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Assessment of toxic and essential heavy metals in imported dried fruits sold in the local markets of Jordan

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ABSTRACT

In the present study, the concentrations of nine heavy metals (Fe, Zn, Mn, Cu, Mg, Cr, Ni, Cd, and Pb) in six different imported dried fruit samples of different brands (Mangoes, black raisins, figs, apricots, plums, and cranberries) were determined by Flame Atomic Absorption Spectroscopy (FAAS) after wet digestion. Samples were collected from different stores in Amman, Jordan. The average concentration of the selected metals in the analyzed samples were found to be in the range of 1.70-8.70 (Fe), 0.15-0.72 (Zn), 0.09-0.59 (Mn), 0.07-0.46 (Cu), 2.5-53.4 (Mg), 0.06-0.15 (Cr), 0.17-0.29 (Ni), 0.01-0.05 (Cd), and 0.11-0.57 (Pb) µg/g. The highest concentrations of Fe, Zn, Mn, Mg, and Ni were found in dried figs, highest concentrations of Cr, Cd, and Pb were found in dried apricots, and highest concentrations of Cu was found in dried black raisins. The results obtained in this study showed that Mg and Fe have the highest concentrations in all analyzed samples, whereas, the lowest concentrations obtained were for Cd and Cr. The concentrations of the highly toxic metals (Pb and Cd) in the all analyzed samples were found to be below or in good agreement with the permissible limits set by different health organizations. The figures of merit obtained for the FAAS calibration curves are brilliant with good linearity (r^2 > 0.99). The FAAS method was validated by determining limit of detection (LOD), limit of quantitation (LOQ), and percent recovery (%R) for all investigated metals. The results obtained in this work were compared with the literature reported values.

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1. Introduction

Fruits and vegetables are an important component of human diet as they are major sources of various nutrients such as vitamins, fibers, sugars, carbohydrates, and essential minerals that are useful for human health [1-12]. Several studies have shown that fruits and vegetables consumption are significantly reduce the risk of several chronic ailments such as cancer, heart disease, and stroke [9,13-16]. Dried fruits are fruits where a large proportion of their water content is removed either through sun drying, shade drying, solar drying, or the use of an artificial dryer [17-19]. Dried fruits such as raisins, dates, plums, figs, apricots, peaches, apples, pears, or berries are one of the most important component of the human diet that is widely consumed around the world due to their availability all the seasons, easy to store, and being a healthy alternative to high sugar foods [13,19-22]. They are important raw materials in the confectionery industry like candies, jams, and cookies [9,19,22,23]. Dried fruits are concentrated sources of various compounds such as phenol antioxidants, essential minerals, sugars, vitamins, and dietary fibers. Therefore, they have several beneficial effects on human health such as antioxidants, anticancerogens, antimutagens, and antibacterial compounds [9,19-22,24]. Although dried fruits are of great importance in human diet, the health benefits of them can be significantly reduced because of the presence of heavy metals contamination. However, the consumption of dried fruits contaminated with toxic heavy metals may result in a serious risk to human health [8,17,25]. In recent years, there is an increasing concern about human exposure to toxic heavy metals as a serious health and environmental problem overall the world [1,7,26-32]. Human exposure to heavy metals has largely increased as a result of rapid urban and industrial developments [6,10,29,33,34]. Heavy metals are commonly classified into two types; essential heavy metals and toxic heavy metals. The first type contains heavy metals that are essential and necessary for human biochemical processes such as iron (Fe), copper (Cu), vanadium

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(V), zinc (Zn), selenium (Se), cobalt (Co), manganese (Mn), chromium (Cr^{2+}), magnesium (Mg), or molybdenum (Mo) [1,2,7,10,11,27,28,30,35,36]. However, excessive levels of these metals in foodstuffs can be toxic and have adverse effects on the human health [8,9,17,25,37]. The second type contains the highly toxic heavy metals even at low concentrations like mercury (Hg), cadmium (Cd), lead (Pb), chromium (Cr^{6+}), tin (Sn), nickel (Ni), or arsenic (As) [2,7,10,27,28,30]. In general, deficiency or excessive levels of both these two types of metals in foodstuffs may have adverse effects on the human health [11,18,21]. Toxic heavy metals are hazardous environmental contaminants since they are not biodegradable, thermostable, and have long biological half-lives [2,12,25,30,38]. Therefore, they have the ability to accumulate in human body, soil, vegetables, fruits, seawater, and sediments leading to serious health problems [2,12,39-42]. Fruits and vegetables can be contaminated by toxic heavy metals through the absorption of them from the contaminated soil, irrigation with contaminated water, adsorption of vehicular and industrial emissions on the fruits or vegetables surfaces, or by using of large quantities of chemical-based fertilizers and pesticides [1,2,6,11,29,32,34,38,41,42]. Additionally, heavy metals contamination might occur during transportation, packaging, marketing, processing, and storage [2,11,25,41,42]. In this context, different analytical techniques have been used to determine the concentrations of heavy metals in dried fruit samples including: flame atomic absorption spectrometry [8,9,23,25,43], graphite furnace atomic absorption spectrometry (GFAAS) [8], inductively coupled plasma optical emission spectroscopy (ICP-OES) [17,18,21], and potentiometric stripping analysis (PSA) [23].

In the last years, there is growing interest in monitoring of contamination levels of toxic and essential heavy metals in a wide variety of dried fruits [8,9,17,18,21,23,25,43]. For example, Ivanović *et al.* [17] determined the concentrations of selected elements (K, Na, Ca, Mg, Fe, Zn, Cu, Mn, Ni, Pb, Co, Al, and B) in the seven samples of dried fruits (plums, figs, apricots, white and black raisins, dates, and cranberries) collected from the local market in Serbia using inductively coupled plasma optical emission spectrometry (ICP-OES). The authors reported that As, Cd and Hg were not detected in the analyzed samples. In addition, they found that the analyzed dried fruit samples contain high concentrations of K, B, and Zn. They concluded that the concentrations of the investigated elements in the analyzed dried fruit samples are safe for human consumption. In a similar study, Saracoglu *et al.* [8] estimated the concent-rations of trace metals (Cu, Ni, Pb, Fe, Mn, Cr, Cd, Zn, Al, and Se) in dried apricot samples collected from Kayseri, Turkey by flame and graphite furnace atomic absorption spectrometry (FAAS and GFAAS). The authors observed that the analyzed dried apricot samples contain high concentrations of Fe, Zn, and Mn. In addition, they found that the concentrations of Cd^{2+} in dried apricot samples are below the permissible limit set by the WHO, whereas the Pb^{2+} and Ni^{2+} concentrations in the analyzed dried apricot samples are above the permissible limit set by the WHO [8].

There is limited information available on the concent-rations of toxic and essential heavy metals in dried fruits sold in the local markets of Jordan, which could give important information about the safeness of dried fruits consumption in Jordan. To the best of the author's knowledge, this is the first study of its kind to investigate heavy metals concentrations in imported dried fruits sold in the local markets of Jordan. Therefore, the main objectives of this study were (i) to determine the concentrations of essential (Mn, Fe, Cu, Mg, Cr, and Zn) and toxic (Cd, Ni, and Pb) heavy metals in imported dried fruits of different brands sold in the local markets of Jordan including: Mangoes, black raisins, figs, apricots, plums, and cranberries and (ii) to compare the results obtained in this study with similar studies performed in neighboring countries and other countries in the world.

2. Experimental

2.1. Chemicals and reagents

All chemicals and reagents used in this study were of analytical grade. A multi-element standard solution of 1000 mg/L of each tested element including; Fe, Zn, Mn, Cu, Mg, Cr, Ni, Cd, and Pb (analytical grade) was obtained from Merck KGaA, Darmstadt, Germany. Nitric acid (HNO_3, 69% *v*:*v*, extra pure-trace analysis grade) was obtained from Carlo ERBA reagents, France. Hydrogen peroxide (H_2O_2, 35% *w*:*w*, extra pure) was obtained from Scharlau Chemie, Barcelona, Spain. Ultrapure deionized water was used to prepare standard and sample solutions. The working solutions of each examined metal were freshly prepared by diluting an appropriate aliquot of the stock solutions using 0.1% (*v*:*v*) HNO_3.

2.2. Sample collection and pretreatment

With the aim to reduce the risk of contamination and ensure accurate results, all required precautions were taken during sample collection, preparation, and analysis. First, the dried fruit samples were collected in dried polyethylene bags and prepared in a clean laboratory. A trace element grade nitric acid HNO_3 (extra pure grade) was used for digestion and solution preparation. All glassware apparatus were effectively cleaned and previously soaked in 20% (*v*:*v*) HNO_3 for 24 hours and then thoroughly rinsed several times with ultrapure deionized water prior to use. Each dried fruit sample was analyzed in triplicate.

A total of 36 samples consisting of six different imported dried fruits of different brands including: Mangoes, black raisins, figs, apricots, plums, and cranberries were purchased from the local markets in Amman, Jordan (6 samples of each type). Each dried fruit item was purchased by systematic random sampling from four different stores. Samples were carefully washed in de-ionized water to remove dust particles. They were then dried at 105 °C for 24 hours to a constant weight. The dried samples were then ground and homogenized using blender with stainless steel cutters and stored in clean dry air-tight polyethylene bags until analysis.

2.3. Sample preparation

In this study, sample solutions were prepared as described by Duran *et al.* [25] with some minor modifications. A 2.0 g of homogenized dried fruit sample was placed in 100 mL Erlenmeyer flask and 20 mL concentrated HNO_3 (69%, *v*:*v*) was added. The sample was then heated at 145-160 °C until the solubilization of the sample was completed and a clear solution was obtained. After that, 3 mL H_2O_2 (35%, *w*:*w*) was added to the solution and left to cool down to room temperature. Finally, the solution was filtered and the volume was made up to 25 mL with ultrapure deionized water and then placed in 100 mL polyethylene bottles. Each extract solution of dried fruit sample was analyzed by flame atomic absorption spectrophotometry. All dried fruit samples were prepared in triplicates. The same procedures were applied for preparation of blank solutions.

2.4. Instrumentation

Atomic absorption spectrophotometer (Varian Spectr AA-55B, Australia) equipped with a deuterium background correction was used for determining the concentration of the examined heavy metals in the investigated dried fruits. Analysis using FAAS was carried out at the most sensitive analytical spectral lines of the metals: Fe: 248.3, Zn: 213.9, Mn: 279.5, Cu: 324.8, Mg: 285.2, Cr: 357.9, Ni: 232, Cd: 228.8, and Pb: 217 nm (Table 1).

Table 1. The wavelength of detection, limit of detection (LOD), limit of quantitation (LOQ), percent recovery (%R), and correlation coefficient (r^2) of each metal.

Element	Wavelength (nm)	LOD (µg/g)	LOQ (µg/g)	Recovery (%)	r^2
Fe	248.3	0.167	0.557	96	0.9981
Zn	213.9	0.073	0.244	98	0.9994
Mn	279.5	0.026	0.068	93	0.9944
Cu	324.8	0.026	0.086	94	0.9996
Mg	285.2	0.074	0.246	106	0.9933
Cr	357.9	0.030	0.100	87	0.9975
Ni	232.0	0.067	0.233	104	0.9995
Cd	228.8	0.030	0.100	96	0.9980
Pb	217.0	0.063	0.210	100	0.9995

2.5. Calibration

A series of freshly prepared working standard solutions for Fe, Zn, Mn, Cu, Mg, Cr, Ni, Cd, and Pb were prepared by diluting an appropriate aliquot of standard solution containing 1000 mg/L for each metal using 0.1% (*v:v*) HNO_3 for constructing the calibration curves. Linear least squares method was employed for calculation of statistical parameters for each metal including: correlation coefficient (r^2), slope with standard error ($m \pm S_b$), and intercept with standard error ($a \pm S_a$). From a linear calibration curve, lowest limit of detection LOD (µg/g of solid sample) and lowest limit of quantitation LOQ (µg/g of solid sample) were calculated using the following equations [44]:

$$LOD = \frac{3 \times S_a}{m} \quad (1)$$

$$LOQ = \frac{10 \times S_a}{m} \quad (2)$$

where S_a is the standard error of y-intercept of regression line and m is the slope of the calibration curve.

2.6. Quality control and assurance

With the aim to confirm the accuracy and validity of the analytical method used for the analysis of the heavy metals in dried fruit samples investigated in this study, recovery experiments of the analytical procedure were performed by spiking of standard solutions of different metals in several homogenized samples. This implies the addition of varying amounts of standard solutions of the different metals to 2.0 g of homogenized dried fruit samples. The spiked samples were then digested and prepared in the same manner as for original samples. Finally, the sample solutions were analyzed for metal concentration to evaluate the validity of the analytical method used in this study. The concentration of spiked metal recovered after the digestion of the spiked samples was used to calculate percent recovery (%R) as follows:

$$\%R = \frac{C_s - C_0}{C_{added}} \times 100\% \quad (3)$$

where R is the recovery, C_s is the concentration of metal in the spiked sample, C_0 is the concentration of metal in the non-spiked sample, and C_{added} is the concertation of metal added to the spiked sample. Results in Table 1 show that the percent recoveries of Fe (96%), Zn (98%), Mn (93%), Cu (94%), Mg (106%), Cr (87%), Ni (104%), Cd (96%), and Pb (100%) were obtained (Table 1). These findings confirm the good accuracy and validity of the FAAS analysis method used for the determination of metals concentrations in the investigated dried fruit samples.

3. Results and discussion

3.1. Limit of detection and limit of quantitation

Limit of detection and limit of quantitation obtained for each metal were listed in Table 1. Data presented in Table 1 show that the figures of merit obtained for the calibration curves for all investigated metals are brilliant. The calibration curves were linear with correlation coefficients, $r^2 > 0.99$ (Table 1). The detection limit values of the tested metals ranged between 0.026 µg/g for Mn and 0.167 µg/g for Fe, while the quantitation limit values ranged between 0.068 and 0.557 µg/g for Mn and Fe, respectively (Table 1). The low values of the detection limits demonstrate the high sensitivity of FAAS method used for the metal analysis in the investigated dried fruit samples.

3.2. Metal concentrations in dried fruit samples

In the present study, 36 samples of six different imported dried fruits of different brands were purchased from the local markets in Jordan, Amman city, including: Mangoes, black raisins, figs, apricots, plums, and cranberries. These samples were evaluated for determining the concentrations of 9 heavy metals including: Fe, Zn, Mn, Cu, Mg, Cr, Ni, Cd, and Pb using flame atomic absorption spectrometry. The concentrations (mean±SD) of each studied metal in dried fruit samples are listed in Table 2. All metals concentrations were determined on a dry weight basis. Metal concentrations in dried fruit samples were found to be in the range of 1.7-8.7 (Fe), 0.15-0.72 (Zn), 0.09-0.59 (Mn), 0.07-0.46 (Cu), 2.5-53.4 (Mg), 0.06-0.15 (Cr), 0.17-0.29 (Ni), 0.01-0.05 (Cd), and 0.11-0.57 (Pb) µg/g (Table 2). In addition, the average metal concentrations was found to be decreased in the following order for dried apricots: Mg > Fe > Pb > Zn > Cu > Ni > Mn > Cr > Cd; dried black raisins: Mg > Fe > Pb > Zn > Cu > Mn > Ni > Cr > Cd; dried plums: Mg > Fe > Zn > Mn > Cu > Pb > Ni > Cr > Cd; dried cranberries: Mg > Fe > Mn > Ni > Pb > Zn > Cu> Cr > Cd; dried figs: Mg > Fe > Zn > Mn > Ni > Pb > Cu > Cr > Cd; dried mangoes: Fe > Mg > Zn > Ni > Cu > Pb > Mn > Cr > Cd (Figure 1a and 1b). According to these results, the highest concentrations for the most selected metals (Fe, Zn, Mn, Mg, and Ni) were found in dried figs, whereas, the lowest concentrations for all selected metals except Mn, Mg, and Pb were found in dried cranberries. Moreover, these data clearly show that Mg and Fe have the highest concentrations in all analyzed samples, whereas, the lowest concentrations obtained were for Cd and Cr.

3.2.1. Essential metals

Iron is an essential metal that is considered as a main constituent of hemoglobin, the substance that is responsible for oxygen transport throughout the human body [8,45].

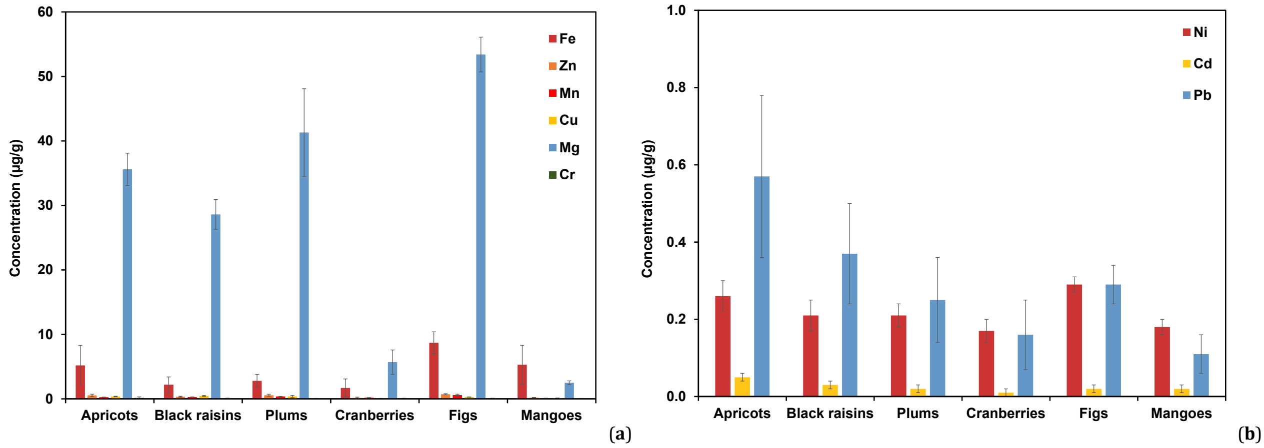

Figure 1. Average concentrations of (a) essential metals (Fe, Zn, Mn, Cu, Mg, and Cr) and (b) toxic metals (Ni, Cd, and Pb) in dried fruit samples.

According to the data shown in Table 2, the highest Fe concentration was found in dried figs with a mean of 8.7 µg/g, while the lowest Fe concentration was found in dried cranberries with a mean of 1.7 µg/g. In the literature, the Fe concentrations in dried fruit samples have been reported in the range of 19.0-45.0 µg/g [23], 11.82-40.80 µg/g [18], 6.76-64.10 µg/g [25], 10.4-80.1 µg/g [8], and 0.21-2.20 µg/g [17]. In addition, the average concentration of Fe was reported as 31.32 µg/g in dried plum samples [21]. According to Turkish Food Codex, the permissible Fe limit in food is 15 µg/g [8].

Zinc is an essential metal that is important for both human growth and reproduction [45]. Zn deficiency leads to adverse health effects to human health such as growth retardation, skin changes, and immunological abnormalities [46,27,28]. Data presented in Table 2 show that the highest Zn concentration was found in dried figs with a mean of 0.72 µg/g, while the lowest Zn concentration was found in dried cranberries with a mean of 0.15 µg/g. In the literature, the Zn concentrations in dried fruit samples have been reported in the range of 2.96-12.0 µg/g [8], 1.7-4.9 µg/g [23], 2.38-24.90 µg/g [17], and 2.16-6.54 µg/g [18]. Moreover, the average concentration of Zn was reported as 7.649 µg/g in dried plum samples [21]. According to Turkish Food Codex, the maximum limit of Zn permitted for food is 5.0 µg/g [8].

Manganese is an important metal to human health as it directly contributes to both structural and the activation of many enzymes [18,45]. Results obtained in this study demonstrate that the highest Mn concentration was found in dried figs with a mean of 0.59 µg/g, while the lowest Mn concentration was found in dried mangoes with a mean of 0.09 µg/g (Table 2). In the literature, the Mn concentrations in dried fruit samples have been reported in the range of 2.14-17.23 µg/g [23], 4.74-25.50 µg/g [25], 0.56-4.87 µg/g [18], 0.215-1.600 µg/g [17], and 0.97-8.27 µg/g [8]. Additionally, the average concentration of Mn was reported as 1.933 µg/g in dried plum samples [21]. According to the WHO (World Health Organization) and the US National Academy of Sciences, the recommended daily intake of Mn for an adult person are 2.0-9.0 mg and 2.5-5.0 mg, respectively [18].

Copper is an essential metal vital for many biological processes in all living organisms [18]. In the present study, the highest Cu concentration was found in dried black raisins with a mean of 0.46 µg/g, while the lowest Cu concentration was found in dried cranberries with a mean of 0.07 µg/g (Table 2). In the literature, the Cu concentrations in dried fruit samples have been reported in the range of 3.90-25.00 µg/g [23], 1.68-4.52 µg/g [25], 0.92-6.49 µg/g [8], 0.43-2.74 µg/g [18], 1.32-3.97 µg/g [17], and 0.396-1.033 µg/g [9]. In addition, the average concentration of Cu found in dried plum samples was reported as 3.482 µg/g [21].

Magnesium enhances bone, teeth, and tissue formation and thus help in the human body growth [45]. Mg presents in a large amounts in vegetables and fruits [45]. Our analysis determined that the highest Mg concentration was found in dried figs with a mean of 53.4 µg/g, while the lowest Mg concentration was found in dried mangoes with a mean of 2.5 µg/g. In the literature, the Mg concentrations found in dried fruit samples have been reported in the range of 39.8-1062 µg/g in different dried fruits commonly consumed in Serbia [17]. In addition, the average concentration of Mg found in dried plum samples was reported as 293.2 µg/g [21].

Chromium is an essential metal for glucose, lipid, and protein metabolism [25,45]. Depending on its oxidation state, this metal can be toxic and carcinogenic. For example, Cr^{2+} is an essential metal, whereas Cr^{6+} is toxic [25]. In the present study, it was found that the highest Cr concentration was found in dried apricots with a mean of 0.15 µg/g, while the lowest Cr concentration was found in dried plums with a mean of 0.06 µg/g (Table 2). In the literature, the Cr concentrations found in dried fruit samples have been reported in the range of 0.314-0.921 µg/g [9], 0.80-6.17 µg/g [25], 0.45-2.30 µg/g [18], and 4.76-28.90 µg/kg [8]. In addition, the average concentration of Cr found in dried plum samples was reported as 1.790 µg/g [21]. Apart from dried apricot samples, the Cr concentrations found in the analyzed dried fruits investigated in this study would agree the United States Food and Drug Administration (FDA) recommended dosage of 0.12 µg/g [45,47].

3.2.2. Toxic metals

Nickel is considered toxic to human health. Generally, Ni accumulates in different body organs such as kidneys, lungs, and liver. Excessive levels of Ni in foodstuffs may be related to toxic symptoms such as abdominal pain, diarrhea, heart attack, kidney and lung damage, and low blood pressure [27]. Results in Table 2 reveal that the highest Ni concentration was found in dried figs with a mean of 0.29 µg/g, while the lowest Ni concentration was found in dried cranberries with a mean of 0.17 µg/g. In the literature, the Ni concentrations found in different dried fruit samples have been reported in the range of 0.6-9.4 µg/g [25], 2.30-5.83 µg/g [8], 0.052-1.070 µg/g [17], 0.61-2.54 µg/g [18], and 4.771-5.447 µg/g [9]. Moreover, Mehta *et al.* [21] reported that the average Ni concentration found in dried plum samples was 1.076 µg/g.

Table 2. Average concentrations of Fe, Zn, Mn, Cu, Mg, Cr, Ni, Cd, and Pb (µg/g) in dried fruits including: Apricots, black raisins, plums, cranberries, figs, and mangoes. Data shown are the average of triplicate runs (standards deviations in brackets).

Dried fruit	Essential metals						Toxic metals		
	Fe	Zn	Mn	Cu	Mg	Cr	Ni	Cd	Pb
Apricots	5.2(±3.1)	0.55(±0.18)	0.26(±0.03)	0.36(±0.05)	35.6(±2.5)	0.15(±0.17)	0.26(±0.04)	0.05(±0.01)	0.57(±0.21)
Black raisins	2.2(±1.2)	0.34(±0.07)	0.29(±0.03)	0.46(±0.08)	28.6(±2.3)	0.09(±0.03)	0.21(±0.04)	0.03(±0.01)	0.37(±0.13)
Plums	2.8(±1.0)	0.57(±0.16)	0.38(±0.01)	0.38(±0.17)	41.3(±6.8)	0.06(±0.02)	0.21(±0.03)	0.02(±0.01)	0.25(±0.11)
Cranberries	1.7(±1.4)	0.15(±0.11)	0.19(±0.02)	0.07(±0.01)	5.7(±1.9)	0.07(±0.03)	0.17(±0.03)	0.01(±0.01)	0.16(±0.09)
Figs	8.7(±1.7)	0.72(±0.09)	0.59(±0.14)	0.28(±0.01)	53.4(±2.7)	0.10(±0.01)	0.29(±0.02)	0.02(±0.01)	0.29(±0.05)
Mangoes	5.3(±3.0)	0.19(±0.04)	0.09(±0.01)	0.11(±0.01)	2.5(±0.3)	0.07(±0.02)	0.18(±0.02)	0.02(±0.01)	0.11(±0.05)

Cadmium is toxic heavy metal and its accumulation in the human body leads to serious health problems such as kidney disfunction, bone diseases, skeletal damage, and reproductive deficiencies [25,28]. According to the Turkish Food Codex and European communities, the maximum Cd concentration permitted in dried fruits is 0.05 µg/g [48,49]. In addition, the Official Gazette of the Republic of Serbia No. 5/92, 11/92, 32/2002, 25/2010 and 28/2011 established the maximum allowable Cd concentration permitted in dried fruits as 0.30 µg/g [17,50]. In this study, results show that the highest Cd concentration was found in dried apricots with a mean of 0.05 µg/g, while the lowest Cd concentration was found in dried cranberries with a mean of 0.01 µg/g (Table 2). These results indicate that the average concentrations obtained for Cd in the analyzed dried fruits in this study were found to be within the acceptable range or below the permissible limits set by different health organizations. This implies that the dried fruits investigated in this study are safe for human consumption. In the literature, the Cd concentrations found in dried fruit samples have been reported in the range of 0.160-0.244 µg/g [43], 0.02-0.10 µg/g [23], 0.10-0.81 µg/g [25], 0.02-0.72 µg/g [8], 0.12-0.54 µg/g [18], and 0.722-7.661 µg/g [9].

Lead is a highly toxic and dangerous heavy metal that increases blood pressure and reduces cognitive development and intellectual performance in children [46]. According to the World Health Organization (1996), the maximum limit of Pb allowed for food is 10 µg/g [51]. In addition, the maximum Pb concentration permitted in dried fruits established by the Official Gazette of the Republic of Serbia No. 5/92, 11/92, 32/2002, 25/2010 and 28/201 is 3.0 µg/g [17,50]. According to the data listed in Table 2, the highest Pb concentration was found in dried apricots with a mean of 0.57 µg/g, while the lowest Pb concentration was found in dried mangoes with a mean of 0.11 µg/g. These findings reveal that the average concentrations obtained for Pb in the analyzed dried fruits in this study were found to be below the permissible limits set by various health organizations. These findings confirm that the dried fruits investigated in this study are safe for human consumption. In the literature, the Pb concentrations in dried fruit samples have been reported in the range of 0.40-2.14 µg/g [18], 5.5-12.4 µg/g [25], 0.41-1.16 µg/g [17], 0.12-0.32 µg/g [23], 0.72-3.77 µg/g [8], and 1.001-10.002 µg/g [9]. In addition, the average concentration of Pb found in dried plum samples was reported as 0.208 µg/g [21].

In summary, metals concentrations obtained in this study were compared with those obtained in similar studies performed in the neighboring countries and other countries in the world. From the comparison, we observed that metals concentrations found in most of the analyzed dried fruit samples investigated in this study were found to be below or in good agreement with those reported in the literature. For instant, with the exception of Fe, all metals measured in this study were found to be lower than those reported for dried fruits collected from Serbia [17].

3.3. Statistical analysis of results

In this work, analysis of variance (ANOVA) was used to assess whether there is a significant difference in metal concentrations between the different types of dried fruits analyzed in this study [52]. From the statistical analysis of the data achieved in this study, the P values obtained for Fe, Zn, Mn, Cu, Mg, Ni, Cd, and Pb concentrations were found to be 1.92×10^{-6}, 9.61×10^{-13}, 3.44×10^{-22}, 6.31×10^{-17}, 9.96×10^{-37}, 7.24×10^{-9}, 2.45×10^{-9}, and 1.02×10^{-8}, respectively. These findings indicate that there was a significant difference in metals concentrations between the different types of dried fruits analyzed in this study ($p < 0.05$). On the other side, the P value obtained for Cr was 1.52 indicating that there was no significant difference in Cr concentrations in the analyzed dried fruits ($p > 0.05$). One possible explanation of the significant difference in metals concentrations existed between the different types of the analyzed dried fruits might be stemmed from several factors that influence the metal concentration in fruit such as air pollution (industrial emission), irrigation with contaminated water, contaminated soil, using excess amounts of chemical-based fertilizers and metal-based pesticides, harvesting process, storage, transportation, and marketing [32,38,41,42].

4. Conclusions

The concentrations of selected heavy metals (Fe, Zn, Mn, Cu, Mg, Cr, Ni, Cd, and Pb) in imported dried fruits (Mangoes, black raisins, figs, apricots, plums, and cranberries) sold in the local markets of Jordan were determined by Flame Atomic Absorption Spectroscopy. Results obtained in this study showed that dried fruits are rich of Mg and Fe, and thus can be used as good dietary resources. On the other hand, the concentrations of toxic heavy metals (Pb and Cd) in the analyzed dried fruits were found to be below or in good agreement with the permissible limits set by different health organizations. Therefore, it can be concluded that consumption of imported dried fruits sold in Jordan markets, Amman city was safe according to these health organizations. Metals concentrations obtained in this study were found to be below or in good agreement with those reported in similar studies performed in the neighboring countries and other countries in the world. Routine analysis of heavy metals has to be performed on all imported food commodities sold in Jordan markets to assure the food safety and thus to protect the human health.

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Disclosure statement DS

Conflict of interests: The authors declare that they have no conflict of interest.
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