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ARTICLE

Assessment of Health Risks for Heavy Metals in Iraqi, Iranian and Turkish of Cheese Samples Available of Iraqi Markets

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Abstract: The purpose of the study was to determine the concentration of Pb, Cd, and Cr in a number of selected cheese samples in Iraqi markets, both locally produced and imported from Iran and Turkey. This assessment was carried out through the application of atomic absorption spectroscopy. In the current investigation, human health risk parameters, such as estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI), and carcinogenic risk (CR), were evaluated in all tested cheese samples. The evaluation of the r lead assay for Iraqi, Iranian, and Turkish cheese samples yielded the following average values: 2.88 ± 0.43, 4.33 ± 0.57, and 3.89 ± 0.63 in units of mg/kg, respectively. In the case of cadmium, the values were 0.131 ± 0.02, 0.135 ± 0.03, and 0.167 ± 0.032, respectively, whereas chromium values were 0.015 ± 0.01, 0.183 ± 0.12, and 0.105 ± 0.07, respectively. The average values of HI for Iraqi, Iranian, and Turkish samples were 0.352 ± 0.05, 0.526 ± 0.07, and 0.483 ± 0.26, respectively. Additionally, the average values of $CR \times 10^{-6}$ for Pb, Cd, and Cr concentrations in Iraqi samples were 0.004 ± 0.0006, 0.297 ± 0.05, and 0.09 ± 0.08, respectively. Meanwhile, the corresponding values for Iranian and Turkish samples were 0.006 ± 0.0007, 1.13 ± 0.0007, and 0.0056 ± 0.7, and 0.005 ± 0.0008, 0.37 ± 0.07, and 0.65 ± 0.4, respectively. The heavy metal content in the Iraqi samples was lower than in Iranian and Turkish samples. Also, no statistical significance was found when comparing the Iranian and Turkish samples, where the P-value was greater than 0.05. Most of the values of Pb, Cd, and Cr concentrations were above the permissible limits according to EU regulations. However, the health risk parameters were within the globally accepted limits. Therefore, the majority of the investigated cheese samples have no health risks when used by Iraqi customers.

Keywords: Heavy metal, Health risk, Canned cheese, Iraqi markets.

1. Introduction

Heavy metal pollution has received widespread attention globally. These minerals are toxic because they are non-biodegradable. Humans are exposed to these pollutants through water, air, soil, and contaminated food [1]. The presence of heavy metals in food directly affects the health of humans and other organisms. Although lead (Pb), cadmium (Cd), and chromium (Cr) are among the micronutrients essential for the healthy development of the human body, they are required in very small quantities, typically a few milligrams per day [2]. Humans are exposed to these environmental pollutants due to urbanization and industry and agriculture development. These pollutants are absorbed by the body via inhalation of contaminated air, as well as the consumption of polluted water and food (as part of the food chain). Excessive exposure to heavy metals through food is dangerous for human health [3]. Various challenges accompany the detection of heavy metals due to matrix complexity and a

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lack of sufficient concentration levels in which the elements appear. Toxic metals can infiltrate dairy products at different stages. Initially, animals can receive heavy metals through their food and water. Subsequently, these pollutants can be accumulated during the manufacturing or cheese-making process, as a result of interaction with processing equipment, inadvertent contamination during storage or packing, and other factors [4]. The affinity of chemicals for heavy metals in certain ingredients has contributed to significant contamination levels in several dairy products, particularly cheese. For instance, casein strongly binds to Pb, while Cd primarily finds its way into the food chain through contaminated crops, trace elements, and supplementary minerals, such as limestone and phosphate [5]. As for Cr, small amounts of this heavy metal are added to animal feed to enhance cows' milk production and bolster their immune systems against diseases [6]. In our daily diet, cheese holds a significant place, valued for its rich content of essential nutrients such as proteins, minerals, and vitamins. However, it's important to keep in mind that cheese can be contaminated by heavy metals, which are among the most complex pollutants [4]. Contamination occurs primarily as a result of animals' ingestion of contaminants or contamination during milk production [5]. Various heavy metals, including lead, cadmium, chromium, nickel, and cobalt, can contaminate milk when they are incorporated into the feed and environment of cattle. Those metals could be excreted into milk at different levels and cause serious problems [6]. Many studies, conducted in different countries, have measured heavy metals in milk and cheese samples [7-10]. Given the absence of existing heavy metal analyses for cheese products consumed in Iraq, this study aims to assess the heavy metal (Pb, Cd, and Cr) content in cheese samples found in Iraqi markets. These samples include both locally produced cheese and imports from Iran and Turkey.

2. Materials and Methods

2.1. Sample Collection

In the present study, a total of thirty-nine types of cheese samples, originating from Iraq, Iran, and Turkey, were collected from Iraqi markets in October 2021. The samples were categorized into three groups based on their country of origin, as shown in Table 1.

Upon collection, the samples were promptly transported to the environmental laboratory for analysis. Before digestion, the samples were dried for 24 hours at 70 ºC following the procedure described in Ref. [11].

TABLE 1. Cheese samples in the present study.

No.	Name of brand cheese	Sample code	Origin
1	Zahret Rabee	IQ1	
2	Slemani with cream	IQ2	
3	Village Alqariah	IQ3	
4	Slemani with white cream	IQ4	
5	Almolok	IQ5	Iraq
6	Twoj Smak	IQ6	
7	Slemani-Smoked	IQ7	
8	Lezzzet	IQ8	
9	Soft agricultural cow's	IQ9	
10	Sabah (Cream)	IN1	
11	Kibi	IN2	
12	Kiri	IN3	
13	Sabah (UF)	IN4	
14	Labneh	IN5	
15	Sabah (Bulgarian paneer)	IN6	Iran
16	Sabah (Arab)	IN7	
17	Pinka	IN8	
18	Mimas	IN9	
19	Kala (Amal)	IN10	
20	Kala (Msdmr)	IN11	

No.	Name of brand cheese	Sample code	Origin
21	Kala (Maac)	IN12	
22	Baf	IN13	
23	Gouda	IN14	
24	Sabah (Feta)	IN15	
25	Aynes	T1	
26	Muratbey (Shallal)	T2	
27	Muratbey (Braided)	T3	
28	Lana	T4	
29	Tulum (With black semsem)	T5	
30	Tulum (With dill)	T6	
31	Mersin (Circassian)	T7	
32	Village (With olives and thyme)	T8	Turkey
33	Village (dill)	T9	
34	Village (With thyme)	T10	
35	Village (With herbs)	T11	
36	Mersin (Village)	T12	
37	Muratbey (Van herby)	T13	
38	Alamera	T14	
39	Manfoush	T15	

2.2. Sample Preparation and Detection

Each sample was digested with a mixture of HNO_3 (ultrapure 65%) and $HClO_4$ (ultrapure 70%) at a 10:1 ratio to provide a clear solution for analysis. 1 g of each cheese sample was weighed on an analytical balance and placed in a digestion tube, then 10 ml of concentrated nitric acid HNO_3 (65%) was added and the mixture was left overnight at room temperature. Later, the mixture was placed on a hot plate and gently heated until it reached a boiling point. This heating process was performed to facilitate the oxidation of materials that were prone to oxidation. As a result, the color of the mixture changed to brown. After cooling, 1 ml of perchloric acid $HClO_4$ (70%) was added to the mixture. It was gently boiled until dense white fumes began to rise and the color of the digestive mixture turned clear; approximately 1 ml of solution remained after evaporation. Following cooling, the mixture was filtered and quantitatively transferred to a volumetric flask. Subsequently, 25 ml of deionized water was added, as described in Ref. [10]. The LOD, or the limit of detection, (BGC-D2 "Background Correction Deuterium-2") values for lead, cadmium, and chromium were 0.03- 0.1, 0.002-0.008, and 0.005-0.02 ppm, respectively; the LOQ, or the limit of quantitation, (BGC-D2) values were 0.1-0.4, 0.007-0.03, and 0.02-0.07 ppm, respectively. SHIMADZU model AAS-7000 atomic absorption spectrophotometer (AAS) was used to determine the levels of Pb, Cd, and Cr. The absorption wavelengths for the determination of Pb, Cd, and Cr were 283.3 nm, 228.8nm, and 357.9 nm, respectively [11]. The AA-7000 provides an adaptable system configuration with a high-performance graphite furnace and 3D double-beam optics for accurate and efficient trace element analysis. For calibration solutions, the required concentrations were 0.2, 0.5, and 0.7 ppm for Pb, and 0.1, 0.2, and 0.5 ppm for Cd and Cr, respectively.

2.3. Health Risk Parameters

Several health risk parameters were computed based on the presence of heavy metals (Pb, Cd, and Cr) in the cheese samples. These parameters include estimated daily intake (EDI), target hazard quotients (THQ), hazard index (HI), and carcinogenic risk (CR).

Equation (1) was used to determine EDI due to heavy metals in cheese samples, which depends on the concentration of heavy metals in cheese (C_{metal}), the daily average consumption of cheese (W_{cheese}), and the weight of the human body (BW), as follows [12, 13]:

$$EDI\left(\frac{mg}{kg}per\ day\right)=\frac{C_{metal}\left(\frac{mg}{kg}\right)\times W_{cheese}\left(\frac{kg}{day}\right)}{BW\ (kg)} \quad (1)$$

In the present study, the value used for BW was that of an adult person with an average weight of 60 kg, while the value of W_{cheese} was determined to be 22 g/day [13, 14].

The values of THQ for the samples were determined according to the Environmental Protection Agency (EPA) regulations. The THQ values depend on the EDI and oral reference dose (RfD) and are calculated using the following equation [15, 16]:

$$THQ = \frac{EDI\ (\frac{mg}{kg}\ per\ day)}{RfD(\frac{mg}{kg}\ per\ day)} \quad (2)$$

The values of RFD in *mg/kg per day* for Pd, Cd, and Cr were 3.5×10^{-3}, 1×10^{-3}, and 3×10^{-3}, respectively [17, 18]. It's important to note that a THQ value of 1 is considered a threshold for safety for people.

The sum of the THQ values for all heavy metals in the study can be used to calculate the HI values [19].

$$HI\left(\frac{mg}{kg}per\ day\right) = \sum THQ \quad (3)$$

The values of CR due to exposure to heavy metals in populations were determined using Eq. (4), which is based on the USEPA guidelines. This calculation involves several parameters, namely exposure frequency (EFr), exposure duration (ED), EDI, the oral carcinogenic slope factor (CSFo), and average time (AT) [20]:

$$CR = \frac{EFr\left(\frac{days}{year}\right)\times ED(year)\times EDI\left(\frac{mg}{kg}\ per\ day\right)\times CSFo(\frac{mg}{kg}\ per\ day)}{AT(\frac{day}{year}\times 70\ year)} \times 10^{-3} \quad (4)$$

In the present study, the values of EFr, ED, and AT were 350 days/year, 30 years, and 365 days/year × 70 years, respectively [21], while, the values of CSFo (in *mg/kg per day*) for Pb, Cd, and Cr were 0.0085, 15, and 41, respectively [22].

3. Results and Discussions

In this work, the concentrations of selected heavy metals (lead, cadmium, and chromium) in Iraqi, Iranian, and Turkish canned cheese samples commonly used in Iraqi markets were determined using AAS techniques. Table 2 shows the concentrations of Pb, Cd, and Cr for 39 cheese samples (9 made in Iraq, 15 made in Iran, and 15 made in Turkey). From Table 2, it can be seen that the range of Pb, Cd, and Cr concentrations in mg/kg for the Iraqi cheese samples of the present study were 1.39-5.11, ND-0.258, and ND-0.131, respectively, while the average values were 2.88 ± 0.43, 0.131 ± 0.02, and 0.015 ± 0.01, respectively. Those produced by Iran ranged from 0.93 mg/kg to 8.36 mg/kg with an average value of 4.33±0.57 mg/kg, from ND to 0.434 mg/kg with a mean value of 0.135 ± 0.03 mg/kg, and from ND to 1.83 mg/kg with an average value of 0.183 ± 0.12 mg/kg, respectively. But those produced by Turkey ranged from ND to 8.36 mg/kg with an average value of 3.89 ± 0.63 mg/kg, from ND to 0.375 mg/kg with an average value of 0.167 ± 0.032 mg/kg, and from ND to 1.05 mg/kg with a mean value of 0.105 ± 0.07 mg/kg, respectively. According to the T-test, the descending order of Iraqi and Turkish cheese samples was Pb > Cd > Cr, and for Iranian cheese samples, it was Pb > Cr > Cd, according to the average value. The differences are significant ($p < 0.05$) in the heavy metal concentrations of all the samples. The maximum value of Pd concentration was found in IQ2 (Slemani with cream), IN7 (Sabah-Arab), and T14 (Alamera). These are attributable to contamination with lead in the manufacture of this sample. It's noteworthy that a significant number of cheese samples in this study showed no detection (ND), particularly with regard to Cr concentrations. Additionally, the results revealed that the Pb concentrations in all the cheese samples collected from Iraqi markets exceeded the global average, which is set at 0.02 mg/kg according to European [23] and Codex standards [24], with the exception of samples T11 and T12 (ND). It was also found that twenty-eight of the Cd concentrations results in the samples of the present study were higher than the world average (0.05 mg/kg) for cheeses according to EU Regulation [25], while the results showed values of Cr concentrations for most samples were less than the world record limit (0.03 mg/kg) for cheeses according to EU Regulation [25]. The average value of Pb, Cd, and Cr concentrations in cheese samples produced by Iraq is lower than that of cheese samples produced by Iran and Turkey. By comparison, the average value of Pb and Cr concentrations in Iranian cheese samples is higher than that of Turkish cheese samples, but the T-test confirmed the presence of non-significant concentrations between Iranian and Turkish samples statistically ($P > 0.05$). Although the average value of Cd concentrations in Iranian cheese samples is lower than that of Turkish cheese samples, the T-test confirmed the presence of no significant difference in the concentration of mg/kg in the samples of the present study between Iranian and Turkish samples statistically ($P > 0.05$).

TABLE 2. Concentrations of Pb, Cd, and Cr in different cheese products from Iraq, Iran, and Turkey.

No.	Sample code	Concentrations of heavy metals (mg/kg or ppm)		
		Pb	Cd	Cr
1	IQ1	3.71	0.158	0.131
2	IQ2	5.11	0.158	ND*
3	IQ3	1.86	0.133	ND
4	IQ4	4.64	ND	ND
5	IQ5	3.25	0.142	ND
6	IQ6	1.39	0.258	ND
7	IQ7	1.39	0.058	ND
8	IQ8	1.86	0.058	ND
9	IQ9	2.79	0.217	ND
Average±S.D		2.88±0.43	0.131±0.02	0.015±0.01
10	IN1	5.57	0.192	ND*
11	IN2	2.79	0.150	ND
12	IN3	4.64	0.350	0.523
13	IN4	4.64	0.050	ND
14	IN5	2.79	0.175	ND
15	IN6	0.94	0.083	ND
16	IN7	8.36	0.042	ND
17	IN8	1.86	0.150	0.392
18	IN9	8.36	0.075	1.83
19	IN10	0.93	ND	ND
20	IN11	5.11	0.067	ND
21	IN12	6.04	0.058	ND
22	IN13	5.11	0.042	ND
23	IN14	3.25	0.158	ND
24	IN15	4.64	0.434	ND
Average±S.D		4.33±0.57	0.135±0.03	0.183±0.12
25	T1	5.57	0.258	ND
26	T2	0.46	0.325	0.261
27	T3	6.04	0.008	ND
28	T4	3.25	0.133	ND
29	T5	4.64	0.325	ND
30	T6	5.57	0.375	ND
31	T7	6.50	0.133	ND
32	T8	3.25	ND	ND
33	T9	5.57	0.108	1.05
34	T10	1.39	0.300	ND
35	T11	ND	0.108	ND
36	T12	ND	ND	ND
37	T13	4.64	0.200	ND
38	T14	8.36	ND	0.261
39	T15	3.25	0.233	ND
Average±S.D		3.89±0.63	0.167±0.032	0.105±0.07
Maximum level		0.02	0.05	0.03

*ND is no detection.

Table 3 shows the results of EDI, THQ, and HI due to the Pb, Cd, and Cr concentrations in all the cheese samples in the present study, which were collected from Iraqi markets. The average values of EDI for Pb, Cd, and Cr concentrations in Iraqi cheese samples were found to be 1.05 ± 0.15 µg/kg per day, 0.05 ± 0.009, µg/kg per day, and 0.005 ± 0.004 µg/kg per day, respectively. Also, the average values of THQ for Pb, Cd, and Cr concentrations were

found to be 0.30 ± 0.04, 0.05 ± 0.009, and 0.002 ± 0.001, respectively. Also from Table 3, the average values of EDI for Pb, Cd, and Cr concentrations in Iran samples were 1.58 ± 0.21 µg/kg per day, 0.05 ± 0.01 µg/kg per day, and 0.07 ± 0.04 µg/kg per day, respectively, while in Turkey samples in units of µg/kg per day were 1.43 ± 0.23, 0.06 ± 0.01, and 0.04 ± 0.02, respectively. Furthermore, the average values of TQH for Pb, Cd, and Cr concentrations in Iranian samples were 0.45 ± 0.06, 0.05 ± 0.01, and 0.022 ± 0.01, respectively, while in Turkish samples they were 0.41 ± 0.06, 0.06 ± 0.01, and 0.013 ± 0.008, respectively. Also, as seen in Table 3, the results of HI due to Pb, Cd, and Cr concentrations for Iraqi cheese samples ranged from 0.167 in sample IQ7 (Slemani-Smoked) to 0.593 in sample IQ2 (Slemani with cream), with an average value of 0.352±0.05. While the range of the results of HI in other countries of the present study was 0.097-1.127 with an average of 0.526±0.07 and ND- 0.907 with an average value of 0.483±0.26. The results presented in Table 3 indicate that the EDI values for the studied cheese samples fell within the upper limits for the intake of toxic heavy metals of Pb and Cd. These upper limits are 3.57 µg/kg/day for Pb and 1.0 µg/kg/day for Cd, as established globally [26]. Also, all values of TQH in Table 3 were less than 1, which means the cheese in the present study is safe. Internal exposure to heavy metals is controlled by the hazard index (HI), which is equal to or higher than 1, and indicates the potential health risk [27]. The HI values of all cheese samples in the present study were less than 1, except for sample IN9. The average value of HI in cheese samples produced by Iraqis is lower than that of cheese samples produced by Iranians and Turks.

TABLE 3. Results of EDI, THQ, and HI due to Pb, Cd, and Cr concentration in cheese samples under study.

No.	Sample code	EDI (µg/kg per day)			THQ			HI
		Pb	Cd	Cr	Pb	Cd	Cr	
1	IQ1	1.36	0.058	0.048	0.389	0.058	0.016	0.463
2	IQ2	1.87	0.058	ND	0.535	0.058	ND	0.593
3	IQ3	0.68	0.049	ND	0.195	0.049	ND	0.243
4	IQ4	1.70	ND	ND	0.486	ND	ND	0.486
5	IQ5	1.19	0.052	ND	0.340	0.052	ND	0.392
6	IQ6	0.511	0.095	ND	0.146	0.095	ND	0.241
7	IQ7	0.51	0.021	ND	0.146	0.021	ND	0.167
8	IQ8	0.68	0.021	ND	0.195	0.021	ND	0.216
9	IQ9	1.02	0.079	ND	0.292	0.079	ND	0.371
Average±S.D		1.05±0.15	0.05±0.009	0.005±0.004	0.30±0.04	0.05±0.009	0.002±0.001	0.352±0.05
10	IN1	2.04	0.070	ND	0.584	0.070	ND	0.654
11	IN2	1.02	0.055	ND	0.292	0.055	ND	0.347
12	IN3	1.70	0.128	0.192	0.486	0.128	0.064	0.679
13	IN4	1.70	0.018	ND	0.486	0.018	ND	0.505
14	IN5	1.02	0.064	ND	0.292	0.064	ND	0.356
15	IN6	0.340	0.031	ND	0.097	0.031	ND	0.128
16	IN7	3.06	0.015	ND	0.876	0.015	ND	0.891
17	IN8	0.68	0.055	0.144	0.195	0.055	0.048	0.298
18	IN9	3.06	0.028	0.67	0.876	0.028	0.224	1.127
19	IN10	0.340	ND	ND	0.097	0.000	ND	0.097
20	IN11	1.87	0.024	ND	0.535	0.024	ND	0.559
21	IN12	2.21	0.021	ND	0.632	0.021	ND	0.654
22	IN13	1.87	0.015	ND	0.535	0.015	ND	0.550
23	IN14	1.19	0.058	ND	0.340	0.058	ND	0.399
24	IN15	1.70	0.159	ND	0.486	0.159	ND	0.645
Average±S.D		1.58±0.21	0.05±0.01	0.07±0.04	0.45±0.06	0.05±0.01	0.022±0.01	0.526±0.07
25	T1	2.043	0.095	ND	0.584	0.095	ND	0.678
26	T2	0.170	0.119	0.096	0.049	0.119	0.032	0.200
27	T3	2.213	0.003	ND	0.632	0.003	ND	0.635
28	T4	1.192	0.049	ND	0.340	0.049	ND	0.389
29	T5	1.702	0.119	ND	0.486	0.119	ND	0.606
30	T6	2.043	0.138	ND	0.584	0.138	ND	0.721
31	T7	2.383	0.049	ND	0.681	0.049	ND	0.730

No.	Sample code	EDI (µg/kg per day)			THQ			HI
		Pb	Cd	Cr	Pb	Cd	Cr	
32	T8	1.192	0.000	ND	0.340	0.000	ND	0.340
33	T9	2.043	0.040	0.383	0.584	0.040	0.128	0.751
34	T10	0.511	0.110	ND	0.146	0.110	ND	0.256
35	T11	ND	0.040	ND	ND	0.040	ND	0.040
36	T12	ND	ND	ND	ND	ND	ND	ND
37	T13	1.702	0.073	ND	0.486	0.073	ND	0.560
38	T14	3.064	ND	0.096	0.876	ND	0.032	0.907
39	T15	1.192	0.086	ND	0.340	0.086	ND	0.426
Average±S.D		1.43±0.23	0.06±0.01	0.04±0.02	0.41±0.06	0.06±0.01	0.013±0.008	0.483±0.26
Maximum level		3.57 [26]	1.0 [26]	---	1[27]	1[27]	1[27]	1[27]

Statistically, the data for HI in each of the Iranian and Turkish samples did not show significance at $p > 0.05$. Using Eq. (4), we calculated the Carcinogenic Risk (CR) values for all the cheese samples in the present study, which are presented in Table 4. For the Iraqi cheese samples, the values of $CR \times 10^{-6}$ were primarily influenced by Pb concentrations varying from 0.002 to 0.007 with an average value of 0.004 ± 0.0006, Cd concentrations varying from ND to 0.584 with an average of 0.297 ± 0.05, and Cr concentrations varying from ND to 0.807 with an average of 0.09 ± 0.08. In contrast, the Iranian cheese samples showed the highest $CR \times 10^{-6}$ value for Pb concentration in IN9 (0.012) and the lowest in the IN6 sample (0.001), with an average value of 0.006 ± 0.0007. Additionally, Cd and Cr concentrations varied from ND to 0.980 (average of 1.13 ± 0.0007) and from ND to 11.302 (average of 0.0056 ± 0.7), respectively. Also, from Table 4 it is seen that the range values of Pb, Cd, and Cr concentrations for Turkish cheese samples were from ND to 0.011 with an average value of 0.005 ± 0.0008, from ND to 0.848 with an average value of 0.37 ± 0.07, and from ND to 6.458 with an average of 0.65 ± 0.4, respectively. According to the Environmental Protection Agency, the range of the CR values of the world limit for heavy metals in food is 10^{-6}-10^{-4} [21, 28]. Therefore, the results of CR based on lead, cadmium, and chromium concentrations for all the Iraqi cheese samples, as well as those produced by Iran and Turkey, have lower values than the world limit [21, 28]. On the basis of these results of health risk parameters due to heavy metals (Pb, Cd, and Cr) in cheese samples, such as estimated daily intake (EDI), target hazard quotients (THQ), hazard index (HI), and carcinogenic risk (CR), it could be said that for most samples, there is a very small chance of potential health risks through consuming those cheeses. The heavy metals transferring through water and food to animals, heavy metals contamination during the manufacturing of cheese, and the chemical affinity of heavy metals with certain ingredients are attributed to the high recorded values and heavy metals variations in some cheese samples.

TABLE 4. Results of CR due to Pb, Cd, and Cr concentration in cheese samples under study.

No.	Sample code	$CR \times 10^{-6}$		
		Pb	Cd	Cr
1	IQ1	0.005	0.358	0.807
2	IQ2	0.007	0.358	ND
3	IQ3	0.002	0.302	ND
4	IQ4	0.006	ND	ND
5	IQ5	0.004	0.320	ND
6	IQ6	0.002	0.584	ND
7	IQ7	0.002	0.132	ND
8	IQ8	0.002	0.132	ND
9	IQ9	0.004	0.490	ND
Average±S.D		0.004±0.0006	0.297±0.05	0.09±0.08
10	IN1	0.007	0.434	ND
11	IN2	0.004	0.339	ND
12	IN3	0.006	0.792	3.229
13	IN4	0.006	0.113	ND

No.	Sample code	CR×10^{-6}		
		Pb	Cd	Cr
14	IN5	0.004	0.396	ND
15	IN6	0.001	0.189	ND
16	IN7	0.011	0.094	ND
17	IN8	0.002	0.339	2.422
18	IN9	0.012	0.170	11.302
19	IN10	0.001	ND	ND
20	IN11	0.007	0.151	ND
21	IN12	0.008	0.132	ND
22	IN13	0.007	0.094	ND
23	IN14	0.004	0.358	ND
24	IN15	0.006	0.980	ND
Average±S.D		0.006±0.0007	1.13±0.0007	0.0056±0.7
25	T1	0.007	0.584	ND
26	T2	0.001	0.735	1.614
27	T3	0.008	0.019	ND
28	T4	0.004	0.302	ND
29	T5	0.006	0.735	ND
30	T6	0.007	0.848	ND
31	T7	0.008	0.302	ND
32	T8	0.004	ND	ND
33	T9	0.007	0.245	6.458
34	T10	0.002	0.678	ND
35	T11	0.001	0.245	ND
36	T12	ND	ND	ND
37	T13	0.006	0.452	ND
38	T14	0.011	ND	1.614
39	T15	0.004	0.528	ND
Average±S.D		0.005±0.0008	0.37±0.07	0.65±0.4
World limit [21,28]			10^{-6}-10^{-4}	

Our measured average values of heavy metal (Pb, Cd, and Cr) concentrations of the investigated cheese samples are compared with the previous studies, as presented in Table 5. The average values of concentrations for Pb, Cd, and Cr in the current study are higher than the values determined in Mexico, India, Georgia, Bulgaria, and Bangladesh, except that the average values of Cr concentrations in Iraqi samples were lower than in Mexico, Georgia, and Bangladesh, as illustrated in Table 5. There are several potential reasons that could account for the higher concentrations of heavy metals observed in this study. These reasons include the contamination of plants by heavy metals, which are subsequently consumed by animals that produce milk. Additionally, contamination during the cheese production process and the type of cheese containers used could also contribute to elevated heavy metal concentrations.

TABLE 5. Comparison of the average concentrations of Pb, Cd, and Cr in cheese samples of various countries.

No.	Country	Average of concentrations mg/kg			Reference
		Pb	Cd	Cr	
1	Mexico	0.11	---	0.02	[7]
2	India	0.006	0.01	---	[8]
3	Georgia	0.258	0.007	0.079	[9]
4	Bulgaria	0.0012	0.0039	---	[10]
5	Bangladeshi	0.025	0.042	0.886	[29]
6	Iraq	2.88	0.131	0.015	
7	Iran	4.33	0.135	0.183	Present study
8	Turkey	3.89	0.167	0.105	

4. Conclusions

In light of the results of the present study, it can be concluded that the concentrations of heavy metals Pb, Cd, and Cr in most samples were higher than the global averages according to the EC Commission, Codex standards, and EU regulations. However, the results of health risk parameters such as non-carcinogenic indicators (EDI, THQ, and HI), as well as carcinogenic risks based on Pb, Cd, and Cr concentrations, were found to be within acceptable global limits. Therefore, our analysis of these health risk parameters leads to the conclusion that the consumption of the cheese examined in this study by the Iraqi population does not pose a significant risk of adverse health effects.

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