Archives of Hygiene Sciences
Qom University of Medical Sciences

https://jhygiene.muq.ac.ir/
10.32592/AHS.13.2.56
Vol. 13, No. 2, 2024,56-61

Original Article

Health Risk Assessment of Exposure to Heavy Metals in Bread Flour from Both Traditional and Industrial Bakeries Supplied in Qom Province

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Abstract

Background & Aims: Considering the importance of wheat and bread in the household food basket, and also due to the lack of records of necessary studies in Qom province, this research was conducted to investigate the concentration of heavy metals (lead, cadmium, chromium, mercury, and arsenic) in bread flour from both traditional and industrial bakeries supplied in Qom province. It also aimed to assess the health risks related to the consumption of bread containing heavy metals.

Materials and Methods: In this study, 42 traditional bakery units and 6 industrial bread production units were randomly selected, and flour samples were evaluated by observing the principles of sampling and completing the necessary forms. Chemical digestion (acidic) and atomic absorption analysis using a furnace method were employed to measure the levels of heavy metals in the flour samples.

Results: The results of the analysis showed that the average levels of lead, cadmium, chromium, mercury, and arsenic in all samples were lower than the values specified by WHO/FAO and the national standard of Iran. The results of the risk assessment for exposure to heavy metals (lead, chromium, cadmium, and arsenic) in bread flour from both traditional and industrial bakeries showed that, given the current dietary patterns of bread consumption in the studied population and the levels of heavy metals in the flour samples from traditional and industrial units, there is no threat to health, particularly regarding carcinogenic risks for major bread consumers in the age groups studied.

Conclusion: Due to the importance of continuous monitoring of heavy metal residues in bread products and maintaining the health of consumers, it is necessary to control the situation of heavy metals in flour production and supply centers.Keywords: Ecological toxicity, Health, Heavy, Heavy Metal Poisoning, Mercury Poisoning, Metals, Nervous System, Poisoning.

Received: January 01, 2024, **Accepted:** March 20, 2024, **ePublished:** May 20,2024

1. Introduction

The health of agricultural and food products is a vital indicator of the overall well-being of communities. In recent decades, the health of agricultural products has been threatened due to the excessive use of various herbicides, pesticides, and hormones, leading to increased mortality rates and a reduction in the average life expectancy of the global population, along with the emergence of various diseases and environmental pollution [1]. Thus, standardizing the production-to-consumption process to ensure the quality and safety of products for consumers poses a significant challenge for many governments. Heavy metals are among the pollutants that have garnered considerable attention due to industrial advances. One of the fundamental issues concerning heavy metals is their failure to metabolize in the body. In fact, heavy metals, once entering the body, accumulate in tissues, such as fat, muscles, bones, and joints, which can lead to numerous diseases and other health issues [2]. Since heavy metals, such as lead, cadmium, and chromium, are recognized as carcinogenic elements associated with various types of cancer, particularly gastrointestinal cancers, continuous monitoring and evaluation of the health aspects of these contaminants in food and edible products hold great significance [3].

The per capita consumption of bread for each Iranian is 160 kilograms per year, while the global average is only 25 kilograms, indicating that Iranians consume bread six times more than the world average. This highlights the special importance of bread as a staple food in Iranian diets, making it a necessity to assess the exposure risks to hazardous compounds in bread [4]. Numerous studies have been conducted on the evaluation of heavy metals in bread and its ingredients in various countries, including Iran. Hence, it is of considerable importance to monitor heavy metal levels in this food product to protect consumer health [5-7].

The Iranian National Standards Organization, in its latest amendment in 2018 (Standard No. 103), set the maximum permissible heavy metal concentrations in wheat flour at 0.15 mg/kg for lead and 0.03 mg/kg for cadmium [8, 9].

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Furthermore, according to clause (v) of Article 34 of the Fifth Development Plan Law and clause (t) of Article 72 of the Sixth Development Plan Law, the Ministry of Health, Treatment, and Medical Education is required to collaborate with the Ministry of Agriculture Jihad to specify the permissible amounts of pesticides and chemical fertilizers for the production of agricultural and horticultural products. It is noteworthy that Qom Province, due to its geographical location and climatic conditions, along with an increasing population trend and various environmental risks in recent years, has become one of the provinces where a significant portion of agricultural products needed for consumption is supplied and distributed from other provinces. Given the significance of wheat and bread in household food baskets and the lack of studies in Qom Province regarding this field, this research aims to investigate heavy metal concentrations (lead, cadmium, chromium, mercury, and arsenic) in bread flour from traditional and industrial bakeries in Qom and assess the health risks related to consuming bread with these metals [10, 11].

2. Materials and Methods

According to the available statistics from the Deputy of Health and Deputy of Food and Drug of Qom University of Medical Sciences, there are approximately 1,000 traditional bakeries and 6 industrial bread production units operating in Qom City. The required sample size was determined using the following sample size formula and a significance level of 95%.

$$n=Z^2_{1-a}*P(1-P)/d2$$

In this study, considering the previous studies in Iran [6, 8, 9] and the ratio of heavy metals in the tested samples, which have been reported to be above standard (on average 20% (P=0.2)), and with an accuracy level of 10% (d=0.1), a total of 42 traditional bakery units were randomly and systematically selected from a list of bakery units under health supervision from the health center. Additionally, 6 industrial bread production units were included in the study. Following the sampling principles, product (flour) specification forms detailing the unit address, extraction percentage, and bran content were completed by environmental health specialists and food monitoring authorities, and the samples were sent to the School of Public Health laboratory for analysis.

To measure the concentration of heavy metals in the flour samples, a chemical (acid) digestion method was employed. One gram of each sample was placed in an oven at 62°C for 29 hours to ensure complete dryness. It was then placed in an electric furnace at a temperature of 420°C until a white ash free of carbon was obtained. The extraction of the samples was performed via acid digestion using 65% nitric acid and 30% hydrogen peroxide. In this method, 3 ml of 65% nitric acid and 1 ml of hydrogen peroxide were added to a 50 ml Erlenmeyer flask containing the sample and heated at 130°C for 3 hours. Subsequently, an additional 3 ml of nitric acid and 1 ml of perchloric acid were added, and the solution was boiled for one hour. After cooling, the solution volume was adjusted to 100 ml by adding distilled water. Once the extraction was complete, the extract was filtered using Grade 42 filter paper and injected into an atomic absorption spectrometer. The concentrations of cadmium, lead, chromium, mercury, and arsenic in the product extract were measured using the atomic absorption device (model PG990, PG Instruments) with a furnace method. To ensure the accuracy of the method, its validation regarding precision and repeatability was carried out, with each reading repeated three times [12, 13].

Risk Assessment and Health Outcomes of Exposure to Heavy Metals in Bread

1. Generally, the risk assessment process for exposure to a hazardous compound, such as heavy metals, includes hazard identification, determination of toxicity data, dose-response assessment, and risk characterization. Accordingly, to characterize the risk, the acceptable daily intake (ADI) of a hazardous compound, for which there is a toxicity threshold, and the average daily dose (ADD) of a hazardous compound should be calculated according to exposure scenarios, such as body weight, lifespan, and bread consumption in individuals. After that, the hazard quotient (HQ) is determined by calculating the ratio of the daily intake of a compound from exposure to its acceptable concentration or dose. In this process, the risk exposure ratio can be characterized by the following parameters:

$$ADD = \frac{C \times IR \times ED \times EF}{BW \times AT}$$

$$HQ = \frac{ADD}{ADI}$$

$$HI = \Sigma HQ$$

C: Concentrations of heavy metals, including lead (Pb), chromium (Cr), cadmium (Cd), mercury (Hg), and arsenic (As) per gram of flour and bread product;
IR: Intake rate (grams per day);
ED: Exposure duration based on the age of individuals (years);
EF: Exposure frequency (365 days per year);
BW: Body weight (kg);
AT: Lifespan of the individual (years).

If the hazard index (HI) is greater than 1 (HI>1), it is expected that the risk of exposure is significant, while for HI less than 1 (HI<1), the risk of exposure is negligible. The reference dose near the toxicity threshold (ADI) for heavy metals has been determined as follows: for lead 0.0036, cadmium 0.001, chromium 0.003, arsenic 0.0003, and mercury 0.0003. The exposure scenarios and factors were

considered for two selected age groups, 5-19 years and 19-59 years, based on data extracted from completed questionnaires for 400 households in the target population [12, 14].

2. Reference to National Standard No. 12968 regarding maximum heavy metals in human food is provided in Table 1 [14].

Table 1. Tolerable daily intake of heavy metals

No	Heavy metals	Tolerable daily intake of heavy metals (kg/bw)
1	Pb	0.0036
2	Cd	0.001
3	Hg	0.0007
4	Sn	2
5	As	0.0021

3. Results

The results of the investigation into the levels of heavy metals (lead, chromium, cadmium, and arsenic) in bread flour from both traditional and industrial bakeries are presented in Figures 1 and 2. The health risk assessment associated with exposure to heavy metals is detailed in Tables 2, 3, and 4.

According to the results shown in Figure 1 regarding the average levels of heavy metals in traditional bakery flour samples, the analysis indicated that the average concentrations of lead, cadmium, chromium, mercury, and arsenic in all samples were below the levels established by World Health Organization (WHO)/Food and Agriculture Organization and the national standards of Iran. However, in two samples from one of the flour production units, the levels of lead exceeded the standard limits (0.38 and 0.159 mg/kg), necessitating immediate investigation by the relevant responsible body. It appears that environmental factors in the region, the proximity to polluting units, and pollution leakage through processes and tools should not be overlooked. Among the analyzed samples from traditional bakeries, 13 units used bran flour; however, no significant correlation was found between the presence of bran and elevated levels of heavy metals (above the standard) ($P<0.001$).

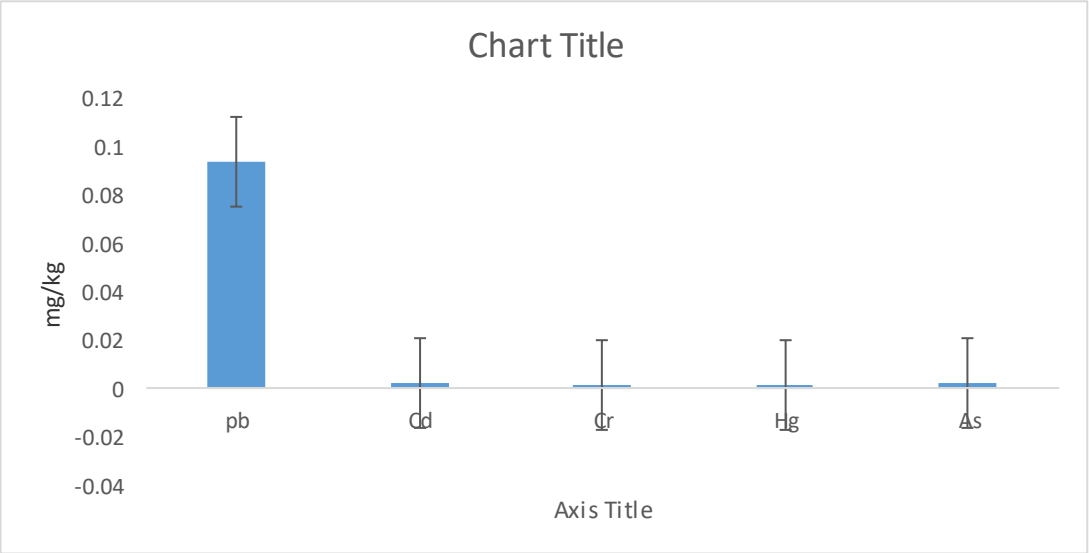

Figure 1. Average heavy metal levels in bread flour from traditional bakery samples

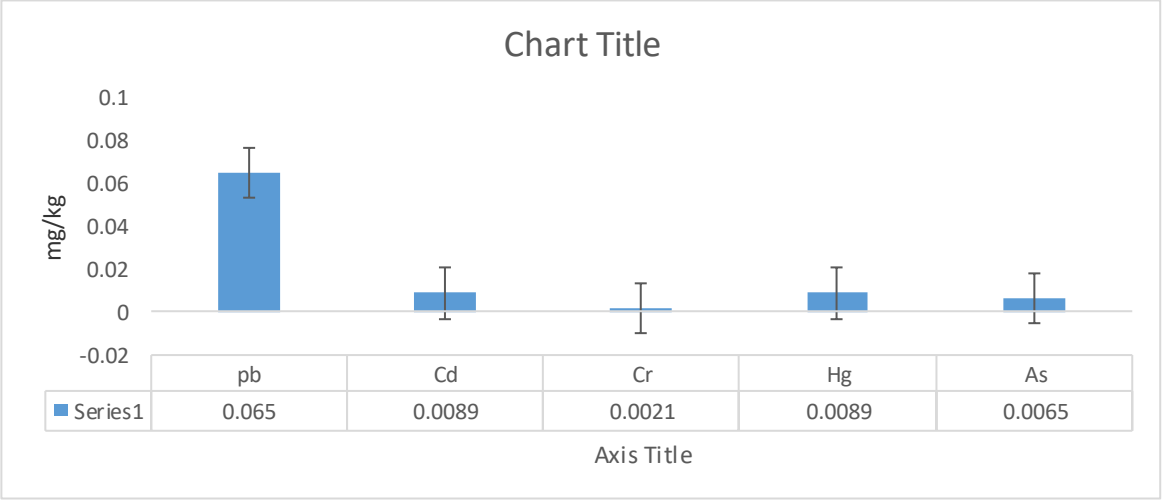

Figure 2. Levels of heavy metals (lead, chromium, cadmium, and arsenic) in flour from industrial bakery units in Qom city

Table 2. Scenarios and factors of exposure to heavy metals from bread consumed in age groups

Age groups (year)	Bread type	IR (g/day)	BW (kg)	ED (year)	EF	AT (day)
5-19	Traditional Industrials	180 10	30	12	365	4380
19-59	Traditional Industrials	400 20	70	40	365	14600

Table 3. Average daily dose values of heavy metals from consumed bread based on (mg/kg bw/day) in age groups

Age groups (year)	Bread type	Pb	Cd	Cr	Hg	As
5-19	Traditional Industrials	0.00056 0.000031	0.000053 0.0000007	0.000012 0.00000046	0.000053 0.00000043	0.000039 0.00000006
19-59	Traditional Industrials	0.00053 0.000018	0.000012 0.0000025	0.000008 0.0000006	0.0000074 0.0000025	0.000011 0.0000018

Table 4. Values of the index and risk ratio of exposure to heavy metals from consumed bread in age groups

Age groups (year)	Bread type	Pb	Cd	Cr	Hg	As	HI (Σ HQ)
5-19	Traditional Industrials	0.15 0.008	0.053 0.0007	0.004 0.00015	0.17 0.0014	0.13 0.0002	0.5 0.01
19-59	Traditional Industrials	0.14 0.005	0.012 0.0025	0.0026 0.0002	0.024 0.008	0.036 0.006	0.21 0.021

4. Discussion

Furthermore, based on the results presented in Figure 2 regarding the average levels of heavy metals in flour samples from industrial bakeries, the analysis showed that the average concentrations of lead, cadmium, chromium, mercury, and arsenic in all samples were below the values specified by Iran's national standards.

It is worth noting that the Institute of Standards and Industrial Research of Iran, in its latest amendment in 2018 (Standard No. 103), established maximum allowable levels of heavy metals in wheat flour at 0.15 mg/kg for lead and 0.03 mg/kg for cadmium. The risk assessment results regarding exposure to heavy metals (lead, chromium, cadmium, and arsenic) in bread flour from both traditional and industrial bakeries available in Qom City, along with the health risk evaluation in 2023, are shown in Tables 1 to 3. The current trend indicates that the levels and concentrations of heavy metals in the flour samples from both traditional and industrial units, combined with the dietary patterns of bread consumption in the studied population, do not pose a health risk, particularly concerning carcinogenicity for the primary consumers in the two age groups studied. However, the total HI for heavy metals in the 5-19 age group regarding traditional bread (HI=0.5) was significantly higher than for other age groups. This indicates that, although it is less than 1, the likelihood of increasing heavy metal levels due to growing environmental hazards and rising per capita bread consumption for economic and cultural reasons poses a serious future risk for this group.

The results in Table 2 regarding the ADD of heavy metals from consumed bread and compliance with the ADI values for heavy metals in National Standard No. 12968 concerning maximum heavy metals in human food indicate that the ADD values of heavy metals from consumed bread are below the ADI levels set in the national standard for all age groups. This suggests that there is no significant attributable health risk.

Given the results and existing records from other regions of the country that monitor heavy metal levels in flour and bread, the findings of this study can be compared and evaluated. In a study by Amir-Abadi et al. examining the levels of certain heavy metals (cadmium, lead, and arsenic) in wheat and flour samples from Golestan and Mazandaran provinces, the results showed that cadmium and lead levels in some flour samples exceeded the recommended and standard values [14, 15]. The findings of studies by Malekpour et al. on determining lead levels in bread components in Shiraz and Kianpour aimed at examining zinc, lead, cadmium, and copper in wheat and bread consumed in Hamadan and other parts of Iran also indicated that cadmium and lead levels in some samples were above the permissible limits recommended by the WHO [6, 13, 16].

Regarding studies in other regions of the world, a risk assessment study examining lead exposure through consumed wheat flour in Benin Province, South Africa, reported lead levels of 5.84±0.53 mg/kg. Considering the high lead levels compared to regional and WHO standards, the cumulative risk of lead in the studied community was expected to be significant. The findings of this study differ from those of the current study concerning lead levels in the samples analyzed [17]. In a study by Linkman et al. [18] assessing the risk of heavy metals from irrigated wheat flour, the average concentrations of heavy metals, including mercury, arsenic, chromium, lead, and nickel, were

significantly below the allowable threshold of Chinese standards, although 15% of the samples exceeded the standard. Furthermore, this study reported that the health risks associated with wheat flour consumption were negligible for both adults and children. Notably, regarding cadmium, the risk of non-carcinogenic effects was found to be higher compared to other elements. The findings of this study share similarities with the current one concerning heavy metal levels and exposure risks [18]. Results from other studies in different parts of the world also indicate that the environmental release of heavy metals and soil contamination, along with the use of nonstandard equipment in wheat processing centers, have contributed to increased levels of heavy metals [19-21].

1. Conclusion

The key finding of this study suggests that continuous monitoring of heavy metal residues is essential in flour production and supply centers, given the importance of health considerations and the control of heavy metal levels to protect consumer health.

Acknowledgments

This project was supported and approved by the Qom University of Medical Sciences (ethical code number IR.MUQ.REC.1402.222).

Authors' Contribution

All authors accept public responsibility for the content submitted for publication. Authors' contributions: Ahmad Reza Yari, data collection; Mohammad Reza Khaksar, analysis and interpretation of the results; Yadollah Ghafuri and Rahim Aali, study conception and design.

Competing Interests

The authors declare that they have no conflict of interest.

Ethical Approval

This project has been supported by the Qom University of Medical Sciences Health Services. number IR.MUQ.REC. 1402.222

Funding

None.

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