, pigments, polyphenols and other compounds from the group of biologically active compounds characterized by high antioxidant activity. Parsley is cultivated and consumed for its leaves and roots with the three most common types: *Petroselinum crispum* ssp. *tuberosum* (turnip-rooted) and *Petroselinum crispum* ssp. *crispum* (curly-leaf), *Petroselinum crispum* ssp. *neapolitanum* (plain-leaf). The aim of this research was to determine the chemical differences and content of bioactive compounds in 6 parsley cultivars: 'Arat', 'Eagle', 'Halblange', 'Rialto', 'Mooskrause' and 'Petra'. Also, to determine the differences in nutritional composition between different parsley plant parts: leaf, stem and root. The highest vitamin C content in leaves (162.09 mg/100 g FW) was determined in cv. 'Rialto'. Root cultivars of *Petroselinum crispum* ssp. *tuberosum* (cv. 'Halblange') had higher vitamin C content. The highest total phenol content (425.76 mg GAE/100 g FW) was determined in leaves of cv. 'Arat'. The highest total chlorophyll content was determined in leaves in cv. 'Mooskrause', while the lowest in cv. 'Arat'. Average total chlorophyll content values in leaves of *Petroselinum crispum* ssp. *neapolitanum* and *Petroselinum crispum* ssp. *crispum* cultivars (0.69 mg/g) not differ from the average total chlorophyll content values of *Petroselinum crispum* ssp. *tuberosum* cultivars (0.69 mg/g). All parsley cultivars show high antioxidant capacity due to significant amounts of bioactive compounds such as chlorophylls, carotenoids, phenols, flavonoids, non-flavonoids and vitamin C.

Keywords: antioxidant capacity, parsley cultivars, pigments, total phenols, vitamin C

SAŽETAK

Peršin se od ostalih povrtnih vrsta ističe visokim sadržajem vitamina C. Sadrži minerale, esencijalna ulja, pigmente, polifenole i ostale iz skupine biološki aktivnih spojeva karakterističnih po tome što ispoljavaju visoku antioksidacijsku aktivnost. Peršin se uzgaja i konzumira zbog lisnih plojki i korijena, a najčešća su tri tipa: *Petroselinum crispum* ssp. *tuberosum* i *Petroselinum crispum* ssp. *crispum* (peršin kovrčavih liski), *Petroselinum crispum* ssp. *neapolitanum* (peršin glatkih liski). Cilj ovog rada bio je utvrditi razlike u kemijskom sastavu i sadržaju bioaktivnih spojeva 6 kultivara peršina: 'Arat', 'Eagle', 'Halblange', 'Rialto', 'Mooskrause' i 'Petra'. Također, utvrditi razlike u nutritivnom sastavu različitih dijelova biljke: lisna plojka, stabljika, korijen. Najveći sadržaj vitamina C u listu (162,09 mg/100 g FW) utvrđen je za kultivar 'Rialto'. U korijenu, kultivari *Petroselinum crispum* var. *tuberosum* ('Halblange') imali su veće vrijednosti vitamina C. Najveći sadržaj ukupnih fenola (425,76 mg GAE/100 g FW) utvrđen je u listu kultivara 'Arat'. Najviši sadržaj ukupnih klorofila utvršen je u listu kultivara 'Mooskrause', dok je najniži utvrđen kod kultivara 'Arat'. Prosječne vrijednosti ukupnih klorofila u listu *Petroselinum crispum* ssp. *neapolitanum* i *Petroselinum crispum* ssp. *crispum* cultivars (0,69 mg/g) ne razlikuju se od projećne vrijednosti Petroselinum crispum ssp. tuberosum kultivara (0,69 mg/g). Svi istraživani kultivari peršina pokazali su visok antioksidacijski kapacitet uslijed značajnog sadržaja bioaktivnih spojeva poput klorofila, karotenoida, fenola, flavonoida, neflavonoida i vitamina C.

Ključne riječi: antioksidacijski kapacitet, kultivari peršina, pigmenti, ukupni fenoli, vitamin C

INTRODUCTION

Parsley (*Petroselinum crispum* Mill.) is a leafy vegetable species mostly used as a culinary aromatic herb to improve an overall sensory characteristics of the food. Aromatic herbs, among parsley also, are a rich source of various phytochemicals with strong antioxidant, anti-inflammatory, antimicrobial and anticarcinogenic activities (Nour et al., 2017). Bioactive compounds, of which especially phenolic compounds, are a main carriers of health benefits mainly because of their biological effects such as inhibition of free radicals and cellular proliferation (Del Rio et al., 2013). All parsley plant parts (leaf, stem and root) are rich in different phytonutrients, from phenolic compounds can be point out flavonoids from which mainly flavones apigenin, chrysin and luteolin; vitamins from which the most abundant vitamin C (parsley leaf is one of the richest natural sources of vitamin C) following vitamin E; from minerals potassium, phosphorus, magnesium, calcium and also the volatile oil compounds from which dominant α-pinene, β-pinene, myrcene, β-phellandrene, 1,3,8-p-menthatriene and myristicin determined in leaf and seeds (Daradkeh and Essa, 2016).

The three most common parsley types are *Petroselinum crispum* ssp. *tuberosum* primarily cultivated for thickened roots (turnip-rooted) and *Petroselinum crispum* ssp. *crispum* (curly-leaf), *Petroselinum crispum* ssp. *neapolitanum* (plain-leaf) intended for leaf cultivation. Parsley are characterized by great morphological and chemical variability and depending of further use commercially are available different cultivars and types primarily intended for cultivation of root or leaves (Karklelienė et al., 2014).

The main aim of this research was to determine the chemical differences and content of most abundant bioactive compounds in 6 parsley cultivars from *Petroselinum crispum* ssp. *tuberosum*, *Petroselinum crispum* ssp. *crispum* and *Petroselinum crispum* ssp. *neapolitanum*. Also, to determine the differences in nutritional composition between different parsley plant parts: leaf, stem and root from mentioned cultivars.

MATERIALS AND METHODS

Plant material

Parsley seeds (Bejo d.o.o., Semenarna Ljubljana) were sown on April 30, 2015 on the experimental station at the Department of Vegetable Crops, University of Zagreb Faculty of Agriculture. In total, 6 parsley cultivars were sown: from *Petroselinum crispum* ssp. *tuberosum* cv. 'Arat', 'Eagle', 'Halblange', from *Petroselinum crispum* ssp. *neapolitanum* cv. 'Rialto' and from *Petroselinum crispum* ssp. *crispum* cv. 'Mooskrause' and 'Petra'. The size of the plot was 100 cm in length, 85 cm wide and the sowing was conducted 25 cm between the rows. According to the physical characteristics, the soil at the experimental station was classified as loamy. Before parsley cultivation, the soil was prepared by autumn plowing, spring soil milling and pre-sowing fertilization with 20 g/m^2 NPK 7-20-30. During the vegetation, weed removing and irrigation have been regularly carried out.

Multiple harvest was conducted in early morning hours when plants reached optimal harvest period, as follows: for cv. 'Rialto' on September 14, for cv. 'Mooskrause' and 'Petra' on September 16, for cv. 'Halblange' on September 21 and for cv. 'Arat' and 'Eagle' on September 23. Plants were picked manually with root.

Immediately after harvest, plants were transported in the laboratory of the Department of Agricultural Technology, Storage and Transport University of Zagreb Faculty of Agriculture. From parsley plants were removed and separated for individual analysis following basic plant parts: leaves, stems and roots. Roots were pilled, while stems and leaves were washed and prepared for intended chemical analysis.

Determination of basic chemical composition

The analysis of basic chemical composition included determination of: dry matter content (DM, %) by drying at 105 °C till constant mass, total soluble solids content (TSS, %) by digital refractometer (Refracto 30 PX, Mettler-Toledo, Switzerland), total acid content (TA, % oxalic acid) by potentiometric titration with NaOH and pH-value by digital pH-meter (Mettler Toledo, SevenMulty, Switzerland) all carried out by standard methods (AOAC, 1995).

Determination of bioactive compounds content

Ascorbic acid content (mg/100 g FW) was determined by titration with 2,6-dichlorindophenol according to the standard method AOAC (2002). Fresh parsley sample total weight of 10 g (±0.01) was homogenized with 100 mL 2% oxalic acid (v/v) and filtered. 10 mL of filtrate was titrated with fresh prepared 2,6-dichlorindophenol till appearance of pink coloration of solution. Total phenol (flavonoid and non-flavonoid) content (mg GAE/100 g FW) was determined by Folin–Ciocalteu colorimeter method according to Ough and Amerine (1988). The extraction procedure of total phenols from plant material was as follows: on 10 g of fresh plant material 40 mL of 80% EtOH (v/v) was added, sample was 10 min boiled with reflux and was filtered. On the filtered liquid fraction additional 50 mL 80% EtOH (v/v) was added, sample was reflux boiled for another 10 min and filtered. The extracted phenol residues were gathered and reaction with reagent was done: 0.5 mL of the prepared ethanol extract, 30 mL of distilled water and 2.5 mL of the Folin-Ciocalteu reagent diluted with dH_2O (1:2) were added in the volumetric flask (50 mL). Additionally, 7.5 mL of a saturated sodium carbonate solution (v/v) was added, the flask was filled to the mark with dH_2O and allowed to stand for 2 h at room temperature with intermittent shaking. The absorbance of the blue color was measured spectrophotometrically (Shimadzu UV 1650 PC) at 750 nm with dH_2O as a blank. For determination of total non-flavonoid (TNFC) the 10 mL of ethanol extract was added into 25 mL volumetric flask, 5 mL of HCl (1:4, v/v) and 5 mL of formaldehyde was added. Such prepared samples were treated with nitrogen (N_2), allowed to stand for 24 h and filtered. Same reaction with Folin-Ciocalteu reagent as for total phenols was conducted. Flavonoid content (TFC) was expressed mathematically as the difference between TPC and TNFC.

Determination of pigment compounds content

From pigment compounds, total chlorophylls (chlorophyll a and b) and total carotenoids content were determined according to the method described by Holm (1954) and Wettstein (1957). For determination of mentioned pigments from parsley leaves 0.2 g of fresh sample was used, while for determination in stem 2 g of fresh sample was used. Total volume of 15 mL of acetone (p.a.) was added on the fresh sample mass in three steps, samples were homogenized (Ultraturax T18, IKA, Germany) and vacuum filtered. Pigment extract was diluted with acetone (p.a.) to the final volume of 25 mL. Amount of chlorophylls and carotenoids were calculated according to the Holm-Wettstein equations (1) and the final results were expressed as mg/g.

$$\text{chlorophyll } a = 9.784 \times A_{662} - 0.990 \times A_{644}\ [mgL^{-1}]$$
$$\text{chlorophyll } b = 21.426 \times A_{644} - 4.65 \times A_{662}\ [mgL^{-1}]$$
$$\text{chlorophyll } a{+}b = 5.134 \times A_{662} + 20.436 \times A_{644}\ [mgL^{-1}]$$
$$\text{carotenoids} = 4.695 \times A_{440} - 0.268 \times (\text{chlorophyll } a{+}b)[mgL^{-1}] \quad (1)$$

Determination of antioxidant capacity by ABTS method

Antioxidant capacity was obtained by ABTS assay according to Miller et al. (1993) and Re et al. (1999). As antioxidant standard Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid; Sigma-Aldrich, St. Louis, MO) was used. Stock standard of Trolox (2.5 mM) was prepared in ethanol (80%). For preparation of ABTS radical solution (ABTS•1) the 5 mL of ABTS solution (7 mM) and 88 µL of potassium persulfate (140 mM) solution were mixed and allowed to stand in the dark at room temperature for 16 h. On the day of analysis 1% ABTS•1 solution (in 96% EtOH) was prepared. A total of 160 µL of ethanol extract (same as for total phenol determination) were directly injected in the cuvette and mixed with 2 mL 1% ABTS•1. After 5 min the absorbance at 734 nm was measured (Shimadzu 1650 PC, Germany) with EtOH (p.a.) as a blank. The final results of the antioxidant capacity were calculated based on calibration curve and expressed as mmol TE/L.

Statistical analysis

The experiment was set up as a randomized block design with 3 repetitions per cultivar and two factors. Generalized linear model with included repetition, parsley cultivar and plant part as a categorical predictor was used. For the analysis procedures PROC GLM in SAS software package, version 9.3. (SAS Institute Inc., 2010) was used. Obtained data were analyzed using analysis of variance (ANOVA). Mean values were compared by the t-test (LSD) and were considered significantly different at $P \leq 0.0001$. In tables are shown different letters which indicates significant differences between mean values within each column and also standard deviation (±SD) was expressed.

RESULTS AND DISCUSSION

Basic chemical composition

Dry matter content (DM) significantly differed ($P \leq 0.0001$) between parsley cultivars and plant parts (Table 1). Regardless of cultivar, in parsley root, as expected was determined the highest DM content, while in stem the lowest. On average, 46% and 65% higher DM content was determined in root in comparison to the leaf and stem. From analyzed parsley cultivars the highest DM content in leaf (20.33%) was determined for cv. 'Mooskrause', in stem (15.6%) for cv. 'Eagle' and in root (28.95%) for cv. 'Mooskrause'. From all analyzed parsley cultivars, cultivars primarily intended for leaf cultivation such as 'Mooskrause' had a significantly higher DM content in leaf and also in root. Other literature data cites average DM content in leaf of *Petroselinum crispum* ssp. *neapolitanum* and *Petroselinum crispum* ssp. *crispum* of 17.3%, while for *Petroselinum crispum* ssp. *tuberosum* cultivars average of 20% (Lisiewska and Kmiecik, 1997). Also, Karklelienė et al. (2014) provides DM content in leaf of *Petroselinum crispum* ssp. *crispum* cultivars from 17.8 – 19.4%. Slightly higher percentages of DM content in root of *Petroselinum crispum* ssp. *tuberosum* cultivars (21 – 23.6%) was published by the author Pokluda (2013).

In general, vegetable species and also a species from family Apiaceae are not characteristic for high content of total soluble solids (TSS), respectively the total sugar content (Parthasarathy et al., 2008). The range of TSS content in analyzed parsley cultivars and plant parts is significant, approximately from 2 - 7% and there is no determined uniformity within the cultivars and plant parts (Table 1). Regardless of the plant part, the highest average TSS content (6.22%) was determined for cv. 'Mooskrause', while the lowest TSS was determined for cv. 'Petra' (average 3.11%) and 'Halblange' (3.33%). Similar, low results of TSS content of different parsley cultivars as determined in this study was also obtained by other authors (Karklelienė et al., 2014; Santos et al., 2014).

Total acid content (TA) significantly varied between parsley cultivars and plant parts. In general, *Petroselinum crispum* var. *tuberosum* cultivars ('Halblange', 'Arat', 'Eagle') contains lower amounts of TA (even 50%) compared to the cultivars of *Petroselinum crispum* var. *neapolitanum* ('Rialto') and *Petroselinum crispum* var. *crispum* ('Mooskrause', 'Petra') regardless of the plant part. Depending on the plant part in root was determined the lowest TA content (on average 1.15%), while in leaf (average 1.51%) and stem (average 1.53) significantly higher. According to the low TA content, pH-values were relatively high in all observed parsley cultivars. Regardless of the cultivar, the highest pH- values were determined in plant root (average 6.13), while in leaf slightly lower (average 5.78) and in stem the lowest values (average 5.65). Also, pH-values were significantly different considering the parsley cultivar, while in general the highest pH-values were determined in *Petroselinum crispum* var. *tuberosum* cultivars compared

Table 1. Basic chemical composition of different parsley cultivars and plant parts

Cultivar	DM (%) P≤0.0001	TSS (%) P≤0.0001	TA (%) P≤0.0001	pH-value P≤0.0001
		Leaf		
'Rialto'	17.7^{g}±0.15	5^{de}	2.54^{a}±0.13	5.73^{h}±0.02
'Petra'	12.81^{n}±0.27	2^{k}	1.27^{h}±0.09	5.81^{f}±0.02
'Mooskrause'	20.33^{d}±0.02	7^{a}	2.22^{b}±0.03	5.74^{h}±0.01
'Halblange'	14.91^{i}±0.25	2^{k}	1.14^{i}±0.01	5.83^{f}±0.02
'Arat'	14.89^{i}±0.14	3^{h}	1^{jk}±0.02	5.78^{g}±0.04
'Eagle'	15.56^{h}±0.11	3^{hi}	0.86^{l}±0.02	5.81^{f}±0.01
		Stem		
'Rialto'	13.45^{l}±0.19	5^{de}	1.84^{c}±0.01	5.61^{j}±0.01
'Petra'	13.68^{k}±0.06	4.33^{fg}	1.53^{ef}±0.03	5.49^{k}±0.01
'Mooskrause'	13.08^{m}±0.05	5.33^{cd}	1.71^{d}±0.02	5.46^{l}±0.01
'Halblange'	14.3^{j}±0.08	5.67^{c}	1.5^{f}±0.02	5.68^{i}±0.01
'Arat'	15.04^{i}±0.05	2.67^{ij}	0.98^{k}±0.01	5.98^{e}±0.01
'Eagle'	15.6^{h}±0.06	4.67^{ef}	1.59^{e}±0.05	5.71^{h}±0.02
		Root		
'Rialto'	27.36^{c}±0.13	4^{g}	1.39^{g}±0.04	6.24^{a}±0.02
'Petra'	28.28^{b}±0.13	3^{hi}	1.08^{ij}±0.01	6.09^{c}±0.01
'Mooskrause'	28.95^{a}±0.16	6.33^{b}	1.41^{g}±0.03	6.15^{b}±0.01
'Halblange'	19.1^{e}±0.05	2.33^{jk}	0.98^{k}±0.02	6.22^{a}±0.03
'Arat'	18.39^{f}±0.03	5.33^{cd}	0.76^{m}±0.04	6.02^{d}±0.02
'Eagle'	18.5^{f}±0.1	7^{a}	1.07^{ij}±0.06	6.08^{c}±0.02
Cultivar (C)	***	***	***	***
Plant part (P)	***	***	***	***
C×P	***	***	***	***

DM - dry matter content; TSS - total soluble content; TA - total acid content; C×P - interaction between cultivar and plant part.
*** P≤0.0001. Different letters indicate significant differences between mean values within each column.

to the *Petroselinum crispum* var. *neapolitanum* and *Petroselinum crispum* var. *crispum* cultivars.

All obtained results of analyzed chemical parameters from this research are in agreement with other literature data and any deviations can be attributed to the different parsley cultivar of plant part (Karklelienė et al., 2014; Santos et al., 2014; Nour et al., 2017).

Bioactive compounds content

Vitamin C (ascorbic acid) is one of the most important essential compounds for human organism. It's specific to exhibit a strong antioxidant activity and recently become one of the most popular vitamins in human nutrition (Peel, 2006). Parsley, specifically parsley leaves, is characteristic for the high content of vitamin C (Catunescu et al., 2012; Najla et al., 2012; Karklelienė et al., 2014; Nour et al., 2017). In this research, the highest ascorbic acid (AA) content (162.09 mg/100 g FW) was determined in leaf for cv. 'Rialto', while the lowest (9.37 mg/100 g FW) in root for cv. 'Petra' (Table 2). Statistically high differences (P≤0.0001) of AA content were determined both between different parsley cultivars and different plant parts. Comparing the content of AA between plant parts, in leaves, regardless of the parsley cultivar, were determined even 3 times higher values compared to the stem, while in root was determined the lowest content, even 8 times lower compared to the leaf. Namely, the ascorbic acid is glucose derivate and is expected that plant tissues with a higher rate of photosynthesis (leaves) synthetize a higher amount of vitamin C (Smirnoff, 1996). In leaves of *Petroselinum crispum* ssp. *tuberosum* cultivars ('Halblange', 'Arat', 'Eagle') was determined significantly lower AA content compared to the leaves of *Petroselinum crispum* ssp. *neapolitanum* and *Petroselinum crispum* ssp. *crispum* cultivars. While, at the same time even 93% higher AA content was determined in root of *Petroselinum crispum* ssp. *tuberosum* cultivars compared to the *Petroselinum crispum* ssp. *neapolitanum* and *Petroselinum crispum* ssp. *crispum* cultivars. Obtained results of AA content in analyzed parsley cultivars and different plant plants are in agreement with other literature data while eventual deviations are related to the different parsley cultivar, genetic characteristics (Atta-Aly, 1999; Najla et al., 2012; Leahu et al., 2013; Poklude, 2013; Santos et al., 2014).

Total phenol content (TPC), including total flavonoid (TFC) and non-flavonoid content (TNFC), significantly differ (P≤0.0001) between cultivar and plant part (Table 2). Regardless of the cultivar, the highest TPC was determined in plant leaves, even 3 times higher values compared to the stem and even 6 times compared to the root. Plant phenols, as main plant secondary metabolites are crucial natural defense plant mechanism and responsible for the protection of plant from abiotic (temperature, UV radiation) and biotic (pathogen, parasite or predator attack) stress factors. TPC is directly influenced by genotype, growth conditions (soil and temperature) and interaction between genotype and growing conditions (Parry et al., 2006). Phenols, are also main compounds in the formation of organoleptic (sensory) characteristic of food, for example responsible for the specific color development and also a food taste. Marinova et al. (2005) in research on onion proved that the plant color change is associated with the redistribution of phenols and flavonoids within plant parts, and determined the highest TPC in green onion parts compared to the white ones. Also, the green plant parts contain significantly higher TFC. The same trend of TPC and TFC was determined in this research, as mentioned all parsley cultivars leaves contained significantly higher content of phenols compared to the root. Considering the genotype, in general *Petroselinum crispum* ssp. *tuberosum* cultivars ('Halblange', 'Arat', 'Eagle') contains 16% higher TPC in leaves and 2 times higher TPC in stem compared to the cv. 'Rialto', 'Mooskrause' and 'Petra' (*Petroselinum crispum* ssp. *neapolitanum* and *Petroselinum crispum* ssp. *crispum*), while opposite trend was determined for TPC in root in which 14% higher TPC was determined for cv. 'Rialto', 'Mooskrause' and 'Petra' compared to the cv. ''Halblange', 'Arat', 'Eagle'. Obtained results of TPC in parsley leaves are in agreement with other literature data (Marinova et al., 2005; Leahu et al., 2013; Santos et al., 2014; Nour et al., 2017).

Since parsley species are a rich source of different phytonutrients specifically specialized metabolites its

Table 2. Bioactive compounds content and antioxidant capacity of different parsley cultivars and plant parts

Cultivar	TPC (mg GAE/100 g FW) P≤0.0001	TNFC (mg GAE/100 g FW) P≤0.0001	TFC (mg GAE/100 g FW) P≤0.0001	AA (mg/100 g FW) P≤0.0001	ANT_CAP (mmol TE/L) P≤0.0001
			Leaf		
'Rialto'	357.68^{e}±1	213.22^{d}±0.37	144.45^{c}±1.28	162.09^{a}±0.38	2.19^{c}±0.006
'Petra'	304.57^{f}±0.39	163.18^{e}±0.91	141.39^{d}±0.72	73.39^{e}±2.15	2.2^{bc}±0.01
'Mooskrause'	403.68^{c}±0.52	230.47^{b}±0.62	173.2^{b}±1.1	74.95^{e}±1.15	2.19^{c}±0.02
'Halblange'	400.58^{d}±1.02	226.69^{c}±1.32	173.89^{b}±2.2	102.71^{b}±2.15	2.23^{abc}±0.01
'Arat'	425.76^{a}±0.87	240.28^{a}±1.86	185.47^{a}±2.61	78.92^{d}±1.26	2.27^{ab}±0.01
'Eagle'	414.69^{b}±0.36	240.71^{a}±0.8	173.98^{b}±0.55	99.33^{c}±0.9	2.29^{a}±0.01
			Stem		
'Rialto'	79.19^{j}±3.02	37.04^{j}±0.43	42.15^{g}±2.84	21.82^{i}±0.38	1.32^{de}±0.02
'Petra'	70.2^{l}±1.02	33.68^{lm}±0.11	36.52^{h}±1.06	19.86^{j}±0.39	1.25^{e}±0.03
'Mooskrause'	65.02^{n}±0.34	34.29^{kl}±1.06	30.73^{k}±1.07	13.6^{m}±0.39	1.33^{d}±0.07
'Halblange'	151.22^{i}±0.57	80.48^{h}±1.27	70.74^{f}±1.18	40.77^{f}±1.77	2.17^{c}±0.006
'Arat'	158.69^{h}±0.53	86.78^{g}±2.37	71.91^{ef}±2.88	36.05^{g}±1.12	2.23^{abc}±0.005
'Eagle'	165.12^{g}±0.65	91.4^{f}±0.72	73.72^{e}±1.35	39.73^{f}±1.2	2.24^{abc}±0.007
			Root		
'Rialto'	75.01^{k}±0.93	41.29^{i}±1.07	33.71^{hij}±0.36	10.04^{no}±0.38	0.69^{h}±0.06
'Petra'	67.83^{m}±0.94	32.17^{m}±0.96	35.67^{hi}±1.5	9.37^{o}±1.16	0.82^{g}±0.03
'Mooskrause'	64.79^{n}±1.35	31.91^{m}±0.32	32.88^{ijk}±1.57	11.83^{mn}±0.77	0.78^{g}±0.08
'Halblange'	64.12^{n}±1.56	32.69^{lm}±0.91	31.44^{jk}±2.46	26.93^{h}±2	0.98^{f}±0.14
'Arat'	55.21^{p}±0.5	29.38^{n}±0.51	25.83^{l}±0.74	15.59^{l}±0.84	0.75^{gh}±0.04
'Eagle'	61.93^{o}±0.59	35.95^{jk}±0.57	25.98^{l}±1.09	17.78^{k}±0.46	0.95^{f}±0.04
Cultivar (C)	***	***	***	***	***
Plant part (P)	***	***	***	***	***
C×P	***	***	***	***	***

TPC - total phenol content; TNFC - total non-flavonoid content; TFC - total flavonoid content; AA - ascorbic acid content; ANT_CAP - antioxidant capacity.
*** P≤0.0001. Different letters indicate significant differences between mean values within each column

antioxidant activity is high (Gougoulias, 2014; Santos et al., 2014). Antioxidant activity is directly correlated to the content of total phenols, flavonoids, vitamins and pigments so samples with higher amounts of mentioned biologically active compounds exhibit a higher antioxidant activity (Heim et al., 2002; Šic Žlabur et al., 2016). Depending on the plant part, the highest antioxidant capacity (ANT_CAP) was determined in leaves, on average 27% higher compared to the stem and 3 times higher compared to the root (Table 2). Distribution of ANT_CAP results among plant parts is expected due to the higher determined TPC, TFC, AA, TCh and TCa in leaves compared to the stem and root. Also, in analyzed plant parts the highest ANT_CAP was determined for *Petroselinum crispum* ssp. *tuberosum* cultivars both in leaves, stem and root in comparison to the *Petroselinum crispum* ssp. *neapolitanum* and *Petroselinum crispum* ssp. *crispum* cultivars. In general, compared to the other literature data, parsley is as a vegetable species characteristic for the high antioxidant capacity (Santos et al., 2014; Nour et al., 2017).

Pigment compounds content

Plant pigments exhibit an important role both in plant and human organism. In plants, pigments are associated with the process of photosynthesis (chlorophylls), have photoprotective role (carotenoids) and protect plants against many abiotic stressors (athocyanins) (Young, 1991; Landi et al., 2015). For humans, plant pigments are also important due to the significant health benefits from antioxidant to anticancer (Chen, 2015). From chlorophylls, in plants are the most abundant chlorophyll a (blue green color) and chlorophyll b (yellow green color) usually present in 1:2 ratio (Sledz and Witrowa-Rajchert, 2012). According to the results obtained in this research, all analyzed plant pigments (total chlorophylls and carotenoids) significantly differ between parsley cultivar and plant part (Table 3). As expected, in roots are not determined any pigments content, while in leaves are recorded significantly higher values, even 5 times higher total chlorophylls content (TCh) and total carotenoids content (TCa) compared to the stem. The highest TCh content of leaves was determined in cv. 'Mooskrause', while the lowest in cv. 'Arat'. Average TCh values in leaves of *Petroselinum crispum* ssp. *neapolitanum* and *Petroselinum crispum* ssp. crispum cultivars (0.69 mg/g) not differ from the average TCh values of *Petroselinum crispum* ssp. *tuberosum* cultivars (0.69 mg/g). Also, in all analyzed parsley cultivars determined TCh_a:TCh_b ratio was 1:2 which is in accordance with literature data (Sledz and Witrowa-Rajchert, 2012). Pigment compounds content are strongly influenced by genotype and ecological factors so deviations of the results among other literature data are expected. For example, Najla et al. (2012) and Kamel (2013) determined even 2 times lower TCh content compared to the results from this research, while Catunescu et al. (2012) and Karkleliene et al. (2014) even 2 times higher, or Antonopoulos et al. (2014a) and Antonopoulos et al. (2014b) 3 times higher TCh content.

Table 3. Pigment compounds of different parsley cultivars and plant parts

Cultivar	Chl_a (mg/g) P≤0.0001	Chl_b (mg/g) P≤0.0001	TCh (mg/g) P≤0.0001	TCa (mg/g) P≤0.0001
		Leaf		
'Rialto'	0.48^{b}±0.13	0.25^{b}±0.09	0.72^{b}±0.22	0.14^{a}±0.01
'Petra'	0.29^{d}±0.01	0.18^{c}±0.01	0.48^{c}±0.02	0.08^{b}±0.01
'Mooskrause'	0.55^{a}±0.01	0.31^{a}±0.01	0.87^{a}±0.03	0.16^{a}±0.01
'Halblange'	0.44^{bc}±0.03	0.25^{b}±0.02	0.69^{b}±0.05	0.14^{a}±0.01
'Arat'	0.41^{c}±0.05	0.24^{b}±0.04	0.65^{b}±0.09	0.14^{a}±0.02
'Eagle'	0.46^{bc}±0.04	0.27^{ab}±0.01	0.73^{b}±0.04	0.14^{a}±0.02
		Stem		
'Rialto'	0.06^{e}±0.01	0.03^{d}±0.01	0.09^{d}±0.01	0.02c±0.01
'Petra'	0.08^{e}±0.01	0.04^{d}±0.01	0.12^{d}±0.01	0.03c±0.01
'Mooskrause'	0.08^{e}±0.01	0.04^{d}±0.01	0.12^{d}±0.01	0.03c±0.01
'Halblange'	0.11^{e}±0.01	0.06^{d}±0.01	0.17^{d}±0.01	0.03c±0.01
'Arat'	0.09^{e}±0.01	0.05^{d}±0.01	0.16^{d}±0.01	0.03c±0.01
'Eagle'	0.12^{e}±0.01	0.07^{d}±0.01	0.19d±0.02	0.03c±0.01
Cultivar (C)	***	*	***	***
Plant part (P)	***	***	***	***
C×P	***	*	***	***

Chl_a - chlorophyll a content; Chl_b - chlorophyll b content; TCh - total chlorophyll content; TCa - total carotenoid content.
* 0.01≤P≤0.05; *** P≤0.0001. Different letters indicate significant differences between mean values within each column.

CONCLUSIONS

Parsley cultivars of *Petroselinum crispum* ssp. *tuberosum*, *Petroselinum crispum* ssp. *crispum* and *Petroselinum crispum* ssp. *neapolitanum* strongly differ among analyzed bioactive compounds. Highest vitamin C content in leaves was determined in cv. 'Rialto', 'Petra' and 'Mooskrase' compared to the cv. 'Halblange', 'Arat', 'Eagle', while cultivars of *Petroselinum crispum* ssp. *tuberosum* had higher vitamin C content in root compared to the cv. 'Rialto', 'Petra' and 'Mooskrase'. Total phenol content was the highest in leaves of *Petroselinum crispum* ssp. *tuberosum* cultivars. Total chlorophylls content was the highest in cv.'Mooskrase' (*Petroselinum crispum* ssp. *crispum*), while in general comparing the total chlorohylls in cultivars of *Petroselinum crispum* ssp. *tuberosum* and *Petroselinum crispum* ssp. *crispum*, *Petroselinum crispum* ssp. *neapolitanum* the average amounts does not differ.

According to the obtained results, parsley leaves but also stem are a rich source of bioactive compounds so is recommended to use as foods both leaves and stem.

Cultivars, primarily intended for root cultivation, in general shows better nutritional composition compared to roots of the cultivars intended for leaves cultivation (*Petroselinum crispum* ssp. *crispum*, Petroselinum crispum ssp. neapolitanum).

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