

Total mineral content and some chemical elements determination in bee honey from Bosnia & Herzegovina (B&H)

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Abstract: - Today, there are many published papers of the content of mineral substances, chemical elements and heavy metals in honey and bee products all around the world. However, the natural content of mineral substances in honey plants changes in a negative direction as the result of global pollution, which puts at risk of the contamination of bee pasture and thus bees and man, finally. Chemical elements in honey and bee products can come in three ways: from the environment, feeding bees, processing and packaging honey. A beekeeper can't control an environmental conditions, but their role is crucial in the last two steps. Metals in honey can change its organoleptic properties. So far, about 54 chemical elements have been detected in honey, of which macro elements, many micro elements and heavy and toxic metals. In this paper, 12 samples of honey were tested, which were collected from beekeepers from different geographical areas of B&H. The beekeepers declared the samples as meadow honeys except one sample. In this paper, a total content of mineral substances, electroconductivity, and the individual content of chemical elements (Na, Mg, Al, K, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, Ag, Ba) were investigated. In work are used conductometer Con 11; Microwave Sineo Jupiter– B; ICPMS Agilent 7700 Series. The average of electroconductivity ranged from 0.228 to 1.116 mS/cm and mineral substances from 0.113 to 0.566 %. Based on the results, no sample of honey belongs to the type of honeydew, however, samples whose electroconductivity values were greater than 0.8 mS/cm belong to the type of mixed honey between nectar honey and honeydew. The content of K was the highest and ranged in 391.73 - 3017.93 mg/kg, then Mg ranged in 11.14 -166.65 mg/kg. According to its content in honey chemical elements have following order: K<Mg<Na<Zn<Al<<Fe<Mn<Co<Ni<Cu<Ba<Cr<V<Ag<Se.

Key-Words: - chemical elements, honey, bee, ICPMS, electroconductivity, sample

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1 Introduction

The metallic elements in honey mainly include K, Na, Ca, Mg, Cu, Zn, Fe, and Mn, which plays a vital role in maintaining normal metabolic and organ functions, improving the activity of enzymes, and enhancing the immune function. The content of metallic elements in honey is relatively low (0.1–1 %) [1], [2]. Chemical elements, i.e., mineral substances, are represented naturally in honey plants in different amounts, which depends on a whole series of evolutionary factors of the country. But the natural content of mineral substances in honey plants changes in a negative direction with the change in the development of civilization, such as the development of industry, traffic, the increase in the number of human population etc. The accumulation of harmful substances in the form of metals is a consequence of

global pollution, which endangers the contamination of bee pasture and thus bees and humans [2], [3], [14].

The mineral composition of honey is correlated with the color of the honey and its antioxidant properties. Additionally, the concentrations of minerals are associated with the electrical conductivity of honey [4]. Metals primarily move from the soil into honey plants through root systems, subsequently transferring into the nectar and eventually becoming part of the honey produced by bees. Hence, the chemical makeup of honey, particularly concerning major and minor metals like Ca, K, Mg, Mn, and Na, is impacted by the soil's composition, which is influenced by factors such as geographical origin, regional conditions, climatic changes in bees' foraging area, and volcanic and hydrothermal activity [5].

The bee as a specific living being on land represents the link between plants and man, where man as a conscious being dominates and very often causes enormous damage to the bees and thus to himself. Chemical elements in honey and bee products can come in three ways: intake through bee grazing - from the environment, through bee feeding or bee processing and packaging. Although the beekeeper has limited control over environmental conditions, he can regulate the other two factors, particularly the latter, for which he primary has responsibility.

From the environment, the bee brings nectar and honeydew from the honey plants, and thus it should bring in useful chemical elements, but the question arises whether this is always the case. If honey is contaminated through ingestion of nectar and honeydew, there is a risk of additional contamination through feeding, processing and packaging. Contamination with metals can lead to changes in the organoleptic properties of honey and other bee products. Increased amounts of chemical elements, especially heavy metals during consumption can lead to harmful consequences for humans. The chemical elements that appear in honey are divided into three groups: major or macroelements (Na, K, Ca, Mg, P, S, Cl), minor or trace elements (Al, Cu, Pb, Zn, Mn, Cd, Tl, Co, Ni, Rb, Ba, Be, Bi, U, V, Fe, Pt, Pd, Te, Hf, Mo, Sn, Sb, La, I, Sm, Tb, Dy, Sd, Th, Pr, Nd, Tm, Yb, Lu, Gd, Ho, Er, Ce, Cr, As, B, Br, Cd, Hg, Se, Sr), and toxic, mainly heavy metals (Pb, Cd, Hg, Cr, Cu, Mn, Ni, Zn, and Ag). In a very systematic review, it was determined that honey can contain up to 54 chemical elements [6].

2 Materials and methods

2.1 Materials

Standard laboratory equipment and materials were used. Teflon tubes and PVC flasks were used throughout the analytical procedure to minimize the risk of metal contamination. Blank honey matrices and blank solvents were used as procedural blanks.

Chemicals:

1. Hydrogen peroxide 30% conc. Supra pure, J.T. Backer
2. Nitrogen acid, $\geq 67\%$ conc. Supra pure, J.T. Backer
3. Hydrochlorid acid 30% conc. Supra pure, J.T. Backer
4. Reference solution: Multi-element Calibration Standard for ICP-MS ; conc.10 mg/L (Ag, Al, As, Ba, B, Ca, Cd, Co, Cr, Cs, Cu, Fe, Ga, K, Li,

Mg, Mn, Mo, Na, Ni, Pb, Se, Sr, Tl, V, Zn, Sn) u 2 % HNO_3 - 100 mL, Agilent

5. Internal Std Mix for ICP-MS; conc.100 $\mu\text{g/mL}$ (Bi, Ge, In, Li⁶, Lu, Rh, Sc,Tb) in 10 % HNO_3 - 100 mL, Agilent

6. Tuning solutions for ICP-MS 1 $\mu\text{g/L}$ (Ce, Co, Li, Mg, Tl, Y) - 500 mL; Agilent

7. Ultra pure water 0,055 $\mu\text{S/cm}$

Equipments:

1. Conductometer: Eutech Instruments, CyberScan Con 11
2. Microvawe for digestion: Sineo Chemistry Technology, Jupiter - B
3. ICPMS Analyzer: Agilent 7700 Series

2.1.1 Samples

In this study, the total mineral matter (MM) content, electrical conductivity (EC), and concentrations of selected chemical elements (Na, Mg, Al, K, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, Ag, and Ba) were determined.

2.1.2 Tested parameters

In this work, the total amount of mineral matter (MM), electrical conductivity (EC), and individual amounts of some individual chemical elements (Na, Mg, Al, K, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, Ag, Ba) were examined.

2.1.3 Methods

The determination of mineral matter (MM) and electrical conductivity was performed according to the ICH method (2009). The determination of chemical elements was carried out using EN 13805:2014 [16] for sample digestion and EN 15763:2009 [17] for element concentration measurements using the instruments described in Section 2.1. Sample weight was 0,5 g. All samples were analyzed in duplicate. Tow type of calibration solutions prepared from stock solution:

1. For micro elements in 5 points: 1, 2, 5, 7 and 10 $\mu\text{g/L}$ respectively and
2. For macro elements in 5 point: 50, 70, 100, 200 and 500 $\mu\text{g/L}$, respectively. The analytical method has been verified by evaluating its performance parameters, which yielded the following acceptance criteria: limit of detection (LOD) $\leq 0.010 \mu\text{g/kg}$, limit of quantification (LOQ) $\leq 0.060 \mu\text{g/kg}$, and recovery ranging from 60% to 140%. Blank sample spiked at 2 $\mu\text{g/L}$ for micro elemnets and 100 $\mu\text{g/L}$ for macro elements.

3 Results and discussion

3.1 Results

The average value of EC ranged from 0.228 to 1.116 mS/cm and MM from 0.113 to 0.566 %. The reading of the MM results was done on the same instrument, and based on the results, not a single honey sample belongs to the type of honeydew, i.e. forest honey, however samples whose EC values are higher than 0.8 mS/cm belong to the type of mixed honeys, nectar and honeydews.

This is characteristic of samples 1, 4, 7, 10 and 11, which are declared as meadow honeys, although according to the EC value they are honeydews. Sample 6 declared as forest honey according to the obtained results belongs to the type of nectar honey (Table 1). Given that bee pastures in B&H are highly heterogeneous in terms of honey plant species, beekeepers are often not completely certain about the botanical origin of the collected honey.

Table 1. Total amount of mineral matter (MM) and electrical conductivity (EC)

No.	Label of the sample	Geographical area	Declared type of honey	EC (mS/cm)	MM (%)	Total amount of tested elements: Na, Mg, Al, K, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, Ag, Ba (%)	Ratio between MM and Total amount of tested elements (%)
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754/19	Konjic	Meadow	11 16, 0	0. 5 6 6	0.0 7	12. 37
756/19	Konjic	Meadow	0.3 8	0. 1 8 8	0.1 78	94. 68
761/19	Ključ	Meadow	0.7 15	0. 3 5 8	0.1 48	41. 34
765/19	Ključ	Meadow	0.9 28	0. 4 6 6	0.1 63	35. 43
768/19	Ključ	Meadow	0.7 49	0. 3 7 7	0.0 96	25. 95
777/19	Zenica	Forest - meadow	0.7 32	0. 3 7	0.1 75	42. 30
788/19	Sarajevo	Mountain's meadow	0.8 64	0. 4 3	0.1 66	38. 60
805/19	Goražde	Meadow	0.4 92	0. 2 5	0.2 09	83. 60
809/19	Goražde	Meadow	0.4 18	0. 2 1	0.2 26	10 7.6 2
824/19	Hadzići	Meadow	0.8 81	0. 4 4	0.0 43	9.7 7
832/19	Ilidža	Mountain's meadow	0.9 56	0. 4 8	0.3 23	62. 29
833/19	Ilidža	Meadow	0.6 14	0. 3 1	0.0 64	20. 64
Average			0.7 37	0. 3 6 9	0.1 55	42. 0

Consequently, mistakes may occur when declaring the type of honey, which can have a negative impact on the market. As shown in Figure 1 and Table 1, the total mineral matter (MM) content and the total content of the 15 chemical elements determined by the ICP-MS method are significantly correlated in most samples.

However, in samples 2 and 9, these values are consistent, indicating that these samples either do not contain other chemical elements or that such elements are present only in negligible amounts.

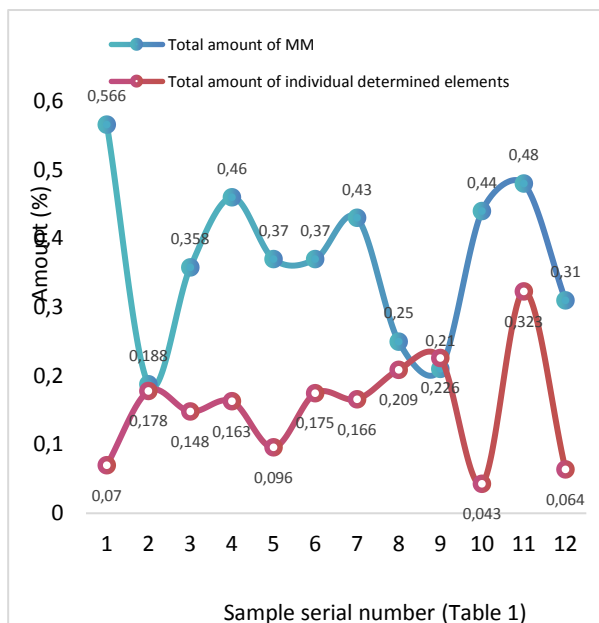


Fig. 1: Relation between of total amount of MM and total amount of determined elements by ICPMS

In most samples, the ratio between the total content of the determined chemical elements and the total MM content is less than 50%. A very low content of chemical elements was recorded in samples 1, 10, and 12, despite their relatively high MM content (Table 1, Figure 1). Sample 1 is particularly noteworthy with regard to its MM content (Figure 1, Table 1), as it contained the highest amount of MM among the analyzed samples, while simultaneously showing very low amounts of the chemical elements determined by the ICP-MS method. Beekeeper declared this sample as meadow honey, and similar results was found in sample 10 which also declared as meadow honey. Relatively small amount of both tested parameters found in samples 2, 8 and 9 as can shown in Figure 1 and Table 1. Therefore, it is clear that, in these samples, in addition to the determined chemical elements, other elements are also present in significant quantities but were not determined in this study.

Table 2. Individual content of the investigated chemical elements by ICPMS (mg/kg)

S a m p l e N o. (T a b l	1	2	3	4	5	6	7	8	9	10	11	12	A v e r a g e ↓

e l)													
T y p e o f h o n e y	M e a d o w	M e a d o w	M e a d o w	M e a d o w	M e a d o w	F o r e s t - m e a d o w	M o u n t a i n ' s m e a d o w	M e a d o w	M e a d o w	M e a d o w	M o u n t a i n ' s m e a d o w	M e a d o w	
K	6 4 1 . 9 8	1 6 6 0 . 8 9	1 4 0 4 . 5 4	1 5 7 1 . 5 7	8 9 7 . 2 5	1 6 0 7 . 3 1	1 5 5 6 . 3 6	1 9 6 1 . 7 4	2 1 7 0 . 3 5	3 9 1 . 7 3	3 0 1 . 9 3	6 0 8 . 4 6 9 8	
M g	3 5 . 9 8	8 8 . 6 9	5 1 . 0 5	4 0 . 8 9	3 2 6 . 9 4	1 0 7 . 4 7	7 9 . 8 8	6 4 . 0 7	6 5 . 2 3	2 5 . 0 6	1 6 5 . 6 6	1 1 . 1 4 8	6 3 . 9 8
N a	1 5 . 0 6	1 3 . 8 2	1 9 . 2 2	1 2 . 6 2	1 2 . 5 7	1 3 . 9 9	1 1 . 0 5	4 9 . 8 3	1 2 . 9 5	9 . 7 8	1 9 . 6 9	2 0 . 4 9	1 7 . 5 9
F e	0 9 7 3 . 0	4 6 4 9 . 0	2 5 6 4 . 0	1	7 . 5 7 . 0	2 . 0 8 . 0	3 . 8 3 . 0	3 . 3 4 . 0	2 . 9 9 . 0	0 . 0 6 . 0	3 . 0 6 . 0	0 . 3 9 . 0	1 . 9 4 .
Z n	0 . 4 0 6 . 0	1 . 4 3 1 . 0	1 . 9 3 1 . 0	0 . 7 2 9 . 0	1 . 5 5 . 0	2 . 3 9 4 . 0	2 . 2 0 6 . 0	0 . 3 5 4 . 0	0 . 2 5 4 . 0	0 . 0 0 . 0	9 . 7 3 0 . 0	0 . 2 5 7 . 0	0 . 3 9 . 0
M n	0 . 3 4 2 . 0	5 . 4 8 4 . 0	4 . 0 3 6 . 0	1 . 4 3 . 0	1 . 1 3 . 0	5 . 7 8 6 . 0	3 . 6 5 . 0	6 . 3 3 . 0	4 . 9 4 . 0	0 . 2 5 . 0	7 . 0 7 3 . 0	0 . 1 8 . 0	1 . 1 1 .
A l	0 . 2 6	5 . 0 8 8	0 . 8 5	2 . 8 5	3 . 1 5	6 . 8 5	2 . 2 3	2 . 3 6	3 . 5 6	0 . 3 1	6 . 0 6	0 . 2 7	2 . 8 1

C	0	0	0	0	0	0	0	0	n	0	0	0	0
r	2	1	2	0	1	0	0	1	d	2	0	0	1
	3	8	1	9	8	3	5	3	.	1	3	2	3
	2	1	1		8		4	9		8	2		
C	0	0	0	0	0	0	0	0	0	0	0	0	0
u	.	.	.	.	.	.	.	.	.	.	.	.	.
	1	6	2	5	3	8	7	5	5	0	9	0	4
	3	1	9	7	5	3	5	1	5	7	7	6	8
	1	5	4	1		3	4	2	3	1	6	5	
B	0	0	0	0	0	0	0	0	0	0	0	0	0
a	.	.	.	.	.	.	.	.	.	.	.	.	.
	0	2	1	1	0	1	0	2	2	0	3	0	1
	5	1	8	0	7	6	7	9	8	3	1	2	5
	8	6	7	3	7	2	6	9	9	6	8	8	
A	0	n	n	0	0	n	0	0	0	n	0	0	0
g	.	.	.	.	.	.	.	.	.	.	.	.	.
	0	d	d	0	0	d	0	0	0	d	0	0	1
	4	.	.	0	0	.	0	0	0	.	0	0	
	2			8	0	3	2	3	2		4		
V	0	0	0	0	0	0	0	0	0	0	0	0	0
	.	.	.	.	.	.	.	.	.	.	.	.	.
	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	2	2	1	2	1	1	1	0	1	1	1	2
	5	8	3	4	3	3	2	3	5	5	3		
N	0	0	0	0	0	0	0	0	0	1	n	0	0
i	.	.	.	.	.	.	.	.	.	.	.	.	.
	0	3	0	6	0	8	8	1	0	1	0	d	3
	2	5	3	7	3	3	4	1	6	5	2	.	1
	5	1	3	8	5	5	1		2	8	0		
C	0	0	0	0	0	0	4	0	0	0	0	0	0
o	.	.	.	.	.	.	2	.	.	.	.	.	.
	0	0	0	0	0	0	5	0	0	0	0	0	0
	0	1	0	0	0	3	8	0	0	0	2	2	1
	2	9	4	7	5	7	0	9	6	2	4		
S	n	n	n	n	n	n	n	n	n	n	0	n	/
e	.	.	.	.	.	.	.	.	.	.	0	d	
	d	d	d	d	d	d	d	d	d	d	0		
											1		
S	6	1	1	1	9	1	1	2	2	4	3	6	1
u	9	7	4	6	5	7	6	0	2	2	2	4	7
m	5	8	8	3	6	4	5	8	6	7	3	1	.
	.	1	4	2	.	7	9	9	0	.	2	.	5
	5	.	.	.	3	.	.	.	.	9	.	0	9
		4	9	7		8	2	2	9		0		
A	4	1	1	1	7	1	1	1	2	3	3	4	4
v	9	7	4	2	9	7	4	7	0	0	5	9	9
e	.	7	7	5	.	3	9	3	4	.	6	.	.
	7	.	.	.	5	.	.	.	.	6	.	3	7
	0	6	5			8	9	3	8		7		

n.d. – not detected

Interestingly, sample 11 contained the highest amount of the determined chemical elements (Table 1, Figure 1), along with a relatively high total MM

content. Selenium (Se) was detected only in this sample, whereas silver (Ag) was not detected (Table 2). The individual content of all elements in all samples is given in Table 2 and the range of content (min-max) is given in Table 3. The content of K in all samples is greater than 90% compared to other elements, and the content of other elements is arranged in a series $Mg < Na < Zn < Al < Fe < Mn < Co < Ni < Cu < Ba < Cr < V < Ag < Se$.

Table 3. Range of amount of chemical elements (mg/kg)

	N	M	A	K	V	C	M	F	C	N	C	Z	S	A	B
	a	g	l			r	n	e	o	i	u	n	e	g	a
m	9	1	0	3	0	0	0	0	0	0	0	0	0	n	0
i	.	1	.	9	.	.	.	.	.	.	.	.	.	.	.
n	7	.	2	1	0	0	1	0	0	0	0	2	0	.	0
	8	1	6	7	0	2	8	6	0	2	6	0	0	d	2
	0	4	0	3	5	0	0	7	2	5	5	4	1	.	8
m	4	1	9	3	0	0	7	7	4	1	0	9	0	0	0
a	9	5	.	1	.	.	.	.	.	.	.	.	.	.	.
x	8	6	7	9	0	2	5	7	5	0	7	3	0	4	1
	3	6	0	3	8	2	3	0	8	2	6	9	1	2	8
		0		0											

The highest content of K and Mg was found in sample 11 and the lowest in sample 10, then in samples 1 and 12 (Figure 2). In other samples, K content ranges between 1000 and 2000 mg/kg.

The concentrations of the individual micro elements are presented in Table 2 and Figure 3. As shown, the concentrations of all analyzed micro elements were below 30 mg/kg, with the lowest values observed in samples 1, 10, and 12 (Table 2 and Figure 3).

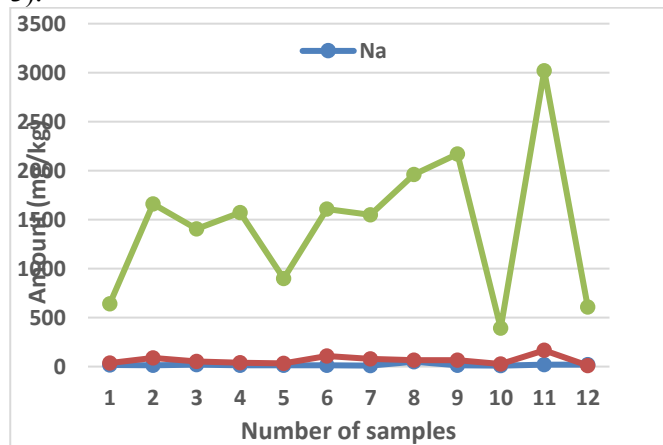


Fig. 2: Amount of macro elements in bee honey (mg/kg)

Among the analyzed micro elements, Fe, Zn, and Mn were present at the highest concentrations, although their average concentrations per sample were relatively low (Table 2, Figure 3). Among the other micro elements, Al was present at relatively higher concentrations, whereas Ba, Ni, Cr, Co, Cu, and V were detected at lower concentrations, below 1 mg/kg. Ag was detected at very low concentrations, while Se was detected only in sample 11 (Table 2 and Figure 3).

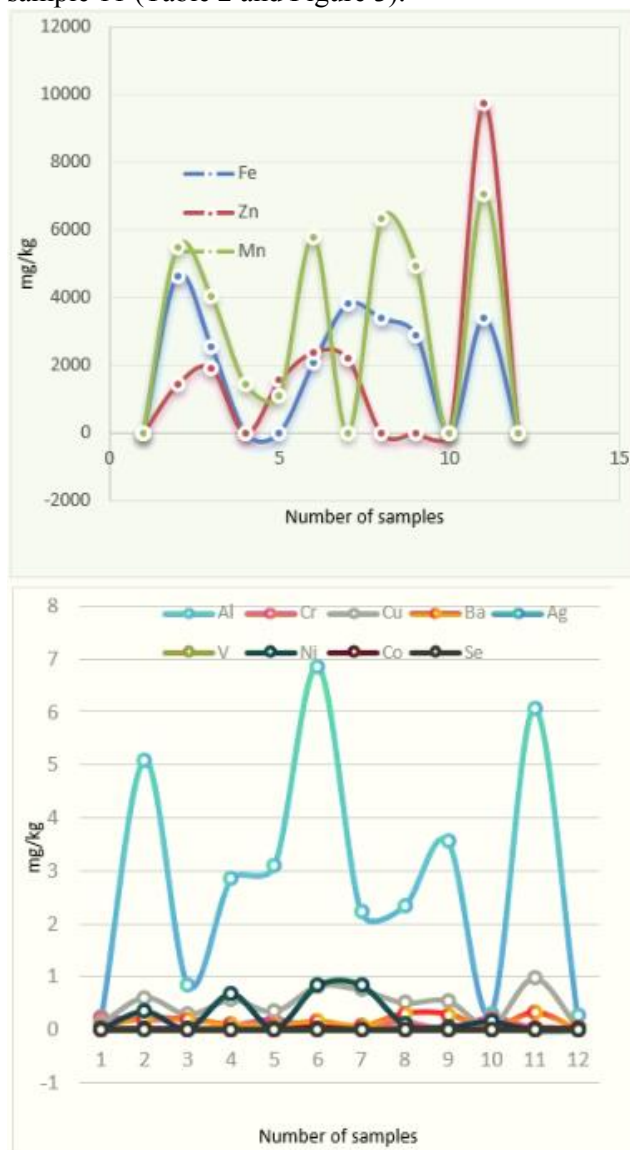


Fig. 3: Amount of micro (trace) elements in bee honey from B&H (mg/kg)

3.2. Discussion

Comparing the concentrations of analyzed chemical elements (Na, Mg, Al, K, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Se, Ag, Ba) with those reported for honey from different regions of the world, several differences

are observed. As some earlier studies show, different factors can affect the amount of metal in the environment [18]. The concentrations of these elements in honey samples from Turkey were generally similar to those observed in the present study. The K content was lower in samples from Algeria and particularly in those from Thailand and China [2, 3, 7, 8]. Na concentrations were slightly lower than reported for honey samples from other geographical regions, whereas the Mg concentrations were very similar. The Fe and Zn concentrations were significantly lower than those reported for samples from Algeria but higher than those found in samples from Poland [8, 9]. In honey samples from Thailand, certain amounts of Ag and Se have been detected in all samples, in contrast to the samples from B&H. However, relatively high concentrations of the toxic elements Pb, Cd, and As were also reported in the Thailand samples. In the present study, Se was detected in only one sample and at a very low concentration, whereas Ag was detected in eight samples (Table 2). In comparison, Se was detected in all honey samples from Thailand at concentrations of approximately 100 µg/kg, while Ag concentrations were approximately ten times lower [3]. Similar concentrations of other chemical elements were reported in honey samples from Turkey [7,10]. When the present results in this study for Ni, Fe, Mg, and Zn compared with those reported for honey samples from Poland, the Ni concentration was approximately four times lower, while the Fe and Mg concentrations were tens of times lower. In contrast, the Zn concentration was similar to that reported in Polish honey samples [9]. The concentrations of Ni, Fe, Zn, Cr, and Mg reported in another study were ten times higher than those obtained in the present study, whereas the Mn concentration was approximately similar. The Na and K concentrations obtained in the present study also differed significantly from those reported for honey samples from Serbia [11]. Potassium (K) has been reported as the most abundant major element in honey, with an average concentration of 809.41 ± 577.92 mg/kg [5] but in this study it was 1,456.98 mg/kg which is much bigger. Compared with the results reported for honey samples from China, the K concentration in the present study was approximately ten times higher, whereas the Na and Mg concentrations were several times lower. The concentrations of Fe, Mn, Cu, and Zn were slightly higher than reported in the Chinese samples [2]. Considering the numerous studies investigating the concentrations of chemical elements in the environment and food, as well as the beneficial and

potentially harmful effects of these elements on human health [12,15], the results obtained for the honey samples from B&H indicate a generally favorable elemental composition. Based on the concentrations determined in this study and the available literature data, the analyzed honey samples can be considered suitable for consumption [12, 13] but with prior necessary testing toxic metal content Pb, Cd, As and Hg in regards with their resistance in environmental in long period of time [19].

4 Conclusion

This research shows that minerals are an essential ingredient of honey and that the amounts found in honey samples from B&H represent the expected average values. Comparing the obtained results with the results of the content of individual macro or micro elements in honey samples from other meridians of the world, it can be seen that the values found in this research correlate with the content values in honey samples from Turkey (Kayseria region) and results from a certain area of China. From the obtained results, it can be seen that the content of macro elements, especially K, is very variable, and is much lower in honey samples from Algeria, Thailand and China, however, the content of micro elements from these areas is significantly higher than the samples examined in this research, i.e. honey samples from B&H. Appreciating the results obtained in this work, it could be said.

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

The authors wrote, reviewed and edited the content as needed and they have not utilised artificial intelligence (AI) tools. The authors take full responsibility for the content of the publication.

References:

- [1] Landeka, V., Kurtagić, H., Pažin, J., & Sarić, E. (2021). Determination of honey quality in the context of physico-chemical and microbiological data in Bosnia and Herzegovina. *Hrvatski časopis za prehrambenu tehnologiju, biotehnologiju i nutricionizam*, 16(1-2), 72-77.
- [2] Zhang, Z. Y., Fan, W. X., Yang, M., & Cui, C. X. (2017). An Analytical Method for Detecting the Content of Metallic Elements in Honey Collected from Henan, China: A Systematic Investigation with ICP-AES. *Kemija u industriji: Časopis kemičara i kemijskih inženjera Hrvatske*, 66(11-12), 661-666.
- [3] Wetwitayaklung, P., Wangwattana, B., & Narakornwit, W. (2018). Determination of trace-elements and toxic heavy minerals in Thai longan, litchi and Siam weed honeys using ICP-MS. *International Food Research Journal*, 25(4).
- [4] Gajger Tlak I., Pavliček D., Oreščanin V., Varenina I., Sedak M. & Bilandžić N. (2024). Mineral Concentrations in Different Types of Honey Originating from Three Regions of Continental Croatia, *Foods* 2024, 13, 2754
- [5] Bora Dumitru F., Andrecean Flavia A., Calugar A., Bunea Joan C., Popesa M., Petrescu-Mag Valentin I., & Bunea A. (2024). Comprehensive Elemental Profiling of Romanian Honey: Exploring Regional Variance, Honey Types, and Analyzed Metals for Sustainable Apicultural and Environmental Practices, *Foods* 2024, 13, 1253
- [6] Solayman, M., Islam, M. A., Paul, S., Ali, Y., Khalil, M. I., Alam, N., & Gan, S. H. (2016). Physicochemical properties, minerals, trace elements, and heavy metals in honey of different origins: a comprehensive review. *Comprehensive reviews in food science and food safety*, 15(1), 219-233.
- [7] Ebubekir, İ. Z. O. L., Enes, K. A. Y. A., & Karahan, D. (2021). Investigation of some metals in honey samples produced in Different Regions of Turkey's Bingöl province by ICP-MS. *Mellifera*, 21(1), 1-17.
- [8] Bereksi-Reguig, D., Allali, H., Bouchentouf, S., Adamczuk, A., Kowalska, G., & Kowalski, R. (2020). Analysis of trace-elements and toxic heavy metals in honeys from Tlemcen Province, north-western. *Agriculturae Conspectus Scientificus*, 85(4), 367-374.
- [9] Formicki, G., Greń, A., Stawarz, R., Zyśk, B., & Gał, A. (2013). Metal Content in Honey, Propolis, Wax, and Bee Pollen and Implications for Metal Pollution Monitoring. *Polish Journal of Environmental Studies*, 22(1).
- [10] Demirezen, D., & Aksoy, A. (2005). Determination of heavy metals in bee honey using by inductively coupled plasma optical emission spectrometry (ICP-OES). *Gazi university journal of science*, 18(4), 569-575.
- [11] Ćirić, J., Spirić, D., Baltić, T., Lazić, I. B., Trbović, D., Parunović, N., ... & Đorđević,

- V. (2021). Honey bees and their products as indicators of environmental element deposition. *Biological Trace Element Research*, 199(6), 2312-2319.
- [12] Šarkanj, B., Delaš, F., Klapac, T., & Rački, Đ. V. (2010). *Kemijske i fizikalne opasnosti u hrani*. Hrvatska agencija za hranu.
- [13] Goletić Šefket, Teški metali u okolišu, Emanet Zenica (2005), Bosnia and Herzegovina.
- [14] Glavašević Arbutina, D. (2020). *Teški metali u organizmu* (Bachelor's thesis, Sveučilište Josipa Jurja Strossmayera u Osijeku, Sveučilište Josipa Jurja Strossmayera u Osijeku, Odjel za kemiju).
- [15] Shah, A., Sikandar, F., Ullah, I., Shah, A., Khan, S. U., Rana, U. A., & McCoy, T. (2014). Spectrophotometric determination of trace elements in various honey samples, collected from different environments. *Journal of Food and Nutrition Research*, 2(9), 532-538.
- [16] Foodstuffs - Determination of trace elements - Pressure digestion (EN 13805:2014, ITD).
- [17] Foodstuffs - Determination of trace elements - Determination of arsenic, cadmium, mercury and lead in foodstuffs by inductively plasma mass spectrometry (ICP-MS) after pressure digestion (EN 15763:2009, ITD).
- [18] Denisa B.-R., Ioan B., Flavia B., Andreea L., Dana C., Lucian C. (2025). The Influence of Heavy Metals Contained in Sludge Used as Fertilizer for the Dahlia Variabilis Plant on Photosynthetic Traits. *WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT*, 35 (21): 417 - 425.
- [19] Baba A. A. and Boudahri F. (2021). Evaluation of the Bioavailability of Heavy Metals by Saline, EDTA and HCL Solutions in Agricultural Soil. *WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT*, 118 (17): 1290 - 1298.

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