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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Determination of Element Contents and Health Risk Assessment of Some Commercial Coffees in Türkiye

Türkiye'deki Bazı Ticari Kahvelerin Element İçeriklerinin Belirlenmesi ve Sağlık Riski Değerlendirmesi

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Abstract

Coffee is one of the most consumed beverages worldwide, which has become an integral part of people's daily lives. The increasing demand for coffee consumption has led to the creation of many coffee brands producing various types of coffee around the world. One of the reasons for the widespread consumption of coffee is that it contains elements necessary for human health. Supplementation of food intake with essential minerals, which are present in large quantities in the body, and trace minerals, which are present in smaller quantities, is an important parameter in nutrition. Determining the total concentrations of the elements in coffee allows the assessment of its nutritive quality and at the same time, its adverse effects on human health can be decided. In the present study, essential- zinc (Zn), selenium (Se), phosphorus (P), sodium (Na), manganese (Mn), magnesium (Mg), potassium (K), iron (Fe), copper (Cu), chromium (Cr), cobalt (Co), calcium (Ca) and boron (B)- and non-essential - titanium (Ti), antimony (Sb), lead (Pb), nickel (Ni), molybdenum (Mo), cadmium (Cd), barium (Ba), arsenic (As) and aluminium (Al)- element content in some coffee types from different brands was analyzed by inductively coupled plasma-optical emission spectroscopy (ICP-OES) and the results were interpreted in terms of human health. Percentages of elements ingested with daily consumption of 300 mL of selected coffee types were also calculated on a person-by-person basis according to gender. Health risk assessment was performed involving carcinogenic risk and non-carcinogenic risk evaluation. In all coffee types, K element concentration has been reported as the highest element. As, Cd, Mo, Sb, and Ti elements were not detected in all types of coffees. A female's highest daily element intake percentage is Mg for all types of coffee with the highest concentration of 15.561% (decaffeinated coffee, P1). For a male, the Mg element daily intake percentage is also the highest except Milicano and filter coffee of P2 and Turkish coffee of P4. The hazard index (HI) of all samples was less than 1, thus, daily consumption of 300 mL of these coffees is defined in a low-risk group. The target carcinogenic risk (TCR) value was calculated below 1×10^{-4} for all coffee types except Classic (Product 1). Classic coffee of Product 1 should be consumed less than 300 mL/day since its TCR value is higher than 1×10^{-4}.

Keywords: Coffee, Essential and non-essential elements, ICP-OES, Risk assessment

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Öz

Kahve, insanların günlük yaşamlarının ayrılmaz bir parçası haline gelen ve dünya çapında en çok tüketilen içeceklerden biridir. Kahve tüketimine yönelik artan talep, dünya çapında çeşitli kahve türleri üreten birçok kahve markasının oluşmasına yol açmıştır. Kahvenin yaygın olarak tüketilmesinin nedenlerinden biri de insan sağlığı için gerekli elementleri içermesidir. Vücutta büyük miktarlarda bulunan başlıca mineraller ve daha küçük miktarlarda bulunan eser minerallerin gıda alımıyla desteklenmesi beslenmede önemli bir parametredir. Kahvede bulunan elementlerin toplam konsantrasyonlarının belirlenmesi, kahvenin besleyici kalitesinin değerlendirilmesini sağlar ve aynı zamanda insan sağlığı üzerindeki olumsuz etkilerine karar verilebilir. Bu çalışmada, farklı markalara ait bazı kahve türlerinde esansiyel -çinko (Zn), selenyum (Se), fosfor (P), sodyum (Na), mangan (Mn), magnezyum (Mg), potasyum (K), demir (Fe), bakır (Cu), krom (Cr), kobalt (Co), kalsiyum (Ca) ve bor (B)- ve esansiyel olmayan - titanyum (Ti), antimon (Sb), kurşun (Pb), nikel (Ni), molibden (Mo), kadmiyum (Cd), baryum (Ba), arsenik (As) ve alüminyum (Al) element içeriği indüktif eşleşmiş plazma-optik emisyon spektroskopisi (ICP-OES) ile analiz edilmiş ve sonuçlar insan sağlığı açısından yorumlanmıştır. Seçilen kahve türlerinin günlük 300 mL tüketimi ile alınan element yüzdeleri de cinsiyete göre kişi bazında hesaplanmıştır. Kanserojen risk ve kanserojen olmayan risk değerlendirmesini içeren sağlık riski değerlendirmesi yapılmıştır. Tüm kahve türlerinde K elementi konsantrasyonu en yüksek element olarak rapor edilmiştir. As, Cd, Mo, Sb, Ti elementleri tüm kahve türlerinde tespit edilmemiştir. Kadınların günlük Mg elementi alım yüzdesi tüm kahve türleri için %15,561 ile en yüksek olarak belirlenmiştir (kafeinsiz kahve, P1). Erkeklerde ise Mg elementi günlük alım yüzdesinin Milicano (P2), filtre kahve (P2) ve Türk kahvesi (P4) ürünleri dışında en yüksek olduğu tespit edilmiştir. Tüm örneklerin tehlike indeksi (HI) 1'den küçüktür, bu nedenle bu kahvelerin günlük 300 mL tüketimi düşük risk grubunda tanımlanmaktadır. Hedef kanserojen risk (TCR) değeri Klasik (Ürün 1) hariç tüm kahve türleri için 1×10^{-4}'ün altında hesaplanmıştır. Ürün 1'in klasik kahvesinin TCR değeri 1×10^{-4}'ten yüksek olduğu için günde 300 mL'den az tüketilmelidir.

Anahtar Kelimeler: Kahve, Esansiyel ve esansiyel olmayan elementler, ICP-OES, Risk değerlendirmesi

1. Introduction

As a result of increasing awareness for healthy nutrition to provide a health body, attention has also increased to the food contents. Healthy nutrition affects the health of the cells the smallest part of the body. Maintaining a balance of about two-thirds of the body fluids inside the cells and one third outside is vital for cell life. The cells direct the movement of the major minerals for controlling the water movement. Major elements or macrominerals are essential mineral nutrients constituted in the human body in amounts larger than 5 g whereas trace elements or microminerals are found in amounts smaller than 5 g. Sodium (Na), chlorine (Cl), potassium (K), magnesium (Mg), phosphorous (P), calcium (Ca), sulphur (S) are some examples of major essential elements and manganese (Mn), copper (Cu), iron (Fe), zinc (Zn), selenium (Se), fluorine (F), chromium (Cr), iodine (I) and molybdenum (Mo) are classified as micro essential elements (Rolfes et al., 2008; Ozdemir Dere et al., 2014; Derun, 2014; Eser and Adiloglu, 2020). Essential elements play important roles in maintaining the functional and structural integrity of living systems (Cacan et al,. 2023). Besides essential elements, non-essential elements include heavy metals that are contained in the food supply by soil, water, and air pollution way. Aluminium (Al), cadmium (Cd), lead (Pb), mercury (Hg), barium (Ba), antimony (Sb), molybdenum (Mo), arsenic (As), nickel (Ni) and titanium (Ti) are some examples of non-essential toxic elements (Rolfes et al., 2008; Ozdemir Dere et al., 2014; Derun, 2014). Knowing and monitoring the essential and non-essential (toxic) element contents of the foods and beverages that are frequently consumed in daily life is important for conscious consumption and product quality, in addition to preventing nutritional deficiency (Bigucu et al., 2016).

Coffee is the fruit of a tree species from the genus Coffea of the *Rubiaceae* family (Acikalin and Sanlier, 2021). It is obtained by processing cores within this fruit. Coffee is involves materials such as caffeine, cafestol, kahveol, trigonelline, chlorogenic acids, various minerals, and trace elements and it consumed the form of beverage widely (Bianchin et al., 2020). Coffee ranks second among the products traded in the world after petroleum, and its consumption with an estimated 165 million 60 kg bags consumed per year is becoming more widespread every day (Agunbiade et al., 2022; Carter et al., 2022). Since coffee is a beverage frequently consumed in the daily nutrition routine, there are several studies in the literature on its element content (essential and non-essential) in terms of nutritional value and healthy nutrition. Várady et al. (2024), determined the heavy metal amounts of green and roasted specialty coffees originated different regions as Kenya, Guatemala, Ethiopia, Nicaragua, Burundi, Rwanda and Peru. The heavy metals aluminium (Al), cadmium (Cd), nickel (Ni), copper (Cu), chromium (Cr), and lead (Pb) were detected by utilizing inductively coupled plasma mass spectrometry. They statistically reported that the technique of process affected the composition of Al, Hg, Cr, Ni, Cd, and Pb in the roasted and green coffees ($p < 0.001$) (Várady et al., 2024). Baqueta et al. (2024), analyzed Conilon and Robusta species of Brazilian Canephora coffees according to their essential element content (Fe, Ca, Zn, Mg, Mn, Cu, and K) by flame atomic absorption spectrometry using diluted nitric acid. Essential element composition data was estimated within independent components-discriminant analysis (IC-DA) which is a type of chemometric tool. When the specificity and sensitivity of the analyses compared, IC-DA showed higher then partial least square-discriminant analysis (PLS-DA). Results implicated that IC-DA is suitable to maintain supervised discrimination of species based on their essential elemental content (Baqueta et al., 2024). Weinberger et al. (2024), used EDXRF (Energy dispersive X-ray fluorescence spectrometry) to determine the K, Ca, Mn, Fe, Cu, Zn, Sr and Rb element composition of some coffees. Different sample treatment methods such as loose powder and pressed pellets and quantification techniques were studied. Several chemometric methods explored for different coffee types showed that the application of PLS-DA on the raw EDXRF spectra is suitable and the fitting and quantification of elemental concentrations is not necessary (Weinberger et al., 2024). Junior et al. (2020), studied the effect of organic and conventional management systems on absorption, storage, and hot water solubility of Mg through chemical fractionation of P and Mg in arabica, commercial, ground, and roasted coffee utilizing acid digestion and flame atomic absorption spectrometry. Results showed that in these samples Mg is possibly mostly exhibited as different inorganic salts (Junior et al., 2020). Silva et al. (2020), performed an extraction of coffee leaves reaped from Brazil and assessed polyphenol and trace element content (Mg, Al, Cu, Sn, Mn, Ni, and Zn) by using ICP-OES. For the establishment of trace elements and polyphenolic content in the leaves to rust infection resistance role, principal component analysis (PCA) was assigned. As a result; polyphenolic concentration was decreased in impressionable cultivars and a diametric impact was seen between Mg and Mn concentrations (Silva et al., 2020). Pohl et al. (2018), aimed to clarify the specimen preparing process of ground (GCs) and soluble coffee (SCs) brew previous to their custom analysis by ICP-OES for the chosen elements (Zn, Mn, Ni, Sr, Fe, Mg, Ca, Cu, Al and Ba). It was found that the contents of elements in brews of SCs were greater those decided in infusions of GCs (Pohl et al., 2018). Habte et al. (2016), were reported the establishment of elemental profiling and provenance of coffee samples obtained from different major coffee fabricating locations of Ethiopia. ICP-OES, direct mercury analyser (DMA), and ICP-MS tests were utilized to analyse forty-five elements in 129 samples. From their results; as a macro element, the concentration of Fe was measured least and K showed the highest levels. The content of micro elements was sorted as Mn > Cu > Sr > Zn > Rb > Ni > B (Habte et al., 2016). Barbosa et al. (2014), evaluated 34 non-organic and 20 organic coffees on the authority of their micro and macro element contents by ICP-MS and determined thirty-eight element contents. Results showed that chemical element contents are higher in conventional coffee (Barbosa et al., 2014). Stelmach et al. (2013), analysed Zn, Mn, Mg, Fe, Cu, and Ca content of coffee specimens by using flame atomic absorption spectrometry and assessed differences in the leachability of elements from one specified coffee into its infusions processed under divergent infusion environments. According to the results; the highest element contents were reported as Mg and Ca in each coffee sample (average data of 14.3 × 103 µg g^{-1} and 1.8 × 103, respectively) and were followed by Mn and Fe (mean concentrations of 25.0 µg g^{-1} and 31.3 µg g^{-1}, respectively). Zn (6.8 µg g^{-1}) and Cu (14.1 µg g^{-1}) had the lowest concentration in coffee samples (Stelmach et al., 2013).

In this study, it is aimed to determine and compare essential (Na, Se, P, Zn, K, Mn, Mg, Co, Fe, Cu, Cr, B, and Ca) and non-essential (Pb, Ni, Ba, and Al) element content of ten types of coffees (classic, milicano, green, gold, decaffeinated, filter and Turkish coffee) from four different product (P1, P2, P3, and P4). For this purpose; infusion process of the selected coffee samples was acquired and element concentrations were interfered with by ICP-OES. Moreover, a health risk assessment study involving non-carcinogenic and carcinogenic risks was accomplished.

2. Materials and Methods

Classic, green, gold, and decaffeinated coffee from Product 1, milicano and gold coffee from Product 2, gold and decaffeinated coffee from Product 3, and filter and Turkish coffee from Product 4 were supplied from a provincial market in Türkiye. GFL distillation unit water purification system (Lauda, GFL) was used to obtain pure water (0,07 µs/cm). PerkinElmer Optima 2100 DV ICP-OES (PerkinElmer Inc., MA, USA) equipped with an AS-93 autosampler was utilized to analyze the element contents of samples. ICP-OES analysis was acquired with power of 1.45 kW, a plasma flow of 15.0 L min^{-1}, an auxiliary flow of 0.8 L min^{-1}, and a nebulizer flow of 1 L min^{-1}. Nitric acid (HNO^3) in 65% purity was obtained from Merck chemicals (Merck KgaA, Darmstadt, Germany) for the standard solution preparation. 2 grams of each coffee sample were weighed and infused with 100 ml of pure water nearly at boiling point (90-100°C), separately. After five minutes, extracted coffee samples were filtered and the filtered coffees were made up with distilled water. For the preparation of the standard solution; 0.3% HNO_3 solution was prepared with ultra-pure water and placed in a standard tube and the elements to be determined were added to the acid solution in predetermined amounts. In the last step, ICP-OES analysis was accomplished for the diluted coffee samples. 3 parallel experiments were conducted and from the analyses results one-way analysis of variance (ANOVA) was used to evaluate significant differences in the data at $P < 0.05$.

2.1. Health Risk Assessment

Non-carcinogenic risk

THQ is the risk factor applied to noncarcinogens and it associates the dose distributed at the exposure point to a toxicological end-point (Bleam, 2016). THQ value below 1 means there is not non-carcinogenic health effect condition. On the other hand, if the THQ is above 1 then there may be contrary health influences. Hazard index (HI) indicates an entire number of the single target hazard quotients of the analysed elements for each type of beverage or food. In the basis of HI, a particular type of food intake would result in coincident disclosure to various potentially toxic elements (Antoine et al., 2017). THQ and HI can be calculated by using the below Equations (1) and (2) (Demir et al., 2020).

$$THQ = \frac{EF \times ED \times FIR \times C}{RfD \times B_W \times A_T} \quad \text{(Eq. 1)}$$

$$\mathrm{HI} = \sum_{i}^{n} \mathrm{THQ_i} \quad \text{(Eq. 2)}$$

where EF is 365 days/year; ED is 73 years; FIR is in mL/person/day; C is in mg/L; RfD (mg/kg/day) is specific to the trace element being assessed; Bw is 60 kg and AT is 365 days/year × 73 years. The RfD data are 1 for Al, 2 × 10-1 for Ba, 2 × 10-2 for Ni and 36 × 10-4 for Pb (Demir et al., 2020; WHO, 2023; Yalcin Gorgulu et al., 2022).

Carcinogenic risk

TCR identifies the possible risk estimation attached to carcinogenic agents receiving end during the lifespan disclosure interval. Behalf an oral reference dose, a CSF is utilized in the decision of TCR. The presumption of overabundance cancer risk throughout the lifetime of the endangered person together with the carcinogen dose is determined within this factor (Antoine et al., 2017). TCR is calculated by applying Equation 3:

$$TCR = \frac{C \times CSF \times ED \times EF \times FIR}{A_T \times B_W} \quad \text{(Eq. 3)}$$

where CSF is in (mg/kg/day)-1 and the CSF values are 17 × 10-1 for Ni and 85 × 10-4 for Pb (Demir et al., 2020).

3. Results and Discussion

The resulting data about the essential and non-essential element contents in selected coffee types are given in *Table 1* and limits of detection and quantification values by ICP-OES are also included in *Table 2*. According to the results, the most abundant element in all analysed coffees was Potassium (K) with the highest concentration of 1186 mg/L in Milicano coffee of P2. Other elements differ according to the type of coffee for several reasons such as coffee plant growing conditions, different processing techniques, errors that may occur during experimental studies. If the coffees are examined according to the essential element contents; the elements in Classic (P1) can be shown as K > Mg > Ca > P > Na > B > Mn > Fe > Se > Co, respectively. Likewise, the elements found in Gold (P1) are K > Mg > P > Ca > Na > B > Mn > Fe> Zn > Se > Cu, and the elements found in Green (P1), Millicano (P2) are K > Mg > P > Ca > Na > Fe > B > Mn, respectively.

The elements in Filter coffee of P2 are K > P > Mg > Ca > Na > Mn > B > Cu > Fe > Zn, in Turkish Coffee (P4) are K > Ca > Mg > P > Na > B > Mn > Zn > Cu > Fe , in Gold coffee (P3) are K > Mg > P > Ca > Na > Mn > Fe > B > Se > Zn > Cr > Co, in Decaf (P3) can be shown as K > Mg > Na > P > Ca > Fe > B > Zn > Mn > Se, respectively.

When the coffees are assessed according to the non-essential element contents, Al is the highest element except Milicano coffee of P2 and decaffeinated coffees of Product 1 and Product 3. Non-essential elemental contents of Classic (P1), Milicano (P2), Gold (P1), Gold (P2), Gold (P3), Decaffeinated (P3), Decaffeinated (P1) are Al > Ni > Ba; Ba > Ni > Al; Al > Ba > Ni; Al > Ba > Pb > Ni; Al > Ba > Pb; Ba > Al > Pb; Ba > Al > Pb > Ni. Non-essential element contents of Green coffee (P1), Filter coffee (P2) and Turkish Coffee (P4) are Al > Ba. Lead is not detected in whole coffees except gold coffees of P2 and P3 and decaffeinated coffees of P1 and P3. As, Cd, Mo, Sb, Ti were not detected in all type of coffees. Essential and non-essential element contents of all selected coffee varieties are statistically analysed and resulted in confidence interval with $p < 0.1$.

The elements found in Gold (P2) are K > Mg > P > Ca > Na > Fe > B > Se > Mn > Zn > Co > Cu > Cr, respectively. The elements found in Decaf (P1) are K > Mg > P > Ca > Na > Zn > Mn > Fe > B > Se > Co > Cr.

Table 1. Essential and non-essential element contents in various types of coffees

Element	Classic (P1)	Milicano (P2)	Green (P1)	Gold (P1)	Gold (P2)
B (µg/L)	225.00±7.1	134.50±9.2	271.50±20.5	171.00±4.2	137.50±2.1
Ca (mg/L)	57.00±4.48	21.07±0.04	21.40±0.51	22.58±2.16	21.01±0.47
Co (µg/L)	6.70±0.4	n.d.	12.50±0.7	n.d.	12.50±0.7
Cr (µg/L)	n.d.	n.d.	13.10±1.3	n.d.	6.00±0.7
Cu (µg/L)	n.d.	5.0±0.0000	8.00±0.7	4.70±0.4	6.60±0.6
Fe (µg/L)	104.00±4.2	409.50±24.7	361.00±15.6	86.50±0.7	287.50±3.5
K (mg/L)	649.50±24.3	1186.00±41.0	728.00±6.7	659.30±32.9	571.90±48.6
Mg (mg/L)	60.52±1.33	50.89±0.16	76.56±0.62	59.97±0.73	53.54±4.00
Mn (µg/L)	206.50±4.9	130.50±0.7	140.00±1.4	170.50±2.1	115.00±7.1
Na (mg/L)	20.60±0.74	13.50±0.01	8.40±0.45	13.36±0.49	10.79±0.02
P (mg/L)	51.49±2.67	43.51±0.20	63.78±2.23	50.78±0.71	53.00±0.35
Se (µg/L)	49.50±3.5	45.00±1.4	77.00±2.8	29.00±2.8	125.50±7.8
Zn (µg/L)	n.d.	n.d.	44.00±2.8	52.00±1.4	49.00±2.8
Al (µg/L)	57.50±2.1	8.50±0.7	34.00±1.4	57.50±2.1	33.00±2.8
As	n.d.	n.d.	n.d.	n.d.	n.d.
Ba (µg/L)	16.50±0.7	22.50±0.7	25.00±0.7	19.50±0.7	20.00±1.4
Cd	n.d.	n.d.	n.d.	n.d.	n.d.
Mo	n.d.	n.d.	n.d.	n.d.	n.d.
Ni (µg/L)	26.50±2.1	12.50±0.7	n.d.	7.50±0.7	7.50±0.7
Pb (µg/L)	n.d.	n.d.	n.d.	n.d.	11.50±0.7
Sb	n.d.	n.d.	n.d.	n.d.	n.d.
Ti	n.d.	n.d.	n.d.	n.d.	n.d.
Element	**Gold (P3)**	**Decaffeinated (P3)**	**Decaffeinated (P1)**	**Filter (P2)**	**Turkish Coffee (P4)**
B (µg/L)	193.50±2.1	270.0±21.2	155.50±10.6	68.50±6.4	133.00±12.7
Ca (mg/L)	34.93±1.54	35.33±2.10	37.49±0.70	7.98±0.45	78.49±3.22
Co (µg/L)	7.50±0.7	n.d.	15.00±1.4	n.d.	n.d.
Cr (µg/L)	11.50±0.7	n.d.	10.50±0.7	n.d.	n.d.
Cu (µg/L)	n.d.	n.d.	n.d.	28.50±2.1	9.50±0.7
Fe (µg/L)	384.00±32.5	934.00±93.3	287.50±4.9	15.50±0.7	8.00±0.7
K (mg/L)	711.60±27.9	770.00±3.5	607.50±27.0	372.90±13.3	294.80±11.7
Mg (mg/L)	129.05±2.05	69.45±0.16	160.80±12.16	19.40±0.67	21.46±0.23
Mn (mg/L)	1.89±0.0587	0.16±0.0007	0.33±0.0007	0.10±0.0042	0.07±0.0028
Na (mg/L)	21.67±1.97	53.23±0.48	4.52±0.12	0.83±0.01	0.81±0.01
P (mg/L)	71.09±4.30	44.29±0.08	67.31±2.72	20.14±0.47	17.99±0.28
Se (µg/L)	139.00±9.9	12.0±0.7	95.00±1.4	n.d.	n.d.
Zn (µg/L)	57.00±2.8	189.00±2.8	575.00±49.5	6.70±0.4	61.50±2.1
Al (µg/L)	57.50±0.7	43.00±0.6	56.50±2.1	25.50±2.1	15.50±0.7
As (µg/L)	n.d.	n.d.	n.d.	n.d.	n.d.
Ba (µg/L)	27.50±0.7	72.50±0.7	68.50±0.7	16.00±0.6	8.00±0.7
Cd	n.d.	n.d.	n.d.	n.d.	n.d.
Mo	n.d.	n.d.	n.d.	n.d.	n.d.
Ni (µg/L)	n.d.	n.d.	7.50±0.7	n.d.	n.d.
Pb (µg/L)	20.50±0.7	36.00±2.8	19.00±1.4	n.d.	n.d.
Sb	n.d.	n.d.	n.d.	n.d.	n.d.
Ti	n.d.	n.d.	n.d.	n.d.	n.d.

*n.d.: Not detected

Table 2. Limits of detection and quantification values by ICP-OES

Element	Limits of detection (mg/L)	Limits of quantification (mg/L)
Ca	0.0063	0.0209
Co	0.0005	0.0016
Cr	0.0001	0.0005
Cu	0.0004	0.0013
Fe	0.0017	0.0055
K	0.0015	0.0049
Mg	0.0010	0.0035
Mn	0.0004	0.0013
Na	0.0029	0.0096
P	0.0038	0.0125
Se	0.0036	0.0120
Zn	0.0002	0.0006
Al	0.0020	0.0069
As	0.0015	0.0053
Ba	0.0018	0.0053
Cd	0.0003	0.0012
Mo	0.0003	0.0011
Ni	0.0008	0.0028
Pb	0.0018	0.0060
Sb	0.0007	0.0024
Ti	0.0003	0.0012

Daily element intake percentages of 300 mL/day selected coffee consumption are also calculated for a person according to gender and given in *Table 3*. According to the table, the highest element intake percentage of a female is Mg for all types of coffee with the highest concentration of 15.561% (decaffeinated coffee, P1). For a male, Mg element intake percentage is also the highest except Milicano and filter coffee of P2 and Turkish coffee of P4. The highest Mg intake percentage of a male can be seen in decaffeinated coffee, P1 as 12.060%.

3.1. Risk assessment

Risk assessment is undertaken to assess the probability of a particular potential harmful health effect occurring over a period of time (Mohammadi et al., 2019).

3.1.1 Non-carcinogenic risk

To evaluate noncarcinogenic human health risks from heavy metal intake, THQ data of non-essential elements in selected coffees were determined and presented in *Table 4*. For the determination of THQ values for each element and coffee type, Equation (1) was utilized. Since the THQ results of each metal for the analysed coffee sample were calculated at less than 1, these coffees can be consumed within safe limits (Yalcin Gorgulu et al., 2014). HI generated by non-essential elements was measured by employing THQ values of the coffee samples and Equation (2). Since the HI number of coffees was estimated below 1, ingestion of 300 mL of these coffees is described in a low-risk group.

3.1.2 Carcinogenic risk

The increased possibility of developing cancer as a result of exposure to a potential carcinogen during a person's lifetime has been defined as target carcinogen risk (TCR) by the US EPA. In the Guidelines for Carcinogen Risk Assessment, the measure of tolerable risk is between 1×10^{-6} and 1×10^{-4}. TCR numbers of evaluated coffee samples were measured and presented in *Table 4*. Consistent with the results, the TCR value was calculated lower than 1×10^{-4} for whole coffees except Classic (P1). Classic coffee of P1 should be consumed less than 300 mL/day as its TCR value is higher than 1×10^{-4}.

Table 3. Daily element intakes (%) for a person who drinks 3 cup of coffee daily (300 mL)

Element	Gender	Classic (P1)	Milicano (P2)	Green (P1)	Gold (P1)	Gold (P2)
B	M	0.338	0.202	0.407	0.257	0.206
Ca	M	0.684 - 1.710	0.253 - 0.632	0.257 - 0.642	0.271 - 0.677	0.252 - 0.630
Co	M	0.201	n.a.	0.375	n.a.	0.375
Cr	M	n.a.	n.a.	11.23	n.a.	5.14
Cr	F	n.a.	n.a.	15.72	n.a.	7.20
Cu	M	n.a.	0.015 - 0.167	0.024 - 0.267	0.014 - 0.157	0.020 - 0.218
Fe	M	0.069 - 0.390	0.273 – 1.536	0.241 – 1.354	0.058 – 0.324	0.192 – 1.078
Fe	F	0.069 – 0.173	0.273 – 0.683	0.241 – 0.602	0.058 – 0.144	0.192 – 0.479
K	M	4.145	7.570	4.646	4.208	3.650
Mg	M	4.539	3.816	5.742	4.497	4.015
Mg	F	5.857	4.924	7.409	5.803	5.181
Mn	M	0.563 – 2.693	0.356 – 1.702	0.382 – 1.826	0.465 – 2.224	0.314 – 1.500
Mn	F	0.563 – 3.442	0.356 – 2.175	0.382 – 2.333	0.465 – 2.842	0.314 – 1.917
Na	M	0.269 – 0.412	0.176 – 0.270	0.110 – 0.168	0.174 – 0.267	0.141 – 0.216
P	M	0.386 – 2.207	0.326 – 1.865	0.478 – 2.733	0.381 – 2.176	0.398 – 2.271
Se	M	3.71 – 27.00	3.38 – 24.55	5.78 – 42.00	2.18 – 15.82	9.41 – 68.45
Zn	M	n.a.	n.a.	0.033 – 0.120	0.039 – 0.142	0.037 – 0.134
Zn	F	n.a.	n.a.	0.033 – 0.165	0.039 – 0.195	0.037 – 0.184
Element	**Gender**	**Gold (P3)**	**Decaffeinated (P3)**	**Decaffeinated (P1)**	**Filter (P2)**	**Turkish Coffee (P4)**
B	M	0.290	0.405	0.233	0.103	0.200
Ca	M	0.419 - 1.048	0.424 - 1.060	0.450 - 1.125	0.096 - 0.239	0.942 - 2.355
Co	M	0.225	n.a.	0.450	n.a.	n.a.
Cr	M	9.86	n.a.	9.00	n.a.	n.a.
Cr	F	13.80	n.a.	12.60	n.a.	n.a.
Cu	M	n.a.	n.a.	n.a.	0.086-0.950	0.029-0.317
Fe	M	0.256 – 1.440	0.623 – 3.503	0.192 – 1.078	0.010 – 0.058	0.005 – 0.030
Fe	F	0.256 – 0.640	0.623 – 1.557	0.192 – 0.479	0.010 – 0.026	0.005 – 0.013
K	M	4.542	4.915	3.878	2.380	1.882
Mg	M	9.679	5.208	12.060	1.455	1.610
Mg	F	12.489	6.720	15.561	1.877	2.077
Mn	M	5.164 – 24.698	0.438 – 2.093	0.899 – 4.298	0.275 – 1.317	0.202 – 0.965
Mn	F	5.164 – 31.558	0.438 – 2.675	0.899 – 5.492	0.275 – 1.683	0.202 – 1.233
Na	M	0.283 – 0.433	0.694 – 1.065	0.059 – 0.090	0.011 – 0.017	0.011 – 0.016
P	M	0.533 – 3.047	0.332 – 1.898	0.505 – 2.885	0.151 – 0.863	0.135 – 0.771
Se	M	10.43 – 75.82	0.86 – 6.27	7.13 – 51.82	n.a.	n.a.
Zn	M	0.043 – 0.155	0.142 – 0.515	0.431 – 1.568	0.005 – 0.018	0.046 – 0.168
Zn	F	0.043 – 0.214	0.142 – 0.709	0.431 – 2.156	0.005 – 0.025	0.046 – 0.231

M: male, F: female
n.a.: not available

Table 4. THQ, HI and TCR values of risk elements in analysed coffee samples

Element	Classic (P1)	Milicano (P2)	Green (P1)	Gold (P1)	Gold (P2)
Al	0.0002875	0.0000425	0.00017	0.0002875	0.000165
Ba	0.0004125	0.0005625	0.000625	0.0004875	0.0005
Ni	0.006625	0.003125	n.d.	0.001875	0.001875
Pb	n.d.	n.d.	n.d.	n.d.	0.015972
Σ HI	0.007325	0.00373	0.000795	0.00265	0.018512222
Pb	n.d.	n.d.	n.d.	n.d.	4.8875E-07
Ni	0.000225	0.000106	n.d.	0.00006375	0.00006375
Σ TCR	0.000225	0.000106	n.d.	0.00006375	6.42E-05
Element	**Gold (P3)**	**Decaffeinated (P3)**	**Decaffeinated (P1)**	**Filter (P2)**	**Turkish Coffee (P4)**
Al	0.0002875	0.000215	0.0002825	0.0001275	0.0000775
Ba	0.0006875	0.0018125	0.0017125	0.0004	0.0002
Ni	n.d.	n.d.	0.001875	n.d.	n.d.
Pb	0.028472	0.05	0.026389	n.d.	n.d.
Σ HI	0.029447222	0.0520275	0.030258889	0.0005275	0.0002775
Pb	8.7125E-07	0.00000153	8.075E-07	n.d.	n.d.
Ni	n.d.	n.d.	0.00006375	n.d.	n.d.
Σ TCR	8.7125E-07	0.00000153	6.46E-05	n.d.	n.d.

*n.d.: Not detected

4. Conclusions

Essential and non-essential element concentrations in some commercial coffees was analysed by ICP-OES and health risk assessment of these coffees were concluded. In all coffee types, it was seen that K element concentration was the highest as essential element. Al concentration was the highest non-essential element in Classic, Green, Gold coffee of P1, Gold coffee and filter coffee of P2, Gold coffee of P3 and Turkish coffee of P4. Ba concentration was the highest non-essential element in decaffeinated coffee of P1 and P3, and Milicano coffee of P2. As, Cd, Mo, Sb, Ti as non-essential elements were not detected in all type of coffees. Results are statistically significant with p value less than 0.1 ($p<0.1$) and in confidence interval. Taking into consideration that HI values of all samples were less than 1, daily consumption of 300 mL of these coffees is defined in low-risk group. Furthermore, the TCR value was calculated lower than 1×10^{-4} for all coffee species except Classic (P1). Classic coffee of P1 should be consumed less than 300 mL/day since its TCR value is higher than 1×10^{-4}.

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Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Kipcak, A.S., Derun, E.; Design: Kipcak, A.S., Derun, E.; Data Collection or Processing: Demir, F.; Statistical Analyses: Uygunoz, D., Kipcak, A.S., Derun, E.; Literature Search: Demir, F., Uygunoz, D.; Writing, Review and Editing: Uygunoz, D., Kipcak, A.S., Derun, E.

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