Available online at www.garmian.edu.krd

Passer Journal of Basic and Applied Sciences

Passer 8 (Issue 2) (2026) 642-647

Original Article

Evaluation Of Selected Heavy Metals in Noodles from Sulaimani Market in Iraq Using Inductive Coupled Plasma Optical Emission Spectrometer

Sakar Mohammed Ali * [1], Khulod Ibrahim Hassan [1] Hiran Sarwar Karim Agha [1]

[1] *University of Sulaimani College of Agricultural Engineering in Sciences Food Science and Quality Control Department, Al Sulaymaniyah 46001 Kurdistan Reign, Iraq.*

Received 16 January 2026; revised 25 February 2026;
accepted 20 March 2026; available online 01 July 2026

DOI: 10.24271/PSR.2026.571889.2521

ABSTRACT

The purpose of this study was to ascertain the amounts of five metals cadmium (Cd), chromium (Cr), lead (Pb), arsenic (As), and nickel (Ni). in different kinds of noodles and pasta products that were gathered from several markets in Sulaimani, Iraq's Kurdistan region. These metals were measured using inductively coupled plasma optical emission spectrometry (ICP-OES) after extraction from noodle and pasta samples. The results showed that the selected noodle samples included the following ranges of heavy metals: cadmium (0.01 to 0.22 mg/kg), Total chromium (0.12 to 0.72 mg/kg), lead (0.31 to 3.16 mg/kg), arsenic (0.05 to 0.94 mg/kg), and nickel (0.29 to 2.08 mg/kg). pb > Ni > As > Cr > Cd is the pattern of metal concentration in noodles. The concentrations of specific heavy metals were comparable to those reported in studies conducted in other counties. All samples contained heavy metals, but the percentage of samples that exceeded the WHO maximum permitted limits varied depending on the metal. Only one sample surpassed the allowable limit for Ni (1.0 mg/kg), whereas all samples above the maximum allowable limits for Cr (0.05 mg/kg), As 94% (0.2 mg/kg), Pb 88% (0.1 mg/kg), and Cd 41% (0.1 mg/kg). According to this study, noodle and pasta produts can be exposed to harmful heavy metals over time, which can have adverse health effects. The Sulaimani market's noodles and pasta products should be properly monitored to ensure that they are safe to eat. The use of noodles is strongly advised, and additional research has focused on the source of contamination, as well as the health concerns of consuming these contaminated noodles.

Keywords: noodles, contamination, heavy metals, ICP-OES.

1 Introduction

Wheat flour noodles are an important part of the diet of numerous people. Since it began in China in 5000 BC, its consumption has rapidly increased worldwide [1]. Due to their easy preparation requirements, attractive organoleptic qualities, extended shelf life, adaptability, nutritional content and relative affordability, they are consumed by people of all ages [2]. Noodle is thought to be the second most popular food after bread and contains proteins, carbohydrate, minerals, fatty acids, and a few chemicals including stabilizers, emulsifiers, antioxidants, and colorants [3]. The classification of noodles can be stimulating because there are numerous varieties available in markets across various locations, each with a unique nomenclature that can be generically categorized as European or Asian. The public can purchase them commercially under a number of brands, and each nation has its own favored production method and raw material. While some are chilled and sold either fresh or frozen, others are sold dried [4]. Both pasta and noodles are made from wheat, bread and noodles are made from common wheat (Triticum aestivum), and pasta is made from durum wheat (Triticum turgidum) [4]. Durum usually has a higher protein content, less starch, and less fat than regular wheat, which increases the temperature at which gelatinization occurs. Because durum wheat contains carotenoids, pasta often has a yellow color and takes longer to cook than noodles [5].

Heavy metals including Pb, As, Cd, Ni, and Cr, are present in water and soil because of the extensive use of inorganic fertilizers and pesticides. Wheat and noodles are among the plants that absorb and store these elements. Additionally, the equipment used throughout the production cycle may introduce contaminants into noodles [3]. Contamination of instant noodle products with heavy metals has been reported in several studies [6]. As some toxic metals pose major risks to human health, the Food and Agriculture Organization (FAO) and the World Health Organization (WHO) have developed guidelines for the regulation of these chemical pollutants in food products. These guidelines are detailed in the Codex Alimentarius, the Official

* Corresponding author
E-mail address sakar.ali@univsul.edu.iq (Other).
Peer-reviewed under the responsibility of the University of Garmian.

Journal of the European Union. [7]. Strict quality assurance procedures were advised, including the use of reputable technologies like Raman spectroscopy, spectrofluorometric, atomic absorption spectrometry, biochemical sensors, and electronic tongues to monitor the levels of these hazardous metals in pasta products. These technologies have been successfully used to identify traces of heavy metals in noodles [8]. The most widely used of these is inductively coupled plasma optical emission spectrometry (ICP-OES), which has relatively low detection limits and can precisely quantify the analysed metals simultaneously in a short amount of time across a large concentration range. [9-10].

Several studies have been conducted to quantify heavy metals in many of the commercially available noodle products using ICP combined with different types of detectors. For instance, ICP combined with mass spectrometry (ICP-MS) was used to determine the concentrations of some heavy metals (Pb, Cd, As) in popular instant noodles from the Malaysian market [6]. In the Canadian market, ICP and tandem mass spectrometry (ICP-MS/MS) have been effectively utilized to identify Pb, As, and Cd in instant noodles, resulting in the temporary ban of numerous well-known brands worldwide [11]. ICP-OES has been used in several studies to measure the levels of hazardous metals in wheat products [12-13].

Heavy metal poisoning, particularly after prolonged exposure, causes these elements to travel and concentrate in numerous organs, resulting in several health issues such as central nervous system dysfunction, as well as diseases of the heart, stomach, blood, liver, kidneys, nervous and reproductive development, immune disorders, and intrauterine underdevelopment [14-15]. Because most noodle and pasta products consumed in the Kurdistan region are imported without any studies applied to their safety, this study was conducted to assess the quality of some noodle and pasta products available in the Sulaymaniyah market by assessing their contamination levels with selected heavy metals (Pb, Cd, Cr, Ni, and As) using ICP-OES.

2 Methods and Materials

2. 1 Sample collection and preparation

A total of 32 composite samples were collected for this study, consisting of 16 noodles and 16 pasta samples. These samples were represented by four popular commercial noodle and pasta brands (A, B, C and D) selected from local markets across Sulaimani, Iraq. Collected samples were taken directly from the laboratory for analysis. Sterile gloves were used for direct handling and the general air exposure of the samples was minimal. The tabs of the packages were opened while making little contact to open the bag.

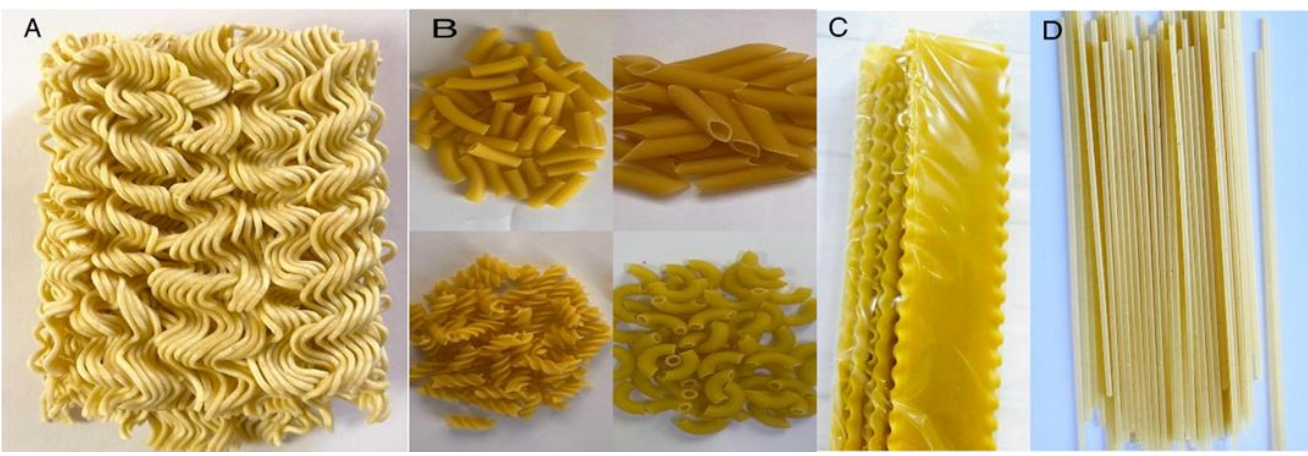

Figure 1: Four brands (A, B, C and D) representative of dried noodle and pasta products, prior to chemical analysis. collected from Sulaimani city, Kurdistan Region, Iraq.

2. 2 Sample Digestion and Analysis

Pasta and noodle samples were dried weight, homogenized and thoroughly ground in a pre-cleaned magic blender. Sample digestion was performed according to a microwave-assisted acid-based digestion process which is commonly applied to grain-based food matrices [11]. Polytetrafluoroethylene (PTFE) microwave digestion vessels were filled with precisely weighed (0.5 g) homogenized noodle samples. Each vessel received a digesting reagent mixture of hydrogen peroxide ($H2O_2$, 30%, 2 mL) and concentrated nitric acid (HNO_3, 65%, 8 mL). To guarantee full mineralization of the organic matrix, the sealed PTFE containers were placed within an ETHOS UP pressurized microwave digestion system (Milestone, Italy), where the temperature was raised to 210 °C and maintained for 30 min. The digesters were then transferred to volumetric vials, and ultrapure water was used to dilute the final volume to create a clear solution suitable for automated analysis after cooling to room temperature and carefully filtering to remove any particle residues.

2. 3 Determination of heavy metal concentration

Metal (Cr, Cd, As, Pb, and Ni) concentrations in the digested noodle and pasta samples were quantified using inductively coupled plasma optical emission spectrometry (ICP-OES-9820 Plasma Atomic Emission Spectrometer; Shimadzu, Japan), equipped with a mini-torch, part number (P/N) S211-81448.The instrumental settings, calibration processes, and quality control checks were optimized according to the manufacturer's recommendations.

A certified Multi-Element ICP Quality Control Standard solution (QCS-27, 27E) with a stock concentration of 100 mg/L was used to generate calibration standards for ICP-OES. To guarantee analyte stability and reduce adsorption losses, the working standards were diluted using ultrapure deionized water acidified with 1-2% (v/v) trace-metal grade nitric acid to final concentrations of 0.01, 0.05, 0.1, 0.5, 1.0, 1.5, and 2.0 mg/L. All dilutions were performed gravitationally or volumetrically using Class, glassware A and the dilution equation ($C1V1 = C2V2$). Every day, new standards were set up, kept in acid-washed polyethylene containers, and used to build calibration curves for quantitative analysis. To maximize sensitivity and accuracy, instrumental parameters, such as nebulizer flow, plasma power, and monitoring mode, were adjusted according to the manufacturer's recommendations. The widely recognized ICH [16] and AOAC [17] were followed for the validation of ICP-OES technology. in terms of linearity, accuracy, including recovery values, sensitivity, limit of detection (LOD), limit of quantification (LOQ), and selectivity.

Samples and ultrapure deionized water blanks were regularly examined to detect loss or cross contamination. Linearity was assessed across 8-point calibration (instrument standards: 0, 0.01, 0.05, 0.1, 0.5, 1.0, 1.5 and 2.0 $mg \cdot L^{-1}$) for each analyte. The limits of detection (LOD) and quantification (LOQ) were calculated using the equations $LOD = 3.3\sigma/S$ and $LOQ = 10\sigma/S$, respectively, based on the standard deviation of the procedural blank measurements (σ) and the slope (S) of the calibration curves. This allowed for the evaluation of the method sensitivity. The method accuracy was evaluated by recovery experiments that were performed by spiking noodle and pasta samples at different concentration levels prior to digestion, and the detected values of the metals were compared with the spiked values. By using background correction to reduce the spectral interferences caused by the food matrix and carefully choosing the analytical wavelengths, selectivity was guaranteed.

2. 4 Statistical analysis

The XLSTAT software version 2019.2.2 was used for statistical data analysis. To find significant differences, one-way analysis of variance (ANOVA) and a post hoc test (Duncan) were employed. Statistical significance was set at $P < 0.05$, and the values are presented as mean ± standard deviation (mean ± SD).

3 Results and Discussions

3. 1 Sample Digestion

Microwave-assisted acid digestion was used to prepare the sample before ICP-OES analysis because of the complex organic composition of pasta and noodle products, which are rich in starch and proteins and require complete mineralization to accurately determine the elements. The use of concentrated nitric acid in combination with hydrogen peroxide under controlled temperature and pressure conditions ensures the effective decomposition of the organic matrix while minimizing the risk of contamination and loss of analytical material. This approach is particularly suitable for the determination of hazardous compounds including Pb, Cr, As, and Cd, which may be partially lost or incompletely recovered using traditional open vessel digestion or dry ash. The chosen method is consistent with the internationally recognized standard procedures for food analysis and has been proven to provide reliable accuracy and accuracy of multiple item identification by ICP-OES.

3. 2 Method validation

The ICP-OES method was validated to demonstrate its accuracy and suitability for determining trace and heavy metals (Pb, As, Cd, Ni, and Cr) in noodles and pasta products. Linearity, sensitivity, precision, and selectivity are examples of validation parameters. Eight standard solution concentration levels that extend the expected ranges of the anticipated target metals were used to create the calibration curves. Each analyte demonstrated outstanding linearity with a coefficient of determination (R^2) greater than 0.999, demonstrated a stable, proportional relationship between the instrument signal and analyte concentration across the working range and confirmed the suitability of the method for quantitative analysis in wheat matrices [18]. Regarding the sensitivity of the technique, The LOD values for Pb is 0.04 mg/kg, As 0.004 mg/kg, Cd 0.006 mg/kg, Ni 0.002 and Cr 0.003 mg/kg, while the LOQ values ranged from Pb is 0.16 mg/kg, for As 0.016 mg/kg, for Cd 0.022 mg/kg, for Ni 0.09 and for Cr 0.012 mg/kg, respectively, while the component. These limitations were sufficiently low to allow for accurate measurements of Pb, Cd, As, Cr, and Ni at concentrations below the highest allowable levels set by EU regulations.

Recovery studies were used to assess the accuracy by spiking food samples with known quantities of each metal before digestion. All the metals examined had recovery values between 97 and 103%, which is within the acceptable range given by AOAC [17]. recommendations, thereby demonstrating the satisfactory accuracy [19]. Selectivity was ensured by the appropriate selection of analytical wavelengths and application of background correction to minimize spectral interferences arising from the food matrix. The chosen analytical wavelengths were 283.306 nm Pb, 189.042 nm As, 226.502 nm Cd, 231.604 nm Ni and 284.325 nm, Cr.

Table 1: Heavy metals concentration (Pb, As, Cd, Ni, Cr) in deferent noodle and pasta samples from four brands sold in Sulaymaniyah markets (mean, n=3).

Sample	Pb (mg/kg)	As (mg/kg)	Cd (mg/kg)	Ni (mg/kg)	Cr (mg/kg)
1	2.75 b	0.44 e f	0.09 b-e	2.08 a	0.72 a
2	ND	0.36 f g	0.11 bcd	0.98 b	0.57 c
3	ND	0.61 c d	ND	0.70 d	0.48 e
4	ND	0.52 d e	0.05 efg	0.61 e	0.39 g
5	2.17 e	0.39 f g	0.12 bc	0.87 c	0.30 k
6	2.31 d	0.94 a	0.13 b	0.53 h	0.50 d
7	1.07 h	0.63 c	0.21 a	0.47 k	0.39 h
8	2.33 d	0.43 e f	ND	0.50 i	0.59 b
9	ND	0.67 c	ND	0.58 f	0.28 l
10	2.60 c	0.21 h	0.02 gh	0.50 i	0.30 j
11	0.57 i	0.90 ab	0.19 a	0.39 n	0.18 o
12	3.16 a	0.64 c	0.07 def	0.34 o	0.40 f
13	1.11 h	0.21 h	0.08 cde	0.43 l	0.26 m
14	1.07 h	0.84 b	0.04 fgh	0.48 j	0.16 p
15	1.43 g	0.71 c	0.10 bcd	0.40 m	0.22 n
16	2.02 f	0.29 g h	ND	0.54 g	0.38 i
17	0.80 h	0.75 ab	0.11 f	0.51 d	0.36 g
18	1.65 f	0.44 ef	0.01 n	0.36 n	0.32 j
19	2.44 c	0.47 de	0.05 l	0.45 h	0.43 e
20	2.71 b	0.02 h	0.15 c	0.38 m	0.21 n
21	1.74 e	0.69 b	0.17 b	0.52 c	0.34 h
22	2.09 d	0.47 de	0.12 de	0.44 i	0.29 l
23	2.03 d	0.34 g	0.12 e	0.44 i	0.30 k
24	1.50 g	0.55 cd	0.10 g	0.29 o	0.66 a
25	2.72 b	0.36 fg	0.08 i	0.54 b	0.63 b
26	2.01 d	0.05 h	0.12 d	0.50 e	0.45 d
27	0.32 j	0.72 ab	0.22 a	0.41 l	0.26 m
28	0.31 j	0.30 g	0.00 o	0.46 g	0.49 c
29	0.56 I	0.58 c	0.09 h	0.60 a	0.38 f
30	1.60 f	0.35 fg	0.06 k	0.50 f	0.32 i
31	2.04 d	0.81 a	0.05 m	0.43 j	0.18 o
32	2.95 a	0.53 cde	0.07 j	0.42 k	0.12 p
WHO	0.1	0.2	0.1	1.0	0.05

The data were tested for homogeneity and analyzed using one-way ANOVA-CRD by XLSTAT software. The means were compared according to Duncan's multiple range test ($p \leq 0.05$). The mean (ND) of the data is not detected. permissible limits (mg/kg) according to (WHO).

Table 1 shows the varying concentrations of heavy metals (Pb, As, Cd, Ni, and Cr) selected for this study for 32 samples of noodles and pasta sold in the Sulaimani market. In general, the metal concentration analysis of the noodle and pasta samples revealed that Cd was present at the lowest levels among all the investigated heavy metals, whereas Pb was the highest. Among these samples, Sample 1 was the highest contaminated whereas sample 9 was the lowest one No measurable Pb concentration was observed in four (12.5%) noodles and pasta samples, the Concentrations of Pb in the other (87.5%) samples ranged between 0.31 mg/kg (S28) to 3.16 mg/kg (S12), in which they all exceed the permissible limits (0.1 mg/kg) set by the WHO [20].

These findings are similar to those of Tajdar-Oranj et al. [21] who examined imported and domestic instant noodles on the Iranian market and discovered that lead levels exceeded the maximum permissible limits, ranging from 0.33 to 2.89 mg/kg. The maximum permissible Pb level was similar to the Pb concentration in the noodle samples in the investigation by Elias et al. [6]. While several samples in the study by Charles et al. [22] had Pb concentrations ranging from 0.043 to 3.163 mg/kg, Katyal et al. [11] revealed no violations of the maximum permissible limits of Pb. who discovered that the levels of Pb in instant noodles in Canada ranged from 0.003 to 0.250 mg/kg? These levels are lower than those found in earlier studies because of the stringent import regulations implemented by the Canadian Food Inspection Agency to safeguard food quality. It is crucial to remember that the biological effects of Pb exposure in humans can vary depending on the amount and duration of exposure. Lead poisoning has a variety of effects, including toxic biochemical effects on the kidneys, gastrointestinal tract, joints, and reproductive system, as well as issues with haemoglobin synthesis and acute and chronic nervous system dysfunction [23]. Children and foetuses are more impacted than adults. Lead contamination of wheat flour can come from a variety of sources, including industrial emissions and traffic, agricultural practices, irrigation with tainted water, use of pesticides and fertilizers based on minerals, and harvesting and storage practices [6]. Therefore, caution should be exercised when consuming such noodles on a regular basis and when taking steps to lower the lead content of such noodles.

The 32 noodle and pasta samples utilized in this investigation had concentrations of (Total As) ranging from 0.05 mg/kg (S 26) to 0.94 mg/kg (S 6). The WHO [20] acceptable limits of 0.2 mg/kg are exceeded by thirty (94%) of the samples. for food items and cereals containing arsenic. According to Elias et al. [6] investigation, the amount of As in instant noodles varied from 0.25 to 0.81 mg/kg The high concentration of heavy metals found in noodles suggests that this noodle can be a source of long-term exposure to heavy metals, particularly when consumed in large quantities, which may subsequently result in health consequences linked to the toxicology of heavy metals. However, low quantities of As were discovered in the investigation by Katyal et al. [11] because of the strict regulations enforced by that the Canadian Food Inspection Agency. Human exposure to As is mostly linked to the side of grain products, which are present in seafood, water, and food items made from algae posing a serious health threat to consumers [24]. Because instant noodles are a highly processed meals, flavors or additional substances used in their manufacture and seasoning may contain heavy metals. It is frequently used as a food preservative [6].

The Concentrations of (Cd) in noodles and pasta samples used in the current study ranged between 0.01 mg/kg (S18) to 0.22 mg/kg (S27). Thirteen (41%) samples exceeded the permissible limits set by WHO [20]. for the Cd (0.1 mg/kg) in cereals and food products. These results are similar to those obtained in a previous study Elias et al.[6]. in which Cd concentrations ranged between 0.03 to 0.37 mg/kg, in which three samples exceeded the permitted limit for Cd in food. However, the Cd concentrations in the study by Katyal et al. [11]. were lower and ranging between 0.009 and 0.149 mg/kg, respectively. Cadmium exposure over an extended period, even at low levels, can be harmful to the kidneys, respiratory system, and bones [24]. The colour dye Cd is used in the food industry. This is one way that eating quick noodles can lead to heavy metal pollution. The addition of water during the preparation of instant noodles can also be a source of contamination [6].

Nickel (Ni) concentrations in noodles and pasta samples used in this study ranged between 0.29 mg/kg (S 24) from 2.08 mg/kg (S1). The WHO [25]. The permissible limits (1.0 mg/kg) for Ni in cereals and food products are exceeded by just one sample. Charles et al. [22] reported that the Ni content varied from 0.012 to 0.354 mg/kg, all of which were below the WHO' recommended levels for food. There are several ways in which nickel can accumulate in wheat grains, but the primary causes are soil contamination, irrigation water, atmospheric sedimentation, and agricultural practices such as fertilizer and pesticide use. These minerals are transported to the edible sections of plants after being absorbed by the root, where they eventually find their way into the human food chain [13]. Long-term exposure to nickel in the body can cause lung fibrosis, kidney and cardiovascular diseases, and respiratory cancer in humans. Previous studies on cereal crops have found that nickel tends to accumulate in the soil, possibly because of external sources such as fertilizers and pesticides [26].

Regarding (Total Cr) their concentrations obtained in this study ranged from 0.12 mg/kg to (S 32) 0.72 mg/kg (S1), in which all samples exceed the Permissible limits (0.05 mg/kg) set by the WHO for the Cr in cereals and food products WHO [25]. These outcomes fall short of the Cr concentration in the noodle samples in the study by Charles et al. [22]. which ranged between 0.40 to 11.00 ppm in which all of them were above the Permissible limits of Cr. High concentrations of Cr were also detected in instant noodle brands in Iran, which are also higher than the WHO-recommended limit of Tajdar-oranj et al. [21]. Therefore, caution should be exercised when consuming these pastas daily to avoid health issues related to chromium exposure and bioaccumulation. Chromium, an essential mineral for animal nutrition, is added to feed for several reasons, such as glucose balance, growth performance, and antidepressant effects. Chronic exposure to chromium can have negative effects on the liver, kidneys, circulatory system, and nervous system [24].

The heavy metals contained in instant noodles may originate from raw (soil and irrigation water) or processed ingredients (cereals, spices, and additives) used in the production of instant noodles. The primary ingredient used to make pasta is wheat flour, and several studies have shown that cereals can accumulate various amounts of heavy metals as a result of agricultural practices and environmental exposure. If the water used to prepare pasta comes from contaminated sources, it could also be a source of contamination [6]. Increased pollution requires constant monitoring of these metals to prevent health risks to humans [15]. Additionally, climatic conditions and crop cultivation practices may further contribute to variability in metal uptake in cereal products across different geographic regions. ICP-OES provides several important advantages, such as the high ability of simultaneous metal detectors with wide focus ranges, accurate detection within a short time and relatively low detection limits [10].

4 Conclusion

The analysis of heavy metals in instant noodle and pasta samples using ICP-OES revealed the detection of heavy metals in most of the samples. The proportions of samples exceeding WHO maximum permissible limits was 100% for Cr, 94% for As, 88% for Pb, and 41% for Cd, whereas only one sample exceeded the limit for Ni. These results suggest that instant noodles and pasta products are likely a source of long-term exposure to heavy metals, which can subsequently lead to health consequences associated with heavy metal toxicity. Therefore, noodle and pasta products cannot be considered safe for domestic consumption in terms of heavy metal content. To ensure their safety, improved recognition and regular investigations are necessary. It is advisable to conduct further research to identify the sources of contamination and to suggest ways to reduce exposure to heavy metals and the health risks associated with eating contaminated food.

References

[1] Siddeeg, A., Salih, Z. A., Ammar, A.-F., Almahi, R. A. Y. & Ali, A. O. Production of Noodles from Composite Flour and it is Nutritional and Sensory Characteristics. Chinese J. Med. Res. **1**, (2018).

[2] Isah Akubor, P. & Fayashe, T. O. Chemical composition, Functional properties and performance of soybean and wheat flour blends in instant fried noodles. South Asian J. Food Technol. Environ. **4**, (2019).

[3] Jakkielska, D., Frankowski, M., Kurzyca, I. & Ziołafrankowska, A. Risk Profiling of Exposures to Potentially Toxic Metals PTM(S) Through Noodles Consumption. A Case Study of Human Health Risk Assessment. Acta Univ. Cibiniensis Ser. E Food Technol. **27**, 91–102 (2023).

[4] Adejuwon, O. H., Jideani, A. I. O. & Falade, K. O. Quality and Public Health Concerns of Instant Noodles as Influenced by Raw Materials and Processing Technology. Food Rev. Int. **36**, 276–317 (2020).

[5] Wang, J., Li, Y., Guo, X., Zhu, K. & Wu, Z. A Review of the Impact of Starch on the Quality of Wheat-Based Noodles and Pasta: From the View of Starch Structural and Functional Properties and Interaction with Gluten. Foods **13**, (2024).

[6] Mohd Elias, S., Hanani Yunus, F., Sabrina Shamsani, N. & Abdullah Aziz, N. Heavy Metals (Pb, Cd, As) Content in Instant Noodles from Malaysian Market. Malaysian J. Med. Health Sci. (2019).

[7] Mustatea, G. & Ungureanu, E. L. Assessing the presence and health risks of potentially toxic metals in food: a comprehensive overview. Explor. Foods Foodomics **2**, 471–496 (2024).

[8] Mukherjee, A. G. et al. Correction: Heavy Metal and Metalloid Contamination in Food and Emerging Technologies for Its Detection. Sustainability **16**, (2024).

[9] Kakoma, F. I. S. & Awofolu, O. R. Contamination And Health Risk Assessment Of Instant Noodles By Heavy Metals From Commercial Outlets In Windhoek, Namibia. Afr. J. Food Agric. Nutr. Dev. **21**, 18245–18260 (2021).

[10] Helaluddin, A. B. M., Khalid, R. S., Alaama, M. & Abbas, S. A. Main Analytical Techniques Used for Elemental Analysis in Various Matrices. Trop. J. Pharm. Res. **15**, 427–434 (2016).

[11] Katyal, D., Chen, D. & Kuo, H. Analysis of lead, arsenic, and cadmium concentrations in instant noodles within the Canadian market. (2020).

[12] Pirhadi, M. et al. Potential toxic elements (PTEs) concentration in wheat and flour products in Iran: A probabilistic risk assessment. Heliyon **8**, e11803 (2022).

[13] Kayisoglu, C., Uzel, S. & Kabak, B. Redistribution and introduction of heavy metals during wheat milling: A process-based study. J. Cereal Sci. **124**, (2025).

[14] Munir, N. et al. Heavy metal contamination of natural foods is a serious health issue: A review. Sustainability **14**, (2022).

[15] Scutarașu, E. C. & Trincă, L. C. Heavy Metals in Foods and Beverages: Global Situation, Health Risks and Reduction Methods. Foods **12**, (2023).

[16] International Council for Harmonisation of Technical Requirements for Pharmaceuticals for Human Use (ICH). ICH Harmonised Guideline: Validation of Analytical Procedures Q2(R2). (2023).

[17] AOAC International. Official Methods of Analysis of AOAC INTERNATIONAL (22nd edn). (2023).

[18] Tan, M., Sudjadi, Astuti & Rohman, A. Validation and quantitative analysis of cadmium, chromium, copper, nickel, and lead in snake fruit by inductively coupled plasma-atomic emission spectroscopy. J. Appl. Pharm. Sci. **8**, 044–048 (2018).

[19] Runge, J., Heringer, O. A., Ribeiro, J. S. & Biazati, L. B. Multi-element rice grains analysis by ICP OES and classification by processing types. Food Chem. **271**, 419–424 (2019).

[20] World Health Organization [WHO]. Exposure to lead: a major public health concern. (2019).

[21] Tajdar-oranj, B. et al. The concentration of heavy metals in noodle samples from Iran's market: probabilistic health risk assessment. Environ. Sci. Pollut. Res. **25**, 30928–30937 (2018).

[22] Charles, I. A., Ogbolosingha, A. J. & Afia, I. U. Health risk assessment of instant noodles commonly consumed in Port Harcourt, Nigeria. Environ. Sci. Pollut. Res. **25**, 2580–2587 (2018).

[23] Collin, M. S. et al. Bioaccumulation of lead (Pb) and its effects on human: A review. J. Hazard. Mater. Adv. **7**, (2022).

[24] Elziani, N., Ben Ghazi, R. & Yaghi, M. Assessment of Heavy Metal Concentrations in Instant Noodles from Local Markets in Benghazi, Libya. J. Pure Appl. Sci. **23**, 149–153 (2024).

[25] WHO. Evaluation of certain contaminants in food: seventy-second report of the joint FAO/WHO expert committee on food additives. WHO Techn Rep Series 959 (2011).

[26] Wahab, M. F. & Jamil, D. M. Determination of some heavy metals in different wheat flour brands in Sulaimani, Kurdistan Region - Iraq. Czech J. Food Sci. **41**, 455–461 (2023).