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Mineral content of bee pollen from Serbia

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In this study we analysed mineral composition of bee pollen of different plant origin collected across Serbia using inductively coupled plasma - optical emission spectrometry. The most abundant elements were potassium, calcium, and magnesium. The samples were also exceptionally rich in iron and zinc, which are very important as nutrients. Judging by our findings, mineral composition of bee pollen much more depends on the type of pollen-producing plant than on its geographical origin.

KEY WORDS: *honey bee; geographical origin; macroelements; microelements; palynology; plant origin, nutritive value; toxicity*

In addition to sugars, proteins, and lipids, bee pollen contains a variety of minerals. Mineral composition of pollen varies with the source location, source plant (1), and handling (2). If pollen has monofloral origin, some consistency in chemical composition can be expected. Otherwise, the composition of pollen can be considered as an average of plants that exist in a particular area (3). According to Campos et al. (4) and Serra-Bonvehí and Jordá (5), the content of major nutritional components can be averaged to 50 % of total carbohydrates, 2-16 % of polysaccharides and dietary fibres, 6-28 % of proteins, 4-8 % of lipids, and 6 % of free amino acids.

Mineral content in pollen is usually expressed as ash content (6) or as the content of macro- and microelements (7-13). Only a few countries in the world (Brasil, Argentina, China, Bulgaria, Poland, Switzerland, and Turkey) define ash content in the range from 2 to 6 g per 100 g of pollen as quality requirement (14-21).

Macro- and microelements in pollen are usually determined from ash, as follows: potassium, calcium, magnesium, sodium, phosphorus, sulphur, iron, copper, manganese, zinc, aluminium, cadmium, chromium, lead, nickel, selenium and some trace elements (22). Knowing the mineral composition is important if pollen is used to supplement human or bee diet. The content of individual elements can vary considerably; some pollen is deficient in potassium (23) and some has too much calcium or sodium (24). Potassium and phosphorus are very important for the normal growth of a bee colony. High concentrations, however, can cause paralysis of adult insects (25). High concentrations of zinc could lead to colony collapse disorder (22), which results in adult worker bees leaving the hive unprotected.

In humans, on the other hand, average zinc and iron content meets 15 % of our daily requirements (5). However, concentrations of heavy metals according to Campos et al. (14) should not exceed 0.1 mg for cadmium, 0.5 mg kg^{-1} for lead, 0.5 mg kg^{-1} for arsenic, and 0.03 mg kg^{-1} for mercury per one kilogram of pollen.

This study extends our earlier physicochemical and techno-functional profiling of bee pollen in Serbia (26) with a comprehensive analysis of its mineral composition. Knowing the plant and geographical origin of our samples, we hoped that the obtained mineral profiles could provide reliable chemometric parameters from which one could infer a variety of information in the future, such as pollen origin, and the processes that occur in the soil-plant-pollen chain.

MATERIALS AND METHODS

Chemicals and materials

Methanol (HPLC grade), formic acid (MS grade), and hydrochloric acid (analytical purity grade) were purchased from Merck (KGaA, Darmstadt, Germany). Solid phase extraction Strata C18-E (500 mg 3 mL^{-1}) cartridges used for extraction and reduction were obtained from Phenomenex (Thermo Fisher Scientific, Waltham, MA, USA). Ultrapure water used to prepare extracts of pollen was obtained using the ThermoFisher TKA MicroPure water

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purification system (0.055 µS cm^{-1}). Syringe filters (13 mm, PTFE membrane 0.45 µm) were purchased from Supelco (Bellefonte, PA, USA).

Bee pollen samples

Bee pollen samples harvested from six districts across Serbia in the late spring and summer of 2011 - 25 of them altogether - were provided by the Beekeeping Association of Serbia (SPOS) with the information on the geographical origin of the samples. In the laboratory the samples were vacuum-packed in bags and stored in a refrigerator at 4 °C until analysis.

Mineral composition

Mineral composition and the content of macro- and microelements in the pollen samples were determined using the inductively coupled plasma-optical emission spectrometry (ICP-OES) (iCAP 6500 Duo ICP, Thermo Fisher Scientific). For this purpose, 0.6 to 0.7 g of the sample was treated with 7 mL of 65 % nitric acid and 1 mL of 35 % hydrogen-peroxide in polytetrafluoroethylene (PTFE) containers. The samples were digested in a closed microwave digestion system (ETHOS 1, Milestone S.r.l., Sorisole, Italy) and the obtained solutions diluted with bidistilled water to 50 mL.

For reference we used 1 g dm^{-3} of the Specpure® multi-element plasma standard solution 4.

Statistical analysis

The mineral content of each sample is the average of triplicate measurements with the 95 % confidence interval (CI_{95}). For descriptive statistics and for the evaluation of differences in mineral content between samples by geographical origin we used the Kruskal-Wallis test run on a demo version of the Number Cruncher Statistical Systems software (Kaysville, UT, USA). For principal component analysis (PCA), whose aim was to establish components responsible for mineral content variation (plant and geographical origin), we ran PLS ToolBox v.6.2.1 (Eigenvector Research, Manson, WA, USA) on MATLAB 7.12.0 R2011a (Natick, Massachusetts, USA) using a singular value decomposition algorithm and a 0.95 confidence level for Q and T^2 Hotelling limits for outliers. Before multivariate analysis, all data were autoscaled.

RESULTS AND DISCUSSION

Palynological analysis showed that three samples were monofloral, as they contained more than 80 % of pollen from one plant species or genus (14). The remaining 22 samples were polyfloral, but in some of these pollen grains one plant family or species dominated with over 45 %.

Dominant were the pollens from the *Brassicaceae* and *Fabaceae* taxa, followed by *Helianthus, Apiaceae, Ranunculaceae, Salix, Fraxinus*, and other families and species frequently cultivated or naturally present in Serbia. Our findings correspond to the geographical distribution of the plants of origin. Other researches also found that the pollen types observed in pollen samples can vary according to geographic origin (27).

Most bee pollen samples originated from northern Serbia (districts of Vojvodina and Belgrade), also known as the Serbian granary. Northern Serbia is mostly cultivated with the species of the *Fabaceae* (soybeans, peas, beans, and clover), *Brassicaceae* (cabbage, cauliflower, kale, and kohlrabi), and *Apiaceae* families as well as the *Helianthus* genus. The rest of the samples were collected in other parts of Serbia, rich in ruderal and forest plants (*Salix* and *Fraxinus*) and honey plants such as meadow and weed plants of the *Ranunculaceae* family.

Table 1 shows the geographical origin of pollen pellets and the most prevalent family or species. A detailed breakdown by plant origin has been published in our earlier article (26).

Tables 2 and 3 show the levels of macro- and microelements in pollen samples, respectively. The most abundant macroelement was potassium (with an average content of 3,391 mg kg^{-1} across all samples), followed by calcium (1,425 mg kg^{-1}), magnesium (749 mg kg^{-1}), iron (70.1 mg kg^{-1}), aluminium (38.6 mg kg^{-1}), zinc (23.7 mg kg^{-1}), and sodium (21.6 mg kg^{-1}). These findings are very similar to other reports (8, 10, 11, 13) and confirm that the three most common elements in bee pollen are potassium, calcium, and magnesium. The average potassium content in our samples was 1.5 to 2 times lower (10, 11), calcium was within average reported range, and magnesium was almost identical to the content reported in South Brazil (10) and half the content found in China (11).

Serra-Bonvehí and Jordá (5) emphasise the nutritional importance of zinc and iron, minerals with which bee pollen is richer than other bee products. If used as food supplement, bee pollen could meet 30 % of adult human daily requirement for iron and 15 % of daily requirement for zinc.

In contrast, aluminium levels exceeding 100 mg kg^{-1}, as is the case with samples 3 and 4 in our study, can be neurotoxic and affect human reproduction (28, 29). As both our samples originate from the district of Belgrade, Serbian capital and the country's main industrial district, the elevated aluminium levels may reflect urban environmental pollution.

The most common microelement in our study was copper (Table 3), with an average content of 7.8 mg kg^{-1} across all samples. This is almost nine times as high as the content reported from Spain (7, 9) and twice as high as the content reported from Poland, China, and South Korea (12). However, this is also half the copper content reported by another Chinese study (11). Followed strontium with 1.38 mg kg^{-1}, barium with 1.22 mg kg^{-1}, and Ni with

Table 1 *The main floral component in bee pollen samples and their geographical origin (27)*

No	Region[a]	Type of pollen samples (monofloral/polyfloral)	% of predominant or main type of pollen grains	Plant family or species
1	Belgrade	polyfloral	60	*Fraxinus*
2	Vojvodina	monofloral	93	*Brassicaceae*
3	Belgrade	polyfloral	48	*Fabaceae*
4	Belgrade	polyfloral	75	*Helianthus*
5	Belgrade	polyfloral	45+35	*Brassicaeae + Salix*
6	Southern Serbia	monofloral	81	*Salix*
7	Western SerbiaWestern Serbia	polyfloral	25+22	*Plantago + Ambrosia*
8	Belgrade	polyfloral	72	*Fabaceae*
9	Western SerbiaWestern Serbia	polyfloral	50	*Fabaceae*
10	Belgrade	polyfloral	69	*Apiaceae*
11	Belgrade	polyfloral	31+18+18	*Brassicaceae + Fabaceae + Moraceae*
12	Eastern Serbia	polyfloral	76	*Brassicaceae*
13	Eastern Serbia	monofloral	81	*Fabaceae*
14	Western SerbiaWestern Serbia	polyfloral	42+23	*Rosaceae + Fabaceae*
15	Western SerbiaWestern Serbia	polyfloral	35+19+19+18	*Plantago + Fabaceae + Ambrosia + Asteraceae*
16	Vojvodina	polyfloral	34+28	*Brassicaceae + Fabaceae*
17	Vojvodina	polyfloral	31+18	*Ambrosia + Asteraceae*
18	Belgrade	polyfloral	18	*Asteraceae*
19	Central Serbia	polyfloral	34+25	*Brassicaceae + Fabaceae*
20	Vojvodina	polyfloral	76	*Ranunculaceae*
21	Vojvodina	polyfloral	57	*Fabaceae*
22	Vojvodina	polyfloral	42	*Sophora*
23	Central Serbia	polyfloral	78	*Fabaceae*
24	Belgrade	polyfloral	46+21	*Sophora + Helianthus*
25	Central Serbia	polyfloral	24+22	*Rannunculaceae + Robinia*

0.76 mg kg^{-1}. As far as we know, this is the first time that strontium is reported in bee pollen in world literature, probably because no one has analysed bee pollen for strontium until now. Our finding however, calls for including strontium as well as barium in the analysis, as both are toxic for humans (30, 31). Chromium, cadmium, and cobalt were present in trace amounts, acceptable for human consumption and their levels were probably the result of man-made contamination. In fact, the average content of cadmium (0.067 mg kg^{-1}) was within the safety limit suggested by Campos et al. (14).

Our mineral findings show great variability between the samples. Somerville and Nicol (22) suggest that large variations such as ours are not related only to the plant origin but also to the way bees carry pollen from plants to the hive. Bee workers moisturise flower pollen with nectar as they carry it in the pollen baskets (*corbiculae*), and part of the mineral content can originate from nectar.

Table 4 summarises our findings by providing mean mineral levels by areas of origin. It shows that pollen from western Serbia has higher content of manganese, barium, nickel, cadmium, and zinc, and lower content of aluminium and sodium than samples from the other parts of Serbia. In addition, samples from west, east, and central Serbia contain more potassium and copper. Considering that minerals enter a plant from soil through the root system, their concentrations, particularly those of potassium, sodium, calcium, magnesium, and manganese could be affected by geochemical and geological features of the soil. There are three main soil profiles in Serbia; the north part is rich in calcium due to the presence of chernozems, and the west and east are rich in aluminium, iron, magnesium, nickel, cobalt, and chrome but poor in calcium (32). However, our findings in pollen do not reflect these soil profiles; calcium content is evenly distributed across the country, and only nickel seems to reflect its higher content in the soil of western Serbia (siliceous rocks). This suggests that mineral content in pollen will depend on the floral type of pollen-producing plants and floral density rather than on soil characteristics. This conclusion is also supported by the fact that mineral levels in pollen from the same area vary considerably over the year as one flowering plant replaces the other (33). The reason why the mineral content of pollen samples from the western Serbia is so different from the rest may be related to the prevalence of the *Fabaceae* family (the *Plantago* genus and *Robinia pseudoacacia* in particular) in this area. In addition, soil is not the only source of minerals in plants. They also bioaccumulate them from water and air, and this process differs between plant species.

In an earlier study (34) we tried to classify a vast number of genuine multifloral honey samples according to geographical origin. Unlike the pollen, these honey samples reflected mineral composition in soils of origin, which suggests that mineral bioaccumulation is different between nectar and pollen in the same flowering species. Furthermore, pollen composition does not simply reflect the distribution of flowering species around a bee hive, as it largely depends on bee preferences (33).

Kruskal-Wallis test of differences between samples of different geographical origin showed significant difference only in the distribution of manganese across Serbia. Multiple comparison (using the Kruskal-Wallis Z-test) pointed to the differences between Vojvodina and Belgrade or west Serbia, and between central and west Serbia.

Our PCA resulted in a four-component model which explains 78.55 % of total variance. The first principal component, PC1, accounted for 30.21 % of the overall data variance, PC2 for 25.95 %, and PC3 for 13.13 %. Figure 1 shows the score and loading plots for the first two principal components. The sample outside the Hotelling T^2 ellipse (sample 7) contains a high share of *Ambrosia* and *Plantago* taxa, unlike any other pollen sample, and can be considered an outlier. The score plot shows that there are no distinctive groups of pollens by geographical origin, but it also shows partial clustering of pollen samples from Belgrade, which points to urban or pollutant effects. In addition, pollen samples with a high proportion of specific flowering species, namely sample 4 (75 % of *Helianthus* species), 22 (42 % of *Sophora* species), 1 (60 % of *Fraxinus* taxa), and 14 (42 % of *Rosaceae* taxa) are characterised by the higher content of aluminium, iron, chromium, cobalt, and zinc, similar to samples from Belgrade (loading plot, Figure 1b). The most influential variables discriminating pollens from other observed regions are calcium, copper, magnesium, potassium, sodium, nickel, and strontium. Sample 7, marked as outlier, is distinguished by higher amount of barium, cadmium, and manganese. Our PCA results show that minerals in pollen depend on the plant, as they group around samples that contain pollen from a certain plant type such as *Brassicaceae* and *Fabaceae*. Therefore, to see if there are differences between geographical areas it would be advisable to analyse mineral content only in monofloral pollen of the same plant collected from different areas.

CONCLUSION

This is the first report about the mineral composition of bee pollen in Serbia. To the best of our knowledge, this is also the first report of strontium in bee pollen in the world. Although most of the samples were polyfloral, maximal and minimal content of these minerals were detected in samples with a high share of specific floral type, which

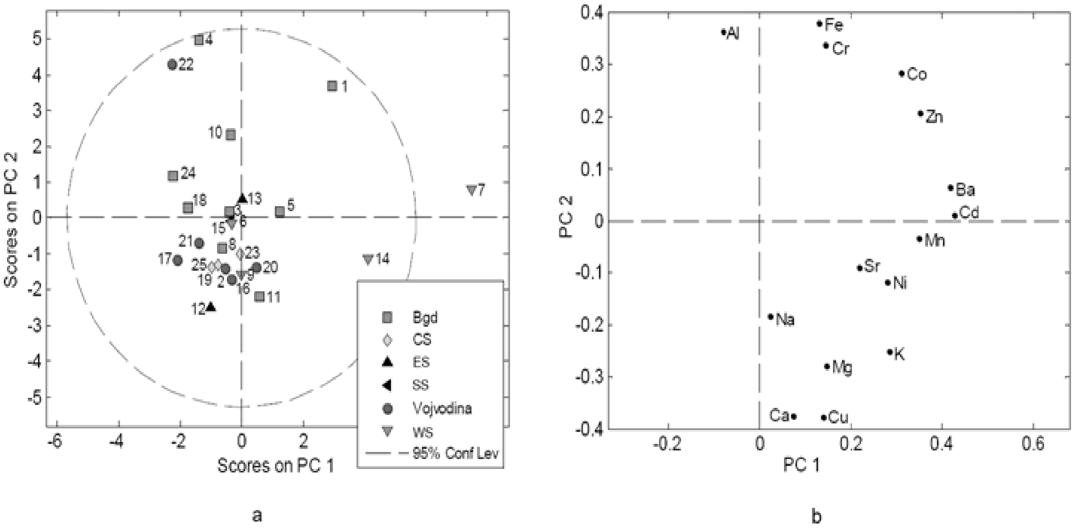

Figure 1 *Principal component analysis, the score plot (a) shows sample clustering, whereas the loading plot (b) reflects the influence of a particular metal on such clustering*

Table 2 *Mean macroelement levels in bee pollen (mg kg^{-1}with 95 % confidence interval)*

Sample no.	K	Ca	Mg	Fe	Al	Zn	Na	Mn
1	3616±71	921±11	747±12	100.39±0.05	53.67±0.55	57.50±0.39	27.51±0.33	31.94±0.22
2	3241±64	1739±35	832±10	48.33±0.49	27.84±0.22	36.95±0.43	26.75±0.16	18.88±0.30
3	3389±56	1462±28	928±10	83.12±0.73	100.8±1.1	36.59±0.06	54.88±0.56	18.38±0.22
4	2462±15	1189±36	503±7	141.29±1.85	111.9±1.1	44.93±0.56	5.84±0.08	16.16±0.31
5	3420±18	1500±49	820±17	74.10±0.84	36.22±0.56	40.36±0.06	17.67±0.32	32.66±0.51
6	3404±17	1196±16	595±7	56.86±0.55	10.98±0.12	41.19±0.38	15.11±0.07	22.75±0.22
7	4236±36	1455±17	829±10	100.12±0.39	27.01±0.06	75.92±0.11	19.44±0.01	47.26±0.22
8	3508±53	1438±29	963±11	60.28±0.78	29.29±0.17	38.05±0.22	16.63±0.02	21.97±0.37
9	3562±13	1588±5	964±15	64.10±0.34	27.01±0.39	39.77±0.22	16.36±0.16	23.40±0.17
10	3046±38	1281±24	623±7	79.61±1.09	62.08±0.27	43.91±0.22	14.93±0.10	19.89±0.28
11	3637±70	1903±47	941±28	74.99±0.71	24.66±0.33	37.43±0.11	29.27±0.33	20.45±0.35
12	3664±14	2032±27	964±17	52.54±0.70	21.56±0.32	31.71±0.21	25.76±0.22	21.32±0.33
13	3512±92	1236±29	875±10	93.64±1.53	61.37±0.71	40.74±0.05	34.70±0.22	18.96±0.22
14	3384±20	1777±43	751±4	68.40±0.16	16.76±0.24	40.89±0.49	15.46±0.08	92.23±1.51
15	3711±11	973±18	657±14	48.14±0.26	8.51±0.15	43.73±0.53	21.32±0.21	21.73±0.21
16	3240±16	2003±55	735±17	66.10±0.77	31.71±0.22	41.14±0.49	14.67±0.18	21.12±0.21
17	2740±40	1748±52	585±14	53.63±0.16	28.54±0.06	28.76±0.22	34.58±0.55	13.52±0.05
18	3186±82	1035±16	620±8	44.10±0.21	26.59±0.05	38.97±0.37	19.49±0.12	15.47±0.09
19	3536±35	1581±18	776±17	53.58±0.27	26.96±0.27	34.79±0.33	21.57±0.09	17.99±0.15
20	3675±59	1734±36	650±9	68.50±0.33	41.95±0.33	40.34±0.22	23.39±0.16	17.67±0.07
21	3219±40	1229±17	703±6	39.56±0.38	16.58±0.33	41.91±0.49	21.74±0.22	13.81±0.14
22	2663±16	856±21	553±4	114.93±0.33	90.05±0.11	39.05±0.05	4.95±0.05	14.91±0.08
23	3820±49	1308±30	848±7	54.63±0.22	22.08±0.33	48.50±0.49	19.62±0.19	18.12±0.24
24	3127±18	921±6	534±8	46.75±0.49	31.57±0.33	44.42±0.16	8.21±0.06	15.08±0.13
25	3788±42	1532±20	731±9	63.89±0.65	30.32±0.16	33.28±0.22	30.76±0.11	16.13±0.39

Table 3 *Mean microelement levels in bee pollen (mg kg^{-1}; with 95 % confidence interval)*

Sample no.	Cu	Ba	Ni	Sr	Cd	Co	Cr
1	5.781±0.033	1.763±0.010	1.513±0.021	0.730±0.008	0.099±0.008	0.098±0.003	0.465±0.014
2	7.904±0.076	0.665±0.009	1.140±0.021	0.957±0.009	0.066±0.004	0.033±0.010	0.208±0.014
3	7.591±0.050	1.244±0.006	0.440±0.020	1.597±0.020	0.055±0.003	0.036±0.013	0.263±0.022
4	6.336±0.123	0.931±0.012	0.252±0.006	0.825±0.010	0.045±0.009	0.049±0.010	0.332±0.007
5	7.363±0.096	1.540±0.027	1.000±0.019	0.925±0.016	0.142±0.012	0.047±0.003	0.262±0.020
6	6.599±0.060	2.047±0.013	0.723±0.015	1.639±0.008	0.055±0.002	0.030±0.005	0.170±0.018
7	9.116±0.044	6.098±0.011	0.941±0.020	3.367±0.011	0.228±0.001	0.083±0.005	0.266±0.026
8	8.081±0.128	0.649±0.009	0.410±0.027	1.154±0.014	0.044±0.001	0.033±0.007	0.235±0.022
9	10.295±0.045	0.728±0.008	0.712±0.015	1.172±0.005	0.054±0.007	0.029±0.012	0.238±0.022
10	6.784±0.071	0.905±0.002	0.367±0.016	1.180±0.13	0.048±0.005	0.090±0.012	0.249±0.002
11	9.817±0.159	1.039±0.012	1.260±0.012	1.782±0.017	0.057±0.002	0.024±0.010	0.244±0.014
12	8.892±0.124	0.383±0.003	0.347±0.010	0.746±0.009	0.050±0.002	0.016±0.005	0.231±0.022
13	7.326±0.098	0.769±0.011	0.300±0.008	3.063±0.022	0.044±0.002	0.042±0.002	0.266±0.012
14	8.620±0.054	2.640±0.016	2.231±0.032	1.198±0.005	0.167±0.004	0.058±0.013	0.197±0.015
15	6.079±0.053	1.845±0.020	0.754±0.032	1.032±0.008	0.049±0.005	0.036±0.001	0.169±0.014
16	10.737±0.071	0.943±0.012	0.293±0.016	3.196±0.033	0.039±0.004	0.017±0.020	0214±0.012
17	8.521±0.038	0.630±0.004	0.810±0.015	0.878±0.002	0.048±0.005	0.026±0.008	0.173±0.018
18	6.252±0.069	0.567±0.004	0.563±0.018	0.858±0.003	0.053±0.002	0.029±0.006	0.190±0.011
19	8.667±0.049	0.681±0.005	0.651±0.021	1.076±0.006	0.050±0.002	0.024±0.005	0.207±0.017
20	10.373±0.126	1.306±0.008	1.125±0.019	2.299±0.011	0.061±0.009	0.030±0.002	0.210±0.013
21	6.858±0.066	0.760±0.004	0.367±0.004	1.592±0.012	0.067±0.004	0.017±0.026	0.169±0.015
22	4.399±0.038	0.782±0.001	0.228±0.017	0.906±0.004	0.028±0.003	0.035±0.006	0.291±0.022
23	8.208±0.082	0.597±0.008	0.804±0.022	1.072±0.011	0.056±0.004	0.031±0.011	0.196±0.006
24	5.261±0.049	0.465±0.007	0.543±0.003	0.510±0.004	0.046±0.011	0.013±0.013	0.201±0.011
25	8.320±0.200	0.640±0.009	1.137±0.024	0.667±0.011	0.036±0.004	0.030±0.014	0.210±0.034

Table 4 *Parameters of descriptive statistics for the investigated pollen samples of different geographical origin*

Region		K	Ca	Mg	Fe	Al	Zn	Na	Mn	Cu	Ba	Ni	Sr	Cd	Co	Cr
Belgrade	mean	3265.62	1294.40	742.17	78.29	52.99	42.46	21.60	21.33	7.03	1.01	0.71	1.06	0.066	0.047	0.27
	stdev	367.13	319.90	180.03	29.58	32.89	6.46	14.65	6.64	1.38	0.44	0.44	0.41	0.033	0.029	0.08
Vojvodina	mean	3120.65	1389.99	656.89	61.51	38.59	37.66	21.82	15.71	7.38	0.78	0.71	1.25	0.054	0.028	0.21
	stdev	371.68	401.49	100.20	28.01	26.48	4.66	9.80	2.14	2.05	0.27	0.38	0.59	0.015	0.006	0.04
Western Serbia	mean	3723.23	1447.98	800.19	70.19	19.85	50.08	18.15	46.15	8.53	2.83	1.16	1.69	0.125	0.052	0.22
	stdev	366.85	343.16	129.92	21.77	8.99	17.31	2.72	32.85	1.78	2.32	0.72	1.12	0.088	0.025	0.04
Eastern Serbia	mean	3588.05	1634.25	919.64	73.09	41.46	36.22	30.23	20.14	8.11	0.58	0.32	1.90	0.047	0.029	0.25
	stdev	107.59	562.71	63.11	29.07	28.15	6.38	6.32	1.67	1.11	0.27	0.03	1.64	0.004	0.018	0.02
Central Serbia	mean	3714.46	1473.81	784.92	57.37	26.45	38.86	23.98	17.41	8.40	0.64	0.86	0.94	0.047	0.028	0.20
	stdev	155.27	146.05	58.90	5.67	4.15	8.38	5.95	1.11	0.24	0.04	0.25	0.23	0.010	0.004	0.01

suggests that plant origin affects the mineral composition of pollen.

Judging by our samples, bee pollen from Serbia is a valuable source of zinc and iron and has low levels of toxic metals, except for two samples with higher aluminium levels.

Our findings also suggest that pollen mineral content does not correspond to soil type but rather to the plant type. An exception is the pollen from the Belgrade district, whose content is distinguished from other regions, probably due to the influence of urban pollutants.

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Sadržaj minerala u uzorcima pčelinjega peluda iz Srbije

U ovom radu analiziran je mineralni sastav pčelinjega peluda različitoga biljnoga podrijetla prikupljenoga diljem Srbije primjenom inducirano spregnute plazme – optičke emisijske spektroskopije. Najzastupljeniji elementi su kalij, kalcij i magnezij. Uzorci su također iznimno bogati željezom i cinkom, što povećava njihovu nutritivnu vrijednost. Prema našim saznanjima, mineralni sastav pčelinjega peluda puno više ovisi o vrsti biljaka koje proizvode pelud nego o njegovu zemljopisnom podrijetlu.

KLJUČNE RIJEČI: *biljno podrijetlo; makroelementi; mikroelementi; palinologija; pčele; zemljopisno podrijetlo; nutritivna vrijednost; toksičnost*