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ORIGINAL PAPER

CONTENT OF Na, K, Ca, Mg, Zn, Cu AND Fe IN FLAVOURED HONEYS

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Abstract

The honey market is characterised by a wide variety of products. Honey producers also introduce modifications, e.g. flavoured honeys, with the addition of fruit, herbs and/or spices. The main purpose of adding this type of substance to honey is to enrich it with biologically active substances, which enhance the product's health-promoting properties. Honey plays both a nutritional and a medicinal role, as it contains many valuable substances, including macro- and microelements. The content of minerals depends on the type of honey, when it is harvested, and its region of origin. The aim of the study was to evaluate the mineral composition (Na, K, Ca, Mg, Zn, Cu, Fe) of flavoured honeys. Twenty-eight types of honey were studied, including 8 multifloral honey and 20 flavoured multifloral honeys enriched with herbs, marshmallow root, seaberry, elderberry, cranberry, hops, cloves, ginger, vanilla, black cumin, lemon, blackberry, strawberry, orange, raspberry, European blueberry, as well as three creamed honeys with ginger and lemon grass, lemon and peppermint, and strawberry. The study showed that honey containing fruit and/or herb juice or extracts generally had higher mineral content than multifloral honey without flavourings. Only the content of Na was lower, probably due to the component composition of flavoured honeys. Although flavoured honey is not a significant source of minerals in human nutrition (supplying less than 1% of the Reference Daily Intake), the minerals present in the highest quantities are commonly deficient in a human diet, and therefore the role of flavoured honeys in rational nutrition should not be overlooked.

Keywords: honey, flavoured honey, macroelements, microelements, Reference Daily Intake

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INTRODUCTION

The honey market is characterised by a wide variety of products. Flavoured honeys, with the addition of fruit, herbs and/or spices, are becoming more common. The main purpose of adding this type of substance to honey is to enrich it with biologically active substances, which enhances the product's health-promoting properties. The information provided on the labels indicates that fruit and herbs are added to honey in the freeze-dried form (maximizing preservation of their nutritional value and bioregulatory properties) or as juice. This provides the consumer with a wide range of products with a variety of quality characteristics. Despite the lack of strong pharmaceutical effects, honey is considered to have medicinal properties, which is reflected in folk medicine. It exhibits antibacterial, immunomodulatory, and anticancer properties, and it also regulates the blood glucose level (Blair et al. 2009, Ahmed, Othman 2013). The health-promoting effects of honey result from its long-term action, and therefore it should be consumed regularly, not only occasionally, to produce health benefits.

Honey has both a nutritional and a medicinal role, as it contains many valuable substances, including macro- and microelements. The content of minerals depends on the type of honey, when it is harvested, and its region of origin (Fernández-Torres et al. 2005, Oroian et al. 2016). Proper functioning of the human body requires intake of essential minerals with the diet. These play a key role by protecting cell membranes and regulating acid-base homeostasis, and also as components of numerous enzymes (including antioxidants) and their activators, as well as hormones (Winiarska-Mieczan et al. 2020, Jachimowicz et al. 2021). All over the world, the human diet is deficient in many minerals, particularly calcium (Ca), magnesium (Mg) and potassium (K), but also copper (Cu), iron (Fe) and zinc (Zn), which is confirmed by numerous studies (Winiarska-Mieczan 2014, Adatorwovor et al. 2015, Fang et al. 2016, Bird et al. 2017, Vasara et al. 2017, Winiarska-Mieczan et al. 2020). Regular consumption of honey can help to correct deficiencies of certain elements in the diet.

MATERIALS AND METHODS

Study material

Twenty-eight types of honey were analysed, including 8 multifloral honey and 20 honeys with great flavour, enriched with: herbs, marshmallow root, seaberry, elderberry, cranberry, hops, cloves, ginger, vanilla, black cumin, lemon, blackberry, strawberry, orange, raspberry, European blueberry, as well as three creamed honeys with ginger and lemon grass, lemon and peppermint, and strawberry. The tested material was purchased from grocery stores in various locations in Poland in October-December 2021. The origin of twenty-five honey samples was Poland, whereas three samples originated from Ukraine. Before the analysis, the honey samples (about 100 ml) were stored in the dark, at room temperature, in sterile single-use plastic containers with screw caps.

Chemical analyses

The minerals whose content was determined in the honey were Na, K, Ca, Mg, Zn, Cu and Fe. To obtain homogenous samples, the honey samples were stirred, and then about 1 g of a sample was weighed out and placed in porcelain crucibles. The honey samples were first dried at 60°C for 24 h in a Labortechnik GmbH drying oven (Tuttlingen, Germany), and then subjected to 12-h mineralization in a muffle furnace (FCF 22 SHM, Czylok, Jastrzębie Zdrój, Poland) at 450°C, with hydrogen peroxide H_2O_2 (30% pure; POCH S.A., Poland) as an oxidant (Winiarska-Mieczan et al. 2021). The ashed samples were dissolved in 10 ml of 1 M nitric acid HNO_3 (65% ultrapure, POCH S.A., Poland), as described in another paper (Winiarska-Mieczan, Kwiecień 2016). The content of Na, K, Ca, Mg, Zn, Cu and Fe was determined by ICP-OES (Inductively Coupled Plasma – Optical Emission Spectrometry) using a 720-ES spectrometer (Varian, Palo Alto, USA). ICP-OES operating conditions: RF generator power – 1.2 kW, plasma gas flow rate – 15.0 dm^3 min^{-1}, auxiliary gas flow rate – 2.25 dm^3 min^{-1}, nebulizer gas flow rate – 0.70 dm^3 min^{-1}, sample flow rate – 0.1 mL min^{-1}, replicates – 4, read time – 15 s, peristaltic pump rotation – 12 rpm (Jachimowicz et al. 2021).

The parameters for each element were as follows:

Na – wavelength 589.592 nm, LOD (limit of detection) 0.25 mg kg^{-1}, LOQ (limit of quantification) 0.39 mg kg^{-1}, recovery rate 101%;

K – wavelength 769.897 nm, LOD 1.04 mg kg^{-1}, LOQ 1.27 mg kg^{-1}, recovery rate 97%;

Ca – wavelength 422.673 nm, LOD 0.03 mg kg^{-1}, LOQ 0.05 mg kg^{-1}, recovery rate 98%;

Mg – wavelength 280.270 nm, LOD 0.03 mg kg^{-1}, LOQ 0.08 mg kg^{-1}, recovery rate 102%;

Zn – wavelength 202.548 nm, LOD 0.06 mg kg^{-1}, LOQ 0.09 mg kg^{-1}, recovery rate 105%;

Cu – wavelength 213.598 nm, LOD 0.03 mg kg^{-1}, LOQ 0.06 mg kg^{-1}, recovery rate 97%;

Fe – wavelength 238.204 nm, LOD 0.03 mg kg^{-1}, LOQ 0.05 mg kg^{-1}, recovery rate 99%.

Each analysis was performed in triplicate. The deviation in the measurements was 3.8% for Na, 4.8% for K, 2.1% for Ca, 2.2% for Mg, 3.7% for Zn, 1.4% for Cu, and 4.0% for Fe.

The results were verified using a blank sample (1 M HNO_3) and the reference material NCS ZC 73009 - Wheat (China National Analysis Center for Iron and Steel, Beijing, China), of which 1 kg contained 17 mg Na, 1400 mg K, 340 mg Ca, 450 mg Mg, 11.6 mg Zn, 2.71 mg Cu, and 18.5 mg Fe. A calibration curve was plotted using LCG standards for preparing solutions of minerals with concentrations of 1, 2, 4 and 8 μg L^{-1} of deionized water. All analyses were performed in triplicate.

CALCULATIONS

Intake of Na, K, Ca, Mg, Zn, Cu and Fe with unflavoured multifloral honey and flavoured multifloral honeys was calculated based on the content of these minerals in the honey and consumption of honey in Poland, which ranges from 0.65 to 1.32 kg per capita per year (Żak 2017). The average value of 1 kg per person per year, which is equal to 2.7 g per day, was adopted for the calculations. The results were compared with Polish Recommended Dietary Allowances (RDA) for Ca, Mg, Cu, Fe and Zn or with Adequate Intake (AI) for Na and K (Jarosz et al. 2020). The RDA and AI were defined as the Reference Daily Intake (RDI).

The contribution of honey to the RDI for minerals was calculated from the following formula (Jachimowicz et al. 2021):

$$\text{Share in reference daily intake} = \frac{(\text{Daily Dietary Intake DDI} \times 100)}{(\text{Reference Daily Intake RDI})},$$

$$\text{DDI} = \text{Daily portion size} \times \text{average content of minerals in honey.}$$

Because we could find no literature data regarding the content of minerals in flavoured honey, their content was compared to the average content of these minerals in unflavoured Polish multifloral honey (*n*=8), which accounted for 93-98.5% of the composition of the flavoured honey.

Statistical analysis

Statistical analysis of the results was performed by one-way analysis of variance (ANOVA). Significant statistical differences ($P<0.05$) were determined using the Duncan's test by one-way analysis of variance (ANOVA). All computations of statistical data were performed using Statistica 13.1 software (StatSoft, Krakow, Poland). Correlations between minerals were calculated using the Pearson's correlation coefficient.

RESULTS

The content of minerals in flavoured honeys

The mineral content of the flavoured honey can be presented as follows: K > Ca > Mg > Na > Fe > Zn > Cu (Table 1). The mineral content differed depending on the type of honey (Figure 1). The honey with blackberry had the highest ($P \leq 0.05$) content of Na (30.4 mg kg^{-1}), K (about 570 mg kg^{-1}) and Mg (about 160 mg kg^{-1}). The honey with marshmallow root and elderberry had the highest ($P \leq 0.05$) content of Zn (more than 4 mg kg^{-1}) and Fe (about 25 mg kg^{-1}). Honey with black cumin had the highest ($P \leq 0.05$) content of K (about 570 mg kg^{-1}) and Ca (about 370 mg kg^{-1}). The lowest Na content ($P \leq 0.05$) was noted in the honey with strawberry (4.01 mg kg^{-1}), while the content of K was lowest in the honey with vanilla and cranberry juice (about 120 mg kg^{-1}), Ca in the honey with lemon juice and cranberry juice (about 60 mg kg^{-1}), Mg in the honey with ginger paste (about 10 mg kg^{-1}), Zn in the honey with lemon juice (less than 1 mg kg^{-1}), Cu in the honey with orange

Table 1

Mean intake of Na, K, Ca, Mg, Zn, Cu and Fe with analysed flavoured honeys per portion

Specification	Na	K	Ca	Mg	Zn	Cu	Fe
Average content (mg)	11.46^{d}	309.8^{a}	144.7^{b}	54.85^{c}	1.385^{f}	0.398^{g}	7.790^{e}
SD	7.550	141.7	81.98	39.31	0.937	0.255	4.098
Minimum	4.010	117.0	59.10	12.90	0.354	0.127	5.290
Maximum	30.40	574.0	380.0	156.0	4.150	1.190	24.30
DDI (mg)	0.031	0.836	0.391	0.148	0.004	0.001	0.021
RDI (mg)							
4-12 years	1000-1300	500-1250	1000-1300	130-240	5 - 8	0.4 - 0.7	10
13-18 years	1500 W	1250 W	1300 W	360 W	9 W	0.9 W	15 W
	1550 M	1250 M	1300 M	410 M	11 M	0.9 M	12 M
> 19 years	1300-1500 W	700 W	1000 W	310-320 W	8 W	0.9 W	18 W
	1500 M	700 M	1000-1300 M	400-420 M	11 M	0.9 M	10 M
Share in RDI (%)							
4-12 years	0.003	0.124	0.036	0.096	0.070	0.179	0.210
13-18 years	0.002 W	0.067 W	0.030 W	0.041 W	0.044 W	0.111 W	0.140 W
	0.002 M	0.067 M	0.030 M	0.036 M	0.036 M	0.111 M	0.175 M
> 19 years	0.002 W	0.119 W	0.039 W	0.047 W	0.050 W	0.111 W	0.117 W
	0.002 M	0.119 M	0.035 M	0.036 M	0.036 M	0.111 M	0.210 M

Average values for samples, each in 3 replications; SD – standard deviation; Daily honey consumption (g) – 2.7 (Żak 2017); DDI – Daily Dietary Intake, calculated on the basis of the daily consumption of honey and mean level of minerals in honey; RDI – Reference Daily Intake (Jarosz 2008); W – woman; M – men; $^{a, b, c, \dots}$ – values with different superscripts differ at $P \leq 0.05$ by the Duncan's test.

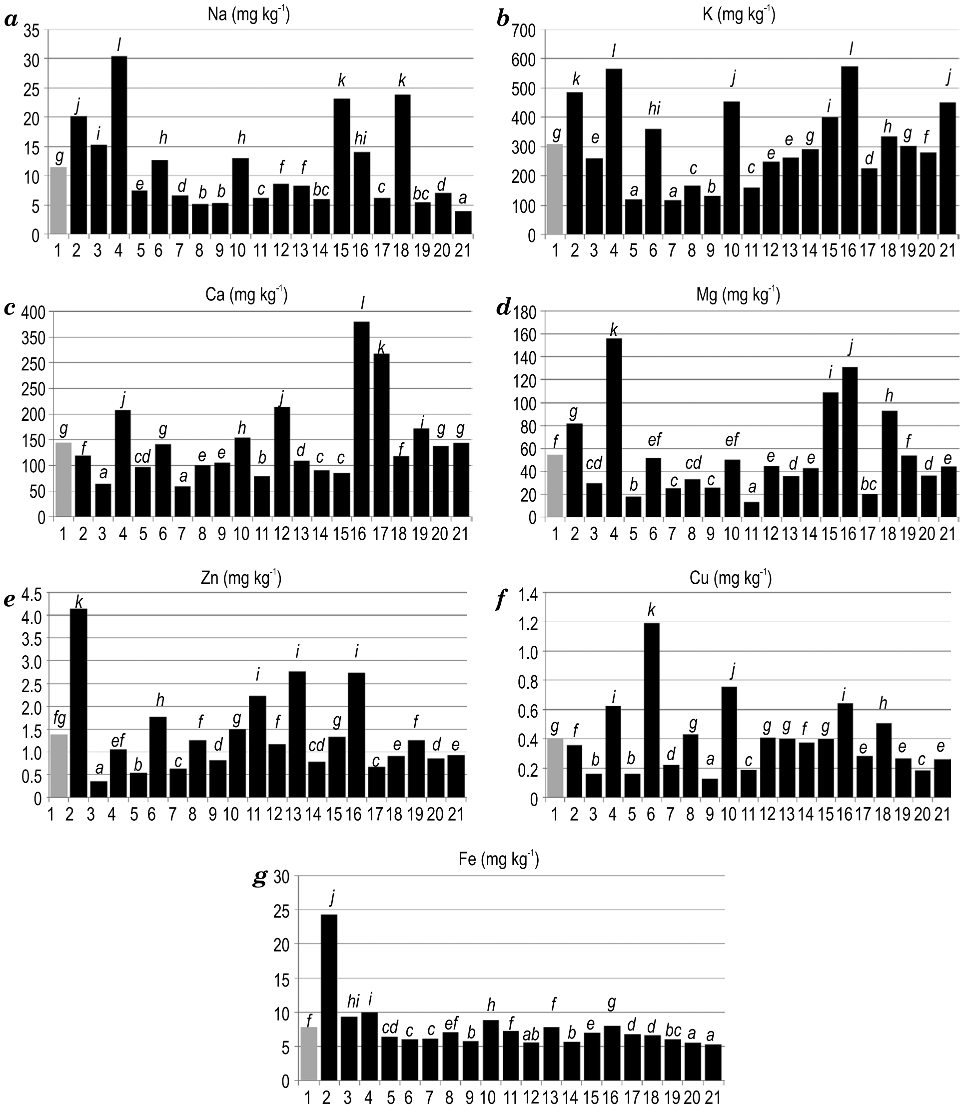

Fig. 1. Content of Na, K, Ca, Mg, Zn, Cu and Fe in flavoured honeys:
1 – multifloral, 2 – marshmallow root 2%, elderberry 2%, 3 – concentrated lemon juice 2%, 4 – blackberry 7%, 5 – vanilla 2%, 6 – strawberry 3%, 7 – concentrated cranberry juice 2%, 8 – hops 2%, 9 – orange paste and cloves 2%, 10 – seaberry 2%, 11 – ginger paste 1%, lemon flavoured paste 1%, 12 – orange 3%, 13 – herbs (20 kinds) 2%, 14 – concentrated raspberry juice 5%, 15 – cranberry 7%, 16 – black cumin 4%, elderberry 2%, 17 – raspberry 2%, 18 – European blueberry 7%, 19 – ginger and lemon grass (2%), 20 – lemon and peppermint (2%), 21 – strawberry (1.5%);
$^{a, b, c,}$ ... – values with different superscripts differ at $P \leq 0.05$ by Duncan's test

and cloves (about 0.1 mg kg^{-1}), and Fe in the honey with strawberry and with lemon and mint (about 5 mg kg^{-1}). The honey with blackberry contained more ($P \le 0.05$) Na, K and Mg than the other honeys, while the honey with marshmallow root contained more ($P \le 0.05$) Zn and Fe. Honey with lemon contained less ($p < 0.05$) Na, Ca, Zn and Fe than all the other flavoured honeys.

The flavoured honeys contained more than twice as much Ca as unflavoured multifloral honey and also more Cu by nearly 66%, Mg by 46%, K by 38%, Fe by 11% and Zn by 4% (Table 2). At the same time, the flavoured

Table 2

Comparison of Na, K, Ca, Mg, Zn, Cu and Fe content in multifloral and flavoured honeys*

Specification	Na	K	Ca	Mg	Zn	Cu	Fe
Nectar honey + marshmallow root 2%, elderberry 2%	68	116	69	118	210	48	248
Nectar honey + concentrated lemon juice 2%	27	15	-8	-21	-74	-33	34
Nectar honey + blackberry 7%	153	152	195	315	-21	160	42
Nectar honey + vanilla 2%	-37	-46	38	-52	-60	-32	-7
Nectar honey + strawberry 3%	6	61	101	38	32	396	-13
Nectar honey + concentrated cranberry juice 2%	-45	-48	-16	-33	-53	-8	-12
Nectar honey + hops 2%	-57	-26	42	-13	-6	79	2
Nectar honey + orange paste and cloves 2%	-56	-41	49	-31	-39	-47	-18
Nectar honey + seaberry 2%	8	102	121	34	11	216	26
Nectar honey + ginger paste 1%, lemon flavoured paste 1%	-48	-28	12	-66	67	-22	5
Nectar honey + orange 3%	-29	11	205	18	-12	70	-19
Nectar honey + herbs (20 kinds)** 2%	-31	17	55	-4	107	68	12
Nectar honey + concentrated raspberry juice 5%	-50	30	28	15	-41	55	-19
Nectar honey + cranberry 7%	93	77	22	190	-1	67	0
Nectar honey + black cumin 4%, elderberry 2%	18	155	441	248	104	169	14
Nectar honey + raspberry 2%	-49	1	351	-46	-50	17	-2
Nectar honey + European blueberry 7%	99	49	68	147	-32	112	-5
Creamed honey + ginger and lemon grass (2%)	-54	35	145	44	-7	11	-13
Creamed honey + lemon and peppermint (2%)	-41	24	96	-3	-36	-23	-22
Creamed honey + strawberry (1.5%)	-67	101	105	17	-31	10	-24
Mean	-5	38	106	46	4	66	11

* Multifloral honey assumed as 100 %; ** Liquorice root, ribwort, blackberry, peppermint, chamomile, eucalyptus, fennel, elderberry, Icelandic artichoke, wild rose, lime blossom, comfrey, hawthorn, calendula, sage, yarrow, primrose, aniseed, lemon balm.

honeys had on average 5% lower content of Na, while in the honey with strawberry (1.5%) the difference was 67%. The honey with blackberry and with cranberry had about twice as much Na as the multifloral honey without fruit. The honey with black cumin seeds and elderberry juice had 5 times the content of Ca and 3 times the Mg content as in the unflavoured honey, while in the honey with raspberry the Ca content was 4 times as high. In the honey with marshmallow root and elderberry, the content of Zn and Fe was about 3 times as high as in the multifloral honey without flavourings, and the content of K and Mg was about twice as high (Table 2). In comparison with the unflavoured multifloral honey, the honey with lemon juice contained 74% less Zn, the honey with strawberry (1.5%) contained 67% less Na, and the honey with ginger and lemon paste contained about 66% less Mg.

There was a significant ($P \leq 0.05$) positive correlation between the content of K and that of Ca, Mg, Na and Cu, as well as between the content of Mg and that of Na and Cu and between Fe and Zn (Table 3).

Table 3

Pearson correlation coefficients between the content of minerals in flavoured honeys

Minerals	Ca	Mg	K	Na	Fe	Cu
Ca		0.412	**0.480**	0.077	-0.026	0.300
Mg	0.412		**0.830**	**0.831**	0.291	**0.452**
K	**0.480**	**0.830**		**0.638**	0.402	**0.544**
Na	0.077	**0.831**	**0.638**		0.443	0.393
Fe	-0.026	0.291	0.402	0.443		0.040
Cu	0.300	**0.452**	**0.544**	0.393	0.040	
Zn	0.169	0.297	0.434	0.212	**0.710**	0.282

Values significant at $P \leq 0.05$ are highlighted in bold.

Flavoured honeys as a source of minerals in the diets of Poles

The flavoured honeys, on average, supply Fe in the amount of about 0.12% of the RDI (women > 19 years) to 0.21% RDI (children 4-12 and men > 19) – Table 1. Consumption of 19 g of flavoured honey a week supplies Cu in the amount of about 0.11% RDI (for people over 13) to about 0.18% RDI (for children 4-12), K in the amount of 0.07% RDI (teenagers 13-18) to about 0.12% RDI (children 4-12 and adults > 19), Mg in the amount of about 0.4% RDI (people > 13) to about 0.1% RDI (children 4-12). The honey supplies Mg, Ca and Zn in the amount of about 0.03-0.05% RDI (people > 13 and children 4-12 for Ca), while for children aged 4-12 years, the amount of Zn is more than 0.07% RDI, and Mg about 1% RDI. The amount of Na supplied with the honey did not exceed 0.003% RDI for any age group.

DISCUSSION

The addition of fruits and/or herbs provides a pleasant flavour and aroma that harmonizes with that of honey. Depending on the flavouring, the flavour and aroma may be more or less perceptible in the final product, but it should not be dominant. The present study showed that honey with the addition of juices or extracts from fruits or herbs generally had higher content of the minerals tested than unflavoured multifloral honey; only the content of Na was lower. However, given the small quantity of added fruit and/or herb components, ranging from 1% to 7%, these differences should most likely be ascribed to the multifloral honey itself which was the base of the flavoured honey. Literature data (Bogdanov et al. 2007, Winiarska-Mieczan et al. 2021, Velimirović et al. 2021) clearly indicate that the mineral composition of honey depends on its botanical composition and, to a lesser extent, on the geographic location and habitat of the plants. Lobos et al. (2022) suggest that the mineral composition of honey is also affected by the climate conditions in which the honey plants grow, e.g., the amount of rainfall.

Determination of the content of minerals in honey is not only interesting in terms of nutrition – honey is known to contain essential minerals needed for the body's growth and development – but also can be used for quality control. In the present study, the flavoured honeys were not a significant source of minerals in the human diet (supplying less than 1% of the RDI), mainly because in Poland honey is consumed in small quantities of less than 2.7 g per day; in contrast, consumption in the USA is three times that level (Żak 2017). Flavoured honey, however, contains minerals that are essential for human development and growth. Among all the minerals analysed in the flavoured honey, the content of K was the highest. K is the most important intracellular cation and one of the most important electrolytes; it regulates insulin secretion, controls muscle contraction and work, activates numerous cellular enzymes, and regulates blood pressure (Aburto et al. 2013, D'Elia et al. 2019). According to the WHO (2012), daily K intake for adults should be no less than 90 mmol. Industrial processing of food generally reduces its content of K while increasing that of Na. Analysis of human nutrition in Poland and other countries has shown that diets are deficient in K, but also in Ca and Mg (Adatorwovor et al. 2015, Merkiel, Chalcarz 2016, Vasara et al. 2017, Winiarska-Mieczan et al. 2020, Palaniveloo et al. 2021, Vargas-Meza et al. 2022). These are the minerals that were present in the highest quantities in the flavoured honey, and there were statistically significant positive correlations between their contents. Therefore, the importance of flavoured honey in supplying these minerals in human nutrition should not be overlooked. On the other hand, the exceptionally high Cu level in some of the flavoured honeys (e.g., 4 times as high in the honey with a 3% addition of strawberry and about 3 times as high in the honey with seaberry in comparison to multifloral honey without flavourings) is most likely due to beekeepers' use of vessels containing Cu (Velimirović et al. 2021) rather than to the addition of fruit.

CONCLUSION

1. The flavoured honeys contained more K, Ca, Mg, Zn, Cu and Fe but less Na than the unflavoured multifloral honey, but these differences should most likely be ascribed to the content of the minerals in the honey itself, which accounted for 93-99% of the composition of the flavoured honey.

2. Although flavoured honey is not a significant source of individual minerals in human nutrition, the minerals present in the highest quantities are commonly deficient in the human diet, and therefore the role of flavoured in rational nutrition should not be overlooked.

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