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ORIGINAL PAPER

MINERAL COMPOSITION OF SOME EDIBLE FLOWERS*

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Abstract

Flowers are grown not only for their ornamental values but also for the nutritive, medicinal, culinary, cosmetic and aromatic properties. They are a rich source of many chemical compounds which play an important role in various metabolic processes in the human body. Among them are minerals. The aim of the study, conducted in 2014-2015, was to determine and compare the content of macro- (N, P, K, Na, Ca, Mg, S), microelements (Fe, Zn, Cu, Mn) and heavy metals (Ni, Pb, Co, Cd) in flowers of different species and cultivars of ornamental plants. The experimental material consisted of dried flowers of *Mimulus* × *hybridus* L. (Magic Yellow, Magic Red), *Antirrhinum majus* L. (Cavalier), *Dianthus chinensis* L. (Chianti), *Hemerocallis* × *hybrida* Hort., *Paeonia officinalis* L. (Sarah Bernardt, Dr Aleksander Fleming, Karl Rosenfield), *Monarda didyma* L., *Monarda fistulosa* L. and *Monarda citriodora* subsp. *austromontana* Cerv. ex Lag. (Bees Favourite). The content of nitrogen was assessed by the Kjeldahls method, phosphorus – by the colorimetric method, potassium, sodium – by the flame photometry method, calcium, magnesium, sulphur, iron, zinc, copper, manganese, nickel, lead, cobalt and cadmium – by the method of atomic absorption spectrophotometry (AAS). The results of the chemical analyses showed that *Monarda* and *Mimulus* × *hybridus* L. flowers were characterised by a significantly higher content of macro- and microelements in comparison with the other species. Among the macroelements, the highest amounts were noted for potassium (on average 30.03 g kg^{-1} d.m.), and from microelements – for iron (on average 154.93 mg kg^{-1} d.m.). Moreover, the edible flower species were characterised by a relatively low concentration of heavy metals: 2.297 mg Ni, 1.298 mg Pb, 0.723 mg Co and 0.342 mg Cd per kg of dry matter on average. The lowest amounts of heavy metals were found in flowers of *Paeonia officinalis* L. cultivars.

Keywords: ornamental crops, macroelements, microelements, heavy metals.

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INTRODUCTION

Nowadays, consumers are demanding increasingly attractive, healthy and tasty meals (Husti et al. 2013, Deepika et al. 2014). Edible flowers have all of these characteristics and are included in many restaurant and home-made dishes (Rop et al. 2012, Deepika et al. 2014). They are served as an ingredient in salads, soups, appetisers, desserts and drinks (Husti et al. 2013, Grzeszczuk et al. 2016, Petrova et al. 2016). Edible flowers are used in different forms, colours and tastes, so they have high impact on the sensory and nutritional value of food.

In recent years, we have observed an increasing interest in nutraceuticals, i.e. functional food which combines nutritional and medicinal values. Edible flowers are considered as an important component of this type of food (Rop et al. 2012, Benvenuti et al. 2016). They are rich in many different biologically active compounds (polyphenols, carotenoids, vitamins, essential oils, dietary fibre, minerals), which play an important role in the prevention of several chronic illnesses like cardiovascular diseases and cancer (Deepika et al. 2014, Navarro-González et al. 2015, Grzeszczuk et al. 2016). However, there is little information in the literature about the mineral composition of edible flowers.

The aim of the study was to determine the content of macro- and microelements, and heavy metals in the flowers of some species and cultivars of ornamental plant flowers.

MATERIAL AND METHODS

A field experiment was carried out in 2014-2015 at The Edible Flower Collection of the Department of Horticulture of the West Pomeranian University of Technology in Szczecin. The laboratory part of the experiment was conducted in the Department of S*oil Science*, *Grassland* Management and *Environmental Chemistry* of the West Pomeranian University of Technology in Szczecin, in 2015. The research material consisted of edible flowers derived from selected species and cultivars of ornamental plants – its detailed specification is given in Table 1. The field experiment was set in a randomised block design with four replications on typical pararendzinas soils, with pH in H_2O of 6.8, and the following nutrient content: N-NO_3 – 27, P – 80, K – 163, Ca – 2932, Mg – 153, Cl – 12 mg dm^{-3}. A single plot area was: 1.08 m^2 for *M.* × *hybridus* cultivars and *D. chinensis* (30×30 cm, 9 plants per plot), 1.44 m^2 for *A. majus* (30×30 cm, 12 plants per plot) and *Monarda* species (60×60 cm, 4 plants per plot), and 1.20 m^2 for *H.* × *hybrida* and *P. officinalis* cultivars (120×100 cm, 1 plant per plot). The seedlings of annual species (*A. majus*, *D. chinensis*) were produced in a greenhouse.

Table 1

Characterisation of the experimental plant material

Plant species and cultivar	Botanic family	Colour and part of the flower
Mimulus × *hybridus* L. Magic Yellow	*Scrophulariaceae*	yellow petals
Mimulus × *hybridus* L. Magic Red	*Scrophulariaceae*	red petals
Antirrhinum majus L. Cavalier	*Plantaginaceae*	orange-pink petals
Dianthus chinensis L. Chianti	*Caryophyllaceae*	dark maroon/almost black, white edged petals
Hemerocallis × *hybrida* Hort.	*Xanthorrhoeaceae*	orange-yellow petals
Paeonia officinalis L. Sarah Bernardt	*Paeoniaceae*	white petals
Paeonia officinalis L. Dr Aleksander Fleming	*Paeoniaceae*	pink petals
Paeonia officinalis L. Karl Rosenfield	*Paeoniaceae*	vibrant cherry-red petals
Monarda didyma L.	*Lamiaceae*	bilabiate, carmine red flowers gathered in 1-3 whorls with reddish bracts
Monarda fistulosa L.	*Lamiaceae*	bilabiate, lilac-purple flowers with green bracts
Monarda citriodora subsp. *austromontana* Cerv. ex Lag. Bees Favourite	*Lamiaceae*	lavender-pink whorled bilabiate flower heads

Seeds were sown on the 17th March 2015. The seedlings were transplanted into open field on the 21st May 2015. The planting material of *M.* × *hybridus* L. was bought in an ornamental plant nursery and planted on the experimental plots on the 20th May 2015. The seedlings of perennial species (*Monarda* species) were produced in a greenhouse. Seeds were sown on the 22th April 2014. The seedlings were transplanted into open field on the 18th August 2014. The planting material of perennial species (*H.* × *hybrida*, *P. officinalis*) was bought in an ornamental plant nursery and planted on the experimental plots on the 19th May 2014. The flowers of perennial species were collected the following year.

The field was prepared according to an adequate agronomic procedure for the tested plant species. Mineral fertilisation was quantified according to the results of the chemical analysis of the soil. Nitrogen (50 kg N ha^{-1}), phosphorus (50 kg P_2O_5 ha^{-1}) and potassium (80 kg K_2O ha^{-1}) fertilisers were applied during the field preparation, in both years of the study. During the growing season, crop management was carried out. It included mainly irrigation, weeding and soil cultivation.

Flowers were harvested in 2015 at the full-bloom stage (*P. officinalis* – in mid-May; *M.* × *hybridus* – in mid-June; *A. majus*, *D. chinensis*, *H.* × *hybrida* – at the beginning of July; *M. didyma*, *M. fistulosa* – in mid-July; *M. citriodora* subsp. *austromontana* Cerv. ex Lag. Bees Favourite – at the beginning of August). An aggregate sample from the four replications weighed from 50 to 150 g, depending on a plant species. Raw plant material was dried in a through-flow laboratory dryer set at 35°C. The concentration of macroelements (N, P, K, Na, Ca, Mg, S), microelements (Fe, Zn, Cu, Mn) and heavy metals (Ni, Pb, Co, Cd) was determined in dried and pulverized material (1 g of each sample). The material was digested in a mixture of concentrated HNO_3 and $HClO_4$ acids (1:1, v/v). The content of nitrogen was assessed by the Kjeldahls method, phosphorus – by the colorimetric method, potassium, sodium – by the flame photometry method, calcium, magnesium, sulphur, iron, zinc, copper, manganese, nickel, lead, cobalt and cadmium – by the method of atomic absorption spectrophotometry (AAS). The analyses were made in three replications.

The results of the study were subjected to an analysis of variance performed using FR-ANALWAR software based on Microsoft Excel. The means were separated by the Tukeys test at $p = 0.05$.

RESULTS AND DISCUSSION

The results of the chemical analyses of the samples of selected edible flowers are provided in Tables 2-4.

There are scant data about edible flower mineral composition in the available literature (Rop et al. 2012, Voon et al. 2013, Navarro-González et al. 2015, Grzeszczuk et al. 2016) and therefore, in order to compare our study results, we also looked for values of the mineral element content in herbal flowers. Regarding the macroelement content, we found data concerning the following species: *Alcea rosea* (Kara 2009), *Calendula officinalis* (Yassen et al. 2010, Ducat et al. 2011), *Echinacea purpurea* (Ražić et al. 2003), *Lavandula angustifolia* (Ražić et al. 2005) and *Matricaria chamomilla* (Özcan, Akbulut 2007). The macroelement amounts (g kg^{-1} d.m.) determined in these species were as follows: nitrogen – from 9.5 to 21.0 (C. *officinalis*); phosphorus – from 2.58 (*M. chamomilla*) to 4.4 (C. *officinalis*); potassium – from 10.15 (*M. chamomilla*) to 24.5 (*L. angustifolia*); sodium – from 0.13 (*A. rosea*) to 1.95 (*M. chamomilla*); calcium – from 5.55 (*M. chamomilla*) to 21.75 (*A. rosea*); magnesium – from 1.17 (*M. chamomilla*) to 4.01 (*E. purpurea*).

In the present study, among the analysed macroelements, the highest amounts were noted for potassium, followed by nitrogen, and then phosphorus (Table 2).

The flowers of *M. fistulosa* and *M. didyma* were characterised by the highest

Table 2

The content of macroelements in the flowers of selected ornamental plant species (g kg^{-1} d.m.)

Plant species and cultivar	N	P	K	Na	Ca	Mg	S
Mimulus × *hybridus* L. Magic Yellow	14.41	8.17	54.45	1.27	1.63	2.51	1.14
Mimulus × *hybridus* L. Magic Red	13.54	7.86	45.86	0.58	2.89	2.51	1.58
Antirrhinum majus L. Cavalier	10.09	7.73	26.52	0.38	1.12	1.31	0.46
Dianthus chinensis L. Chianti	15.09	7.88	20.43	0.26	0.43	1.58	0.67
Hemerocallis × *hybrida* Hort.	20.11	8.41	26.96	0.37	0.59	1.10	0.63
Paeonia officinalis L. Sarah Bernardt	6.96	6.62	8.15	0.04	1.49	1.45	0.37
Paeonia officinalis L. Dr Aleksander Fleming	7.87	6.56	28.67	0.06	0.85	1.13	0.40
Paeonia officinalis L. Karl Rosenfield	9.10	6.01	27.70	0.09	1.06	1.44	0.27
Monarda didyma L.	24.41	9.16	32.97	0.10	16.78	3.97	1.25
Monarda fistulosa L.	25.00	9.12	34.07	0.10	17.60	3.28	1.15
Monarda citriodora subsp. *austromontana* Cerv. ex Lag. Bees Favourite	19.62	7.34	24.52	0.11	2.63	4.79	1.10
Mean	15.11	7.71	30.03	0.31	4.28	2.28	0.82
$LSD_{a = 0.05}$	1.193	1.398	19.598	0.313	2.013	0.616	0.537

content of nitrogen. High levels of this macroelement were also found in the flowers of *H.* × *hybrida* and *M. citriodora* subsp. *austromontana* Bees Favourite, while the least amounts were noted in flowers of *P. officinalis* cultivars: Dr Aleksander Fleming and Sarah Bernardt. On the basis of these results and the results of our previous study (Grzeszczuk et al. 2016), we can conclude that the amount of nitrogen in edible flowers usually ranges from 10 to 24 g kg^{-1} d.m.

The content of phosphorus in the flower species compared in our study ranged from 6.01 to 9.16 g kg^{-1} d.m. Higher amounts of this macroelement were determined in flowers of *M. didyma, M. fistulosa*, *H.* × *hybrida, M.* × *hybridus* Magic Yellow, *D. chinensis* Chianti and *M.* × *hybridus* Magic Red, while lower phosphorus content was assessed in flowers of *M. citriodora* subsp. *austromontana* Bees Favourite and the three cultivars of *P. officinalis*. The results which we obtained for both cultivars of *M.* × *hybridus* are in agreement with research data of Rop et al. (2012) concerning flowers of *Centaurea cyanus*, *Dianthus caryophyllus*, *Viola* × *wittrockiana* and *Chrysanthemum parthenium*. However, the phosphorus content of the other species

Table 3

The content of microelements in the flowers of selected ornamental plant species (mg kg^{-1} d.m.)

Plant species and cultivar	Fe	Zn	Cu	Mn
Mimulus × *hybridus* L. Magic Yellow	368.23	39.92	19.35	18.20
Mimulus × *hybridus* L. Magic Red	683.50	25.53	8.85	30.64
Antirrhinum majus L. Cavalier	75.52	13.23	4.10	9.90
Dianthus chinensis L. Chianti	82.57	31.62	6.36	18.76
Hemerocallis × *hybrida* Hort.	37.90	28.26	6.61	10.01
Paeonia officinalis L. Sarah Bernardt	35.66	12.61	3.03	10.59
Paeonia officinalis L. Dr Aleksander Fleming	21.80	15.25	2.92	6.02
Paeonia officinalis L. Karl Rosenfield	26.79	22.68	4.47	9.16
Monarda didyma L.	165.40	42.76	13.66	21.24
Monarda fistulosa L.	105.02	29.13	9.98	24.12
Monarda citriodora subsp. *austromontana* Cerv. ex Lag. Bees Favourite	101.86	25.76	8.73	15.08
Mean	154.93	26.07	8.01	15.79
$LSD_{\alpha = 0.05}$	68.088	9.226	2.999	10.170

determined in our study was higher than demonstrated by Rop et al. (2012) and Voon et al. (2013). For example, the content of phosphorus assessed in our study for *Antirrhinum majus* Cavalier was 7.73 g kg^{-1} d.m., while Rop et al. (2012) determined 3.31 g kg^{-1} d.m. in flowers of *A. majus* Zluty Kral. Voon et al. (2013) recorded 4.2 g of phosphorus per kg d.m. in flowers of *Paeonia suffruticosa*, while in our study flowers of *Paeonia officinalis* contained 6.4 g of phosphorus per kg d.m. on average for the three cultivars. Table 2 also shows that flowers of *M.* × *hybridus* Magic Yellow were characterised by a significantly higher concentration of potassium and sodium in comparison with the other species.

Potassium is usually the mots abundant mineral element in plant tissues (Chizzola 2012). In the opinion of Shaibur et al. (2008), a K concentration of 2-5% of plant dry weight (which equals 20-50 g kg^{-1} d.m.) is required for a plants optimal growth. In our paper, only *P. officinalis* Sarah Bernardt flowers contained less of this macroelement (8.15 g kg^{-1} d.m.). A low potassium concentration was also noted by Voon et al. (2013) in *Paeonia suffruticosa* flowers – 15.40 and in *Malus* spp. flowers – 11.26 g kg^{-1} d.m. In the study of

Table 4

The content of heavy metals in the flowers of selected ornamental plant species (mg kg^{-1} d.m.)

Plant species and cultivar	Ni	Pb	Co	Cd
Mimulus × *hybridus* L. Magic Yellow	2.946	4.317	0.563	0.250
Mimulus × *hybridus* L. Magic Red	6.971	2.811	0.812	0.358
Antirrhinum majus L. Cavalier	1.282	1.085	0.997	0.491
Dianthus chinensis L. Chianti	0.805	1.431	1.626	0.621
Hemerocallis × *hybrida* Hort.	5.048	1.491	0.956	0.506
Paeonia officinalis L. Sarah Bernardt	0.907	0.197	nd*	0.125
Paeonia officinalis L. Dr Aleksander Fleming	0.637	0.609	0.207	0.285
Paeonia officinalis L. Karl Rosenfield	1.614	nd	0.752	0.278
Monarda didyma L.	1.725	0.840	0.941	0.320
Monarda fistulosa L.	2.173	0.336	1.035	0.417
Monarda citriodora subsp. *austromontana* Cerv. ex Lag. Bees Favourite	1.157	1.159	0.072	0.116
Mean	2.297	1.298	0.723	0.342
$LSD_{\alpha = 0.05}$	2.252	1.966	0.782	0.152

* nd – not detected

Rop et al. (2012), the content of potassium ranged from 12.98 for *Begonia boliviensis* to 39.61 for *Viola* × *wittrockiana*. The present study shows that *P. officinalis* flowers were also characterised by the least sodium content (0.04-0.09 g kg^{-1} d.m.). Voon et al. (2013) reported that *Paeonia suffruticosa* flowers contained 0.13 g Na kg^{-1} d.m. In our study, low Na amounts were also recorded in the *Monarda* flowers. The sodium concentrations in edible flowers investigated by Rop et al. (2012) were slightly higher. The lowest Na amount they noted was in *Impatiens walleriana* flowers (0.64), while the highest one was in *Fuchsia* × *hybrida* flowers (1.50 g kg^{-1} d.m.).

The average calcium content of the flowers of all the species determined in this study was low with respect to the results given for herbal flowers. However, two species were definitely distinguished by a very high content of this macroelement and they were: *M. fistulosa* and *M. didyma*. Significantly lower amounts of calcium were noted in flowers of *M.* × *hybridus* Magic Yellow, *P. officinalis* Sarah Bernardt, *A. majus* Cavalier, *P. officinalis* Karl Rosenfield and Dr Aleksander Fleming, *H.* × *hybrida* and *D. chinensis* Chianti.

Moreover, there were no significant differences found between the calcium content determined for the first four flower cultivars mentioned above and the flowers of *M.* × *hybridus* Magic Red and *M. citriodora* subsp. *austromontana* Bees Favourite. The calcium content assessed by Rop et al. (2012) for the 12 edible flower species ranged from 2.46 for *Begonia boliviensis* to 4.86 g kg^{-1} d.m. for *Viola* × *wittrockiana*. In our experiment, the range was much wider – from 0.43 for *D. chinensis* Chianti to 17.60 g kg^{-1} d.m. for *M. fistulosa*.

Based on the results of our study, *Monarda* flowers were found to be the best source of magnesium in comparison with the other edible flower species. The highest content of this macroelement was found in flowers of *M. citriodora* subsp. *austromontana* Bees Favourite, followed by flowers of *M. didyma*, and then *M. fistulosa*. The content of magnesium determined by Ražić et al. (2005) in seven medicinal plants, including *Lavandula angustifolia* flowers, varied from 0.17 to 0.67% (1.7 to 6.7 g kg^{-1}) in dry matter.

A similar trend was noted in regard to the sulphur content – *Monarda* flowers were characterised by a significantly higher content of this macroelement (on average 1.17 g kg^{-1} d.m.). Moreover, it did not differ significantly from the results obtained for *M.* × *hybridus* (Magic Red – 1.58 and Magic Yellow – 1.14 g kg^{-1} d.m.). There are no other results given in the literature about the sulphur content in herbal or ornamental plant flowers. The only known literature report was about the leaf + flower of *Lavandula officinalis*, in which the sulphur content was 1.25 g kg^{-1} d.m. (Özcan 2004).

Considering the results of our study, we fully agree with the fact already underlined by the other authors (Rop et al. 2012, Navarro-González et al. 2015) that the concentrations of macroelements in edible flowers are comparable or higher than those assessed for common fruit and vegetable species (Nurzyński et al. 2009, Chełpiński et al. 2010, Domagała-Świątkiewicz, Sady 2011), especially in terms of the content of phosphorus and potassium.

As regards the microelements, their concentrations in the edible flowers we investigated decreased as follows: Fe > Zn > Mn > Cu (Table 3). The highest amounts of iron were determined in flowers of *M.* × *hybridus* cultivars. A high content of iron was also noted in *Monarda* flowers. The iron concentration in herbal and ornamental plant flowers is highly varied: *Begonia boliviensis* – 18.66 mg kg^{-1} d.m. (Rop et al. 2012), *Taraxacum officinalis* – 37.69 mg kg^{-1} d.m. (Diaconu et al. 2012), *Tropaeolum majus* – 51.6 mg kg^{-1} d.m. (Navarro-González et al. 2015), *Tagetes erecta* – 61.8 mg kg^{-1} d.m. (Navarro-González et al. 2015), *Calendula officinalis* – from 89.55 (Ducat et al. 2011) to 137.53 mg kg^{-1} d.m. (Veličković et al. 2014), *Echinacea purpurea* – 62.4-184 mg kg^{-1} d.m. (Kostić et al. 2011), and *Matricaria chamomilla* – from 160.61 (Özcan, Akbulut 2007) to 291.8 mg kg^{-1} d.m. (Diaconu et al. 2012). Higher values have also been recorded, approximating our highest data noted for *M.* × *hybridus* flowers. Tokalioğlu (2012) determined 723 mg Fe in *Malva silvestris* flowers, 575 mg Fe in *Lavandula angustifolia* and 276 mg

Fe kg^{-1} d.m. in *Lavandula stoechas* flowers. Voon et al. (2013) obtained higher values (50.1 mg kg^{-1} d.m.) in *Paeonia suffruticosa* flowers than found in our study in flowers of *P. officinalis* (28.08 mg kg^{-1} d.m. on average).

In most crops, a typical leaf zinc concentration required for adequate growth is 15-20 mg kg^{-1} d.m. (Broadley et al. 2007). Based on the literature, the concentration of zinc in herbal flowers ranges from 14.8 – *Echinacea purpurea* (Ražić et al. 2003) to 126.76 mg kg^{-1} d.m. – *Taraxacum officinalis* (Diaconu et al. 2012) while in edible flowers from ornamental plants it varies from 29.7 – *Spilanthes oleracea* (Navarro-González et al. 2015) to 137.29 mg kg^{-1} d.m. – *Tagetes patula* (Rop et al. 2012). The results of our study are in agreement with these values. A significantly higher content of zinc was determined in flowers of *M. didyma* and *M.* × *hybridus* Magic Yellow, while the least Zn was found in flowers of *P. officinalis* Dr Aleksander Fleming, *A. majus* Cavalier and *P. officinalis* Sarah Bernardt.

The highest content of copper was determined in flowers of *M.* × *hybridus* Magic Yellow, followed by *M. didyma*, *M. fistulosa*, *M. citriodora* subsp. *austromontana* Bees Favourite and *M.* × *hybridus* Magic Red, while the highest content of manganese was recorded in flowers of *M.* × *hybridus* Magic Red, *M. fistulosa* and *M. didyma*. Rop et al. (2012) determined higher values in comparison with ours in the majority of the species they tested. In the cited study, the least copper was assessed in *Impatiens walleriana* – 8.88 mg and the highest was found in *Fuchsia*× *hybrida* – 32.26 mg kg^{-1} d.m. The lowest and highest concentrations of manganese were: 23.51 (*Centaurea cyanus*) and 82.13 mg kg^{-1} d.m. (*Chrysanthemum frutescens*).

Table 4 shows the results of the content of four heavy metals: nickel, lead, cobalt and cadmium, in some edible flower species. On average for all the edible flowers we compared, the concentration of these elements decreases as follows: Ni > Pb > Co > Cd. A high concentration of nickel in the flowers is due to the fact that Ni, like Zn, is one of the essential elements for the plant growth and it is mobile within the plant (Bennett et al. 2000, Ražić et al. 2003, Broadley et al. 2007). Among all the species and cultivars we investigated, significantly higher amounts of nickel were noted in flowers of *M.* × *hybridus* Magic Red and *H.* × *hybrida*, while the least nickel was in flowers of *P. officinalis* Dr Aleksander Fleming. *Mimulus* × *hybridus* flowers were also characterised by the highest content of lead. In flowers of *P. officinalis* Karl Rosenfield lead was not detected.

On the basis of the experimental results shown in Table 4, significantly higher amounts of cobalt were found in flowers of *D. chinensis* Chianti, *M. fistulosa*, *A. majus* Cavalier, *H.* × *hybrida* and *M. didyma*. Moreover, there were no significant differences noted between the cobalt content assessed in the last four species mentioned above and the flowers of *M.* × *hybridus* Magic Red and *P. officinalis* Karl Rosenfield. In flowers of *P. officinalis* Sarah Bernardt the occurrence of cobalt was not detected. The flowers of *D. chinensis* Chianti, *H.* × *hybrida* and *A. majus* Cavalier were also characterised by a significantly higher content of cadmium. Lower amounts of this element were noted in flowers of *M.* × *hybridus* Magic Yellow, *P. officinalis* Sarah Bernardt and *M. citriodora* subsp. *austromotana* Bees Favourite. Regarding the cadmium content in edible flowers, the only report in the literature is given by Voon et al. (2013), where less than 0.5 mg kg^{-1} d.m. was determined in *Paeonia suffruticosa* and *Malus* spp. flowers; there are no results for cobalt concentrations. The results reported for herbal flowers are usually lower than ours. Tokalioğlu (2012) determined 0.32 mg of Co in flowers of *Lavadula angustifolia*, 0.20 mg Co in *Lavandula stoechas* and 0.40 mg Co in *Malva silvestris*, Özcan et al. (2008) – 0.24 mg Co in *Matricaria chamomilla*, Özcan, Akbulut (2007) – 1.05 mg Cd in *Matricaria chamomilla*, Diaconu et al. (2012) – 1.98 mg Cd in *Matricaria chamomilla*.

CONCLUSIONS

1. Edible flowers are a rich source of macro- and microelements, particularly phosphorus, potassium and iron.

2. *Monarda* and *Mimulus* × *hybridus* flowers were characterised by a significantly higher content of macroelements in comparison with the other species. *M. didyma* and *M. fistulosa* flowers had the highest content of N, P, Ca, S, *Monarda citriodora* subsp. *austromontana* Bees Favourite – Mg, and *Mimulus* × *hybridus* – K, Na, and S.

3. Microelements were accumulated in high quantities by flowers of *Mimulus* × *hybridus* Magic Red (Fe, Mn), *Mimulus* × *hybridus* Magic Yellow (Zn, Cu), *Monarda didyma* (Zn, Mn) and *Monarda fistulosa* (Mn).

4. Edible flowers are characterised by a relatively low concentration of heavy metals. Among the investigated plant species, the least amounts of heavy metals were found in flowers of *Paeonia officinalis* cultivars, while the highest appeared in flowers of *Mimulus* × *hybridus* (Ni – Magic Red, Pb – Magic Yellow) and *Dianthus chinensis* Chianti (Co, Cd).

REFERENCES

Bennett J.P., Chiriboga E., Coleman J., Waller D.M. 2000. *Heavy metals in wild rice from Northern Wisconsin*. Sci. Total Environ., 246: 261-269.

Benvenuti S., Bortolotti E., Maggini R. 2016. *Antioxidant power, anthocyanin content and organoleptic performance of edible flowers*. Sci. Hort., 199: 170-177.

Broadley M.R., White P.J., Hammond J.P., Zelko I., Lux A. 2007. *Zinc in plants*. New Phytol., 173: 677-702.

Chełpiński P., Skupień K., Ochmian I. 2010. *Effect of fertilization on yield and quality of cultivar Kent strawberry fruit*. J. Elem., 15(2): 251-257.

Chizzola R. 2012. *Metallic mineral elements and heavy metals in medicinal plants*. Med. Aromat. Plant Sci. Biotech., 6(1): 39-53.

Deepika S.D., Lakshmi S.G., Sowmya L.K., Sulakshana M. 2014. *Edible flowers – A Review article.* Int. J. Adv. Res. Sci. Technol., 3(1): 51-57.

Diaconu D., Diaconu R., Navrotescu T. 2012. *Estimation of heavy metals in medicinal plants and their infusions.* Ovidius University Annals of Chemistry, 23(1): 115-120.

Domagała-Świątkiewicz I., Sady W. 2011. *Effect of nitrogen fertilization on P, K, Mg, Ca and S content in soil and edible parts of white cabbage.* J. Elem., 16(2): 177-193. DOI: 10.5601/jelem.2011.16.2.02

Ducat G., Torres R.Y., Santa H.S.D., Kaminski C.I., Kleinubing S.A., Tussolini L., Justo T.H., Quinaia S.P. 2011. *Correlation of metal ions and phenolic compounds in tea infusions of medicinal plants.* J. Food Tech., 9(4): 12-118.

Grzeszczuk M., Stefaniak A., Pachlowska A. 2016. *Biological value of various edible flower species.* Acta Sci. Pol.-Hortoru., 15(2): 109-119.

Husti A., Cantor M., Buta E., Hort D. 2013. *Current trends of using ornamental plants in culinary arts.* ProEnvironment, 6: 52-58.

Kara D. 2009. *Evaluation of trace metal concentrations in some herbs and herbal teas by principal component analysis.* Food Chem., 114: 347-354.

Kostić D., Mitić S., Zarubica A., Mitić M., Randjelović S. 2011. *Content of trace metals in medicinal plants and their extracts.* Hem. Ind., 65(2): 165-170. DOI: 10.2298/HEMIND101005075K

Navarro-González I., González-Barrio R., García-Valverde V., Bautista-Ortín A.B., Periago M.J. 2015. *Nutritional composition and antioxidant capacity in edible flowers: Characterisation of phenolic compounds by HPLC-DAD-ESI/MS^n.* Int. J. Mol. Sci., 16: 805-822. DOI: 10.3390/ijms16010805

Nurzyński J., Dzida K., Nowak L. 2009. *Yielding and chemical composition of lettuce in dependence on nitrogen fertilisation and liming.* Acta Agrophys., 14(3): 683-689. (in Polish)

Özcan M.M. 2004. *Mineral contents of some plants used as condiments in Turkey.* Food Chem., 84: 437-440. DOI: 10.1016/S0308-8146(03)00263-2

Özcan M.M., Akbulut M. 2007. *Estimation of minerals, nitrate and nitrite contents of medicinal and aromatic plants used as spices, condiments and herbal tea.* Food Chem., 106: 852-858. DOI: 10.1016/j.foodchem.2007.06.045

Özcan M.M., Ünver A., Uçar T., Arslan D. 2008. *Mineral content of some herbs and herbal teas by infusion and decoction.* Food Chem., 106: 1120-1127. DOI: 10.1016/j.foodchem.2007.07.042

Petrova I., Petkova N., Ivanov I. 2016. *Five edible flowers – valuable source of antioxidants in human nutrition.* Int. J. Pharm. Phyto. Res., 8(4): 604-610.

Ražić S., Dogo S., Slavković L., Popović A. 2005. *Inorganic analysis of herbal drugs.* Part I. *Metal determination in herbal drugs originating from medicinal plants of the family Lamiacae.* J. Serb. Chem. Soc., 70(11): 1347-1355. DOI: 10.2298/JSC0511347R

Ražić S., Onjia A., Potkonjak B. 2003. *Trace elements analysis of Echinacea purpurea – herbal medicinal.* J. Pharm. Biomed. Anal., 33: 845-850. DOI: 10.1016/S0731-7085(03)00338-8

Rop O., Mlcek J., Jurikova T., Neugebauerova J., Vabkova J. 2012. *Edible flowers – A new promising source of mineral elements in human nutrition.* Molecules, 17: 6672-6683. DOI: 10.3390/molecules17066672

Shaibur M.R., Shamim A.H.M., Kawai S. 2008. *Growth response of hydroponic rice seedlings at elevated concentrations of potassium chloride.* J. Agric. Rural Dev., 6(1&2): 43-53.

Tokalioğlu Ş. 2012. *Determination of trace elements in commonly consumed medicinal herbs by ICP-MS and multivariate analysis.* Food Chem., 134: 2504-2508.

Veličković J., Dimitrijević D, Mitić S., Mitić M., Kostić D. 2014. *The determination of the phenolic composition, antioxidative activity and heavy metals in the extracts of Calendula officinalis* L. Adv. Technol., 3(2): 46-51.

VOON H.C., RAJEEV B., KARIM A.A., ROSMA A. 2013. *Composition of tree peony (Paeonia suffruticosa) and Chinese apple flower (Malus* spp.*) buds*. Int. Food Res. J., 20(3): 1173-1179.

YASSEN, A.A., HABIB A. M., SAHAR M.Z., KHALED S.M. 2010. *Effect of different sources of potassium fertilizers on growth yield, and chemical composition of Calendula officinalis*. J. Am. Sci., 6(12): 1044-1048.