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Heavy Metals, Trace Elements and Biochemical Composition of Different Honey Produce in Turkey

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In this work, the biochemical composition, trace elements and heavy metal contents of honey samples, which were collected from different regions and different botanical origin in Turkey were evaluated. The average content of minerals, moisture, acidity, hydroxymethylfurfural, diastase, invert sugar, pH, sucrose, electrical conductivity and heavy metal contents were determined. The biochemical composition of different botanical originated honeys were determined within the limits of Turkish Standard Institution (TSE), CODEX and EU standards. Level of invert sugar in cotton honey and sucrose level in sunflower honey weren't found agree with TSE and EU standards. In addition to biochemical compositions, the presence of Al, Ba, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb and Zn were determined agree with ICP AES. The highest value of Cr, Cu, K, Mn, Na and Al, contents were found in pine honeydew honey with a levels of 0.50, 2.14, 1931, 1.46, 285, 7.49 mg kg^{-1}, respectively. The highest level of Cd, Co, Mg, Ni and Pb (0.32, 0.22, 103, 0.64, 1.29 mg kg^{-1}) were found in cotton honey. The highest level of Ba and Zn were determined in multifloral honey with a level of 1.47 ppm and 3.29 ppm, respectively. K, Na and Mg were the major macro elements in all honey samples. This study showed that the source of nectar and ecological regions have an important effect on the biochemical compositions, trace elements and heavy metals contents of honey.

Key Words: Honey, Biochemical composition, Heavy metals, Minerals.

INTRODUCTION

Honey is a semi-liquid product which contains a complex mixture of carbohydrates, mainly glucose, fructose, sucrose and other sugars depending on floral origin. There are also, organic acids, lactones, amino acids, minerals, vitamins, enzymes, pollen, wax and pigments presenting honey[1-3]. Honey can be produced both from a single flower's nectar and multifloral nectar sources. Unifloral honeys, in fact, may have a highly characteristic aroma, indicating the presence of various components, which mainly depend on the original sources of nectar[1].

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The contents of these components in honey are the most important quality criteria of honey and indicate important properties of the honey sample (Table-1). The honey having high water content is easier to get ferment. Mineral contents of honey are used to determine the botanical origin of honey. The mineral contents of honeydew honey are higher than other honeys[4]. Period and conditions of honey storage have important influence on the increase of invert sugar content[5]. Honey fermentation causes an increase on honey acidity and so maximum acidity value is used as a quality criteria. The value of hydroxymethylfurfural depends on heat process after harvest pH of honey the storage time and the temperature of storage. Diastase activity of honey is a quality criteria that is influenced by time and temperature of the honey storage, heating and that is used as an indicator for overheating and honey freshness[6]. Conductivity is a good criterion for determining the botanical origin of the honey and it has been used in routine honey analysis instead of the mineral content. This measurement depends on the mineral and acid content of honey. There is a linear relationship between the mineral content and electrical conductivity[7,8].

TABLE-1
HONEY QUALITY STANDARDS ACCORDING TO THE DRAFT CL 1998/12-S OF THE CODEX ALIMENTARIUS, TO THE DRAFT 96/0114 (CNS) OF THE EU AND TSE 90/3036 (Anonymous, 1990; AOAC, 1990; CODEX, 1993)

Quality criteria	TSE	CODEX	EU
Mineral content (%)	≤ 0.6 (blossom) ≤ 1.0 (honeydew)	≤ 0.6 (blossom) ≤ 1.0 (honeydew)	≤ 0.6 (blossom) ≤ 1.2 (honeydew)
Moisture content (%)	≤ 21g/100g	≤ 21g/100g	≤ 21g/100g
Acidity (meq kg^{-1})	≤ 40 meq kg^{-1} (blossom) ≤ 40 meq kg^{-1} (honeydew)	≤ 50 meq kg^{-1} (blossom) ≤ 50 meq kg^{-1} (honeydew)	≤ 40 meq kg^{-1} (blossom) ≤ 40 meq kg^{-1} (honeydew)
Hydroxymethyl-furfural (mg kg^{-1})	≤40 mg kg^{-1} (blossom) ≤40 mg kg^{-1} (honeydew)	≤ 80 mg kg^{-1} (blossom) ≤ 80 mg kg^{-1} (honeydew)	≤ 40 mg kg^{-1} (blossom) ≤ 40 mg kg^{-1} (honeydew)
Diastase level	≥ 8 (blossom) ≥ 8 (honeydew)	≥ 8 (blossom) ≥ 8 (honeydew)	≥ 8 (blossom) ≥ 8 (honeydew)
Invert sugar content (%)	≥ 65 (blossom) ≥ 60 (honeydew)	≥ 65 (blossom) ≥ 60 (honeydew)	≥ 65 (blossom) ≥ 60 (honeydew)
Sucrose (%)	≤ 5 (blossom) ≤ 10 (honeydew)	≤ 5 (blossom) ≤ 10 (honeydew)	≤ 5 (blossom) ≤ 10 (honeydew)
Electrical conductivity (mS/cm)	≤ 0.8 (blossom) ≥ 0.8 (honeydew and castane)	≤ 0.8 (blossom) ≥ 0.8 (honeydew and castane)	≤ 0.8 (blossom) ≥ 0.8 (honeydew and castane)

TSE = Turkish Standard Institute; EU = European Union.

The mineral content of the total intake of all nutrients in the diets is change between 0.2-0.3 %. They are potent and so important for living organism are not be able to utilize 99.7 % of food without them. The potassium content of honey is considered responsible for the bactericidal characteristics of the honey. There is no correlation between the content of heavy metals, such as Ag, Cd and Pb present in the soil and honey. However, heavy metals of honey are effected by the origin of source, floral density, season of the year and rainfall. Honey containers are important that the honey can be contaminated with heavy metals. Contact with steel surfaces during harvesting, processing and preparation of honey for the market, can increase Cr content due to the corrosive effect of honey acidity. The storage of honey in galvanized containers can also be a source of Zn contamination[9]. Ni, Al and Cr concentrations can be affected by the type of storage container used after honey harvest[9]. Honey quality standards according to the draft CL 1998/12-S of the CODEX Alimentarius, to the draft 96/0114 (CNS) of the EU and TSE 90/3036 are given in Table-1.

This study was conducted to determine, the biochemical parameters (mineral (%), moisture (%), acidity (meq kg^{-1}), hydroxymethylfurfural (mg kg^{-1}), contents, diastase level, invert sugar (%), pH, protein (%) sucrose (%) content, electrical conductivity (µS/cm), the trace elements and the heavy metals contents in sunflower, cotton citrus, pine, chestnut, red brush, astragallus and multiflora honey's honey samples produced different geographical regions in Turkey. The results of biochemical measurements were compared with TSE, CODEX and EU standard limits are giving in Table-2.

TABLE-2
MEANS AND STANDARD ERRORS OF MEANS ($\bar{x}$ ± SE) FOR EACH BIOCHEMICAL COMPONENT IN HONEY SAMPLES (n = 3) ACCORDING TO ORIGIN

Biochemical properties	Honey types			
	Sunflower	Multiflora	Cotton	Citrus
Mineral contents (%)	0.36±0.23a T C E	0.13±0.05 T C E	0.47±0.018a T C E	0.32±0.008a *T C E
Moisture (%)	18±0.20b T C E	15.23±0.17 T C E	18.46±0.12b T C E	18.43±0.38b T C E
Acidity (meq kg^{-1})	40.73±2.45c C	32.3±2.19	25.25±0.83a T C E	34.96±0.20b T C E
Hydroxymethylfurfural (mg kg^{-1})	2.17±0.00a T C E	5.73±0.18 T C E	4.60±0.88b T C E	3.77±0.36ab T C E
Diastase level	23.43±3.32b T C E	17.9±0.44 T C E	23.00±0.0b T C E	10.90±0.0a T C E
Invert sugar (%)	71.66±0.66c T C E	66.20±0.96 T C E	59.95±1.98a	67.43±0.58b T C E
pH	5.63±0.03b	6.36±0.03	3.93±0.05c	3.57±0.02a
Sucrose (%)	6.46±0.78b	2.84±0.44 T C E	4.67±0.23a T C E	3.34±0.24a T C E
Electrical conductivity (mS/cm)	0.78±0.41a T C E	0.95±0.02	0.95±0.03a	0.69±0.02a T C E

	Pine	Chestnut	Red Bush	Astragallus
Mineral contents (%)	0.57±0.055a T C E	0.14±0.02 T C E	0.38±0.06 T C E	0.47±0.03 T C E
Moisture (%)	17.20±0.06a T C E	18.40±0.14 T C E	17.70±0.01 T C E	16.50±0.00 T C E
Acidity (meq kg^{-1})	25.73±1.02a T C E	15.55±0.41 T C E	5.1±0.26 T C E	4.6±0.52 T C E
Hydroxymethylfurfural (mg kg^{-1})	5.45±0.65b T C E	30.78±1.28 T C E	6.85±0.28 C	13.50±0.65 T C E
Diastase level	29.40±0.0c T C E	13.90±0.00 T C E	50±0.00 T C E	17.90±0.00 T C E
Invert sugar (%)	67.50±1.03b T C E	76.42±0.09 T C E	71.56±0.12 T C E	72.39±0.07 T C E
pH	4.45±0.02d	3.05±0.25	3.83±0.17	3.89±0.32
Sucrose (%)	3.99±0.16a T C E	2.38±0.08 T C E	1.98±0.14 T C E	2.75±0.06 T C E
Electrical conductivity (mS/cm)	1.13±0.10a T C E	0.38±0.03 T C E	0.80±0.10 T C E	0.95±0.04

*There were no differences between same letters ($p < 0.05$).
T = TSE, C = CODEX, E = EU.

EXPERIMENTAL

Honey samples: The honey samples, which were freshly harvested were picked up from various beekeepers in different local areas. These local areas and botanical origin of honey were giving in Table-3. The original samples were collected between 2004 and 2005. The samples were analyzed immediately after harvesting.

TABLE-3
BOTANICAL AND GEOGRAPHICAL ORIGIN OF HONEY TYPES

Botanical origin	Geographical origin	Botanical origin	Geographical origin
Multiflora (*Medicago sativa, Onobrychis sativa, Astragalus globosus L., Echinops ritr L. Trifolium montanum L. Thymus vulgaris, Verbascum densiflorum*)	Adana (Aladag), Adana, Sanliurfa (Halfeti), Nigde, Bingöl (Karliova), Kilis, Kahramanmaras (Afsin), Sinop, Osmaniye (Bahçe) Kastamonu, Osmaniye (Kadirli), Artvin	Chestnut (*Castanea sativa*)	Ordu, Giresun
Red Brush (*Erica manipuliflora*)	Hatay (Samandag)	Pine (*Pinus nigra*)	Mugla
Orange (*Citrus spp*)	Hatay (Dörtyol)	Sunflower (*Helianthus annuus*) L	Hatay (Hassa)
Astragallus (*Astragalus L.*)	Kahramanmaras, (Göksun)	Cotton (*Gossypium herbaceum*)	Sanliurfa, Hatay (Antakya)

Biochemical analysis: The honey samples were analyzed by the standard methods of the Association of Official Analytical Chemists[10,11]. Moisture content of honey was determined by refractometer[12]. Protein content of honey was determined by using Kjeldahl apparatus[10]. Mineral percentage was measured by calcinations at 600 ºC in the mineral furnace. Hydroxymethylfurfural was determined calorimetrically after dilution with distilled water and addition of *p*-toludine solution. Absorbance of solution was determined at 550 nm using 1 cm cells in an LKB-Biochrom spectrophotometer. In order to test for acidity, 10 g of the honey samples were dissolved in 75 mL CO_2 with free distilled water and titrated with 0.1 N NaOH, pH of the honey solution was measured with a pH meter. The diastase activity was measured according to Anonymous[10].

Determination of trace element and heavy metals: Approximately 1g samples were placed into pre washed crucible with nitric acid and burned at 450 ºC for 24 h until gray ash obtained. Concentrated nitric acid (5 mL) was added to the resultant ashes and the mixture was stirred on a hot plate until dry. Then 10 mL of the same acid was added and continued to stir until the clear solution was obtained then made up to 25 mL with ultra pure water. ICP-AES (Varian Model-Liberty series II) was used to determine the elements which Al, Mg, Cu, K, Ba, Mn, Fe, P, Ca, Na, Co, Cd, Ni, Sn, Pb, Zn. Macro and trace element concentrations were calculated in mg kg^{-1} on wet weight basis. Macro and trace element concentrations and wavelength are given below.

Measurement of wavelengths are Al (396,152 nm), Mg (279,533 nm), Cu (324,754 nm), K(766,49 nm), Ba (455,403 nm), Mn (257,61 nm), Fe (259,94 nm), P (213,618 nm), Ca (317,933 nm), Na (588,995 nm), Co (238,892 nm), Cd (228,802 nm), Ni (231,604 nm), Sn (189,926 nm), Pb (220,353 nm), Zn (213,856 nm).

Operational parameters for ICP AES as fallow: power: 650 V, rinse time: 10 s, plasma gas flow rate l/min: 15, auxillary flow L min^{-1}: 1.5, sample up take delay: 30 s.

Statistical analysis: Data were analyzed by using ANOVA and MANOVA of SPSS univariate and multivariate statistical analysis of variance methods software. Means were compared using Duncan multiple range test[13,14].

RESULTS AND DISCUSSION

Biochemical analysis in different honey types: The means and ranges of values for each biochemical component of honey samples are summarized in Table-2. Variations between biochemical components values are plotted in Fig. 1.

The averages of the honey samples from four origins were compared using Duncan's multiple range comparison test and the differences among the origins indicated with different letters in Table-3 ($p < 0.05$). The averages of different honey origin means in terms of all biochemical component were compared with TSE, CODEX and EU standards and results are given in Table-3 and indicated with the letter T (for TSE), C (for CODEX) and E (for EU). In addition, all biochemical

components of different origins honey were compared by using the multivariate variance analysis. There were found statistically significant ($p < 0.01$) differences among the biochemical component of honey origin (Fig. 1). There wasn't found any statistically significant ($p < 0.05$) among the honey origin on moisture and sucrose content.

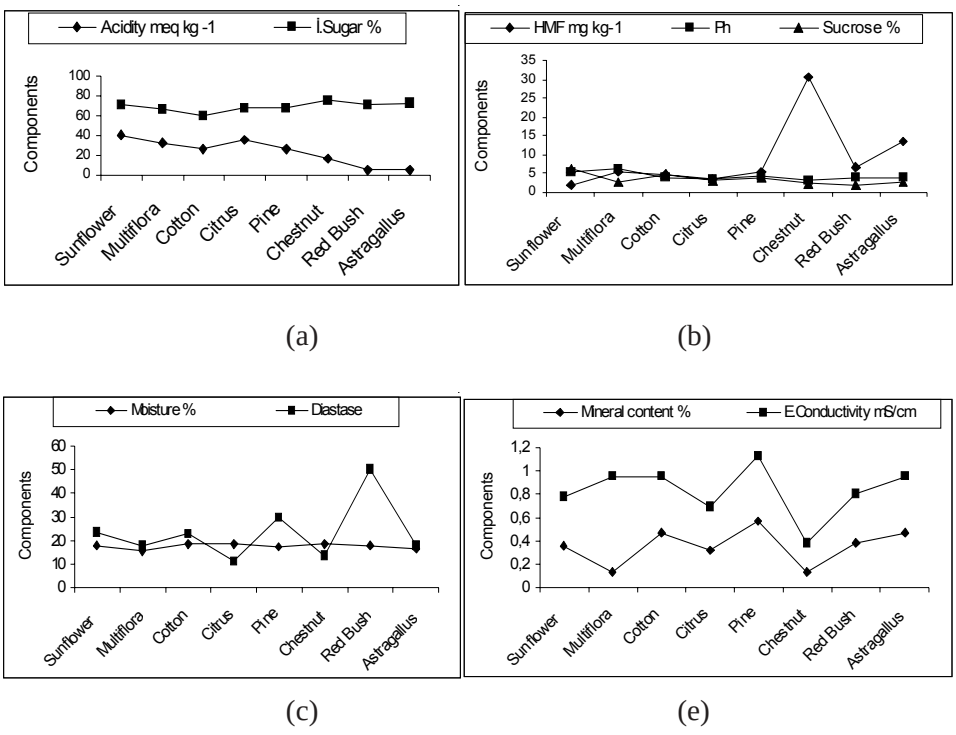

Fig. 1. Biochemical components of different honey types produced in Turkey
(a) Mineral content (%), Electrical conductivity (mS/cm),
(b) Diastase level, moisture content (%),
(c) Acidity (meq kg^{-1}), Invert sugar content (%),
(d) Hydroxymethylfurfural (mg kg^{-1}), pH, Sucrose content (%)

Results of trace and macro element contents in different honey types: Trace and macro element contents of 20 honey samples are given in Table-4.

Regarding to the botanical origin of this honey groups, cotton honey contained high levels of Al, Cd, Co, K, Mg, Ni and Pb pine honeydew honey have higher level of Al, Cr, Cu, K, Mn, Na had sunflower and chestnut honey compare to other honey types. Red brush honey have high levels of K, Mg and Na, astragallus honey had high levels of K and Na. The sunflower and chestnut honey types have the lowest trace elements content in all of the honey types. Citrus and cotton honey samples

TABLE-4
MEANS AND STANDARD ERRORS OF MEANS ($\overline{x}$ ± SE) FOR EACH ELEMENTS IN HONEY SAMPLES ACCORDING TO ORIGIN

Elements	Citrus honey	Multiflora honey	Cotton honey	Pine honeydew honey
Al	5.05±0.06	5.36±0.61	7.49±1.33	7.55±0.19
Ba	1.12±0.07	1.47±0.28	1.29±0.09	1.09±0.08
Cd	0.32±0.01	0.30±0.01	0.32±0.01	0.30±0.01
Co	0.14±0.04	0.06±0.12	0.22±0.04	0.00±0.14
Cr	0.48±0.03	0.46±0.07	0.46±0.01	0.50±0.06
Cu	2.01±0.03	2.04±0.05	2.06±0.05	2.14±0.05
Fe	38.33±10.35	26.22±10.74	11.99±3.35	18.91±3.30
K	404.76±10.49	437.86±39.21	1442.66±148.52	1931.97±647.36
Mg	25.31±2.17	33.05±2.99	103.24±12.37	60.69±1.03
Mn	0.87±0.02	1.17±0.06	1.22±0.11	1.46±0.02
Na	52.89±1.79	69.76±6.68	97.15±17.79	285.68±5.70
Ni	0.34±0.01	0.48±0.41	0.64±0.14	0.40±0.12
Pb	0.97±0.19	0.82±0.05	1.29±0.09	0.78±0.06
Zn	2.67±0.54	3.29±0.43	3.06±0.77	1.20±0.01
	Sunflower honey	Chestnut honey	Red brush honey	Astragallaus honey
Al	0.9980±0.3180	2.1540±1.2440	0.000±0.000	0.000±0.000
Ba	0.0220±0.0050	0.0110±0.0060	0.000±0.000	0.000±0.000
Cd	0.0001±0.0000	0.0000±0.0000	0.004±0.000	0.000±0.000
Co	0.0017±0.0003	0.0020±0.0004	0.000±0.000	0.000±0.000
Cr	0.0030±0.0003	0.0029±0.0010	0.000±0.000	0.000±0.000
Cu	0.0250±0.0020	0.0340±0.0060	0.022±0.130	0.250±0.060
Fe	0.1430±0.0520	0.2260±0.0417	1.810±0.330	1.940±0.130
K	21.885±0.7680	17.276±1.0210	593.400±45.80	602.600±241.2
Mg	2.6990±0.1951	1.4524±0.1550	74.680±16.71	26.320±9.570
Mn	0.0380±0.0090	0.0583±0.0040	0.400±0030	0.680±0.310
Na	8.0490±0.2423	4.7606±0.9970	23.660±2.050	39.090±4.660
Ni	0.0030±0.0015	0.0000±0.0000	0.055±0.050	0.060±0.040
Pb	0.0001±0.0000	0.0001±0.0000	0.170±0.060	0.310±0.070
Zn	0.0380±0.0133	0.1452±0.0080	1.310±0.050	2.670±1.580

have the highest Cd (0.32, 0.32 mg kg^{-1}) content and Pb (0.97, 1.29 mg kg^{-1}) contents. These honey samples were obtained from beekeepers whose beehives were close to main roads and industrial areas.

The highest value of Cr, Cu, K, Mn, Na and Al contents were found as 0.50, 2.14, 1931, 1.46, 285, 7.49 mg kg^{-1} in pine honey, respectively. The highest value of Cd, Co, mg, Ni and Pb were determined in cotton honey as 0.32, 0.22, 103, 0.64, 1.29 mg kg^{-1}, respectively. The highest value of Ba and Zn were determined in multifloral honey as 1.47, 3.29 mg kg^{-1}, respectively. Na and K content of pine honeydew honey were found significantly ($p < 0.05$) higher than the other honey types. The average value of Na and K content of pine (*Pinus nigra*) honeydew honey was found as 285.68 mg kg^{-1}; 1931.37 mg kg^{-1}. The main reason for these high values could be due to the Na and K content of the soil and water in the region.

It is known that the soil and water are rich with Na and K in this area (Western Mediterranean region of the Turkey). The macro and microelement contents of the honey samples are given in Table-4.

The averages of biochemical component in different honey samples were found generally appropriate with TSE, CODEX and EU standards except invert sugar content cotton, honey (Table-2). The means of mineral content, moisture content, acidity, hydroxymethylfurfural, diastase level and sucrose of the citrus, sunflower, cotton and pine honeydew honey were appropriate with TSE, CODEX and EU standards. Also invert sugar means (> 65 %) of citrus, sunflower and pine honeydew honey were found appropriate with TSE, CODEX and EU standards. However invert sugar mean (59.94 %) of cotton honey was not appropriate with TSE, CODEX and EU standards. Moisture contents of citrus, sunflower, cotton and pine honeydew honey (varies from 16.99 to 18.46 %) were found similar. In terms of mineral content, pH, diastase level, hydroxymethylfurfural and electrical conductivities, in pine honeydew honey have the highest values. The cotton, honey showed the highest values of moisture content and sucrose content. The lowest value of hydroxymethylfurfural was found in sunflower honey and lowest diastase level was found in citrus honey. The reason of high enzyme level of sunflower honeys may be high level of these honeys. Yilmaz and Kufrevioglu[15] and Tolon[16] reported the means of moisture content, as 17.05 and 16 %, hydroxymethylfurfural content as 3.3 and 12.11 mg kg^{-1} and sucrose content as 4.18 and 1.8 %, respectively. Tolon[16] reported 0.44 % mineral content in honey samples. Diastase levels in Tolon[16], Yilmaz and Kufrevioglu[15] studies were 11.23 and 14.6. Crane[2], Dogaroglu[17], Keskin[18], Tolon[16] reported that enzymes in honey produce acid and the level of the acid can be higher in the honeys containing high diastase. Sengonca and Temiz[19] and Tolon[16] reported that the invert sugar content as 73 and 72.32 %.

Fallico *et al.*[1] reported that the moisture content, pH, diastase level and hydroxymethylfurfural as, 18.5 %, 3.4, 7.4 and 5.95 mg kg^{-1}, respectively in citrus (*Citrus spp*) honey and these value are appropriate with values of current study and all standards. Reported acidity (25 meq kg^{-1}) and ash (0.03 %) by Facillo *et al.*[1] were found lower than present study's acidity (34.96 meq kg^{-1}) and ash (0.31 %), in citrus honey.

Silici and Tolon[20] revealed the mineral content, moisture content, acidity pH, hydroxymethylfurfural, invert sugar and sucrose as 0.36 %, 19.80 %, 27.0 meq kg^{-1}, 4.5, 8.80 mg kg^{-1}, 67.60 and 1 %, respectively in pine honeydew honey and these values were found appropriate with all standards and close to values of this study.

Hussein[21] reported that the average content of Na and K as 162 mg/kg and 2495 mg/kg, respectively and suggested that the content of Na and K honey could be different in light and dark coloured honeys. High level of potassium were recently reported as one of the characteristic of avocado honey with average of 1762 ppm[22] and 1774 ppm[23], those value are close to with K content of pine honeydew honey (1931 mg kg^{-1}) in this study. Dag *et al.*[24] reported that the average level of Mg and Na as 64 ppm and 69.76 ppm, respectively. Level of Mg is similar to Mg level of

pine honeydew honey and level of Na is agree with multifloral honey's Na level (61.6 mg kg^{-1}) in this research. However Pb levels of all types honey origin of this research were found lower than Pb level (2.56 ppm) that reported by Dag *et al.*[24].

Tong *et al.*[25] analyzed 19 honey samples taken from near zinc mines, industrial area, near highway. They determined 47 elements such as aluminium, barium, calcium, copper, magnesium, nickel and silicon. Ferrer *et al.*[23] reported that average of Na, K, Ca, Mg, Cu, Fe, Mn and P as 353, 1774, 237, 52, 0.76, 13.5, 0.92 and 1642 mg/kg respectively. Erbilir and Erdogrul[26] reported that average level of Cu (0.01 ppm) and Mn as 0.03 ppm that values were found similar with sunflower, chestnut, red brush and astragallus honeys' Cu and Mn values in this study. However, finding of same authors about Cd (0.32) is close to citrus, multiflora, cotton and pine honeydew honey in present research.

Demirezen and Aksoy[27] reported that metal concentration in honey samples ranged between 0.11-018 ppm for Cd; 0.15-0.66 ppm for Cu;2.2-11 ppm for Zn; 0.2-0.8 ppm for Ni; 0.1-0.85 ppm for Pb.

In a report of Uren *et al.*[28], the average level of Cd, Fe, Cu, Mn, Mg in honeydew honey derived from Turkey were found 10.8, 10.4, 1.05, 0.752, 55 ppm, respectively. Taddia *et al.*[29] reported that average level of Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn in commercial honey were 0.07, 0.06, 6.2, 67.1, 68.7, 0.388, 0.401, 58.8 µg g^{-1}, respectively. All the trace element and the heavy metal's concentrations of this research were found higher than detected in a previous research[22].

Yilmaz and Yavuz[30] reported that average level of Na, K, Ca, Mg, Cu, Fe, Mn, Zn and Co in honey (30 samples) derived from different parts of South-eastern of Anatolia (Turkey) as 118, 296, 51, 33, 1.8, 6.6, 1.0, 2.7 and 1.0 mg/kg, respectively.

In conclusion, biochemical components of citrus, sunflower, cotton and pine honeydew honeys except for invert sugar content of cotton, honey are appropriate to the quality standards of TSE, CODEX and EU, even if there are some differences among the different honey origin. These differences among the honey can be explained the origin of flora, the faulty processes in harvest and storage of honey by beekeepers such as over or under heating of honey and unsuitable storage conditions. The better quality of honey appropriate to TSE, CODEX and EU standards would be produced by training of the beekeepers on the importance of biochemical contents of honey for human health and export. The analyzed honeys come from various species of plants, fact which determines a significant variation of the results. In terms of trace elements and heavy metal contents the highest value were found in pine honeydew honey and cotton honey all of other honey types.

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