ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)
Food Science and Technology



DOI: https://doi.org/10.1590/fst.19718

# Levels of Chromium, Copper, Iron, Magnesium, Manganese, Selenium, Zinc, Cadmium, Lead and Aluminium of honey varieties produced in Turkey

Sema Sandıkcı ALTUNATMAZ[1*], Duygu TARHAN[2], Filiz AKSU[1], Nural Pastacı OZSOBACI[2], Mehmet Erman OR[3], Umit Bora BARUTÇU[2]

**Abstract**

Honey is a natural animal product. The elemental composition of honey varies greatly depending on the source of nectar, honeydew, pollen and environmental conditions. The aim of the present study was to determine the levels of chromium (Cr), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn), selenium (Se), zinc (Zn), cadmium (Cd), lead (Pb) and aluminium (Al) in a total of 65 honey samples procured from different regions of Turkey. Element levels were measured by using an inductively coupled plasma optical emission spectrophotometer (ICP-OES). Minimum and maximum levels of the elements, indicated as µg/g wet weight were as follows: Cr: 0.126-7.964, Cu: 0.223-198.361, Fe: 3.506-1278.778, Mg: 5.830-309.783, Mn: 0.096-29.496, Se: 0.418-19.879, Zn: 1.734-245.205, Cd: 0.000-0.297, Pb: 0.000-3.035, Al: 0.775-155.585.

**Keywords:** trace element; toxic element; heavy metal; ICP-OES; honey.

**Practical Application:** Honey contains many elements necessary for life. Alongside its nutritional value, honey may also contain toxic elements.

## 1 Introduction

Turkey ranks second among the other honey producing countries with an annual (2017) production of 114.471 tons (Turkish, 2017; Kaftanoglu, 2017). Botanical and geographical origin of honey is of great importance in terms of its chemical quality (Bargańska et al., 2016; Kılıç Altun et al., 2017). Turkey, owing to its rich plant diversity and favorable climate due to geographical features comes to the forefront in terms of production of high quality honey varieties with high mineral content (Kılıç Altun et al., 2017). Pine honey which is rich in mineral content is mainly produced in Turkey. Honeydew honey is known to have a higher mineral content (0.6-2%) in comparison with blossom honey (0.1-0.5%) (Mutlu et al., 2017). Honey contains high levels of potassium, sodium, calcium and magnesium, the sources of which were shown to be pollen and nectar (Kılıç Altun et al., 2017; Turhan, 2007; Batista et al., 2012; Fernández-Torres et al., 2005). Apart from the above mentioned minerals, honey may contain Fe, Cr, Se, Cu, Mn, Zn, Al, Pb, As, Cd and Hg, depending mainly on environmental factors (Kılıç Altun et al., 2017; Mutlu et al., 2017; Fernández-Torres et al., 2005). Environmental factors may be listed as soil, air, water and environmental pollution as well as the contaminated materials, tools and equipment used in beekeeping. Therefore, honey is recognized as one of the indicators of environmental pollution (Mutlu et al., 2017; Turhan, 2007).

Different descriptions have been defined for the metals currently known as heavy metals which have deleterious effects on human health. A heavy metal is essentially defined as a metal of relatively high density (above 5g/cm$^3$). In medicine, the concept is used for metals with toxic properties regardless of their atomic weights. Although more than sixty elements were identified as heavy metals, the most frequently encountered and the most pronounced heavy metals are Hg, Mn, Fe, Co, Ni, Cu, Zn, Cd, As, Sn, Pb, Ag and Se. Heavy metals are accumulated particularly in certain organs, ultimately reaching up to toxic levels (Yılmaz-Aksu & Sandikci-Altunatmaz, 2017; Jaishankar et al., 2014). Some of them, for instance zinc, selenium and copper are essential for maintaining metabolic activities, however may elicit toxic effects at high concentrations. Elements which are required in minor quantities for physiology of organism are referred to as trace elements. In this regard, Fe, Cu, Se, Zn, Ni and Mn are recognized as trace elements which are needed by the organism for maintaining vital activities (Kılıç Altun et al., 2017). It has been indicated in research studies that honey may contain several minerals, trace elements and heavy metals at various concentrations, which differ according to regional and environmental conditions, seasonal and annual differences, as well as beekeeping and agricultural techniques applied (Batista et al., 2012; Fernández-Torres et al., 2005).

The objective of the present study was to determine the elemental composition of different honey samples consumed in Turkey by taking into account the regional differences. The results were considered to assist the establishment of legal permissible limits for certain minerals, trace elements and toxic heavy metals that may be found in honey and as well as to contribute to the assessment of the levels of trace elements from a nutritional perspective.

*Received 06 June, 2018*
*Accepted 02 Oct., 2018*
[1]*Food Technology Programme, Food Processing Department, Veterinary Medicine Vocational High School, Istanbul University-Cerrahpasa, Avcilar, Istanbul, Turkey*
[2]*Department of Biophysics, Cerrahpasa Medicine Faculty, Istanbul University-Cerrahpasa, Cerrahpasa, Istanbul, Turkey*
[3]*Department of Internal Medicine, Faculty of Veterinary Medicine, Istanbul University-Cerrahpasa, Avcilar, Istanbul, Turkey*
*Corresponding author: sandikci@istanbul.edu.tr

## 2 Materials and methods

### *2.1 Sample collection*

Honey samples were collected from areas of intensive beekeeping. Measurements for pre-determined minerals, trace elements and heavy metals were carried out in a total of 65 honeys. These samples were obtained from different regions of Turkey representing; Central Anatolia, the Black Sea, Eastern Anatolia, Aegean, Marmara, the Mediterranean, and Southeastern Anatolia (Table 1).

### *2.2 Preparation of samples for measurements*

Honey samples were placed into tared tubes, weighed using a precision balance and the results were recorded. 2 mL of nitric acid ($HNO_3$) was added to honey samples placed into a heat-resistant graduated tubes and left to dissolve in a drying oven at 150 °C. The honey and nitric acid mixture was left to cool at room temperature and then 1 mL of perchloric acid ($HClO_4$) was added into the mixture which was returned to oven and subjected to wet ashing. Finally, all samples were vortexed and distilled water was added into the tubes to a total volume of 12 mL and vortexed once again getting ready to conduct elemental analysis in an ICP-OES device.

### *2.3 Measurements of elements*

Suitable wavelengths of 267.716, 324.754, 259.940, 285.213, 257.610, 196.090, 206.200, 228.802, 220.353 and 167.079 nm were used for the analysis of Cr, Cu, Fe, Mg, Mn, Se, Zn, Cd, Pb and Al respectively in an ICP-OES device (Thermo ICAP 6000 series) (Ali et al., 1988). Samples were subjected to wet ashing and prepared for measurements. Four samples were prepared from each honey type and mean values were calculated based on the results of elemental analysis.

## 3 Results and discussion

Levels of macroelement, Mg; microelements Cr, Cu, Fe, Mn, Se and Zn and toxic elements (heavy metals) Cd, Pb and Al were determined in a total of 65 honey samples. The results of the analyses were presented in Table 2 as μg/g wet weight. Minimum, maximum and mean values of the results were shown in Table 3 as μg/g honey.

On the basis of the findings, it may be assumed that lead and cadmium contamination was prevalent in honey samples. Out of 65 samples, only 5 and 2 honeys did not contain cadmium and lead, respectively. Cadmium free honeys were from the Black Sea (2 samples) and Thrace regions, the cities of Kars and Muş; whereas lead free honeys came from the Thrace region and Kars city. Cadmium concentration was detected to be below the level of 0.01 μg/g in 7 samples while lead levels exceeded 0.01 μg/g in all samples that contained lead. Mean lead concentration was found to be 0.349 μg/g and the highest lead level of 3.035 μg/g was detected only in one sample. Lead concentrations of other honey samples from the same city were 0.356; 1.586; 0.715 and 0.044 μg/g, which was considered to be associated with subsequent contamination through water, tinware and etc. Lead is a naturally occurring element; however emerges as an environmental pollutant at excessive amounts by means of several factors such as mining, battery manufacturing, brazing, water pipe production, usage of paint and gasoline (Yılmaz-Aksu & Sandikci-Altunatmaz, 2017). It is worldwide proposed that all bee products, particularly honey must be free of any foreign substances in order to be considered valuable and beneficial (Cukur et al., 2016). Lead, cadmium, arsenic and mercury are involved in the list of toxic substances published by the Agency for Toxic Substances and Disease Registry (The Agency for Toxic Substances and Disease Registry, 2015). The Joint FAO/WHO Expert Committee on Food Additives (JECFA) withdrew the previously suggested provisional tolerable weekly intake (PTW1) level for lead in 2011 and indicated that there is no such threshold limit value that can be adopted as healthy (World Health Organization, 2011). Therefore, it is of utmost importance that honey is by no means contaminated with any heavy metals including lead. There are several studies available worldwide and also in Turkey with respect to the determination of lead and other elemental concentrations in honey (Kılıç Altun et al., 2017; Turhan, 2007; Batista et al., 2012; Fernández-Torres et al., 2005; Nascimento et al., 2015; Vanhanen et al., 2011; Doker et al., 2014; Tuzen et al., 2007; Kolayli et al., 2008; Sireli et al., 2015; Czipa et al., 2015; Chua et al., 2012; Liberato et al., 2013; Čelechovská & Vorlová, 2001; Caroli et al., 1999; Golob et al., 2005; Bontempo et al., 2017; Bilandžić et al., 2017; Formicki et al., 2013; Rashed & Soltan, 2004).

In the present study, minimum and maximum levels of 0.126 μg/g and 7.964 μg/g for chromium were found in Kars and Artvin honeys, respectively. In other studies carried out in Turkey, chromium levels in honey were indicated as <1 ppb, 88.1 ng/g (Doker et al. 2014) and 2.4-37.9 μg/g (Tuzen et al., 2007) and in one study chromium was below the detection limit (No Detection, ND) in selected honey samples (Kolayli et al., 2008). In worldwide studies, chromium levels were detected as 4.80-36.7 μg/g, 1.845-3.835 mg/kg, 0.023-0.170 μg/kg, 1.03-3.93 ng/g, 0.78-3.55 mg/kg, 0.0-0.0 mg/kg and 2.69-49.9 mg/kg in Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Brazil (Liberato et al., 2013), Czech (Čelechovská & Vorlová, 2001), Italy (Caroli et al., 1999), Slovenia (Golob et al., 2005), Italy (Bontempo et al., 2017) and Croatia (Bilandžić et al., 2017) respectively. The amount of chromium in honey is strongly affected by geographical, floral, environmental and geological factors. Furthermore, it was assumed that stainless steel surfaces might have been responsible for high levels of chromium contamination (Doker et al., 2014).

**Table 1**. Regional distribution of honey samples.

| Region | Honey Sample No |
|---|---|
| Central Anatolia | 1-2-3-6-41-62-63-64 |
| Black Sea | 4-5-7-8-9-10-20-24-38-43-47-49-50-53-54-57-58 |
| Eastern Anatolia | 11-21-25-26-30-31-33-35-40-44-45-55-59-61-65 |
| Aegean | 13-17-34-39-42-46 |
| Marmara | 12-14-15-16-18-27-28-29-32-37-56 |
| Mediterranean | 19-22-23-36-51-52-60 |
| Southeastern Anatolia | 48 |

**Table 2**. Mean values of the elements analyzed in honey samples (μg/g honey).

| No | Cr | Cu | Fe | Mg | Mn | Se | Zn | Cd | Pb | Al |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6.635 | 4.941 | 117.318 | 152.824 | 1.129 | 6.706 | 16.729 | 0.282 | 3.035 | 49.624 |
| 2 | 1.305 | 4.365 | 566.769 | 41.314 | 1.451 | 0.910 | 5.116 | 0.040 | 0.356 | 25.385 |
| 3 | 2.700 | 2.871 | 135.043 | 78.514 | 0.814 | 3.343 | 8.357 | 0.086 | 1.586 | 36.900 |
| 4 | 2.320 | 3.400 | 81.720 | 91.840 | 0.720 | 1.680 | 21.000 | 0.120 | 0.840 | 110.880 |
| 5 | 1.320 | 1.350 | 61.800 | 38.850 | 0.390 | 2.340 | 7.080 | 0.060 | 1.050 | 40.380 |
| 6 | 1.615 | 1.477 | 19.777 | 40.869 | 0.300 | 2.192 | 7.038 | 0.046 | 0.715 | 35.885 |
| 7 | 1.521 | 1.436 | 141.000 | 57.086 | 0.771 | 1.907 | 5.421 | 0.043 | 1.050 | 33.279 |
| 8 | 2.032 | 2.067 | 30.986 | 86.055 | 11.465 | 2.376 | 5.596 | 0.297 | 0.154 | 1.592 |
| 9 | 7.964 | 27.382 | 411.655 | 103.091 | 1.636 | 4.964 | 35.291 | 0.164 | 1.800 | 8.400 |
| 10 | 1.148 | 1.156 | 37.679 | 61.760 | 0.530 | 1.936 | 4.807 | 0.007 | 0.088 | 3.983 |
| 11 | 4.629 | 3.257 | 115.303 | 140.743 | 2.331 | 4.457 | 18.857 | 0.000 | 0.960 | 13.097 |
| 12 | 2.924 | 2.858 | 70.364 | 202.233 | 4.560 | 3.840 | 13.549 | 0.022 | 0.524 | 8.487 |
| 13 | 0.285 | 0.986 | 12.722 | 15.142 | 0.132 | 0.915 | 4.332 | 0.010 | 0.122 | 11.786 |
| 14 | 1.059 | 3.362 | 32.374 | 122.294 | 5.462 | 2.179 | 6.150 | 0.009 | 0.309 | 4.262 |
| 15 | 1.539 | 2.764 | 25.961 | 148.386 | 1.349 | 1.705 | 6.331 | 0.000 | 0.174 | 4.452 |
| 16 | 1.888 | 1.438 | 27.400 | 74.300 | 0.438 | 1.825 | 10.813 | 0.013 | 0.188 | 7.200 |
| 17 | 1.319 | 3.891 | 57.742 | 161.366 | 2.169 | 1.461 | 11.672 | 0.007 | 0.060 | 15.980 |
| 18 | 0.812 | 0.889 | 17.816 | 55.426 | 0.275 | 1.525 | 3.656 | 0.014 | 0.085 | 5.619 |
| 19 | 0.545 | 0.669 | 13.324 | 35,217 | 0.392 | 0.992 | 4.983 | 0.010 | 0.069 | 5.197 |
| 20 | 0.779 | 2.862 | 18.407 | 134,690 | 21.076 | 1.269 | 11.848 | 0.000 | 0.097 | 155.586 |
| 21 | 0.384 | 0.351 | 9.320 | 14.343 | 0.194 | 0.678 | 2.220 | 0.005 | 0.104 | 3.581 |
| 22 | 0.282 | 1.444 | 8.395 | 14.699 | 1.140 | 0.662 | 7.482 | 0.005 | 0.152 | 6.174 |
| 23 | 5.326 | 9.684 | 80.505 | 28.295 | 0.842 | 1.916 | 39.137 | 0.021 | 0.253 | 12.611 |
| 24 | 5.120 | 1.394 | 76.366 | 51.840 | 2.560 | 0.971 | 18.274 | 0.011 | 0.309 | 14.823 |
| 25 | 0.914 | 0.700 | 13.314 | 30.571 | 0.271 | 1.671 | 14.014 | 0.014 | 0.357 | 29.586 |
| 26 | 0.794 | 5.848 | 21.718 | 25.690 | 0.338 | 1.099 | 14.096 | 0.000 | 0.439 | 41.037 |
| 27 | 0.806 | 1.110 | 16.442 | 49.039 | 0.430 | 1.075 | 4.925 | 0.018 | 0.143 | 20.812 |
| 28 | 0.538 | 0.766 | 6.610 | 16.097 | 0.114 | 0.476 | 6.083 | 0.021 | 0.000 | 10.459 |
| 29 | 0.863 | 0.327 | 11.623 | 21,332 | 0.208 | 0.714 | 5.296 | 0.010 | 0.099 | 7.567 |
| 30 | 0.682 | 0.567 | 20.712 | 36.879 | 0.173 | 0.863 | 1.734 | 0.016 | 0.123 | 2.877 |
| 31 | 0.447 | 0.404 | 17.498 | 33.327 | 0.185 | 1.058 | 3.905 | 0.000 | 0.305 | 22.451 |
| 32 | 0.185 | 0.223 | 9.761 | 16.125 | 0.096 | 0.418 | 2.331 | 0.003 | 0.069 | 7.505 |
| 33 | 0.408 | 0.400 | 5.224 | 16.992 | 0.128 | 0.872 | 2.104 | 0.016 | 0.320 | 13.536 |
| 34 | 0.752 | 4.352 | 16.640 | 50.704 | 0.432 | 1.200 | 10.608 | 0.032 | 0.240 | 33.664 |
| 35 | 0.126 | 7.529 | 3.506 | 12.207 | 0.151 | 0.496 | 7.904 | 0.008 | 0.000 | 3.364 |
| 36 | 0.240 | 2.741 | 37.277 | 60.836 | 1.022 | 0.542 | 5.543 | 0.039 | 0.031 | 92.903 |
| 37 | 1.418 | 3.678 | 120.031 | 52.769 | 1.060 | 3.319 | 5.283 | 0.094 | 0.327 | 11.610 |
| 38 | 0.672 | 0.561 | 14.020 | 9.963 | 0.187 | 1.960 | 2.736 | 0.033 | 0.094 | 1.817 |
| 39 | 2.046 | 3.010 | 94.190 | 50.597 | 0.826 | 2.597 | 7.770 | 0.079 | 0.138 | 10.938 |
| 40 | 1.296 | 1.147 | 66.018 | 20.286 | 1.191 | 2.470 | 4.756 | 0.026 | 0.131 | 4.923 |
| 41 | 0.372 | 11.984 | 46.455 | 12.071 | 0.210 | 1.461 | 14.297 | 0.012 | 0.048 | 1.921 |
| 42 | 0.345 | 1.248 | 41.028 | 42.092 | 0.679 | 2.051 | 1.985 | 0.011 | 0.088 | 2.382 |
| 43 | 1.035 | 6.066 | 41.659 | 14.059 | 0.495 | 2.587 | 84.330 | 0.044 | 0.319 | 3.457 |
| 44 | 0.506 | 2.176 | 31.104 | 7.862 | 0.146 | 1.711 | 3.824 | 0.018 | 0.068 | 0.808 |
| 45 | 0.911 | 33.482 | 315.214 | 15.086 | 1.211 | 2.239 | 37.093 | 0.096 | 0.407 | 6.043 |
| 46 | 0.594 | 10.885 | 44.170 | 32.800 | 0.479 | 19.879 | 12.830 | 0.018 | 0.224 | 3.745 |
| 47 | 1.493 | 3.224 | 1278.779 | 50.913 | 29.496 | 3.151 | 6.357 | 0.027 | 0.330 | 5.405 |
| 48 | 0.689 | 2.074 | 18.222 | 17.902 | 0.203 | 2.123 | 6.382 | 0.018 | 0.283 | 2.332 |
| 49 | 0.931 | 20.620 | 39.714 | 12.824 | 0.408 | 2.294 | 30.702 | 0.041 | 0.212 | 2.694 |
| 50 | 0.670 | 7.886 | 25.645 | 51.605 | 18.696 | 2.566 | 9.321 | 0.021 | 0.064 | 1.784 |
| 51 | 1.333 | 1.600 | 159.911 | 18.800 | 0.498 | 2.996 | 5.324 | 0.044 | 0.204 | 1.449 |
| 52 | 0.497 | 4.552 | 7.850 | 5.830 | 0.099 | 1.622 | 7.920 | 0.021 | 0.017 | 1.167 |
| 53 | 0.925 | 3.126 | 79.796 | 309.783 | 0.359 | 2.117 | 4.716 | 0.038 | 0.352 | 0.986 |

**Table 2**. Continued...

| No | Cr | Cu | Fe | Mg | Mn | Se | Zn | Cd | Pb | Al |
|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 1.077 | 1.738 | 25.144 | 20.938 | 0.325 | 1.996 | 3.914 | 0.045 | 0.269 | 2.007 |
| 55 | 0.667 | 7.052 | 22.308 | 13.463 | 0.310 | 1.625 | 15.101 | 0.027 | 0.155 | 1.962 |
| 56 | 0.483 | 2.432 | 89.233 | 21.180 | 0.329 | 1.489 | 5.134 | 0.018 | 0.086 | 1.101 |
| 57 | 0.918 | 7.667 | 196.349 | 21.987 | 0.926 | 1.973 | 19.643 | 0.024 | 0.129 | 2.923 |
| 58 | 0.592 | 13.232 | 8.841 | 18.608 | 0.151 | 1.491 | 13.647 | 0.016 | 0.140 | 0.775 |
| 59 | 0.740 | 3.413 | 23.880 | 9.993 | 0.200 | 2.000 | 6.827 | 0.027 | 0.160 | 4.427 |
| 60 | 2.154 | 198.361 | 87.716 | 47.133 | 0.607 | 3.267 | 245.205 | 0.058 | 0.333 | 2.169 |
| 61 | 0.645 | 22.545 | 18.105 | 18.795 | 0.255 | 1.350 | 28.103 | 0.030 | 0.210 | 2.168 |
| 62 | 1.420 | 29.561 | 500.341 | 22.171 | 1.302 | 2.722 | 27.556 | 0.044 | 0.673 | 4.215 |
| 63 | 0.551 | 189.031 | 271.361 | 20.394 | 0.619 | 0.612 | 202.639 | 0.025 | 0.346 | 1.571 |
| 64 | 0.613 | 10.489 | 114.993 | 16.368 | 0.345 | 1.494 | 10.049 | 0.060 | 0.354 | 2.849 |
| 65 | 0.885 | 2.872 | 876.393 | 8.361 | 1.761 | 1.495 | 5.331 | 0.030 | 0.315 | 3.895 |

**Table 3**. Minimum, maximum and mean values for each element analyzed in honey samples (μg/g honey).

| Elements | Cr | Cu | Fe | Mg | Mn | Se | Zn | Cd | Pb | Al |
|---|---|---|---|---|---|---|---|---|---|---|
| Min. | 0.126 | 0.223 | 3.506 | 5.830 | 0.096 | 0.418 | 1.734 | 0.000 | 0.000 | 0.775 |
| Max. | 7.964 | 198.361 | 1278.779 | 309.783 | 29.496 | 19.879 | 245.205 | 0.297 | 3.035 | 155.586 |
| Mean ± SE | 1.364 ± 1.27 | 11.030 ± 10.03 | 107.824 ± 20.02 | 50.548 ± 7.59 | 1.985 ± 3.56 | 2.183 ± 1.67 | 18.201 ± 9.12 | 0.038 ± 0.27 | 0.349 ± 0.81 | 15.299 ± 6.75 |

Mean ± SE: Mean ± Standard Error.

In the present study, minimum 0.223 μg/g and maximum 198.361 μg/g levels of copper were detected in Thrace honey and Muğla pine honey, respectively. Pine honey is known to have higher total mineral content in comparison with other types of honey. Copper levels in honeys were reported as <1-929 ppb (68.5 mean) (Kılıç Altun et al., 2017), 0.70-4.12 mg/kg (1.90 mean) (Turhan, 2007), 0.12-0.25 μg/g (0.17 mean) (Doker et al. 2014), 0.23-2.41 μg/g (Tuzen et al., 2007), 1.2-2.2 μg/g (Kolayli et al., 2008), 0.011-0.098 mg/kg (0.06 mean) (Sireli et al., 2015) in other studies conducted in Turkey. Levels of copper content were detected as 0.531-2.117 mg/kg, 0.046-0.236 mg/kg, 0.07-1.29 mg/kg, 0.057-1.55 mg/kg, 144-216 ng/g, 1.4-2.70 mg/kg, 0.1-0.6 mg/kg, 0.07-2.14 mg/kg and 1.0-1.75 mg/kg in Spain (Fernández-Torres et al., 2005), Malaysia (Chua et al., 2012), Brazil (Liberato et al., 2013), Czech (Čelechovská & Vorlová, 2001), Italy (Caroli et al., 1999), Slovenia (Golob et al., 2005), Italy (Bontempo et al., 2017), Croatia (Bilandžić et al., 2017) and Egypt (Rashed & Soltan, 2004), respectively.

In the present study, minimum and maximum iron levels of 3.506 μg/g and 1278.779 μg/g were detected in Kars and Bolu honeys, respectively. In other studies carried out in Turkey, iron levels in honey samples were found to be <1-7254.62 ppb (268 mean) (Kılıç Altun et al., 2017), 0.84-18.21 mg/kg (7.95 mean) (Turhan, 2007), 9.70-11.60 μg/g (10.5 mean) [15], 1.1-12.7 μg/g (Tuzen et al., 2007), 3.2-6.7 μg/g (Kolayli et al., 2008), and 13.45-97.30 mg/kg (41.13 mean) (Sireli et al., 2015). Iron levels in honeys in other countries such as Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Brazil (Liberato et al., 2013), Italy (Caroli et al., 1999), Italy (Bontempo et al., 2017), Croatia (Bilandžić et al., 2017, Poland (Formicki et al., 2013) and Egypt (Rashed & Soltan, 2004) were detected as <0.005-2.86 mg/kg, ND-32.480 ppm, 0.12-8.76 mg/kg, 191-651 ng/g, 0.5-3.1 mg/kg, 1.03-2.4 mg/kg, 0.08-0.24 μg/g x $10^2$ and 58-202 mg/kg, respectively.

In the study, minimum 5.830 μg/g and maximum 309.783 μg/g levels of magnesium were found in honey samples collected from Rize and Muğla cities, respectively. Other studies from Turkey revealed levels of 23-64 mg/kg (39.10 mean) (Turhan, 2007) and 10.90-93.90 μg/g (26.7 mean) (Doker et al., 2014) for magnesium in honeys analyzed. Magnesium levels in honey samples from Spain (Fernández-Torres et al., 2005), Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Brazil (Liberato et al., 2013), Italy (Bontempo et al., 2017), Croatia (Bilandžić et al., 2017), Poland (Formicki et al., 2013) and Egypt (Rashed & Soltan, 2004) were detected to be 13.26-74.38 mg/kg, <0.104-35.1 mg/kg, 5.209-89.502 ppm, 2.48-28.33 mg/kg, 5.0-79.0 ppm, 11.0-195 mg/kg, 0.42-0.86 μg/g × $10^2$ and 102-300 μg/g, respectively.

In the present study, minimum and maximum manganese levels of 0.096 μg/g and 29.496 μg/g were detected in Bolu and Thrace honeys, respectively. In other studies carried out in Turkey, manganese levels in honey samples were found to be <1-274 mg/kg (45.6 mean) (Kılıç Altun et al., 2017), 0.47-2.60 mg/kg (1.13 mean) (Turhan, 2007), 0.04-0.25 μg/g (0.13 mean) (Doker et al., 2014), 0.32-4.56 μg/g (Tuzen et al., 2007) and 1.2-17.20 μg/g (Kolayli et al., 2008). Manganese levels in honey samples from Spain (Fernández-Torres et al., 2005), Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Brazil (Liberato et al., 2013), Italy (Caroli et al., 1999), Slovenia (Golob et al., 2005), Italy (Bontempo et al., 2017), Croatia (Bilandžić et al., 2017) and Egypt (Rashed & Soltan, 2004) were detected as 0.133-9.471 mg/kg, 0.026-4.23 mg/kg, 0.455-6.859 ppm, 0.06-1.96 mg/kg, 223-580 ng/g, 0.3-2.30 mg/kg, 0.2-8.3 mg/kg, 0.19-3.77 mg/kg and 0.50-1.70 mg/kg, respectively.

In the study, minimum 0.418 μg/g and maximum 19.879 μg/g selenium levels were obtained from Thrace honey and Muğla pine honey, respectively. Other studies in Turkey revealed levels of <1-65.9 μg/g (54.1 mean) (Kılıç Altun et al., 2017), 54.1-67.50 ng/g

(60.7 mean) (Doker et al., 2014) and 38-113 μg/g (Tuzen et al., 2007) for selenium content in selected honey samples. Honeys from Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Brazil (Liberato et al., 2013) and Croatia (Bilandžić et al., 2017) contained selenium at the levels of 2.66-36.4 μg/kg, ND-17.202 ppm, 0.0036-0.062 μg/kg and 0.16-36.3 μg/kg, respectively.

In the present study, minimum and maximum levels of 1.734 μg/g and 245.205 μg/g for zinc were found in Muğla pine honey and Kars honey, respectively. In other studies carried out in Turkey, zinc levels in honey were indicated as <1-237 ppb (49.9 mean) (Kılıç Altun et al., 2017), 0.98-4.35 mg/kg (2.69 mean) (Turhan, 2007), 0.43-0.96 μg/g (0.67 mean) [15], 1.1-12.7 μg/g (Tuzen et al., 2007), 1.2-17.2 μg/g (Kolayli et al., 2008) and 6.76 mg/kg (Sireli et al., 2015). Zinc levels were detected to be 0.132-7.825 mg/kg, 0.185-7.20 mg/kg, 2.353-18.112 ppm, 0.07-1.85 mg/kg, 0.190-22.9 mg/kg, 565-1144 ng/g, 2.92-4.73 mg/kg, 0.5-1.5 mg/kg, 0.46-7.19 mg/kg, 1.66-5.97 μg/g and 5.0-9.3 μg/g in honey samples collected in Spain (Fernández-Torres et al., 2005), Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Brazil (Liberato et al., 2013), Czech (Čelechovská & Vorlová, 2001), Italy (Caroli et al., 1999), Slovenia (Golob et al., 2005), Italy (Bontempo et al., 2017), Croatia (Bilandžić et al., 2017), Poland (Formicki et al., 2013) and Egypt (Rashed & Soltan, 2004), respectively.

Minimum and maximum cadmium levels in honeys were found to be 0.000 μg/g and 0.297 μg/g, respectively in the present study. Other studies from Turkey revealed different results regarding cadmium content in honey samples such as <1 ppb (Kılıç Altun et al., 2017), below the detection limit-2.20 μg/g (<1 mean) (Doker et al., 2014), 0.9-17.9 μg/kg (Tuzen et al., 2007) and 0.343 mg/kg (Sireli et al., 2015). Levels of cadmium content in honey samples were detected as <0.003-3.31 μg/g, ND-4.502 ppm, 0.5-77.4 g/kg, <0.50-0.74 ng/g, 0.12-16.4 μg/kg, 1.0-6.5 μg/g × $10^{-3}$and 0.01-05 μg/g in Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Czech (Čelechovská & Vorlová, 2001), Italy (Caroli et al., 1999), Croatia (Bilandžić et al., 2017), Poland (Formicki et al., 2013) and Egypt (Rashed & Soltan, 2004), respectively.

Minimum and maximum levels of 0.000 μg/g and 3.035 μg/g were detected for lead concentration in honeys analyzed in the present study. According to other studies carried out in Turkey with different honey samples revealed levels of <1 ppb (Kılıç Altun et al., 2017), < below the detection limit-59.40 mg/kg (12.1 mean) (Doker et al., 2014), 8.4-105.8 μg/kg (Tuzen et al., 2007), ND (Kolayli et al., 2008) and 1.101 μg/g (Sireli et al., 2015) for lead. Lead content in honeys from Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Czech (Čelechovská & Vorlová, 2001), Italy (Caroli et al., 1999), Slovenia (Golob et al., 2005), Italy (Bontempo et al., 2017), Croatia (Bilandžić et al., 2017), Poland (Formicki et al., 2013) and Egypt (Rashed & Soltan, 2004) were detected to be 11.2-133 μg/kg, ND-4.502 ppm, 18.4-1000.3 μg/kg, 3.20-186 ng/g, 1.86-4.3mg/kg, 0.0-0.1 ppm, 3.28-50.0 μg/kg, 0.06-0.13 μg/g and 4.2-6.3 μg/kg, respectively.

In the present study, minimum and maximum aluminium levels of 0.775 μg/g and 155.586 μg/g were detected in Kastamonu mad honey and Rize honey, respectively. In other studies carried out in Turkey, aluminium levels in honey samples were found to be <1-960 ppb (69.7 mean) (Kılıç Altun et al., 2017), 0.74-1.35 μg/g (1.06 mean) (Doker et al., 2014) and 83-325 μg/kg (Tuzen et al., 2007). Aluminium levels in honey samples from Hungary (Czipa et al., 2015), Malaysia (Chua et al., 2012), Italy (Bontempo et al., 2017) and Croatia (Bilandžić et al., 2017) were reported as <0.004-4.39 mg/kg, 0.708-1.872 ppm, 0.6-3.8 mg/kg and 0.46-28.8 mg/kg, respectively.

Industrial applications and agricultural chemicals including pesticides pollute the soil, water resources and plants. These chemicals may contain various elements in their compositions. Bees and bee products including honey are exposed to the contaminants via polluted pollen, water and air. Furthermore, poor beekeeping practices may be the source of elemental and heavy metal residues in honey. Honeys can be contaminated with miscellaneous elements through many factors such as containers used in beekeeping, packaging materials (paints and finish-coat materials used in the internal surfaces of the containers, uncoated tins), metal lids, caring chemicals, tranquilizer bee smoke, cleaning materials (residues on contact surfaces) and feeding syrups given to bees. The mineral composition of honey differs tremendously based on its geographic, geologic and floral origins as well as the diversity of elemental resources. Therefore, despite the concordant results recorded in some studies, different mineral compositions may be obtained even from the honey samples collected from the same region in the same study. Determination of the mineral and heavy metal contents of honeys is a useful tool for monitoring environmental pollution; therefore it is of utmost importance that the consumers are informed about the geographic origin (including the altitude and source of honey) of the products in details by proper labeling.

## 4 Conclusion

The aim of the present study was to investigate the levels of certain heavy metals and trace elements that may be found in honeys. It is considered that the findings of the study will be a contribution to assess whether or not honey varieties sold in Turkey pose a risk for public health in terms of heavy metal content and also it is assumed that demonstration of trace element composition of honeys will elucidate the nutritional value of these products. Moreover, it is anticipated that the findings will serve as a tool for estimating the permissible limit of elements in honey, which are yet neither nationally nor internationally established.

## Acknowledgements

We are grateful to Dr. Deniz Aktaran Bala for her contributions to this research and her assistance in providing the honey samples and also we would like to thank Dr. Damla Haktanir for the translation of the manuscript. This work was supported by Scientific Research Projects Coordination Unit of Istanbul University. Project number: BYP-2018-28916.

## References

Ali, M. W., Zoltai, S. C., & Radford, F. G. (1988). A comparıson of dry and wet ashıng methods for the elemental analysıs of peat. *Canadian Journal of Soil Science*, 68(2), 43-447. http://dx.doi.org/10.4141/cjss88-041.

Bargańska, Ż., Ślebioda, M., & Namieśnik, J. (2016). Honey bees and their products: bioindicators of environmental contamination. Publication Cover. *Critical Reviews in Environmental Science and Technology*, 46(3), 235-248. http://dx.doi.org/10.1080/10643389.2015.1078220.

Batista, B. L., Silva, L. R. S., Rocha, B. A., Rodrigues, J. L., Berretta-Silva, A. A., Bonates, T. O., Gomes, V. S. D., Barbosa, R. M., & Barbosa, F. (2012). Multi-element determination in Brazilian honey samples by inductively coupled plasma mass spectrometry and estimation of geographic origin with data mining techniques. *Food Research International*, 49(1), 209-215. http://dx.doi.org/10.1016/j.foodres.2012.07.015.

Bilandžić, N., Tlak Gajger, I., Kosanović, M., Čalopek, B., Sedak, M., Solomun Kolanović, B., Varenina, I., Luburić, Đ. B., Varga, I., & Đokić, M. (2017). Essential and toxic element concentrations in monofloral honeys from southern Croatia. *Food Chemistry*, 234, 245-253. http://dx.doi.org/10.1016/j.foodchem.2017.04.180. PMid:28551232.

Bontempo, L., Camin, F., Ziller, L., Perini, M., Nicolini, G., & Larcher, R. (2017). Isotopic and elemental composition of selected types of Italian honey. *Measurement*, 98, 283-289. http://dx.doi.org/10.1016/j.measurement.2015.11.022.

Caroli, S., Forte, G., Iamiceli, A. L., & Galoppi, B. (1999). Determination of essential and potentially toxic trace elements in honey by inductively coupled plasma-based techniques. *Talanta*, 50(2), 327-336. http://dx.doi.org/10.1016/S0039-9140(99)00025-9. PMid:18967723.

Čelechovská, O., & Vorlová, L. (2001). Groups of honey-physicochemical properties and heavy metals. *Acta Veterinaria Brno*, 70(1), 91-95. http://dx.doi.org/10.2754/avb200170010091.

Chua, L. S., Abdul-Rahaman, N. L., Sarmidi, M. R., & Aziz, R. (2012). Multi-elemental composition and physical properties of honey samples from Malaysia. *Food Chemistry*, 135(3), 880-887. http://dx.doi.org/10.1016/j.foodchem.2012.05.106. PMid:22953800.

Cukur, F., Yucel, B., & Demirbas, N. (2016). Food safety applications towards beekeeping activities in the EU and Turkey: problems and suggestions. *Journal of Agricultural Economics*, 22(1), 87-95.

Czipa, N., Andrasi, D., & Kovacs, B. (2015). Determination of essential and toxic elements in Hungarian honeys. *Food Chemistry*, 175, 536-542. http://dx.doi.org/10.1016/j.foodchem.2014.12.018. PMid:25577117.

Doker, S., Aydemir, O., & Uslu, M. (2014). Evaluation of digestion procedures for trace element analysis of Cankiri, Turkey honey by inductively coupled plasma mass spectrometry. *Analytical Letters*, 47(12), 2080-2094. http://dx.doi.org/10.1080/00032719.2014.895908.

Fernández-Torres, R., Pérez-Bernal, J. L., Bello-López, M. A., Callejón-Mochón, M., Jiménez-Sánchez, J. C., & Guiraúm-Pérez, A. (2005). Mineral content and botanical origin of Spanish honeys. *Talanta*, 65(3), 686-691. http://dx.doi.org/10.1016/j.talanta.2004.07.030. PMid:18969853.

Formicki, G., Gren, A., Stawarz, R., Zysk, B., & Gal, A. (2013). Metal content in honey, propolis, wax and bee pollen and implications for metal pollution monitoring. *Polish Journal of Environmental Studies*, 22(1), 99-106.

Golob, T., Doberšek, U., Kump, P., & Nečemer, M. (2005). Determination of trace and minor elements in Slovenian honey by total reflection X-ray fluorescence spectroscopy. *Food Chemistry*, 91(4), 593-600. http://dx.doi.org/10.1016/j.foodchem.2004.04.043.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 7(2), 60-72. http://dx.doi.org/10.2478/intox-2014-0009. PMid:26109881.

Kaftanoglu, O. (2017, September-October 29-04). Future of beekeeping. In *Proceedings of the 45th Apimondia International Apicultural Congress* (pp. 9-10). Turkey: Apimondia/Turkish Association of Beekeepers.

Kılıç Altun, S., Dinç, H., Paksoy, N., Temamoğulları, F. K., & Savrunlu, M. (2017). Analyses of mineral content and heavy metal of honey sample from South and East Region of Turkey by using ICP-MS. *International Journal of Analytical Chemistry*, 2017, 6391454. http://dx.doi.org/10.1155/2017/6391454. PMid:28584526.

Kolayli, S., Kongur, N., Gundogdu, A., Kemer, B., Duran, C., & Aliyazicioglu, R. (2008). Mineral composition of selected honeys from Turkey. *Asian Journal of Chemistry*, 20, 2421-2425.

Liberato, M. C. T. C., Morais, S. M., Magalhães, C. E. C., Magalhães, I. L., Cavalcanti, D. B., & Silva, M. M. O. (2013). Physicochemical properties and mineral and protein content of honey samples from Ceará state, Northeastern Brazil. *Food Science and Technology*, 33(1), 38-46. http://dx.doi.org/10.1590/S0101-20612013005000028.

Mutlu, C., Erbas, M., & Tontul, A. S. (2017). Some characteristics of honey and other bee products and their effects on human health. *Academic Food*, 15(1), 75-83.

Nascimento, A. S., Marchini, L. C., Carvalho, C. A. L., Araújo, D. F. D., Silveira, T. A., & Olinda, R. A. (2015). Determining the Levels of Trace Elements Cd, Cu, Pb and Zn in Honey of Stingless Bee (Hymenoptera: Apidae) Using Voltammetry. *Food and Nutrition Sciences*, 6(07), 591-596. http://dx.doi.org/10.4236/fns.2015.67062.

Rashed, M. N., & Soltan, M. E. (2004). Major and trace elements in different types of Egyptian mono-floral and non-floral bee honeys. *Journal of Food Composition and Analysis*, 17(6), 725-773. http://dx.doi.org/10.1016/j.jfca.2003.10.004.

Sireli, U. T., Iplikcioglu Cil, G., Yurdakok Dikmen, B., Filazi, A., & Ulker, H. (2015). Detection of Metals in Different Honey Brands. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi*, 21(6), 915-918.

The Agency for Toxic Substances and Disease Registry – ATSDR. (2015). *Priority list of hazardous substances*. Atlanta: ATSDR. Retrieved from https://www.atsdr.cdc.gov/spl/resources

Turhan, K. (2007). Chemical contents and some trace metals of honeys produced in The Middle Anatolia Region of Turkey. *Fresenius Environmental Bulletin*, 16(5), 460-465.

Turkish. (2017). *Turkish statistical institute*. Turkish: Tuik. Retrieved from http://www.tuik.gov.tr/PreHaberBultenleri.do?id=27704

Tuzen, M., Silici, S., Mendil, D., & Soylak, M. (2007). Trace element levels in honeys from different regions of Turkey. *Food Chemistry*, 103(2), 325-330. http://dx.doi.org/10.1016/j.foodchem.2006.07.053.

Vanhanen, L. P., Emmertz, A., & Savage, G. P. (2011). Mineral analysis of mono-floral New Zealand honey. *Food Chemistry*, 128(1), 236-240. http://dx.doi.org/10.1016/j.foodchem.2011.02.064. PMid:25214355.

World Health Organization – WHO. (2011). *Evaluations of the joint FAO/WHO Expert Committee on Food Additives (JECFA): lead general information*. Geneva. Retrieved from http://apps.who.int/food-additives-contaminants-jecfa-database/chemical.aspx?chemID=3511

Yılmaz Aksu, F., & Sandikci Altunatmaz, S. (2017). Risks related to heavy metal contamination in foods. *J Food Hyg Technol-Special Topics*, 3(3), 218-230.