ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230**, ISSN (online):** 2412-3986**, DOI: http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

EVALUATION OF HEALTH RISK ASSESSMENT FOR CADMIUM, LEAD AND ZINK IN SOME COMMON CANNED FOODS IN ERBIL CITY MARKETS

Shahla Sherwan Rasool [1], Dalshad Aziz Darwesh [2]

[1,2]Department of environmental health and science, College of Science, Salahaddin University-

Erbil, KRG-Iraq

A B S T R A C T:

This study was conducted to assess health hazards and the concentration of some heavy metals including, Zinc (Zn), Cadmium (Cd), and Lead (Pb) in canned fish, canned cheese, and canned tomato paste from various markets in Erbil city. The data were statistically analyzed using one-way ANOVA (CRD). The metal contents were determined using atomic absorption spectroscopy. The non-carcinogenic health risk of determined heavy metals was assessed using the target hazard quotient (THQ) and hazard index (HI). The outcomes showed that the maximum Pb, Cd, and Zn levels in canned tomato pastes are, 0.480, 0.205, and 2.00 mg/kg in brands 5,2, and 5 respectively, and all studied metals mean were within the acceptable limit provided by FAO/WHO. The highest mean content of Pb, Cd, and Zn in canned fishes are 1.553,0.436 and 5.655 mg/kg in brands 3,1 and 4 respectively, the mean value of Cd and Zn were within the acceptable range, except for Pb 20% of samples have exceeded the limit (FAO/WHO). In addition, the highest mean of Pb, Cd, and Zn in canned cheeses are 1.515, 0.532, and 9.794 mg/kg in brands 3,1, and 2 respectively, All the studied metals exceeded the codex limit. The metals level follows this order in canned foods; Zn > Pb >Cd. According to the values of HQ and HI heavy metals studied in canned foods, poses no health concern with HI < 1

KEY WORDS: food contamination, heavy metals, health risk assessment, canned foods
DOI: http://dx.doi.org/10.21271/ZJPAS.34.6.14
ZJPAS (2022), 34(6);125-134.

1.INTRODUCTION:

Heavy metals are found naturally that have a high atomic weight as well as a density at least 5 times greater than water, Numerous industrial, residential, agricultural, medical, & technical activities have resulted in their widespread in the environment, increasing worries about their possible health and environmental impacts (Tchounwou et al. 2012). Assessing the quantities of trace heavy metals in food has become increasingly popular.

* **Corresponding Author:**
Shahla Sherwan Rasool
E-mail: shahla.rasool@su.edu.krd
Article History:
Received: 15/07/2022
Accepted: 23/08/2022
Published: 20/12/2022

Food is the main source of metal exposure, not just because several metals are naturally present in foods, but also because of environmental contamination & contaminating throughout food processing and packaging. Concerns regarding food quality are growing in numerous parts of the world (Cubadda and Raggi 2005). Canned products have a long shelf-life, do not require refrigeration, and do not need special handling during transportation or distribution (Kapica and Weiss 2012). Furthermore, processing aids in the preservation of nutritive value but this can occasionally be connected to the potential for chemical migration from the package to the meal.

Tin, glass, ceramics, and plastic may release minuscule amounts of toxins when they come into touch with food. Health risks to people could result from this chemical migration from packaging and other food contact materials to food. (Al Ghoul et al. 2020). Metals like, Mn, Fe, Cu & Zn are critical metals in trace quantities because they perform a crucial function in biological systems, particularly human physiology. Non-essential metals like As, Hg, Cr, Cd, as well as Pb are harmful. (Türkmen et al. 2008). Because of their long half-life, lack of biodegradability, and bioaccumulation, metals can have substantial negative health consequences on humans (Harmanescu et al. 2011). Zn causes nephritis, anuria, and widespread kidney lesions at high doses. (Abou-Arab et al. 1996).

Cd and Pb are extremely harmful to humans, they are only handled at very low doses, and excessive amounts are linked to a variety of health problems. (Khansari et al. 2005). Moreover, it may harm the kidneys and induce chronic toxicity signs such as decreased organ function, infertility, hypertension, tumors, and hepatic malfunction (Abou-Arab et al. 1996). Pb can also interfere with neurotransmitter release and synapse development which can impact brain function. Pb poisoning has been linked to lower intelligence quotient, learning impairments, delayed growth, hyperactivity, antisocial conduct, and hearing loss (Dahiya et al. 2005). Heavy metal contamination is a result of growing global industrialization which has infiltrated all parts of the food industry. Chemical migration from food containers used in product packaging is a severe food safety problem. Tinned foods are widely eaten in Erbil and there is little knowledge about the metal contents, particularly their hazardous effect, however, a big quantity of canned food is imported into Erbil city without being inspected for quality. The objects of this study are to determine the level of heavy metals (cadmium, zinc & lead) in some canned foods (fish, cheese, tomato paste) in some markets in Erbil city and also estimate the human health risk related to the consumption of Cd, Pb and Zn contents.

2. MATERIALS AND METHODS

2.1 Sampling

In August 2021, sixty samples of canned items (fish, cheese, tomato paste) from various brands and production countries were acquired from five local supermarkets in Erbil. Twenty-five samples of canned tomato paste from five various brands (Altunsa, Nawras, Marjan, Rojin, and Sharazoor), as well as twenty samples of canned fish (tuna), from four different brands(Shabab, Shilana, Altunsa, and Tazaj) and fifteen samples of canned cheese from three main companies (craft, smile, and al-marai).

2.2 Chemicals & instrumentation

All glassware was cleaned by immersing it in 10% nitric acid overnight and then rinsing it with de-ionized water. The acids used for wet digestion were of high purity analytical reagent (Merck, Darmstadt, Germany) quality. Nitric acid (HNO3) (65%) & hydrochloric acid (HCl) (37%) were used for sample digestion. Heavy metals were determined by using the atomic absorption spectrophotometer Perkins-Elmer USA 1100D (Kowalska et al. 2020).

2.3 Sample preparation and digestion

After opening the cans, the contents were completely homogenized using a food blender with stainless steel cutters (Boadi et al. 2011). Pre-digestion of samples is conducted by weighing about 2 grams of each sample then a mixture of nitric acid (HNO3) at a concentration of 65% & 37% HCl at a ratio of (2:1) was added. After most of the sample was dissolved by standing overnight, at a temperature of 150 C, the solution was set on the electric heater. As recommended by (Demirel et al. 2008). The solution was heated until it was reduced to around 5 ml of the solution turned clear. The solution was left to cool before being used. This solution is then filtered through No. 1 Whatman filter paper into a 25 ml volumetric flask and diluted with de-ionized water to the desired concentration. After that, the solution is examined with an atomic absorption spectrometer with a graphite furnace(Hussein et al. January 6). Before analyzing the samples were kept at 4ºC in a refrigerator as recommended by (Korfali and Abou Hamdan 2013).

2.4 Standards

Standard stock solutions containing 1000 mg /L of each element (Zn and Pb) were acquired from Fisher scientific company-USA. And Cd standard (1000 mg/L) from Merck-Germany.

3. Statistical analysis

Graphpad prism 8 was used to evaluate the results. The data were statistically analyzed using one-way ANOVA (CRD) The significance of the differences in Pb, Zn, and Cd concentrations between samples were assessed using Tukey's test, with the findings provided as mean standard error. statistical significance is defined as probability values less than 0.05 ($p < 0.05$) (Sobhanardakani 2017).

4. Health risk assessment

A health risk assessment is a helpful method for making a quantitative risk management choice in the future. For persons living in Erbil, the values of non-carcinogenic health risks associated with dairy consumption were established. The average daily intake of metal (DIM) was computed using Eq.1 to determine serious risks to health (Guo et al. 2016).

4.1 Daily intake of metal

$$DIM = \frac{Cmetal \times Cfactor \times Dfood\ intake}{Baverage\ weight} \quad \ldots\ldots (1).$$

Where,

C_{metal} = metal concentration in canned food (mg/kg^{-1})
C_{factor} = conversion factor (0.085) is used to convert fresh weight into dry weight (Falcó et al. 2006; Omar et al. 2013).
$D_{food\ intake}$ = daily intake of canned food (Df for canned fish = 3.5E-03 kg/person/day)(Guo et al. 2016) , (Df for canned tomato paste = 300-400 g (Uroko et al. 2020) And Df for canned cheese = 139 g (Enb et al. 2009; Abdi et al. 2015).
$B_{average\ weight}$ = average body weight (70kg for an adult) (Tang et al. 2015).

4.2Hazard quotient

The hazard quotient index for the local population through the consumption of canned foods was assessed by the ratio for the Daily Intake Rate (DIR) to the oral reference dose (RfDo) for each metal Eq 2:

$$HQ = \frac{DIM}{RfD} \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$ (Dorsey and Ingerman 2004).

Here, DIM and R_fD characterize daily intake of metal & reference dose of metal, respectively. The oral reference doses for Cd, Pb, and Zn were 0.001, 0.0035, and 0.30 mg/ kg/day, respectively, (Zhuang et al. 2009). If the value of HQ is (<1), then the affected local population is regarded to be safe, but if HQ is equal to or greater than 1, it is considered unsafe for human health (Uroko et al. 2020).

4.3Hazardous index (HI)

The hazard index (HI) established by (USEPA 1989) collected the hazard quotients for all HMs to quantify the risk to human health from multiple HMs. The below equation was used to determine the hazard index (Dawodu 2019).

$$HI = \Sigma HQ = HQ\ contaminant\ 1 + HQ\ contaminant\ 2 + HQ\ contaminant\ 3 + \ldots\ldots HQ\ contaminant\ n \ldots\ldots (3).$$

5. RESULTS AND DISCUSSION

The heavy metals Cadmium (Cd), Zinc (Zn), and Lead (Pb), were measured in 60 different canned food brands. The outcomes were then compared between various canned food brands and types, as well as a health risk assessment for every metal was calculated. Using the acquired data, a human risk assessment was calculated to quantify the health risk associated with eating canned foods.

5.1 Canned tomato paste

Through plant uptake from contaminated soil, contaminated water, or used agrochemicals, heavy metals could be found in canned tomato paste. During the canning process or through metal leaching into the canned products during storage, harvested fruits may potentially get contaminated (Ninčević Grassino et al. 2009). Preservatives, stabilizers, and artificial coloring additives may also contaminate processed tomato paste with heavy metals .(Oduoza 1992). Table 1 shows the Pb, Cd, and Zn contents in canned tomato paste. According to Codex standard 193-1995(Codex Alimentarius Commission 2011), the maximum allowable lead level in canned tomato paste is 1.0 mg kg , the results showed that the Pb level in 100% of tomato paste samples were within the permissible limit. The maximum mean concentration of Pb was 0.480 mg/kg in brand 5 and the minimum was 0.324 mg/kg wet weight in brand 1. The maximum allowable level of cadmium by (FAO 1983) was 0.5 mg/kg, based on this limit Cd levels in 100% of canned tomato paste were within the acceptable limit. The highest mean concentration of Cd was 0.205 mg/kg in brand 2 and the lowest was 0.127 mg/kg in brand 4. WHO/FAO minimum allowable intake data of Zinc is 30 mg kg Zn (FAO 1983), also Zn level in all canned tomato paste was within the accepted level. The highest mean concentration of Zn was 2.009 mg/kg in brand 5 while the lowest was 0.760 mg/kg in brand 1. The results of the statistical analysis showed that there were no significant differences ($p > 0.05$) for Pb & Cd between brands, while for Zn there is a significant difference between brands 1&5 with the p-value (0.01). The metal levels in five canned tomato pastes seemed in a declining trend Cd < Pb < Zn.

Table 1: Metal contents (mg/kg wet weight) along with relevant statistical parameters in various varieties of canned tomato paste

metals	Brand 1 Mean ± SE	Brand 2 Mean ± SE	Brand 3 Mean ± SE	Brand 4 Mean ± SE	Brand 5 Mean ± SE
Pb	0.324±0.055	0.392±0.041	0.437±0.068	0.393±0.075	0.480±0.099
Cd	0.194±0.028	0.205±0.014	0.200±0.025	0.127±0.026	0.129±0.019
Zn	0.760±0.066	1.609±0.076	1.802±0.202	1.267±0.302	2.009±0.415

5.2Canned fish

Water chemistry, period of fish exposure to contaminants from water, accumulation of contaminants in the water column, feeding habits of fish, contamination of fish during processing and handling, canned fish quality, as well as the expiration date of canned fish are all variables that can impact the level of contaminants in fish. Metal levels in canned fish, on the other hand, are impacted by the pH of the canned product, oxygen content in the headspace, quality of canned product lacquer coatings, coating quality, & storage location (Hosseini et al. 2013). Contaminants in fish may endanger the health of the fish, their predators, and the people who eat them. (Burger and Gochfeld 2005). The mean content of metals including (Pb, Cd & Zn) and other statistical characteristics are shown in table 3, based on the (Joint FAO/WHO Codex Alimentarius Commission et al. 2007) guidelines for contaminants in food, the permissible level of Pb, Cd, and Zn in canned fish is (0.5,0.5 and 50 mg/kg) respectively. According to this guideline, the concentration of Pb in all 20 samples (100% of samples) exceeded the limit, with the maximum and minimum mean content of 1.553 mg/kg in brand 3 and 0.702 mg/kg in brand 2 respectively. While for cadmium metal content were within the acceptable limit in all brands (100%) with the highest and lowest mean content 0.436 mg/kg in brand 1 and 0.337 mg/kg in brand 2 correspondingly. As well as Zn level was within the permissible limit in all brands (100%) the maximum and minimum mean content was as follow, 5.655 mg/kg in brand 4 and 3.607 mg/kg in brand 2 respectively. The P-value for all three metals was > 0.05 so there is no significant difference in metal content between brands.

Table 2: Metal contents (mg/kg wet weight) along with relevant statistical parameters in various brands of canned fish

Metals	Brand 1 Mean±SE	Brand Mean±SE	Brand 3 Mean±SE	Brand 4 Mean±SE
Pb	1.274±0.047	0.702±0.096	1.553±0.723	1.106±0.228
Cd	0.436±0.077	0.337±0.054	0.358±0.051	0.341±0.017
Zn	5.199±0.611	3.607±0.289	5.238±0.726	5.655±0.725

5.3Canned cheese

Due to changes in species, geographic location, manufacturing process characteristics, and potential equipment contamination during processing, packaging, and storage, cheese's trace metal level varies. Controlling the manufacturing process at each stage is essential to identifying the origin and extent of contamination and ensuring the desired degree of product quality (Ayar et al. 2009). Table 1 shows the Pb, Cd, and Zn contents in canned cheese, as well as key statistical characteristics. Comparing the heavy metal concentrations in the studied canned cheeses with the maximum permissible limits (µg kg^{-1}) (2.60, 20.0, and 328.0 for Cd, Pb, and Zn, respectively) established by (Codex Alimentarius Commission 2011) and (International Dairy 1992).shows that all metals (Pb, Cd, and Zn) in all the samples (100%) exceeded the Codex limit with the highest and lowest mean concentration 1.515 (brand 3) & 1.215 mg/kg (brand 2) for Pb , 0.532(brand 1) & 0.493 mg/kg (brand 3) for Cd and 9.794 (brand 2) , 6.764(brand 1) mg/kg for Zn respectively. P-value for all three metals were > 0.05 so there is no significant difference of metal content between brands.

Table 3: Metal contents (mg/kg wet weight) along with relevant statistical parameters in various brands of canned cheese

Metals	Brand1 Mean±SE	Brand 2 Mean±SE	Brand 3 Mean±SE
Pb	1.356±0.219	1.215±0.177	1.515±0.406
Cd	0.532±0.114	0.495±0.132	0.493±0.074
Zn	6.764±1.601	9.794±0.822	8.275±1.748

5.4Health risk indices

In this study, health risk was assessed using Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI). Tables 4,5,6 shows the EDI, THQ of metals in some canned foods and figure 1,2,3 show HI of metals in some canned foods The EDI values in mg. kg^{-1}. day^{-1} for canned tomato paste (Table 4). ranged from 1.18E-04-1.75E-04 for pb, 4.64E-05 – 7.5 E-05 for Cd and 2.77E-04 – 7.31E-04 for Zn. while EDI for canned fish (table 5) ranged from 2.98E-06 – 6.60E-06 for Pb, 1.43E-06 – 1.85E-06 for Cd and 1.53E-05 – 2.4E-05. EDI for canned cheese (table 6) was as follow, 2.05E-04 – 2.55E-04 for Pb, 8.33E-05 – 8.98E-05 for Cd and 1.14E-03 – 1.65E-03 for Zn. THQ for all metals in all samples of canned foods were < 1 it means there is no risk associated with these metals in studied canned products. HI also in all canned foods <1 it means pose no risks to human.

Table 4: Daily intake of metals (DIM) (mg/kg/day) & hazard quotient (HQ) in canned tomato paste

Brands	DIM Pb	DIM Cd	DIM Zn
B1	1.18E-04	7.07E-05	2.77E-04
B2	1.43 E-04	7.49E-05	5.86E-04
B3	1.59 E-04	7.32E-05	6.56E-04
B4	1.43 E-04	4.64E-05	4.61E-04
B5	1.75 E-04	4.71E-05	7.31 E-04
HQ			
B1	0.033	0.070	0.000
B2	0.040	0.074	0.001
B3	0.045	0.073	0.002
B4	0.040	0.046	0.001
B5	0.049	0.047	0.002

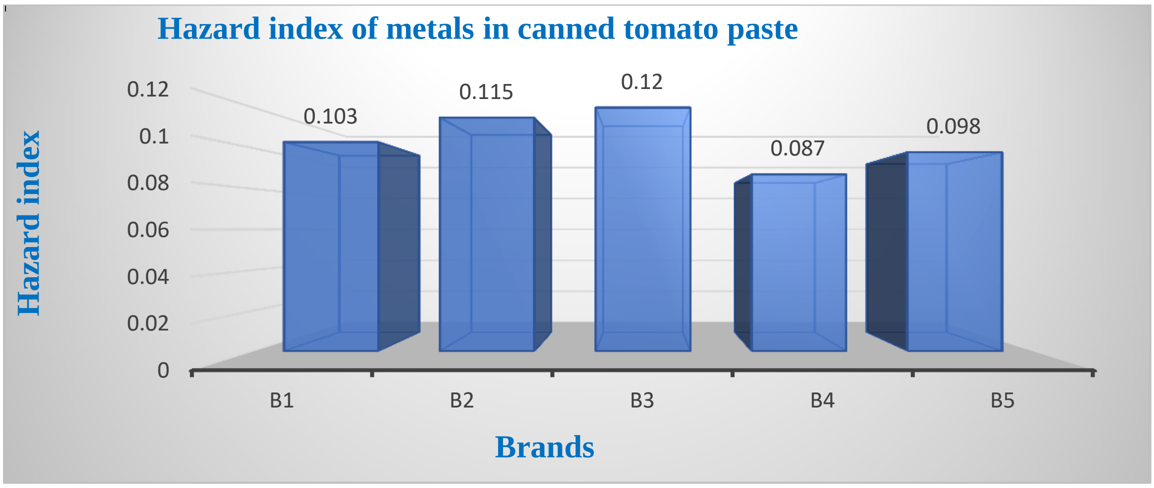

Figure 1 shows the hazard index of metals in different brands of canned tomato past

Table 5: Daily intake of metals (DIM) (mg/kg/day) & hazard quotient (HQ) in canned fish

Brands	DIM Pb	DIM Cd	DIM Zn
B1	5.41E-06	1.85E-06	2.21E-05
B2	2.98E-06	1.43E-06	1.53E-05
B3	6.60E-06	1.52E-06	2.23E-05
B4	4.70E-06	1.45E-06	2.40E-05
HQ			
B1	1.54E-03	1.85E-03	7.36E-05
B2	8.52E-04	1.43E-03	5.10E-05
B3	1.88E-03	1.52E-03	7.42E-05
B4	1.34E-03	1.45E-03	8.01E-05

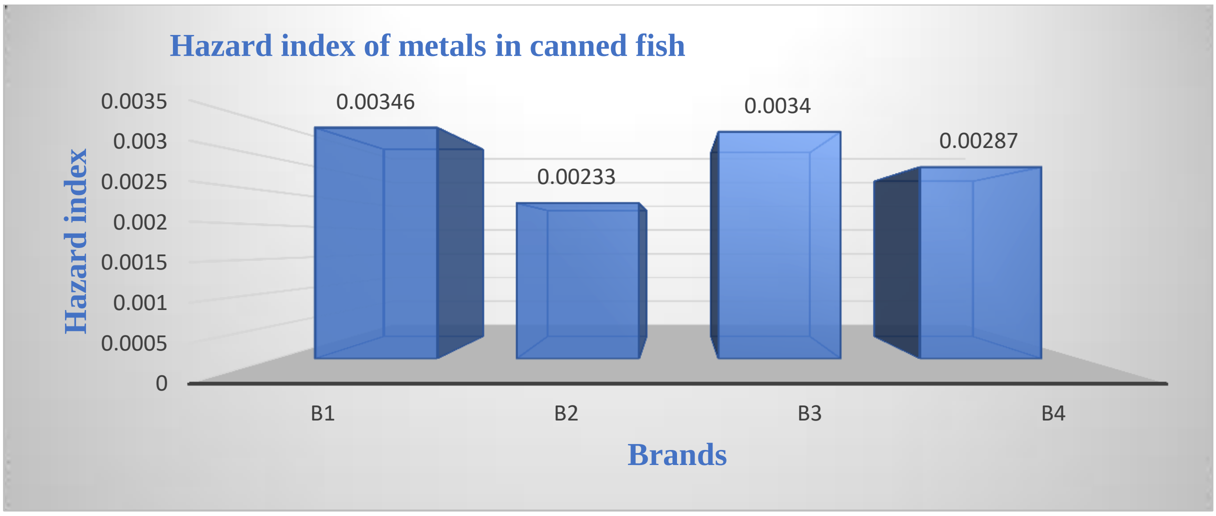

Figure 2 shows the hazard index of metals in different brands of canned fish

Table 6: **Daily intake of metals (DIM) (mg/kg/day) & hazard quotient (HQ) in canned cheese**

Brands	DIM Pb	DIM Cd	DIM Zn
B1	2.28E-04	8.98E-05	1.14E-03

B2	2.05E-04	8.37E-05	1.65E-03
B3	2.55E-04	8.33E-05	1.39E-03
HQ			
B1	6.53E-02	8.98E-02	3.80E-03
B2	5.85E-02	8.36E-02	5.51E-03
B3	7.30E-02	8.33E-02	4.65E-03

6. Conclusion

The overall goal of this research effort was to know more about the level concentration of heavy metals (Zn, Cd, and Pb) present or thought to be present in various canned food samples, as well as their associated health concerns to people. According to the study's findings, all three metals were found in the canned samples, but they were all under the WHO-FAO-acceptable range, except for canned cheese all studied metals were exceeded the acceptable limit of codex. The study found that these elements are altered at different scales in all types of samples. Lead, Cadmium, and Zinc amounts in the samples examined do not provide a health risk, in accordance with the WHO-FAO Guidelines for the Assessment of Heavy Metal in Food. The examined ingredients in canned goods had a THQ parameter value that was less than 1, which indicates that there is no chance that adverse effects will occur. We also urge the government to review and revise the fundamental standards for the quality control laboratory and the detection of heavy metals in canned food. More thorough research is advised in order to determine the quantity of heavy metals present in various types of canned foods generally as well as to determine the effects of food additives on human health.

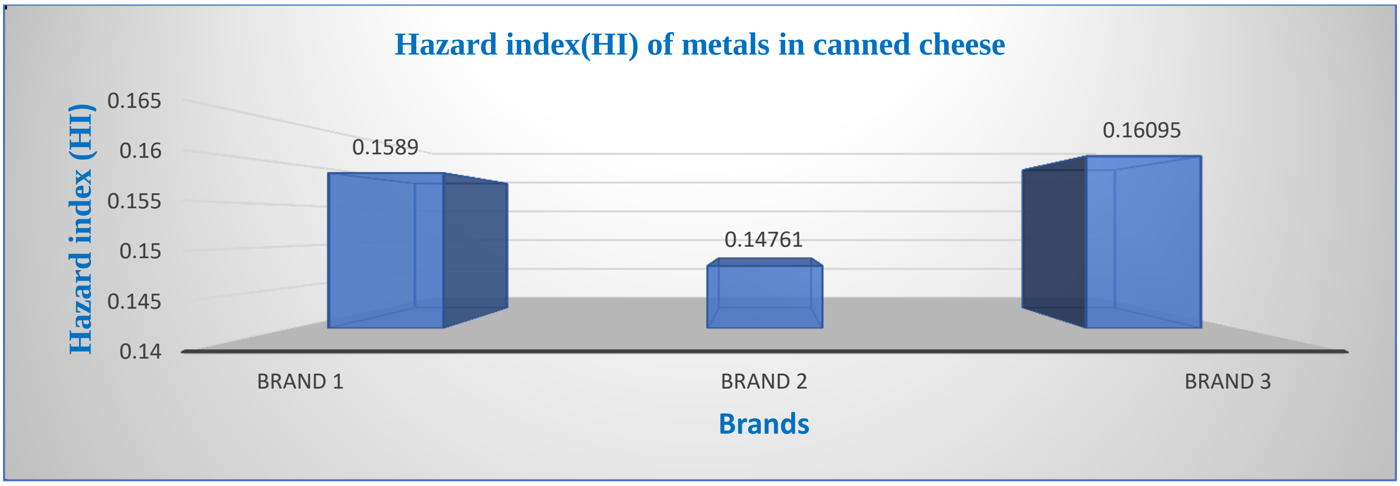

Figure 3 shows the hazard index of metals in different brands of canned cheese

REFERENCES

ABDI, Fateme, KASHANI Z ATARODI, Parvin MIRMIRAN and Taraneh ESTEKI. 2015. 'Surveying Global and Iranian Food Consumption Patterns: A Review of the Literature'.

ABOU-ARAB, AAK, AM AYESH, HA AMRA and Khayria NAGUIB. 1996. 'Characteristic Levels of Some Pesticides and Heavy Metals in Imported Fish'. *Food chemistry* 57(4), 487–92.

AL GHOUL, Lara et al. 2020. 'Zinc, Aluminium, Tin and Bis-Phenol a in Canned Tuna Fish Commercialized in Lebanon and Its Human Health Risk Assessment'. *Heliyon* 6(9), e04995.

AYAR, Ahmet, Durmuş SERT and Nihat AKIN. 2009. 'The Trace Metal Levels in Milk and Dairy Products Consumed in Middle Anatolia—Turkey'. *Environmental monitoring and assessment* 152(1), 1–12.

BOADI, Nathaniel Owusu, Mercy BADU, Sylvester K MENSAH and Irene OSEI. 2011. 'Heavy Metal

Contamination in Canned Fish Marketed in Ghana'.

BURGER, Joanna and Michael GOCHFELD. 2005. 'Heavy Metals in Commercial Fish in New Jersey'. *Environmental Research* 99(3), 403–12.

CODEX ALIMENTARIUS COMMISSION. 2011. 'Joint FAO/WHO Food Standards Programme Codex Committee on Contaminants in Foods'. *fifth session, The Hague, the netherlands* 21–5.

CUBADDA, Francesco and Andrea RAGGI. 2005. 'Determination of Cadmium, Lead, Iron, Nickel and Chromium in Selected Food Matrices by Plasma Spectrometric Techniques'. *Microchemical Journal* 79(1–2), 91–6.

DAHIYA, Sudhir, Rupali KARPE, AG HEGDE and RM SHARMA. 2005. 'Lead, Cadmium and Nickel in Chocolates and Candies from Suburban Areas of Mumbai, India'. *Journal of Food Composition and Analysis* 18(6), 517–22.

DAWODU, Modupe O. 2019. 'Dietary Intake and Risk Assessment of Heavy Metals from Selected Biscuit Brands in Nigeria'. *ARCHIVOS DE MEDICINA* 4(2), 3.

DEMIREL, S., M. TUZEN, S. SARACOGLU and M. SOYLAK. 2008. 'Evaluation of Various Digestion Procedures for Trace Element Contents of Some Food Materials'. *J Hazard Mater* 152(3), 1020–6.

DORSEY, Alfred and Lisa INGERMAN. 2004. 'Toxicological Profile for Copper'.

ENB, A et al. 2009. 'Chemical Composition of Raw Milk and Heavy Metals Behavior during Processing of Milk Products'. *Global veterinaria* 3(3), 268–75.

FALCÓ, Gemma, Juan M LLOBET, Ana BOCIO and José L DOMINGO. 2006. 'Daily Intake of Arsenic, Cadmium, Mercury, and Lead by Consumption of Edible Marine Species'. *Journal of agricultural and food chemistry* 54(16), 6106–12.

FAO, FAO. 1983. 'Fishery Circular No. 464, 5–100'. *Compilation of legal limits for hazardous substances in fish and fishery products. Food and Agriculture Organization of the United Nations, Rome*.

GUO, Jing, Tianli YUE, Xiaotong LI and Yahong YUAN. 2016. 'Heavy Metal Levels in Kiwifruit Orchard Soils and Trees and Its Potential Health Risk Assessment in Shaanxi, China'. *Environmental Science and Pollution Research* 23(14), 14560–6.

HARMANESCU, Monica et al. 2011. 'Heavy Metals Health Risk Assessment for Population via Consumption of Vegetables Grown in Old Mining Area; a Case Study: Banat County, Romania'. *Chemistry Central Journal* 5(1), 1–10.

HOSSEINI, SV et al. 2013. 'Analysis of Mercury, Selenium, and Tin Concentrations in Canned Fish Marketed in Iran'. *Environmental monitoring and assessment* 185(8), 6407–12.

HUSSEIN, S. A., M. H. RATHI and T. J. KADHIM. January 6. 'Determination of the Levels of Lead and Cadmium in Canned Fish and Meat, Imported to the Local Markets of Diyala Province, Iraq'. *IOP Conference Series: Earth and Environmental Science* 790, 012043.

INTERNATIONAL DAIRY, Federation. 1992. 'INTERNATIONAL DAIRY FEDERATION,1992, Trace Elements in Milk and Milk Products. International Dairy Federation Bulletin (Brussels), No. 278'.

JOINT FAO/WHO CODEX ALIMENTARIUS COMMISSION, JOINT FAO/WHO FOOD STANDARDS PROGRAMME, and WORLD HEALTH ORGANIZATION. 2007. *Codex Alimentarius Commission: Procedural Manual*. Food & Agriculture Org.

KAPICA, Cathy and Wendy WEISS. 2012. 'Canned Fruits, Vegetables, Beans and Fish Provide Nutrients at a Lower Cost Compared to Fresh, Frozen or Dried'.

KHANSARI, F Emami, M GHAZI-KHANSARI and M ABDOLLAHI. 2005. 'Heavy Metals Content of Canned Tuna Fish'. *Food chemistry* 93(2), 293–6.

KORFALI, Samira I and Weam ABOU HAMDAN. 2013. 'Essentail and Toxic Metals in Lebanese Marketed Canned Food: Impact of Metal Cans'. *Journal of food research* 2(1), 19.

KOWALSKA, Grażyna, Urszula PANKIEWICZ and Radosław KOWALSKI. 2020. 'Determination of the Level of Selected Elements in Canned Meat and Fish and Risk Assessment for Consumer Health'. *Journal of Analytical Methods in Chemistry* 2020, 2148794.

NINČEVIĆ GRASSINO, A et al. 2009. 'Corrosion Behaviour of Tinplate Cans in Contact with Tomato Purée and Protective (Inhibiting) Substances'. *Food Additives and Contaminants* 26(11), 1488–94.

ODUOZA, Chike F. 1992. 'Studies of Food Value and Contaminants in Canned Foods'. *Food chemistry* 44(1), 9–12.

OMAR, Wael A, Khalid H ZAGHLOUL, Amr A ABDEL-KHALEK and S ABO-HEGAB. 2013. 'Risk Assessment and Toxic Effects of Metal Pollution in Two Cultured and Wild Fish Species from Highly Degraded Aquatic Habitats'. *Archives of environmental contamination and toxicology* 65(4), 753–64.

RAHIMI, Ebrahim et al. 2010. 'Analysis and Determination of Mercury, Cadmium and Lead in Canned Tuna Fish Marketed in Iran'. *African Journal of Biotechnology* 9(31), 4938–41.

SOBHANARDAKANI, Soheil. 2017. 'Tuna Fish and Common Kilka: Health Risk Assessment of Metal Pollution through Consumption of Canned Fish in Iran'. *Journal of Consumer Protection and Food Safety* 12(2), 157–63.

TANG, Wei, Jinping CHENG, Wenchang ZHAO and Wenhua WANG. 2015. 'Mercury Levels and Estimated Total Daily Intakes for Children and Adults from an Electronic Waste Recycling Area in Taizhou, China: Key Role of Rice and Fish Consumption'. *Journal of Environmental Sciences* 34, 107–15.

TCHOUNWOU, Paul B, Clement G YEDJOU, Anita K PATLOLLA and Dwayne J SUTTON. 2012.

‘Heavy Metal Toxicity and the Environment’. *Molecular, clinical and environmental toxicology* 133–64.

TÜRKMEN, Mustafa et al. 2008. ‘Determination of Metal Contaminations in Sea Foods from Marmara, Aegean and Mediterranean Seas: Twelve Fish Species’. *Food Chemistry* 108(2), 794–800

UROKO, RI, VE OKPASHI, NE ETIM and AC FIDELIA. 2020. ‘Quantification of Heavy Metals in Canned Tomato Paste Sold in Ubani-Umuahia, Nigeria’. *Journal of Bio-Science* 28, 1–11.

ZHUANG, Ping et al. 2009. ‘Health Risk from Heavy Metals via Consumption of Food Crops in the Vicinity of Dabaoshan Mine, South China’. *Science of the total environment* 407(5), 1551–61.