J. Fac. Pharm. Ankara / Ankara Ecz. Fak. Derg., 48(1): 86-96, 2024
Doi: 10.33483/jfpau.1279257
ORIGINAL ARTICLE / ÖZGÜN MAKALE

DETERMINATION OF TOXIC METALS IN SOME FOOD SUPPLEMENTS BY ICP-MS

ICP-MS İLE BAZI GIDA TAKVİYELERİNDEKİ TOKSİK METALLERİN BELİRLENMESİ

Çağatay OLTULU[1]*, Mustafa DAŞMAN[1]

[1]Trakya University, Faculty of Pharmacy, Department of Pharmaceutical Toxicology, 22030, Edirne, Türkiye

ABSTRACT

Objective: *The presence of toxic metals in foods poses a significant risk to human health. Even low-level exposure to these metals can cause various health problems over a long period of time. In this study, we investigated the levels of toxic metals (Li, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Cd, Sb, Ba, Pb and Bi) in 34 food supplement samples purchased from pharmacies in Edirne.*
Material and Method: *The samples were digested using HNO_3 in a microwave system and the metal content was analyzed using ICP-MS.*
Result and Discussion: *Our results showed that none of the food supplements exceeded Turkish authority limits. Only Cd levels of two food supplements (0.431 µg/g and 0.316 µg/g) exceeded WHO guideline limits. We discussed the potential health effects of these metals and their compounds. Our findings suggest the need for increased regulation and monitoring of food supplements to ensure their safety and quality.*
Keywords: *Cadmium, dietary supplements, heavy metals, trace elements*

ÖZ

Amaç: *Gıdalarda toksik metallerin bulunması insan sağlığı için önemli bir risk oluşturmaktadır. Bu metallerin düşük dozda dahi uzun süreli maruziyeti çeşitli sağlık sorunlarına neden olabilir. Bu çalışmada, Edirne ili eczanelerinden satın alınan 34 gıda takviyesi örneğinde toksik metallerin (Li, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Cd, Sb, Ba, Pb ve Bi) seviyeleri araştırılmıştır.*
Gereç ve Yöntem: *Örnekler mikrodalga sistemde HNO_3 kullanılarak sindirilmiş ve metal içeriği ICP-MS kullanılarak analiz edilmiştir.*
Sonuç ve Tartışma: *Sonuçlarımız, hiçbir gıda takviyesinin Türk otorite sınırlarını aşmadığını göstermiştir. Sadece iki gıda takviyesinin Cd seviyeleri (0.431 µg/g ve 0.316 µg/g) Dünya Sağlık Örgütü (WHO) kılavuz sınırlarını aşmıştır. Bu metallerin ve bileşiklerinin potansiyel sağlık etkileri tartışılmıştır. Bulgularımız, gıda takviyelerinin güvenliği ve kalitesinin sağlanması için artan düzenleme ve izleme ihtiyacını göstermektedir.*
Anahtar Kelimeler: *Ağır metaller, eser elementler, kadmiyum, takviye edici gıdalar*

INTRODUCTION

Dietary supplements are defined in the Turkish Food Codex Regulation on Dietary Supplements as products that are prepared in capsule, tablet, lozenge, single-use powder packet, liquid ampoule, dropper bottle, and other similar liquid or powder forms, with a daily intake dose specified, of concentrated or extracted nutrients such as vitamins, minerals, proteins, carbohydrates, fiber, fatty acids,

* **Corresponding Author / Sorumlu Yazar:** Çağatay Oltulu
e-mail / e-posta: cagatayo@trakya.edu.tr, **Phone / Tel.:** +902842350180

Submitted / Gönderilme : 07.04.2023
Accepted / Kabul : 21.10.2023
Published / Yayınlanma : 20.01.2024

amino acids, or other nutrients, or plant, herbal, and animal-based substances, bioactive substances, and similar substances with nutritional or physiological effects, for the purpose of supplementing normal nutrition [1]. These food supplements are generally produced from plant-based substances or different natural sources. While it is easier for people to think that medicinal herbs, phytotherapy, and natural food supplements do not show adverse effects on health, it is important to note that the consumption of these substances can also pose potential risks and adverse effects on health [2]. Additionally, the quality and purity of herbal products and supplements can show variability, which can also affect their safety and efficacy [3]. Therefore, it is necessary to monitor the content of potentially toxic elements in these products. In addition to the different metals present in these products, plant material may be contaminated with pesticides, microbial contaminants, and other chemical toxins [4]. They can also be contaminated during chemical treatment or storage [5].

The European Commission has set maximum levels for certain contaminants in foods in Commission Regulation (EC) No 1881/2006 [6]. These regulations are also available in Turkish Food Codex Legislation [7]. In addition to other maximum levels of contaminants such as dioxins, nitrates, melamine, mycotoxins, and polycyclic aromatic hydrocarbons, certain metals such as lead, cadmium, arsenic, mercury, and tin are explained in these regulations.

The use of food supplements as a means of improving health and wellness has become increasingly popular in recent years. This trend has increased due to the health impact of the COVID-19 pandemic on the community to strengthen their immune system and protect their overall health [8]. While these products are often marketed as being safe and effective, there is growing concern about the potential presence of harmful substances, including metals. In particular, toxic metals such as lead, cadmium, arsenic and nickel pose inherent health risks even at relatively low concentrations. The toxic effects of metals such as lead, cadmium, arsenic, and nickel encompass a spectrum of health consequences. Lead exposure, especially in children, can result in plumbism, manifesting with cognitive impairments, neurological deficits, and developmental issues. Lead, inorganic lead, and organic lead compounds categorized for humans as Group 2B (Possibly carcinogenic), Group 2A (Probably carcinogenic), and Group 3 (Not classifiable as carcinogenic), respectively [9,10].

Cadmium is implicated in kidney damage, lung pathologies, and bone disorders, and it is established as a carcinogen, particularly associated with lung cancer upon extended exposure therefore classified as class 1 (Carcinogenic for humans) carcinogens by the The International Agency for Research on Cancer (IARC). Arsenic, when chronically consumed, is linked to carcinogenic effects, notably skin, lung, and bladder cancers, and classified as class 1 carcinogens by the IARC. Arsenic can also induce skin lesions, cardiovascular complications, and neurotoxicity. Nickel, upon prolonged dermal contact, can lead to skin allergies, such as dermatitis. Nickel compounds are classified as class 1 carcinogens by IARC with substantial evidence suggesting their capability to induce cancer in humans [10,11].

Some metals (such as Cr, Mn, Zn, Fe, Co, Cu, Al) are essential nutrients at trace levels and play vital roles in various physiological processes, they can become detrimental to health when ingested in excessive amounts [11].

Metals are usually determined by techniques, such as inductively coupled plasma optical emission spectrometry (ICP-OES) [12], atomic absorption spectrometry (AAS) [13], and inductively coupled plasma mass spectrometry (ICP-MS) [14]. For a convenient result, a sensitive analysis technique such as ICP-MS, more advanced than the generally used AAS, is performed in this study. This technique is widely recognized as one of the most sensitive and accurate methods for the determination of trace metals in a wide range of matrices, including food supplements. In addition to its sensitivity and accuracy, ICP-MS is also highly versatile. It can be used to analyze a wide range of sample types, including solids, liquids, and gases, and can be applied to a variety of different matrices. It provides also fast, with good reproducibility and low sample preparation requirements [15].

This study aimed to assess the metal content of food supplements in order to better understand the potential risks to human health. 34 food supplement samples randomly purchased from pharmacies in Edirne, Turkey and, analyzed them for 17 different metals content (Li, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Sr, Cd, Sb, Ba, Pb, and Bi) by using ICP-MS. Our findings provide insights into the recent status of Turkish food supplement market product safety and quality.

MATERIAL AND METHOD

Chemicals and Apparatus

All solutions were prepared with reagent grade chemicals and ultra-pure water (18 MΩ cm); nitric acid was ultrapure from Sigma Aldrich (St. Louis, MO, USA). The element standard solutions were prepared by diluting 1000 mg/l stock solution (ICP standard CertiPUR, Merck, Germany). Digestion of samples are conducted by using a closed microwave digestion system CEM Mars 5 (CEM Corporation, Mathews, North California, USA). Agilent 7700 Series ICP-MS instrument (Agilent Technologies, Waldbronn, Germany) was employed for metal analysis.

Samples

In our study, 34 dietary supplement samples were randomly selected and purchased as one package from those available in pharmacies in Edirne, Turkey. The dietary supplements had not expired, and their packages were unopened and intact. The intended uses of these supplements were diverse, including maintaining health and mental function, sexual enhancement, strengthening the immune system, and regulating the bone system, among others. The supplements were available in a variety of dosage forms, including bars, tablets, powders, lozenges, pastes, and capsules. The information about the samples is shown in Table 1.

Table 1. Sample properties

Sample No	Form of the Product	Product Specifications from Its Label	One Serving Size	Purpose of the Product
1	Bar	A Protein Bar	35 g	Sports
2	Paste	Bee Product Mixed with Herbs	7 g	Immunity
3	Tablet	Multivitamin	1.042 g	Bone System
4	Tablet	Contains Vitamin C	0.75 g	Immunity
5	Capsule	*Boswellia Serrata* Extract	0.46 g	Osteoarthritis
6	Tablet	Contains Vitamin D	0.333 g	Bone System, Immunity
7	Powder	Concentrated Herbal Tea	1.7 g	Weight Loss
8	Tablet	Contains *Panax ginseng*, Multivitamin and Minerals.	0.72 g	Maintaining Health, Immune System Enhancement
9	Tablet	Contains *Panax ginseng*, Multivitamin and Minerals	0.75g	Maintaining Health, Immune System Enhancement
10	Capsule	Contains Fish Oil	1.4 g	Heart health, Conditioning Mental Stability
11	Powder	Nutritious Meal Replacement Shake Mix	26.19 g	Weight Loss
12	Tablet	Contains Vitamin C, Green Tea, Caffeine and Mate Leaf	0.877 g	Weight Loss
13	Tablet	Contains Multivitamin and Minerals	0.9 g	Maintaining Health, Immune System Enhancement
14	Lozenge	Contains Eucalyptus, Mint and Menthol	2.8 g	Immunity, Sore Throat
15	Lozenge	Contains Vitamin C, Honey, Zinc and *Sambucus nigra*	2.5 g	Immunity, Sore Throat
16	Lozenge	Contains Linden, Lemon and Propolis	2,8 g	Immunity, Sore Throat
17	Tablet	Contains High Amounts of Calcium and Vitamin D	1.456 g	Bone System
18	Capsule	Contains Omega 3, Multivitamin and Minerals	2 g	Pregnancy Support
19	Tablet	Vitamin and Mineral Complex for Women	1.405 g	Maintaining Health, Immune System Enhancement
20	Powder	Sports Food Supplement Contains Amino Acid	26g	Sports, Muscle Building
21	Capsule	Contains Vitamin C, Zinc and *Sambucus nigra*	1 g	Maintaining Health, Immune System Enhancement
22	Powder	Contains Vitamin C, Zinc and *Sambucus nigra*	7.5 g	Maintaining Health, Immune System Enhancement

Table 1 (*continue*). Sample properties

Sample No	Form of the Product	Product Specifications from Its Label	One Serving Size	Purpose of the Product
23	Powder	Contains Multivitamin, Minerals and *Sambucus nigra*	5 g	Maintaining Health, Immune System Enhancement
24	Powder	Contains Creatine, Arginine, Beta alanine, Multivitamins, and Minerals.	7 g	Maintaining Health, Immune System Enhancement, Skin, and Hair Health
25	Paste	Bee Product Mixed with Herbs	7 g	Immunity
26	Powder	Probiotic Supplement	0.75 g	Intestinal regulator
27	Powder	Probiotic Supplement	2 g	Intestinal regulator
28	Powder	Contains Vitamin C and Zinc	1.5 g	Immunity
29	Powder	Contains Iron, Multivitamin and Minerals	1 g	Iron deficiency, Immunity
30	Tablet	Herbal Drug	0.259 g	Constipation Regulation
31	Powder	Food Supplement Containing L-Carnitine, L-Arginine, PABA, Coenzyme Q10, Multivitamin and Plant Extracts	5 g	Sexual Enhancement
32	Powder	Contains Mixed Herbs	5 g	Constipation Regulation
33	Capsule	Contains *Carthamus tinctorius* Oil	1.385 g	Weight Loss
34	Capsule	Contains *Opuntia ficus-indica* Extract, *Cinnamomum zeylanicum* Extract and Chromium	0.477 g	Weight Loss

Sample Preparation

Firstly, the homogenization of the food supplement samples is executed by using a mechanical homogenizer. This step was designed to ensure that the samples were well-mixed and representative of the entire batch. Then, a precise amount of each sample, typically in the range of 0.5 g is weighed. Nitric acid (%65) was used for the digestion of samples. Digestion of samples is executed by CEM Mars 5 closed microwave digestion system. Microwave parameters are shown in Table 2.

Table 2. Microwave device parameters

Level	Max. Power (%)	Power (W)	Time (min.)	Pressure (psi)	Temperature (°C)	Standby (min)
1	100	1800	20	800	210	15

Metal Analysis

Determination of metals in food supplement samples was performed by using the Agilent 7700 ICP-MS instrument. To proceed with the analysis, the procedure outlined in Environmental Protection Agency (EPA) Method 200.8 was followed [16]. ICP-MS Device Parameters are shown in Table 3.

Table 3. Parameters of the ICP-MS device used for element analysis

ICP-MS Device Parameters			
Power: 1550 W	Sample Acquisition Rate: 0.3 rps	OctP RF: 180 V	Deviation: 13 V
Depth: 8 mm	Max Blank Concentration: %100	Stabilization Time: 50 sec	OctP Slope: -8 V
Nebulizer Pump: 0.1 rps	Matching Voltage: 1.80 V	Energy Separator: 5 V	Calibration Curve Confidence Interval: 0.95
Omega Lens: 10 V	Carrier Gas Flow Rate: 1.05 L/min	Sample Acquisition Time: 50 sec	Relative Standard Deviation: %5
Cell Output: -50 V	S/C Temperature: 2°C	Layer Slope: -40 V	Cell Input: -30 V

ICP-MS analysis was employed to determine the metal content in food supplements by EPA Method 200.8. To evaluate the accuracy and precision of our analytical approach, recovery study was conducted with 25 ppb spike samples for each element. The results from the spike recovery study (Table 4) demonstrated the reliability and accuracy of our analytical method. The average recoveries for all elements were within acceptable ranges, indicating that our analytical method is capable of accurately measuring metal content in food supplement samples.

Table 4. Recovery values of the elements in spiked samples (n=10)

Metals	Recovery values (%)
^{7}Li [He]	101.51 ± 2.84
^{27}Al [He]	95.20 ± 2.10
^{51}V [He]	96.36 ± 2.00
^{52}Cr [He]	96.89 ± 2.14
^{55}Mn [He]	100.50 ± 2.25
^{56}Fe [He]	96.30 ± 6.20
^{59}Co [He]	101.35 ± 2.64
^{60}Ni [He]	100.09 ± 1.75
^{63}Cu [He]	98.87 ± 1.66
^{66}Zn [He]	102.38 ± 2.30
^{75}As [He]	100.10 ± 1.37
^{88}Sr [He]	96.96 ± 1.97
^{111}Cd [No Gas]	105.70 ± 1.98
^{121}Sb [No Gas]	102.40 ± 3.24
^{137}Ba [No Gas]	102.09 ± 1.42
^{208}Pb [No Gas]	100.56 ± 2.11
^{209}Bi [No Gas]	101.88 ± 2.06

The capabilities of the instrumentation were evaluated through the determination of the Limit of Detection (LOD) and Limit of Quantification (LOQ) using spike samples prepared at various concentrations for each individual metal. Moreover, the LOD values, which represent the minimum concentrations at which metals can be detected with a high degree of reliability, and the LOQ values, signifying the lowest concentrations at which these metals can be accurately measured with acceptable precision, were established for each specific element (Table 5).

Table 5. Method validation results of the studied elements

Metals	LOD (ppb)	LOQ (ppb)	%RSD
^{7}Li [He]	0.393	1.309	10.854
^{27}Al [He]	0.020	0.065	1.087
^{51}V [He]	0.007	0.023	0.284
^{52}Cr [He]	0.296	0.988	13.317
^{55}Mn [He]	0.040	0.133	1.863
^{56}Fe [He]	0.40	0.134	2.194
^{59}Co [He]	0.006	0.018	0.278

Table 5 (*continue*). Method validation results of the studied elements

Metals	LOD (ppb)	LOQ (ppb)	%RSD
^{60}Ni [He]	0.024	0.079	0.894
^{63}Cu [He]	0.042	0.140	1.522
^{66}Zn [He]	0.090	0.298	4.753
^{75}As [He]	0.009	0.031	0.383
^{88}Sr [He]	0.529	1.764	9.117
^{111}Cd [No Gas]	0.005	0.016	0.239
^{121}Sb [No Gas]	0.097	0.322	2.938
^{137}Ba [No Gas]	0.418	1.393	6.587
^{208}Pb [No Gas]	0.015	0.049	0.550
^{209}Bi [No Gas]	0.021	0.070	0.680

RESULT AND DISCUSSION

Toxic metals such as Al, Cd, Pb, As, Bi, Zn, Ba, and Ni are naturally present in the environment due to weather conditions, biological activities, and volcanic processes. However, human activities, including agricultural practices and industrial processes such as the use of chemical fertilizers and pesticides, irrigation of wastewater, intense coal combustion, and metalliferous mining, significantly amplify the contamination levels in soil, surface, and groundwater. As a result, these activities contribute to a substantial increase in the concentration of toxic elements in the environment.

The European Food Safety Agency (EFSA) and the Turkish Food Codex have established upper limits for lead and cadmium levels in toxic elements, which were evaluated in this study. The limit values for both metals are set at 3 μg/g [6,7]. Additionally, the European Pharmacopeia stipulates that the levels of cadmium in herbal drugs should be below 0.5 μg/g, while lead levels should not exceed 5.0 μg/g [17]. The World Health Organization (WHO) published an overview of the maximum limits for toxic metals set by countries in 2007, which recommends a limit of 10 μg/g for Pb and 0.3 μg/g for Cd in herbal products [18].

Heavy metals such as Cd, Pb, and As are among the most notable contaminants found in food supplements [9,15]. In the study we conducted Cd levels range from 0.002 μg/g to 0.431 μg/g, Pb levels range from 0.035 μg/g to 0.684 μg/g, and As levels range from 0.011 μg/g to 0.267 μg/g (Table 3 and 4). Our analysis of the supplements revealed that the lead and cadmium levels were below the established limits, except for samples 17 and 28. It is important to note that regulations regarding toxic metals only apply to the concentration of Pb, Cd, and Hg in plants, herbs, medicines, and food products. For other toxic metals, we have not found any authority establishments. Only, the water level of different toxic metal contaminations was established [19].

Lithium is not an essential element. Its presence in the environment can increase due to reasons such as the disposal of lithium-containing batteries. When taken through food and dietary supplements, lithium can compete to bind to carrier proteins for transport into cells due to its similarity to sodium and potassium and can cause toxic effects depending on the dose [20]. Our study found that lithium was present in very low levels ranging from 0 to 1.649 μg/g in the evaluated dietary supplements and below the recommended daily allowance level [20,21].

Natural and herbal food supplements have become increasingly popular in recent years, leading to a surge in production. As a result, the quality and safety of these supplements have become a major concern worldwide. Our research shows that most food supplements contain low levels of toxic metals (Tables 6 and 7). However, we found high concentrations of Cd (0.431 μg/g and 0.316 μg/g) in samples 17 and 28, respectively, which exceed the WHO limit for Cd in herbal products. Prolonged exposure to elevated concentrations of toxic metals can lead to a range of harmful health consequences, including skin and internal cancers, as well as cardiovascular and neurological effects [11,15]. As a result, it is essential to ensure that plants used for producing food supplements are completely devoid of harmful and toxic components.

Table 6. Levels of Li, Al, V, Cr, Mn, Fe, Co and Ni elements (µg/g) detected (n=3) by ICP-MS

Sample	Li	Al	V	Cr	Mn	Fe	Co	Ni
1	1.649 ±0.24	1.178 ±0.06	0.019 ±0.00	0.074 ±0.01	0.441 ±0.01	4.893 ±0.05	0.025 ±0.00	0.245 ±0.02
2	1.101 ±0.15	2.666 ±0.20	0.008 ±0.00	0.032 ±0.00	0.652 ±0.01	2.692 ±0.04	0.008 ±0.00	0.216 ±0.02
3	0.935 ±0.27	20.416 ±1.05	0.858 ±0.03	1.591 ±0.02	22.801 ±0.09	106.211 ±0.96	0.473 ±0.00	0.870 ±0.02
4	0.369 ±0.17	15.655 ±0.11	0.026 ±0.00	1.195 ±0.01	0.204 ±0.00	21.494 ±1.01	0.041 ±0.00	0.569 ±0.01
5	0.386 ±0.08	7.490 ±0.08	0.008 ±0.00	0.048 ±0.00	0.104 ±0.01	2.921 ±0.03	0.002 ±0.00	0.056 ±0.01
6	0.447 ±0.14	1.221 ±0.06	0.015 ±0.00	0.060 ±0.01	0.213 ±0.01	2.299 ±0.04	0.009 ±0.00	0.128 ±0.01
7	0.308 ±0.21	7.050 ±0.19	0.027 ±0.00	0.759 ±0.01	19.625 ±0.31	58.117 ±0.17	0.085 ±0.00	0.516 ±0.02
8	1.005 ±0.22	6.289 ±0.31	0.234 ±0.00	16.969 ±0.13	321.852 ±3.51	4634.714 ±46.41	1.811 ±0.03	1.393 ±0.02
9	0.621 ±0.21	13.419 ±0.40	0.303 ±0.01	0.714 ±0.01	269.875 ±1.09	2527.304 ±15.33	0.178 ±0.01	0.517 ±0.01
10	0.360 ±0.12	0.648 ±0.12	0.003 ±0.00	0.027 ±0.00	0.315 ±0.01	4.355 ±0.13	0.001 ±0.00	0.029 ±0.01
11	0.647 ±0.13	4.603 ±0.23	0.036 ±0.00	0.266 ±0.06	14.790 ±0.10	48.343 ±0.61	0.157 ±0.01	1.142 ±0.01
12	0.395 ±0.11	433.181 ±2.84	0.167 ±0.01	0.798 ±0.01	95.212 ±0.70	26.297 ±0.42	0.341 ±0.01	3.539 ±0.08
13	0.360 ±0.16	7.158 ±0.22	0.628 ±0.02	1.633 ±0.02	805.887 ±13.61	4781.454 ±72.38	0.737 ±0.03	1.148 ±0.03
14	0.264 ±0.05	0.359 ±0.12	0.003 ±0.00	0.097 ±0.00	0.11 ±0.01	1.997 ±0.08	0.001 ±0.00	0.035 ±0.01
15	0.194 ±0.13	1.37 ±0.38	0.013 ±0.00	0.087 ±0.00	2.112 ±0.01	4.672 ±0.02	0.022 ±0.00	0.057 ±0.00
16	0.220 ±0.06	0.476 ±0.12	0.004 ±0.00	0.053 ±0.00	0.072 ±0.00	1.061 ±0.07	0.002 ±0.00	ND
17	0.177 ±0.07	11.22 ±0.16	2.036 ±0.06	2.910 ±0.04	127.078 ±1.56	22.131 ±0.50	0.565 ±0.00	1.4 ±0.02
18	0.029 ±0.14	1.304 ±0.16	0.095 ±0.01	0.038 ±0.00	8.630 ±0.05	2325.056 ±7.60	0.365 ±0.00	0.262 ±0.01
19	0.029 ±0.09	16.597 ±0.29	0.206 ±0.01	8.044 ±0.07	107.294 ±0.86	2356.312 ±20.88	0.504 ±0.01	0.233 ±0.01
20	0.055 ±0.09	1.574 ±0.10	0.028 ±0.00	0.069 ±0.00	9.692 ±0.07	153.181 ±0.64	0.034 ±0.00	ND
21	ND	18.146 ±0.26	0.107 ±0.01	0.350 ±0.01	0.774 ±0.01	10.623 ±0.05	0.010 ±0.00	0.141 ±0.02
22	ND	0.548 ±0.04	0.005 ±0.00	0.122 ±0.00	4.047 ±0.05	10.312 ±0.09	0.024 ±0.00	0.157 ±0.02
23	0.133 ±0.11	0.337 ±0.03	0.013 ±0.00	0.246 ±0.01	4.655 ±0.09	158.878 ±2.20	0.048 ±0.00	0.203 ±0.00
24	0.020 ±0.05	1.392 ±0.49	0.021 ±0.00	0.420 ±0.01	0.543 ±0.00	661.933 ±2.01	0.005 ±0.00	0.007 ±0.01
25	0.046 ±0.15	13.399 ±0.60	0.015 ±0.00	0.049 ±0.00	5.095 ±0.03	8.912 ±0.18	0.030 ±0.00	0.381 ±0.02
26	0.090 ±0.10	0.150 ±0.03	0.005 ±0.00	0.828 ±0.02	0.153 ±0.00	2.405 ±0.02	0.009 ±0.00	0.111 ±0.01
27	0.125 ±0.02	0.059 ±0.05	0.004 ±0.00	0.018 ±0.00	4.476 ±0.05	0.582 ±0.03	0.009 ±0.00	ND
28	0.255 ±0.13	21.986 ±0.54	0.056 ±0.00	0.172 ±0.01	5.408 ±0.05	5.431 ±0.05	0.087 ±0.01	0.221 ±0.01
29	0.891 ±0.35	3.970 ±0.04	0.198 ±0.00	0.286 ±0.01	196.882 ±0.84	11930.25±128.86	1.693 ±0.04	0.234 ±0.01
30	0.133 ±0.07	0.941 ±0.14	0.006 ±0.00	0.918 ±0.02	0.074 ±0.01	3.271 ±0.00	0.003 ±0.00	0.086 ±0.01
31	0.090 ±0.08	0.565 ±0.05	0.012 ±0.00	0.325 ±0.01	0.323 ±0.01	3.609 ±0.01	0.211 ±0.00	0.134 ±0.02
32	1.318 ±0.08	103.515 ±1.50	0.353 ±0.01	0.288 ±0.01	25.966 ±0.29	95.965 ±2.05	0.250 ±0.00	0.790 ±0.03
33	0.186 ±0.06	0.157 ±0.05	0.002 ±0.00	0.029 ±0.00	0.008 ±0.00	1.097 ±0.02	0.001 ±0.00	ND
34	0.613 ±0.07	48.180 ±0.49	0.080 ±0.01	149.011 ±2.28	21.747 ±0.48	56.236 ±0.81	0.119 ±0.00	0.561 ±0.03

Abbreviations: Not Detected (ND)

Table 7. Levels of Zn, As, Sr, Cd, Sb, Ba, Pb, Bi and Cu elements (µg/g) detected (n=3) by ICP-MS

Sample	Zn	As	Sr	Cd	Sb	Ba	Pb	Bi	Cu
1	5.691 ±0.10	0.023 ±0.00	1.485 ±0.01	0.008 ±0.00	0.105 ±0.02	0.549 ±0.00	0.047 ±0.00	2.321 ±0.00	0.916 ±0.01
2	2.199 ±0.03	0.022 ±0.01	0.581 ±0.01	0.008 ±0.00	0.100 ±0.07	0.294 ±0.00	0.055 ±0.00	2.328 ±0.03	0.289 ±0.00
3	1.111 ±0.04	0.210 ±0.02	156.516 ±1.02	0.250 ±0.00	0.044 ±0.01	1.754 ±0.03	0.176 ±0.00	1.269 ±0.13	0.387 ±0.00
4	0.135 ±0.02	0.054 ±0.02	0.264 ±0.01	0.006 ±0.00	0.072 ±0.02	0.162 ±0.00	0.101 ±0.00	2.146 ±0.02	0.356 ±0.00
5	0.279 ±0.05	0.022 ±0.00	0.254 ±0.01	0.004 ±0.00	0.038 ±0.01	0.240 ±0.00	0.052 ±0.00	2.222 ±0.01	0.046 ±0.00
6	12.51 ±0.03	0.048 ±0.01	0.532 ±0.01	0.011 ±0.00	0.177 ±0.08	0.678 ±0.00	0.041 ±0.00	2.059 ±0.02	0.292 ±0.01
7	139.14 ±1.2	0.026 ±0.00	2.832 ±0.04	0.025 ±0.00	0.012 ±0.00	3.350 ±0.04	0.061 ±0.00	1.939 ±0.05	18.45 ±0.00
8	3500 ±19.3	0.099 ±0.02	61.733 ±0.62	0.204 ±0.00	0.120 ±0.03	0.759 ±0.00	0.167 ±0.00	1.596 ±0.02	242.85 ±1.2
9	331.6 ±2.32	0.033 ±0.01	13.142 ±0.06	0.027 ±0.00	0.037 ±0.00	1.375 ±0.01	0.074 ±0.00	1.839 ±0.01	209 ±0.49
10	0.446 ±0.03	0.025 ±0.01	0.124 ±0.01	0.010 ±0.00	0.030 ±0.02	0.275 ±0.00	0.045 ±0.00	2.444 ±0.45	0.298 ±0.01
11	99.67 ±1.73	0.017 ±0.00	6.280 ±0.08	0.051 ±0.00	0.011 ±0.00	2.359 ±0.00	0.065 ±0.00	1.906 ±0.02	18.08 ±0.02
12	11.71 ±0.14	0.044 ±0.01	25.29 ±0.52	0.224 ±0.01	0.060 ±0.07	15.32 ±0.04	0.206 ±0.01	1.738 ±0.02	7.065 ±0.07
13	5597 ±122	0.041 ±0.00	32.544 ±0.97	0.192 ±0.01	0.044 ±0.02	1.334 ±0.03	0.142 ±0.00	1.600 ±0.04	626.03 ±12
14	0.846 ±0.05	0.024 ±0.01	0.188 ±0.00	0.005 ±0.00	0.013 ±0.01	0.052 ±0.01	0.052 ±0.01	2.127 ±0.03	0.395 ±0.01
15	1303 ±7.30	0.019 ±0.00	19.122 ±0.15	0.012 ±0.00	0.008 ±0.00	18.39 ±0.22	0.062 ±0.00	2.019 ±0.03	0.770 ±0.02
16	0.547 ±0.04	0.012 ±0.01	0.266 ±0.01	0.002 ±0.00	0.007 ±0.00	0.128 ±0.00	0.043 ±0.00	2.114 ±0.03	0.252 ±0.00
17	1184 ±12.5	0.085 ±0.00	54.179 ±0.50	0.431 ±0.01	0.024 ±0.00	7.108 ±0.02	0.095 ±0.00	1.381 ±0.00	205.35 ±2.5
18	1547.2 ±4.9	0.012 ±0.00	0.101 ±0.00	0.033 ±0.00	0.009 ±0.01	0.054 ±0.00	0.199 ±0.00	2.164 ±0.00	0.194 ±0.00
19	1527.1 ±11	0.036 ±0.01	16.507 ±0.08	0.083 ±0.01	0.315 ±0.00	0.628 ±0.01	0.145 ±0.00	1.563 ±0.06	91.27 ±1.09
20	94.94 ±1.26	0.022 ±0.01	2.567 ±0.03	0.007 ±0.00	0.019 ±0.00	0.967 ±0.01	0.036 ±0.00	1.90 ±0.03	10.47 ±0.06
21	8135 ±76.5	0.018 ±0.01	1.5 ±0.02	0.058 ±0.01	0.017 ±0.01	3.067 ±0.03	0.206 ±0.00	1.846 ±0.06	1.124 ±0.01
22	587.15 ±5.5	0.018 ±0.01	0.230 ±0.00	0.009 ±0.00	0.009 ±0.01	0.148 ±0.00	0.049 ±0.00	2.008 ±0.02	0.045 ±0.01
23	934.3 ±19.5	0.014 ±0.00	1.691 ±0.04	0.281 ±0.01	0.002 ±0.00	0.137 ±0.00	0.094 ±0.00	1.859 ±0.02	0.284 ±0.00
24	505.14 ±1.6	0.013 ±0.00	0.441 ±0.01	0.005 ±0.00	0.007 ±0.00	0.125 ±0.01	0.045 ±0.00	1.712 ±0.00	0.049 ±0.01
25	2.554 ±0.04	0.023 ±0.01	1.678 ±0.03	0.021 ±0.00	0.002 ±0.00	1.625 ±0.01	0.086 ±0.00	1.897 ±0.00	1.294 ±0.01
26	10.78 ±0.17	0.018 ±0.01	0.140 ±0.01	0.005 ±0.00	0.001 ±0.00	0.059 ±0.00	0.047 ±0.00	2.01 ±0.01	0.124 ±0.00
27	0.942 ±0.05	0.039 ±0.01	0.098 ±0.00	0.005 ±0.00	0.001 ±0.00	0.015 ±0.00	0.035 ±0.00	1.987 ±0.02	0.046 ±0.00
28	8884 ±33.4	0.021 ±0.00	0.681 ±0.01	0.316 ±0.01	0.005 ±0.00	0.837 ±0.00	0.084 ±0.00	2.048 ±0.1	0.048 ±0.00
29	11303 ±115	0.034 ±0.01	0.095 ±0.01	0.197 ±0.01	0.02 ±0.00	0.086 ±0.00	0.151 ±0.00	2 ±0.00	0.127 ±0.04
30	1.002 ±0.08	0.011 ±0.01	0.224 ±0.01	0.004 ±0.00	0.001 ±0.00	0.090 ±0.00	0.043 ±0.00	2.257 ±0.01	0.04 ±0.01
31	2298 ±9.73	0.038 ±0.01	0.397 ±0.02	0.020 ±0.01	0.004 ±0.00	0.135 ±0.01	0.169 ±0.00	2.099 ±0.02	0.408 ±0.01
32	20.07 ±0.3	0.267 ±0.03	298.412 ±1.96	0.042 ±0.00	0.027 ±0.01	53.84 ±0.43	0.694 ±0.01	1.874 ±0.02	6.419 ±0.03
33	0.632 ±0.04	0.005 ±0.00	0.090 ±0.00	0.003 ±0.00	ND	0.016 ±0.00	0.040 ±0.00	2.213 ±0.03	0.030 ±0.00
34	8.476 ±0.27	0.262 ±0.01	15.217 ±0.2	0.041 ±0.00	0.015 ±0.00	6.704 ±0.05	0.315 ±0.01	2.109 ±0.02	0.382 ±0.01

Abbreviations: Not Detected (ND)

The multiple use of dietary food supplements (Samples 11, 17, 23, 28, and 29) which are used for different health effects, may increase the risk of high cadmium intake. When taken together in a day as one serving, these supplements can provide a total of 4.04 µg of cadmium. This is 28.9% of the minimum recommended daily intake of cadmium, which is 14 µg. If these supplements are taken twice daily or if other supplements are also taken, the cadmium intake could be even higher. In addition, if the individual is exposed to other sources of cadmium, such as food, smoke, or fumes, it would be even easier to exceed the minimum recommended daily intake.

Prolonged exposure to elevated levels of aluminum has been associated with neurological and bone disorders, such as Alzheimer's disease and osteomalacia. The exact mechanisms of aluminum toxicity are still the subject of ongoing research, but minimizing exposure to high levels of aluminum, especially through daily sources, remains an important public health concern [22]. In our study the aluminum levels were ranging from 0.150 ±0.03 to 433.181 ±2.84 (Table 6).

According to Table 8, none of the food supplements have exceeded the daily intake limits with their single-size serving use. However, it is important to note that the hazardous effects of metals may occur due to the multiple uses of these supplements. Accumulation of toxic metals may lead to intoxication in individuals. The limits in the table are based on literature and daily intakes may vary depending on an individual's conditions, physiological factors, sex, and other factors.

Table 8. Minimum Risk Levels/Recommended Dietary Allowances/No Observed Adverse Effect Levels of the Elements/Day

Elements	AI/RDA/NOAEL/MRL/DI/PTDI	References
Li	RDA: 1 mg/day for adults	[20,21]
Al	DI: 0.10-0.12 mg of Al/kg/day for adults	[14]
V	MRL: 210 µg for adults	[14]
Cr	RDA: 35 µg for males and 25 µg for females	[23]
Mn	RDA: 2.3 mg for males and 1.8 mg for females	[23]
Fe	PTDI: 48 mg	[24]
Co	DI: 0.005-1.8 mg	[14]
Ni	DI: 100-300 µg	[24]
Cu	RDA: 900 µg for adults	[23]
Zn	AI: 11 mg for males and 8 mg for females	[23]
As	MRL: 21 µg	[23]
Sr	DI: 2-4 mg	[25]
Cd	MRL: 14 µg	[14]
Sb	MRL: 0.4 and 6 µg/kg/d	[26]
Ba	MRL: 0.2 mg/kg/d	[26]
Pb	DI: 490 µg	[27]
Bi	RDA: 0.6-0.8 g	[28]

Abbreviations: AI, adequate intake; DI, daily intake; RDA, recommended dietary allowance; PTDI, provisional tolerable daily intake; NOAEL, no observed adverse effect level; MRL, minimum risk level. Non-specified intakes are for 70kg healthy adults

In conclusion, the use of ICP-MS to measure trace elements in food supplements enables rapid analysis with high precision and accuracy. Our results demonstrate that the food supplements examined contained elements in the microgram per gram range, and the concentrations of these elements varied significantly. Notably, the levels of toxic elements differed significantly among the samples analyzed, which can be attributed to a range of factors such as environmental and agronomic conditions, varying exposure to pollutants, inconsistent storage conditions, and unreliable supply sources. Additionally, differences in geographic location, composition, and production processes may also contribute to variations in the levels of toxic metals. Therefore, our findings suggest that it is crucial to monitor the concentration of toxic metals in food supplements, particularly those used for human consumption.

AUTHOR CONTRIBUTIONS

Concept: Ç.O., M.D.; Design: Ç.O., M.D.; Control: Ç.O., M.D.; Sources: Ç.O., M.D.; Materials: Ç.O., M.D.; Data Collection and/or Processing: Ç.O., M.D.; Analysis and/or Interpretation: Ç.O., M.D.;

Literature Review: Ç.O., M.D.; Manuscript Writing: Ç.O., M.D.; Critical Review: Ç.O., M.D.; Other: Ç.O., M.D.

CONFLICT OF INTEREST

The authors declare that there is no real, potential, or perceived conflict of interest for this article.

ETHICS COMMITTEE APPROVAL

The authors declare that the ethics committee approval is not required for this study.

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