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Assessment of Heavy Metal Concentrations in Instant Noodles from Local Markets in Benghazi, Libya

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Abstract

This study aimed to determine the concentrations of heavy metals in various types of instant noodles collected from different markets in Benghazi, Libya. The levels of five metals—cadmium (Cd), chromium (Cr), lead (Pb), arsenic (As), and tin (Sn)—were measured using a triple quadrupole inductively coupled plasma mass spectrometer (ICP-MS). The results were reported in parts per billion (ppb). The detected ranges of heavy metals in instant noodles were as follows: cadmium (1.75 to 33.63 ppb), chromium (0.46 to 15.47 ppb), lead (2.11 to 47.48 ppb), arsenic (0.22 to 3.54 ppb), and tin (2.01 to 8.04 ppb). The trend of metal concentrations in the noodles was Pb > Cd > Sn > Cr > As. The levels of the selected heavy metals were comparable to data reported in studies conducted in other countries. The heavy metals measured in this study were found to be within the WHO permissible limits, except for Sample No. 2, which showed a cadmium level exceeding the WHO limit. Therefore, long-term consumption of these noodles could lead to the accumulation of heavy metals in the body, posing potential health risks over time.

تقييم تراكيز المعادن الثقيلة في المعكرونة سريعة التحضير التي تم جمعها من الأسواق المحلية في بنغازي، ليبيا

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الكلمات المفتاحية:
المعكرونة سريعة التحضير.
الهضم الرطب.
العناصر الثقيلة.
مطياف الكتلة-البلازما المقترنة حثيا.

الملخص

إن الهدف من هذه الدراسة هو تحديد تراكيز المعادن الثقيلة في سبعة أنواع مختلفة من المعكرونة سريعة التحضير(الأندومي)، حيث تم جمع هذه العينات من أسواق مختلفة في مدينة بنغازي – ليبيا؛ ولقد تم قياس مستويات خمسة من المعادن باستخدام مطياف كتلة البلازما رباعي الثلاثي القطب (ICP-MS) وهذه المعادن هي: الكادميوم (Cd) والكروم (Cr) والرصاص (Pb) والزرنيخ (As) والقصدير (Sn). تم قياس تركيز المعادن قيد الدراسة في أجزاء في المليار (جزء في البليون ppb). كان مدى المحتوى المقاس لهذه المعادن الثقيلة في المعكرونة سريعة التحضير على النحو التالي: (1.75 - 33.63 ppb)، (0.46 - 15.47 ppb)، (2.11 - 47.48 ppb)، (0.22 - 3.54 ppb)، و (2.01 - 8.04 ppb) لكل من الكادميوم والكروم والرصاص والزرنيخ والقصدير، على التوالي؛ وكان الترتيب التصاعدي لمستويات المعادن في المعكرونة سريعة التحضير كالتالي: Pb > Cd > Sn > Cr > As. كما تم مقارنة نتائج مستويات المعادن الثقيلة المختارة في هذه الدراسة مع البيانات المتحصل عليها من الدراسات التي أجريت في بلدان أخرى. تم العثور على المعادن الثقيلة التي تم قياسها في جميع العينات لهذه الدراسة بمستويات نسبيا في الحد المسموح به من قبل منظمة الصحة العالمية باستثناء العينة رقم 2 حيث أنها أظهرت مستوى أعلى من الكادميوم، والذي كان أعلى من المستوى المسموح به لمنظمة الصحة العالمية. لذلك فإن الاستهلاك طويل الأجل لهذه المعكرونة (الأندومي) يؤدي إلى تراكم المعادن الثقيلة في الجسم، مما يشكل مخاطر صحية محتملة بمرور الوقت.

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1. Introduction

Food plays a crucial role in human survival and well-being. It is more than just sustenance; it fuels both body and mind. Food is essential for life, providing the energy necessary for basic functions such as breathing, digestion, circulation, growth, and development. Without adequate nutrition, the body begins to deteriorate, leading to serious health issues [1]. Throughout Libya, instant noodles have become a popular convenience food. Made from wheat or rice flour, they are quick and easy to prepare, making them accessible and convenient for consumption anytime and anywhere. Instant noodles, a key part of the 'convenience food' category, have their origins in North China, but they are now widely exported to other nations. Noodles rank second only to bread in terms of global consumption, with billions of people 3
consuming them regularly [2]. This segment of the food market is growing rapidly due to the convenience, ease of preparation, low cost, and relatively long shelf life of instant noodles [3]. Compared to many other foods, noodles cook quickly—dried noodles take only a few minutes in boiling water, while fresh noodles can be ready even faster—making them an ideal solution for those with busy lifestyles.

Over the twentieth century, the consumption of instant noodles has steadily increased and continues to rise. According to data from the World Instant Noodles Association in 2016, the wheat flour commonly used to make instant noodles is not only low in fiber and protein but also deficient in the essential amino acid lysine. Lysine is crucial for 4
human health, as the body cannot synthesize it; it must be obtained 5
through diet. The low lysine content of wheat flour can pose a concern, particularly for those who rely heavily on instant noodles as a major part of their diet, putting them at risk of protein deficiency [4]. The widespread consumption of instant noodles in Libya has raised concerns regarding their industrial production and potential health risks, particularly in relation to heavy metal contamination.

Heavy metal contamination in food is a growing issue, exacerbated by rising pollution in the air, soil, and water due to industrial activities, agricultural practices, and other human actions. Harmful elements such as cadmium, lead, mercury, and arsenic are accumulating in our food supply, including instant noodles [5]. While certain micronutrients like manganese, cobalt, selenium, and zinc are essential for enzyme function, cell signaling, and antioxidant defense, heavy metals can accumulate in soft tissues and lead to toxic effects. The impact of these metals varies depending on the specific metal and its target organ. For instance, high levels of lead can cause brain damage in children, leading to learning difficulties, behavioral issues, and a reduced intelligence quotient (IQ). In adults, lead exposure can result in memory loss, headaches, and even dementia [6].

Cadmium, though rare, is highly toxic and naturally abundant. It contributes to various illnesses and is present in phosphate fertilizers used in cereal grains such as wheat, a key ingredient in noodles, thereby posing a significant health risk [7]. Arsenic is another harmful element found in food. Chronic exposure can lead to conditions such as cirrhosis and damage to the oral or nasal mucosa [8-16]. Arsenic-based herbicides also pose significant risks to human health and the environment due to soil contamination and plant uptake. The toxicity of arsenic depends on its chemical form and environmental factors like pH, oxidation potential, and organic matter content, which influence its bioavailability in plants. Under acidic and oxidizing conditions, arsenic becomes more soluble, increasing the risk of plant absorption [17].

Given the risks associated with heavy metal contamination, periodic monitoring of food products is essential to safeguard public health. This study focuses on the detection of heavy metals—cadmium (Cd), chromium (Cr), lead (Pb), arsenic (As), and tin (Sn)—in seven randomly selected noodle brands from Algeria, China, Egypt, Korea, Tunisia, and Turkey, purchased from markets in Benghazi, Libya.

2. Materials and Methods

2.1 . Chemicals and Reagents

Analytical-grade nitric acid (69%, BDH Ltd., Pool, England) and perchloric acid (60%, Riedel-de Haen AG, Germany) were used without further purification. Deionized water, produced using a Milli-Q water purification system (Millipore, Bedford, MA, USA), was used for sample preparation and calibration standards. Calibration standards for arsenic, tin, chromium, cadmium, and lead were prepared by diluting 1000 mg/L stock solutions of each element, which were obtained from BDH. All containers and glassware were soaked in 20% nitric acid for at least 16 hours and subsequently rinsed with distilled and deionized water before use.

2.2. Sample Collection and Analysis

Seven different noodle samples were randomly collected from various local markets in Benghazi, Libya, as listed in Table 1. The samples were removed from their packaging, sorted, numbered, and stored in plastic containers labeled 1 to 7. The concentrations of heavy metals, including cadmium (Cd), chromium (Cr), lead (Pb), arsenic (As), and tin (Sn), were measured using an iCAP Triple Quadrupole Inductively Coupled Plasma Mass Spectrometer (ICP-MS) from Thermo Scientific, Inc., with Thermo Scientific Qtegra Intelligent Scientific Data Solution Software. The instrument's operating parameters, such as radiofrequency (RF) power, nebulizer gas flow rate, and sample position in the plasma, were optimized for maximum signal-to-noise ratio.

2.3. Sample Digestion

Dried and powdered noodle samples were prepared in Pyrex containers with a capacity of 150 mL. A portion of each sample (0.5 ± 0.0005 g) was accurately weighed into the beaker. To each beaker, 10 mL of nitric acid (HNO_3) and 3 mL of 60% perchloric acid ($HClO_4$) were added. The mixture was gently heated on a hot plate until frothing subsided. Heating continued until white fumes of perchloric acid appeared. After cooling, 10 mL of hydrochloric acid (HCl) was added, and the mixture was quantitatively transferred into a 50 mL volumetric flask. The final solution was analyzed for heavy metals using ICP-MS.

3.Results and Discussion

3.1. Concentration of Heavy Metals in Noodles

Table 1 presents the concentrations of heavy metals (Cd, Cr, Pb, As, and Sn) in seven different instant noodle samples collected from local markets in Benghazi, Libya. The results obtained from this study are discussed in detail in the following section

Table 1: The Heavy Metals Concentration in Various Noodles Samples (ppb).

Number Of Samples	Concentration in (ppb)									
	Cd		Cr		Pb		As		Sn	
	Conc.	SD	Conc.	SD	Conc.	SD	Conc.	SD	Conc.	SD
1	5.14	0.020	1.25	0.020	9.98	0.032	0.64	0.005	4.87	0.010
2	33.63	0.005	15.47	0.005	47.48	0.010	3.54	0.020	8.04	0.010
3	1.75	0.005	0.46	0.010	2.11	0.015	0.28	0.015	2.01	0.020
4	8.95	0.005	2.65	0.005	12.89	0.026	0.73	0.010	6.25	0.000
5	5.12	0.020	3.14	0.011	7.92	0.000	0.39	0.020	5.47	0.010
6	4.71	0.005	1.87	0.000	7.19	0.015	0.22	0.010	4.35	0.015
7	3.90	0.000	1.62	0.005	5.31	0.005	0.25	0.010	4.46	0.015
Min	1.75	0.000	0.46	0.005	2.11	0.000	0.22	0.005	2.01	0.000
Max	33.63	0.020	15.47	0.020	47.48	0.032	3.54	0.020	8.04	0.020
Avg.	9.028	0.008	3.780	0.008	13.268	0.014	0.864	0.012	5.064	0.011
WHO	3.00		50.00		25.00		10.00		25.00	

3.1.1. Concentration of Cadmium (Cd)

All seven samples contained cadmium, with varying concentrations ranging from 1.75 ppb to 33.63 ppb. The higher Cadmium concentration was obtained in sample number 2 as presented in **Fig1**, was estimated at 33.63 ppb. The level of cadmium permitted by the World Health Organization should not exceed 3.00 ppb, so the level of cadmium in Noodles samples are in the permitted range, while considered slightly higher than the concentration permitted by the World Health Organization observed in sample No. 2. Long-term exposure to cadmium, even at low levels, can pose health risks, affecting the kidneys, respiratory system, and bones [18-19]. In Nigeria's study, Odidika *et al.* [20] found that Cd concentration ranged from 260.00 to 13330.00 ppb which was higher than the maximum permissible levels for Cadmium in noodles in Nigeria's national legislation and WHO (30.00 ppb) [21,22], but Jothi and Uddin determined that the values for cadmium varied from 530.00 to 820.00 ppb [23], according to reports from researchers. Given that these noodles are often taken thousands of years to bioaccumulate and harmful to humans, they may be viewed as potentially harmful if consumed.

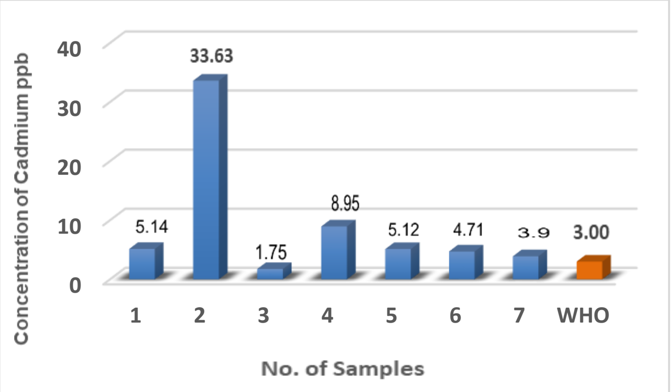

Fig 1: Cadmium (Cd) concentrations (ppb) in Noodles samples.

3.1.2. Concentration of Chromium (Cr)

Humans are thought to require chromium, as evidenced by the discovery of the latter [24]. Chromium is a vital mineral in animal nutrition and is included in feed additives for various purposes, including glucose homeostasis, growth performance, antidepressant effects, and growth performance. Chromium is present in a variety of materials, such as metal alloys, paint pigments, cement, paper, rubber, and other materials, such as rubber. Skin irritation and ulceration may occur as a result of insufficient exposure at low levels. Long-term exposure can negatively impact the kidneys and liver, as well as the circulatory and nervous systems, due to its long-term effects [25]. The ingestion of chromium-containing food can result in stomach problems, ulcers, convulsions, and sometimes death [26] when consumed. According to the data reported in (Table 1), Chromium (Cr) concentrations varied from 0.46 ppb to 15.47 ppb. It has been estimated that human requires nearly 1 µg per day [24]. We see the convergence of chromium levels in certain samples and fluctuation in other samples, as shown in **Fig 2**. This could be due to various factors, such as the type of sample (food source, soil, etc.), and environmental conditions. Odidika and *et al.* discovered that concentrations of Cr in the noodle samples ranged from 400.00 to 1100 ppb [20]. Cr^{3+} is an essential nutrient necessary for glucose metabolism and insulin action, while Cr^{6+} is highly toxic and can cause various health problems as it leads to gastrointestinal bleeding, destruction of red blood cells, sudden kidney failure, decreased sperm production, lung scarring, and lung cancer [27]. The WHO tolerable limit of Cr concentration is (50.00 ppb) [28].

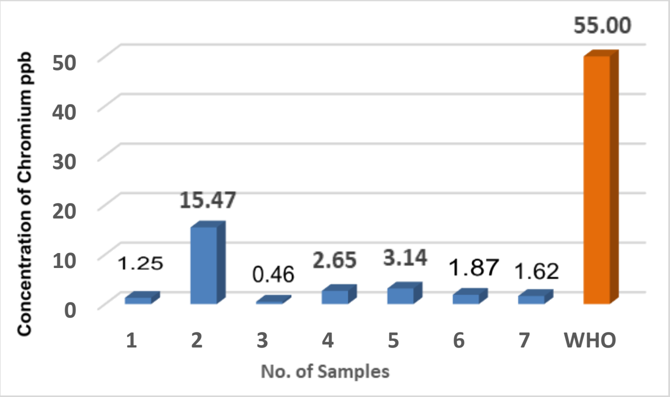

Fig 2: Chromium (Cr) concentrations (ppb) in Noodles samples.

3.1.3. Concentration of Lead (Pb)

It's important to note that the safety limits for lead vary depending on the regulatory body and the specific food product. Lead exposure in humans can have varying biological effects, each dependent on the level and time frame, as either acute or chronic, depending on the level and duration of exposure. The effects are diverse, with the developing foetus and babies being more affected by the heightened sensitivity of the foetus compared to adults, and over a wide range of dosages, different effects occur. Lead poisoning has toxic biochemical effects on the kidneys, gastrointestinal tracts, joints, and reproductive systems, as well as issues with haemoglobin synthesis and acute and chronic nervous system impairment [29, 30]. The broad concentration range of 2.11 to 47.48 ppb indicates a considerable amount of sampled lead concentration, suggesting that there is significant variation between samples. Samples 2 and 4 showed lead concentrations exceeding 40 ppb, making them the highest. Sample 3 yielded the lowest lead concentration, which is more reassuring. Lead concentrations in Noodles samples are shown in **Fig 3**. According to WHO standard [24], the permissive level of lead metal in food should be 25.00 ppb, and none of the samples conformed to this standard. Hence caution should be taken in the constant consumption of these noodles and measures taken to curtail the presence of Pb in these noodles. In this study, the detected concentration of Pb in instant noodles was lower compared to previous research. For instance, in Bangladesh, Jothi and Uddin found Pb concentrations ranging from 1170.00 to 1670.00 ppb [23], which is below the maximum allowable levels for lead in noodles according to Bangladesh national regulations but higher than the Codex Alimentarius standard of 200.00 ppb [23]. Another study conducted in Nigeria where Odidika *et al.* reported Pb concentrations ranging from 25.00 to 106.00 ppb [20], exceeding the international standard limit [31].

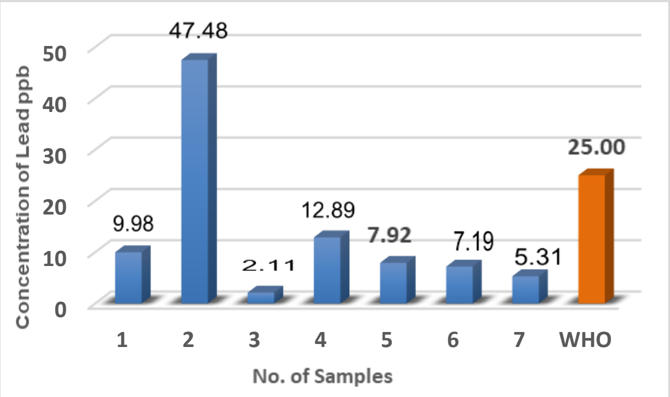

Fig 3: lead (Pb) concentrations (ppb) in Noodles samples.

3.1.4. Concentration of Arsenic (As)

Arsenic, a highly toxins trace element, occurs in both inorganic and organic form in the environment found in the environment both from natural and anthropogenic sources, including both organic and man-made sources. The International Agency for Research on Cancer (IARC) [32] has determined that As (III) and As(V) were the primary carcinogenic molecules for group I (C) and were considered classified as a human cancer type, necessitating the creation of a well-validated method for detecting both or partially and fully isolated arsenic and inorganic species. Human exposure to As (An) is primarily linked to the food chain. The most concentrated sources of arsenic are those found in water, seafood, cereals, and algae-based food products, as well as those found in foods like drinking water or consuming cereals. The quotient of total inorganic arsenic (t-inAs) to total arsenic (t-As) varies among the different food categories and among the various foodstuffs [33–34]. The concentration of arsenic in seven samples of noodles was measured, and the results are depicted in **Fig 4**. Arsenic, classified as a hazardous element despite being a semi-metal, ranged from 0.22 ppb to 3.54 ppb in the noodle samples. Few studies have specifically investigated arsenic levels in noodles. However, a separate study on noodle samples in Namibia -Kakoma and Awofolu, [35] reported arsenic levels from 500.00 to 2500.00 ppb, but Jothi and Uddin found arsenic values varying between 170.00 and 410.00 ppb [23]. The concentration of arsenic according to WHO's recommended limit for drinking water (10 ppb). Additionally, people living in homes are continuously exposed to cumulative levels of arsenic due to consuming wheat, water, and animal products [36], which poses a significant health risk.

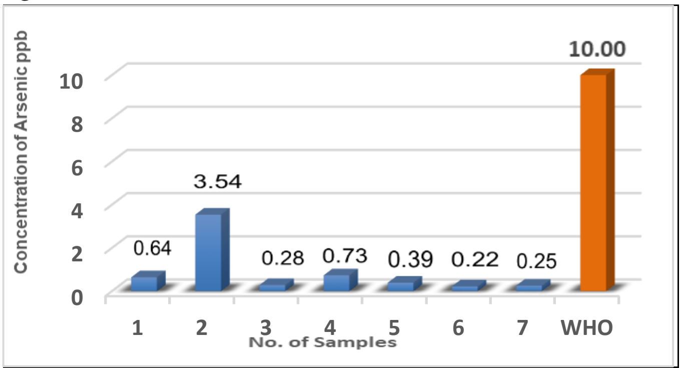

Fig 4: Arsenic (As) concentrations (ppb) in Noodles samples.

3.1.5. Concentration of Tin (Sn)

A study was carried out by the University of Medical Sciences in Iran to investigate the effects of tin and other metals on sperm creatine kinase in vitro. The reason for male infertility being associated with reduced sperm metabolism was found to be reduced in these studies [37]. It has also been established that exposure to arsenic, cadmium, lead, mercury, and tin exposure damages the blood vessel walls in the haematological system [38]. Tin dust can cause irritation on the skin and soft tissues, with a particular focus on the eyes and respiratory system, in addition to affecting the breathing and resting areas. Two Japanese studies [39, 40] confirmed the detrimental effects of tin exposure on the lungs, particularly occupational lung disease, on the chronic disease of the respiratory system. According to a study conducted by the Department of Biotechnology and Molecular Biology at Opole University [41], Tin was found to be particularly harmful to human embryonic kidney cells. Various kinds of metals are entrained in the neural circuit. Neurotoxins such as aluminum, arsenic, lead, and mercury have been acknowledged. Neurotransmitter interference by lead and tin has been suggested as a potential mechanism that could impact energy metabolism due to the impact of tin and lead.

In this study, the tin content ranged from 2.01 ppb to 8.04 ppb in the noodles. Tin contamination primarily stems from tin-plated containers used in various processed foods, with potential minor additions from aluminum utensils in contact with food. According to WHO [21], the maximum permissible level for tin is 250.00 ppb. Previous studies on tin levels in noodles are limited. Jothi and Uddin found Tin concentrations in commercial noodle samples were found to be below the maximum allowable limits (2600.00 to 3720.00 ppb) [23]. The Sn levels in noodles are seen in **Fig 5**.

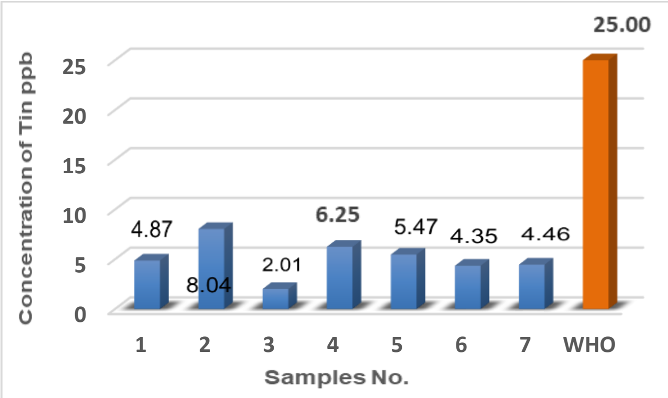

Fig 5: Tin (Sn) concentrations (ppb) in Noodles samples

4. Conclusion

The analysis of heavy metals in instant noodle samples from Benghazi markets revealed the presence of cadmium (Cd), chromium (Cr), lead (Pb), arsenic (As), and tin (Sn), generally within permissible limits. However, the detection of these metals, even at low concentrations, highlights the importance of continuous monitoring and stringent regulation to mitigate potential health risks. While these levels are considered safe by current standards, the long-term accumulation of heavy metals through frequent consumption remains a concern. Therefore, ongoing efforts to reduce heavy metal contamination in food products are essential to safeguard public health. Precautions should be taken regarding the frequent dietary intake of instant noodles to prevent health issues associated with the bioaccumulation of these metals in the human body over time, particularly for samples with higher concentrations. Enhanced regulatory policies and routine monitoring are crucial to ensure that safe and nutritious noodles remain available to consumers.

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