Food Research 9 (4) : 226 - 231 (August 2025)
Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

RESEARCH PAPER

Health risk assessment of lead in some commercial turmeric brands collected from local markets in Los Angeles, California, United States of America

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Article history:
Received: 11 April 2023
Received in revised form: 1 June 2023
Accepted: 17 May 2024
Available Online: 9 August 2025

Keywords:
Lead,
Health risk assessment,
Turmeric

DOI:
https://doi.org/10.26656/fr.2017.9(4).141

Abstract

Lead present as a contamination in turmeric may have serious adverse health effects due to its toxicity. The present study compared the estimated daily intake (EDI) of lead based on concentrations in turmeric samples collected from local markets in Los Angeles with a reference dose calculated using the California Office of Environmental Health Hazard Assessment (OEHHA) maximum allowable dose level (MADL). Turmeric samples (n = 15) representing five brands were analyzed for lead using inductively coupled plasma–mass spectrometry (ICP-MS). The lead concentrations in the five turmeric brands were 0.105±0.095, 0.051±0.002, 0.206±0.014, 0.072±0.041, and 0.204±0.062 mg/kg, respectively. The EDIs based on lead concentrations in all turmeric samples were lower than the calculated reference dose (7.1E-6 mg kgbw^{-1} day^{-1}). The target hazard quotients (THQs) for all turmeric brands were 0.21, 0.10, 0.40, 0.14, and 0.40, indicating minimal risk of non-carcinogenic effects associated with consuming these turmeric brands. The cancer risk (CR) values associated with the five turmeric brands were 1.27E-8, 6.20E-9, 2.46E-8, 8.50E-9, and 2.46E-8, which were all below the acceptable cancer risk limits of 1E-6 set forth by the US Environmental Protection Agency.

1. Introduction

Turmeric is consumed in different countries for various reasons, including as a culinary spice, a dietary coloring, as a pharmaceutical, and in folk medicines for the treating various illnesses such as biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis (Kermanshahi *et al*., 2006; Withanage *et al*., 2015).

A health concern associated with the use of turmeric and other spices is exposure to heavy metal contaminants, including lead. Lead is known as a powerful neurotoxin that permanently damages the brain and decreases Intelligence Quotient (Forsyth *et al*., 2019). Lead is a metabolic toxin and a neurotoxin that attaches to crucial enzymes and several other cell components and inactivates them. In addition to its toxic effects on the nervous system, lead has toxic effects on the hemopoietic, gastrointestinal, and renal systems (Nordin and Selamat, 2013; Onakpa *et al*., 2018; Humaeda, 2018; Agency for Toxic Substances and Disease Registry (ATDSR), 2020).

The New York State Department of Agriculture and Markets (NYSAGM) removed over 95 different types of spices from the market between 2016 and 2019 due to lead concentrations over their Class II recall action level for lead of >0.21 mg/kg (Ishida *et al*., 2022). According to Hore *et al*. (2019), over 50% of the spice samples from 41 countries contained detectable lead and nearly 30% had lead concentrations exceeding 0.21 mg/kg during investigations of lead poisoning cases among New York City children and adults. The predicted increase in the use of turmeric in the United States raises concerns about its potential as a lead source (Cowell *et al*., 2017).

The importation rate of turmeric in the United States (US) increased by 89% over the past 50 years, with approximately 12 million pounds imported in 2014 (Cowell *et al*., 2017). This increase is likely due to the increasing diversity of the US population and the presentation of turmeric as a healthy, flavor-enhancing alternative to salt (Cowell *et al*., 2017). As the market for natural food additives increases, turmeric will be used more often in foods, including cheeses, cereals, mustard,

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eISSN: 2550-2166 /
Published by Rynnye Lyan Resources

ice cream and margarine (Cowell *et al*., 2017).

A risk assessment is necessary to determine the health risk associated with the consumption of spices, specifically turmeric, contaminated with lead. The US Food and Drug Administration (FDA) does not have a specific limit for lead that can be present in spices. Food manufacturing companies have difficulty addressing lead levels due to a lack of regulation (Angelon-Gaetz *et al*., 2022). The present study compared the estimated daily intake (EDI) of lead based on its concentrations in turmeric samples collected from local markets in Los Angeles with a reference dose calculated using the California Office of Environmental Health Hazard Assessment (OEHHA) maximum allowable dose level (MADL) for lead by calculating target hazard quotients (THQs). Additionally, the cancer risk (CR) associated with consumption of lead-contaminated turmeric samples was compared to the acceptable cancer risk established by the U.S. Environmental Protection Agency (USEPA, 2022).

2. Materials and methods

2.1 Sample collection

Five commercial turmeric powder brands were purchased randomly from different markets in Los Angeles. The samples were coded as A-1, A-2, A-3, B-1, B-2, B-3, C-1, C-2, C-3, D-1, D-2, D-3, E-1, E-2 and E-3 with the same alphabet code representing one brand. Each sample bag was labeled with the appropriate code, and all sampling locations and dates were recorded. Each sample (115 g) was packed in a zipped polyethylene bag and sent to Eurofins Product Testing (Seattle, WA) for lead analysis.

2.2 Reagents

Reagent water: 18-MΩ ultra-pure deionized water starting from a pre-purified (distilled) source was used for all dilutions (AOAC 2011.19, 2016). Nitric acid (HNO3): 65-70% (w/v) HNO3 was used to digest samples, prepare standards, and rinse solutions (AOAC 2011.19, 2016). Hydrogen peroxide (H_2O_2): 30% reagent grade was used for sample digestion (AOAC 2011.19, 2016). Methanol: 99.99% analytical reagent grade was used for matrix matching (AOAC 2011.19, 2016). Lead stock solution (1000 µg Pb/mL): Dissolved 0.1599 g Pb $(NO_3)_2$ in 5 mL (1+1) HNO_3 solution and diluted to 100 mL (AOAC 993.14, 2005).

2.3 Digestion procedure

The digestion of each sample was conducted according to the AOAC method 2013.06 (Julshamn *et al*., 2013). For each sample, 0.5 g of dried turmeric powder was added to the vessels. Vessels were filled with 1.0 mL of 30% H_2O_2 and 5.0 mL of 65% concentrated HNO_3. A microwave oven was used to heat the vessels. The digestion was allowed to reach 11.72 bar and 170°C for 10 min and then maintained at 170°C for 10 min. The digested solutions were filtered (Whatman no. 42) after the microwave procedure, and 50 mL of deionized water was added to dilute the solution (Julshamn *et al*., 2013).

2.4 Sample preparation for instrument analysis

Approximately 20 mL of MilliQ water was added to the contents of the vessel with the digested samples and transferred into a 50 mL sample vial. The vessel was rinsed and the rinse water was transferred into the sample vial. Methanol (0.5 mL; matrix matching) was added to the sample vial and diluted to approximately 50 mL with MilliQ water (Pacquette *et al*., 2011).

2.5 Inductively coupled plasma–mass spectrometry apparatus

The method for measuring lead at trace concentrations was inductively coupled plasma-mass spectrometry (ICP-MS, Perkin-Elmer, model 350 XX) after the appropriate digestion steps. ICP-MS has a wide range of applications and is more sensitive than other techniques.

2.6 Health risk assessment

The EDIs of lead from turmeric, THQs, and CR values were calculated to assess the health risks associated with lead consumption from turmeric. The EDI (mg kg bw^{-1} day^{-1}) was calculated using the equation EDI = C×D/BW where C is the concentration of lead (mg/kg) in the turmeric sample, D is the daily intake of turmeric (kg) and BW = average adult body weight (kg) (Karimi *et al*., 2021). According to the U.S. Food and Drug Administration (2022), guidelines for the amount of turmeric consumed per eating occasion are 0.5 g. Assuming two meals per day, the daily intake of turmeric is considered 1 g (0.001 kg) for an individual. In this study, the average human body weight (BW) used was 70 kg (Karimi *et al*., 2021).

Target hazard quotient values were used to estimate the non-carcinogenic risk of lead consumption. The THQ is the ratio of the estimated daily intake of a toxicant (EDI expressed as mg kg $bw^{-1}day^{-1}$) to an established reference dose (RfD expressed as mg kg $bw^{-1}day^{-1}$) for the chemical in question, or THQ = EDI/RfD. The RfD is defined by the US Environmental Protection Agency (2022) as “an estimate (with uncertainty spanning perhaps an order of magnitude) of daily exposure to the human population (including sensitive subgroups), that is

https://doi.org/10.26656/fr.2017.9(4).141

likely to be without a noticeable risk of harmful effects during a lifetime.” The RfD is calculated by dividing the No Observable Adverse Effect Level (NOAEL), Lowest Observable Adverse Effect Level (LOAEL), or categorical regressions, by uncertainty factors reflecting limitations of the data. Most often, RfDs are used to evaluate non-cancer health effects (USEPA, 2022). In this study, the RfD was calculated based on the California Office of Environmental Health Hazard Assessment (2022) MADL for lead of 0.5 µg/day. The MADL was converted to mg/day (0.0005 mg/day), and then divided by body weight (70 kg) to result in an RfD of 7.1 E-6 mg kg $bw^{-1}d^{-1}$. An exposed population is considered to be at risk if the ratio is equal to or greater than 1 (Antoine *et al*., 2017).

The formula used to calculate the CR associated with lead exposure in the population was CR = EDI × CSF (Kowalska, 2021), where CSF is the cancer slope factor for lead that has a value of 8.5 E-3 mg kg bw^{-1} day^{-1} (Nag and Cummins, 2022). A slope factor represents the cancer risk (proportion of the population affected) per dose unit. In this study, the calculated CR value was compared with the upper limit allowed by the USEPA, which is ≤ 1E-6 (Karimi *et al*., 2021).

2.9 Statistical analysis

Descriptive statistical parameters, mean ± standard deviation (SD), were calculated using the Statistical Package for Social Sciences (SPSS, version 22.0). The lead concentrations represent the mean of three independent experiments (triplicate).

3. Results and discussion

3.1 Lead concentrations in turmeric samples

Lead concentrations in the five turmeric brands are presented in Table 1. Brand C had the highest lead concentration (0.206 mg/kg), while brand B had the lowest concentration of lead (0.0511 mg/kg). Lead concentrations in this study were compared to the Codex Alimentarius Commission acceptance limit (0.3 mg/kg), and the New York State Department of Agriculture and Markets (NYSAGM) Class II recall action level for lead (>0.21 mg/kg) (Goswami and Mazumdar, 2014; Ishida *et al*., 2022). All samples in this study had mean lead concentrations below the Codex permissible level and NYSAGM Class II recall action levels, suggesting no threat to consumers posed by the specific lots of these turmeric brands in Los Angeles. However, the maximum lead concentrations in brands A, B, and C (0.2160, 0.2230 and 0.2640 mg/kg) exceeded the NYSAGM Class II recall action level (>0.21 mg/kg). Because some samples exceeded the NYSAGM Class II recall action level, they would have been recalled in New York, but not in California.

Studies examining lead concentrations in turmeric samples reported a wide range of values. According to Krejpcio *et al*. (2007), lead concentrations in turmeric vary based on its origin, environmental pollution levels, plant part and technological processes.

Results of the present study differed from Mohamed *et al*. (2014) who reported the lead concentration in turmeric from a Libyan market as 0.63 mg/kg in the wholesale market and 1.005 mg/kg in the retail market. In this study, the concentrations of lead in both wholesaler and retail markets were higher than the Codex permissible level and the NYSAGM Class II recall action levels. Some of the results from the present study also differed from Cowell *et al*. (2017) who found that the concentration of lead in turmeric in the Boston markets ranged from 0.03mg/kg (lower than the NYSAGM class II recall action level (of >0.21 mg/kg) to 99.50 mg/kg (significantly higher than the NYSAGM level).

Table 1. Lead concentrations in turmeric samples representing five different brands (n = 3).

Brand	Lead concentration (mg/kg)		
	Mean±SD	Minimum	Maximum
A	0.105±0.095	0.045	0.216
B	0.051±0.002	0.048	0.052
C	0.206±0.014	0.195	0.223
D	0.072±0.041	0.025	0.097
E	0.204±0.062	0.139	0.264

In the present study, lead concentrations were lower than those found in an Iranian market for turmeric, which was 2.05 mg/kg (Bazargani-Gilani and Pajohi-Alamoti, 2017), in Iraq, 0.387 mg/kg (Matloob, 2016), in Malaysia, 5.54 mg/kg (Nordin and Selamat, 2013), in Poland, 0.38 mg/kg (Krjpcio *et al*., 2007) and in India, 0.269 mg/kg (Goswami and Mazumdar, 2014).

Ishida (2022) investigated lead concentrations in imported and domestic turmeric in the New York market. Lead concentrations in this study ranged from 1.25 to 54.1 mg/kg. In all turmeric samples with different countries of origin, including Vietnam (2.30 mg/kg), Thailand (1.25 mg/kg), Bangladesh (5 mg/kg), India (2.40 mg/kg) and US (2.03 and 54.1 mg/kg), lead concentrations exceeded the NYSAGM action level as well as Codex permissible levels.

3.2 Daily intake of lead

The EDI is important in determining the degree of exposure to food contaminants in the population's diet. The EDI values of lead for the five different turmeric brands are given in Table 2. The lowest and highest

https://doi.org/10.26656/fr.2017.9(4).141

mean EDIs of lead were associated with brand B (7.3E-7 mg kg bw^{-1} day^{-1}) and brand D (1.0E-6 mg kg bw^{-1} day^{-1}), respectively (Table 2). Brand E had the lowest (1.9E-6 mg kg bw^{-1} day^{-1}) as well as the highest (3.7E-6 mg $kgbw^{-1}$ day^{-1}) daily intake value among all turmeric brands. Results of the present study revealed that the daily intakes of lead from all collected turmeric samples from the Los Angeles market were lower than the reference dose calculated (7.1E-6 mg $kgbw^{-1}$ day^{-1}) using California OEHHA maximum allowable dose level (MADL) for lead, suggesting that the specific lot from the sampled turmeric brands poses no health risks.

Table 2. Estimated daily intake (EDI) of lead from turmeric samples collected in Los Angeles.

Brand	EDI (mg $kgbw^{-1}day^{-1}$)		
	Mean	Minimum	Maximum
A	1.50E-06	6.40E-07	3.00E-06
B	7.30E-07	6.80E-07	7.50E-07
C	2.90E-06	2.70E-06	3.10E-06
D	1.00E-06	3.60E-07	1.30E-06
E	2.90E-06	1.90E-06	3.70E-06

3.3 Target hazard quotients

The health risk from consuming turmeric contaminated by lead was assessed by calculating THQ values. The THQ values for lead corresponding to five brands of turmeric sampled are presented in Table 3. The results showed that the rank order of THQs for turmeric brands sampled was E, C > A > D (Table 3). The THQs for the investigated lead-contaminated turmeric samples were less than 1, indicating no health risk for non-carcinogenic effects associated with consuming these turmeric brands. In a study conducted in Bangladesh by Rahman (2020), the THQ associated with the consumption of turmeric was 2.4E-3, which is similar to the results in the present study.

Table 3. Target hazard quotient (THQ) for lead in turmeric samples collected in Los Angeles.

Brand	THQ		
	Mean	Minimum	Maximum
A	0.21	0.09	0.42
B	0.10	0.09	0.10
C	0.40	0.38	0.43
D	0.14	0.05	0.18
E	0.40	0.26	0.05

3.4 Carcinogenic risk values

The CR values for adults based on lead concentration in turmeric samples were calculated and presented in Table 4. As stated by Karimi *et al.* (2021), the CR can be assigned to one of four categories: safe limit (1E-6), acceptable limit (1E-4 > CR > 1E-6), threshold risk (CR > 1E-4), and considerable risk (CR > 1E-3). Results of this study for lead carcinogenic risk associated with lead in turmeric samples for the lot numbers sampled revealed that the CR index was within the safe limit (<1E-6) for all samples.

Table 4. Cancer Risk values of lead in turmeric in samples collected in Los Angeles.

Brand	CR		
	Mean	Minimum	Maximum
A	1.27E-08	5.44E-10	2.55E-08
B	6.20E-09	5.78E-09	6.37E-09
C	2.46E-08	2.29E-08	2.63E-08
D	8.50E-09	3.06E-09	1.10E-08
E	2.46E-08	1.61E-08	3.14E-08

4. Conclusion

In this study, the lead concentrations in 5 different brands of turmeric powder were determined using inductively coupled plasma–mass spectrometry (ICP–MS). The lead concentrations in all turmeric samples were compared with the Codex Alimentarius Commission acceptance limit and the NYSAGM Class II recall action level. The results indicated that the concentration of lead in all turmeric samples was lower than the NYSAGM and Codex Alimentarius Commission permissible levels. The results also indicated that the daily intakes of lead for all turmeric samples were lower than the reference dose calculated using the California OEHHA maximum allowable dose level for lead, as indicated by THQ values less than 1. This suggests the turmeric brands sampled from local markets in Los Angeles pose an insignificant health risk to the consumer due to the uptake of lead, based on the specific samples collected. The results of this study for carcinogenic risk associated with lead-contaminated turmeric samples indicated that the CR index was within the safe limits recommended by the EPA. The research results suggest that consumption of turmeric from these lot numbers of five brands posed no health risk to the consumer.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

We would like to thank Dr. Joanne Allen for her support during this project, which was crucial for its completion.

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