Assessment of Lead Concentration in Turmeric Powder Marketed in Bangladesh: Ensuring Consumer Safety

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Abstract

Background: Turmeric, derived from the Curcuma longa plant, is widely consumed in Bangladesh for culinary and medicinal purposes. Its bright yellow color, attributed to curcumin, makes it a prized spice. However, concerns over heavy metal contamination, especially lead, pose potential health risks to consumers. Lead toxicity is associated with severe neurological, cardiovascular, and developmental health problems. Therefore, evaluating the lead concentration in turmeric powder is essential to safeguard public health. Methods: A laboratory-based analytical study was conducted at Hamdard University Bangladesh to determine lead concentrations in turmeric powder samples obtained from the local market. A total of three samples (TR, TA, and TB) were analyzed using the titration method with EDTA as the complexing agent. Results: The permissible lead limit for turmeric powder, as set by the Bangladesh Standards and Testing Institution (BSTI), is 2.5 mg/kg. The study found that lead concentrations in Sample 1 (TR) averaged 0.53 mg/kg, Sample 2 (TA) averaged 0.57 mg/kg, and Sample 3 (TB) averaged 0.55 mg/kg. All samples were within the permissible safety limit. Conclusion: The findings indicate that turmeric powder marketed in Bangladesh generally adheres to regulatory safety standards for lead content. Continuous monitoring and quality control are necessary to maintain this compliance and ensure public safety. Efforts should also focus on educating producers and consumers to minimize contamination risks and promote safer agricultural and processing practices.

Keywords: Turmeric Powder, Lead Contamination, Heavy Metal Toxicity, Titration Method, Food Safety

Significance | This study demonstrated the importance of ensuring safe turmeric consumption by monitoring lead contamination, protecting public health in Bangladesh.

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Introduction

In Bangladesh, turmeric powder is more than just a kitchen staple; it is an essential component of daily life, valued for its culinary, medicinal, and cultural significance (Alam et al., 2023). Derived from the dried root of the Curcuma longa plant, turmeric imparts a vibrant yellow hue to traditional dishes, while its health benefits have been celebrated in Ayurvedic and traditional medicine for centuries (Apostoli et al., 1998). Rich in curcumin, a powerful bioactive compound, turmeric is known for its antioxidant, anti-inflammatory, antiviral, antifungal, antibacterial, and even anticancer properties (Apostoli et al., 1998). Its versatility makes it indispensable not only in the culinary world but also in health and wellness practices throughout the country (Barbosa et al., 2005). However, this beloved spice faces a troubling contamination issue

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that threatens the health of consumers. Studies have revealed that some turmeric products in Bangladesh are adulterated with lead chromate (PbCrO4), a toxic compound used to artificially enhance the spice's bright yellow color (Baş et al., 2015). Lead chromate is highly carcinogenic and poses serious health risks.

Prolonged exposure to this substance can lead to respiratory ailments such as bronchitis, pneumonia, and asthma. More alarmingly, it is linked to cardiovascular and neurological disorders, including heart disease and cognitive impairments (Bellinger, 2008a).

The problem of lead exposure is not new in Bangladesh, but it remains a significant public health concern. Numerous epidemiological studies have shown a high prevalence of elevated blood lead levels among both urban and rural populations (Bellinger, 2008b). Contaminated turmeric is just one of many sources contributing to this crisis. Lead exposure has wide-ranging and severe health consequences, particularly for children, whose developing nervous systems are highly sensitive to toxins (Dias-sardinha & Antunes, 2007). Even low levels of lead in the bloodstream can impair cognitive development, hinder learning abilities, and cause behavioural problems (Billings et al., 2004).

Adults are not immune to the dangers of lead exposure. Long-term exposure can lead to chronic health issues such as hypertension, kidney damage, and neurological disorders (Breeher et al., 2015). Pregnant women are especially vulnerable, as lead can cross the placental barrier, posing a significant risk to the developing fetus. Lead exposure during pregnancy has been associated with premature birth, low birth weight, and developmental delays in infants (Holstege et al., 2008).

Moreover, lead contamination exacerbates nutritional and health challenges in Bangladesh, where many people already suffer from micronutrient deficiencies and poor dietary intake (Holstege et al., 2008). Lead competes with essential minerals such as calcium and iron, worsening nutritional imbalances and further undermining health (Cohen et al., 1981). The toxic effects of lead are therefore compounded in populations already struggling with inadequate nutrition.

The study highlighted the alarming extent of lead exposure in Bangladesh, with respondents exhibiting dangerously high blood lead concentrations (Cowell et al., 2018). These findings underscore the urgency of addressing this public health threat. Immediate steps must be taken to identify and eliminate sources of lead contamination, including rigorous monitoring of turmeric production and supply chains (Cowell et al., 2017).

Preventing lead toxicity requires a multi-pronged approach. Government agencies, health organizations, and industry stakeholders must collaborate to establish stringent quality control measures for turmeric products. Regular testing for contaminants should become standard practice to ensure the safety and purity of this widely consumed spice (Freitas Araujo & Maria, 2012). Public awareness campaigns are also essential to educate consumers about the dangers of lead exposure and encourage them to seek verified, lead-free turmeric products (De Medeiros et al., 2015).

Beyond regulatory measures, efforts should focus on supporting farmers and producers in adopting safe, sustainable practices that eliminate the need for harmful additives like lead chromate (Ekong et al., 2006). By investing in education and resources for the turmeric supply chain, stakeholders can help ensure that Bangladesh's turmeric remains a symbol of health and vitality rather than a source of harm (Forsyth et al., 2019).

Safeguarding the integrity of turmeric powder is essential not only for protecting public health but also for preserving the cultural and economic significance of this cherished spice. As a nation that takes pride in its culinary heritage, Bangladesh must prioritize the purity and safety of its food products. Addressing the issue of lead contamination in turmeric is a vital step toward protecting the health of its people and upholding the longstanding value of this golden spice in both traditional and modern contexts.

Materials and Methods

Study Design

This study employed a laboratory-based analytical approach to evaluate the presence of lead contamination in turmeric powder samples obtained from various markets in Bangladesh. The research was conducted with a focus on quantitative analysis using titration techniques and standardized chemical procedures to assess the concentration of lead in the samples.

Study Area

The investigation was carried out at the Pharmacology Laboratory of Hamdard University Bangladesh, which is equipped with essential facilities for conducting chemical analyses and titration experiments.

Sample Size and Collection

Three turmeric powder samples were collected from different markets across Bangladesh to ensure diversity and variability in the analysis. The selection of multiple sources was intended to capture potential variations in contamination levels across different vendors and regions. The samples were stored in clean, airtight containers to maintain their integrity and prevent contamination prior to analysis.

Materials Used

To carry out the chemical analysis, the following chemicals, reagents, and laboratory instruments were employed:

Chemicals:

- Hydrochloric acid (HCl)
- Nitric acid (HNO_3)
- 0.01M EDTA solution (Ethylene Diamine Tetraacetic Acid)

- Eriochrome Black T indicator
- Distilled water
- 0.01M zinc sulfate solution

Instruments and Apparatus:

- Beakers (various sizes)
- Hot plate
- White Whatman filter paper No. 1
- Burette
- Volumetric flasks
- Graduated cylinders
- Analytical balance
- Magnetic stirrer (optional)
- Digital pH meter

Sample Preparation

The Acid Digestion method was employed for preparing the turmeric powder samples. This method ensures the complete breakdown of organic components, leaving behind soluble metals for analysis. One gram of each turmeric sample was accurately weighed using an analytical balance and transferred into a clean beaker. A digestion mixture consisting of 10 mL of nitric acid and hydrochloric acid in a 3:1 ratio was added to the sample. The beaker was placed on a hot plate set at a low temperature for approximately 30 minutes to facilitate the evaporation of the liquid component and enhance digestion. After digestion, the sample was allowed to cool to room temperature. Subsequently, 50 mL of distilled water was added, and the solution was filtered using Whatman filter paper No. 1. The filtrate was collected for titration analysis.

Preparation of Reagents and Solutions

Preparation of 0.01M Zinc Sulfate Solution:

To prepare 1 liter of 0.01M zinc sulfate solution, 1.6145 grams of zinc sulfate ($ZnSO_4$) was accurately weighed using an analytical balance. The weighed zinc sulfate was transferred to a clean container, and distilled water was added to make up the total volume to 1000 mL. The solution was mixed thoroughly until all the zinc sulfate dissolved completely.

Preparation of 0.01M EDTA Solution:

To prepare 1 liter of 0.01M EDTA solution, 10 mL of a 1N EDTA solution was measured using a graduated cylinder and transferred into a 1-liter volumetric flask. Distilled water was added to reach the final volume of 1000 mL. The solution was mixed thoroughly and labeled appropriately.

Preparation of Buffer Solution (pH 10):

A buffer solution of pH 10 was prepared using a dilution method with potassium hydroxide (KOH). A 0.75 mL volume of 0.1M KOH solution was carefully measured and diluted with distilled water to make a final volume of 500 mL. The solution was mixed thoroughly, and the pH was confirmed using a digital pH meter.

Analytical Procedure

The lead content in the turmeric powder samples was determined using the titration method with EDTA as a complexing agent. The procedure involved the following steps:

A 50 mL aliquot of the prepared turmeric solution was pipetted into a clean 250 mL conical flask.

An excess known amount of 0.01M EDTA solution was added, followed by 2-3 mL of the pH 10 buffer solution.

Approximately 50 mg of Eriochrome Black T indicator was added to the mixture.

The solution was titrated rapidly with 0.01M zinc sulfate solution until the color changed from blue to wine red, indicating the endpoint.

The volume of zinc sulfate solution used was recorded.

The procedure was repeated three more times to obtain an average reading for accurate results.

Calculation Formula

The concentration of lead in the turmeric samples was calculated using the following formula:

$$\text{Lead}\left(\frac{mg}{kg}\right)=\left|\frac{\text{Volume of EDTA used (mL)}\times\text{Molarity of EDTA}\times\text{Atomic Weight of Lead}\left(\frac{207.2\text{ g}}{\text{mol}}\right)}{\text{Weight of turmeric sample (g)}}\right|\times 1000$$

Where:

Volume of EDTA used: Average titration volume (mL)

Molarity of EDTA: 0.01M

Atomic Weight of Lead: 207.2 g/mol

Weight of Turmeric Sample: 0.5 g

Comparison with Regulatory Standards

The calculated lead concentrations were compared against the permissible limits set by regulatory authorities in Bangladesh to determine whether the samples met safety standards for consumption.

Results

The analysis of lead concentration in turmeric powder samples collected from different markets in Bangladesh yielded consistent results across the three test samples. Table 1 summarizes the lead concentrations from three independent readings for each sample, along with their average values. All recorded lead levels were found to be within the permissible limit for turmeric powder (2.5 mg/kg) as per food safety guidelines.

Detailed Observations

Sample 1 (TR)

The lead concentration for Sample 1 showed consistent readings of 0.55 mg/kg, 0.51 mg/kg, and 0.53 mg/kg, with an average concentration of 0.53 mg/kg.

These values indicate a stable and acceptable level of lead contamination, remaining well below the permissible threshold of 2.5 mg/kg.

Sample 2 (TA)

Table 1. Different reading of Lead concentration in Sample-1(TR), Sample-2(TA), Sample-3(TB)

Sample	**1st reading (mg/kg)**	**2nd reading (mg/kg)**	**3rd reading (mg/kg)**	**Average (mg/kg)**
Sample 1 (TR)	0.55	0.51	0.53	0.53
Sample 2 (TA)	0.58	0.55	0.59	0.57
Sample 3 (TB)	0.54	0.57	0.56	0.55

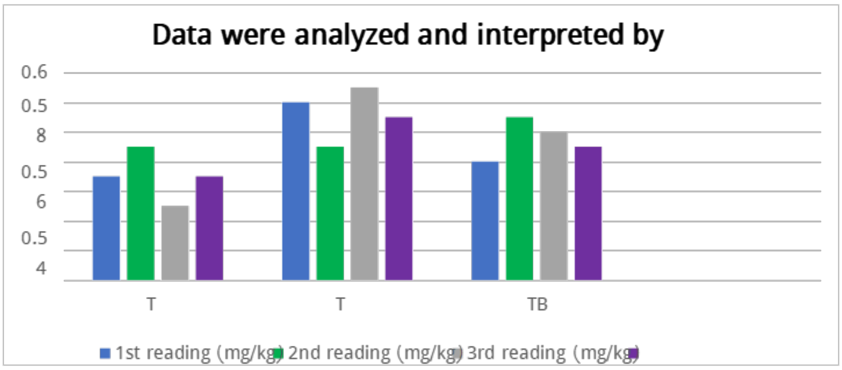

Figure 1. Different reading Lead concentration in TR, TA and TB.

Sample 2 recorded lead concentrations of 0.58 mg/kg, 0.55 mg/kg, and 0.59 mg/kg, with an average value of 0.57 mg/kg.

Although slightly higher than Sample 1, the lead levels in Sample 2 are still well within the safe range, indicating good compliance with safety standards.

Sample 3 (TB)

Sample 3 showed lead concentrations of 0.54 mg/kg, 0.57 mg/kg, and 0.56 mg/kg, resulting in an average of 0.55 mg/kg.

This sample exhibited minimal variation across readings, with lead levels remaining within permissible limits.

Graphic Presentation

A graphical representation (Figure 1) illustrates the lead concentration readings across all three samples (TR, TA, and TB). The chart visually demonstrates the minor variations between the readings and highlights that all values remain significantly below the regulatory safety limit of 2.5 mg/kg.

The results clearly indicate that the turmeric powder samples tested have acceptable lead concentrations, posing minimal health risks to consumers. The consistent results across three readings for each sample underscore the reliability of the analytical procedure and support the conclusion that turmeric powders from these market sources meet safety requirements.

The average lead levels of 0.53 mg/kg (Sample 1), 0.57 mg/kg (Sample 2), and 0.55 mg/kg (Sample 3) provide evidence that turmeric powder marketed in Bangladesh generally adheres to regulatory standards. However, continued monitoring and vigilance are essential to maintain this safe status and prevent any potential increase in contamination levels over time.

Discussion

The findings of this study indicate that the lead concentrations in turmeric powder marketed in Bangladesh are within safe limits, as prescribed by international standards (Ganapathy et al., 2019). The measured average concentrations in the samples were 0.53 mg/kg for Sample 1 (TR), 0.57 mg/kg for Sample 2 (TA), and 0.55 mg/kg for Sample 3 (TB). These results are well below the permissible limit of 2.5 mg/kg for lead in turmeric powder, highlighting the general safety of these samples for consumption (Gleason et al., 2014).

Comparison with Previous Studies

The results of this study align with previous research conducted and reported an average lead concentration of 1.04 mg/kg across 11 samples collected from various countries, including Bangladesh and Pakistan (Gleason et al., 2014). Although slightly higher than our findings, the Lopez study still reported lead levels below permissible limits, confirming that lead contamination in turmeric can be managed with proper agricultural and processing practices (Gleason et al., 2014).

Our results also corroborate the findings and analyzed 51 samples from different markets in Dhaka and found lead concentrations ranging from 0.4 mg/kg to 13.39 mg/kg. While the upper range in Kabir's study far exceeds the regulatory limit, the lower and average values are comparable to those in our study (Grant et al.,2009). This wide variation may be due to differences in sampling locations, the origin of turmeric rhizomes, or variations in contamination during processing (He et al., 2015).

Interestingly, a study by reported alarmingly high lead levels in turmeric powder, with concentrations reaching up to 483 ppm (483 mg/kg). The stark contrast between Kelsey's findings and our results could be attributed to advancements in regulatory enforcement, quality control measures, and consumer awareness over time (Islam et al., 2023). Additionally, the turmeric sourced in Kelsey's study may have come from regions with higher environmental contamination or where adulteration practices were more prevalent.

Health and Environmental Implications

The presence of lead, even at low concentrations, remains a public health concern due to its cumulative toxic effects. Chronic exposure to lead can impair neurological development in children and increase the risk of cardiovascular disease and kidney damage in adults (Jacobs et al., 2002). Therefore, while the detected levels in this study are within safe limits, ongoing vigilance is necessary to prevent potential exposure to higher concentrations over time.

The contamination of turmeric powder may originate from various sources, including:

Soil and Water Contamination: Lead naturally occurs in the environment, and contaminated soil or irrigation water can introduce it into turmeric crops.

Post-Harvest Processing: Inadequate or contaminated machinery during drying, grinding, and storage can contribute to lead contamination.

Adulteration: In some cases, lead chromate may be intentionally added to enhance the color of turmeric powder, posing a significant health threat.

Recommendations for Contamination Control

To minimize the risk of lead contamination in turmeric powder, several steps can be taken:

Improved Agricultural Practices: Farmers should adopt practices that reduce soil and water contamination, including the use of clean water for irrigation and soil testing.

Processing and Quality Control: Ensuring that machinery and equipment used in turmeric processing are free from contaminants is critical. Manufacturers must adhere to stringent quality control protocols.

Regulatory Enforcement: Authorities should conduct regular inspections and testing to monitor lead levels in turmeric products.

Consumer Awareness: Educating consumers on the importance of purchasing certified, tested turmeric powder can help reduce the risk of exposure to lead.

Conclusion

This study successfully evaluated the lead concentration in turmeric powder marketed in Bangladesh, revealing that all tested samples remained within the permissible limits set by regulatory authorities. The average concentrations of lead were consistently below the 2.5 mg/kg threshold, indicating that the turmeric powders tested pose minimal health risks to consumers. While the findings are reassuring, continuous monitoring and enforcement of quality control standards are essential to ensure that lead contamination remains under control. Addressing potential sources of contamination, including environmental factors and adulteration, will further safeguard public health. This study underscores the importance of maintaining rigorous standards for food safety, particularly for widely consumed spices like turmeric, which hold significant cultural and medicinal value in Bangladesh.

Author contributions

S.A.A.A. and M.M.H.S. conceptualized, conducted lab and field works, analyzed data, wrote the original draft, reviewed, and edited; A.A.N., T.B and S.M.A.L., conducted research design, validated methodology, analyzed, visualized the data, reviewed, and edited; D.C.D. and M.S.A., validated the methodology, analyzed data, investigated, visualized, reviewed, and proof-read; S.J. and N.I. conceptualization, conducted research design, validated methodology, conducted analysis, investigated, visualized the data, reviewed, obtained grant, supervised and edited the paper. All authors read and approved the paper for publication.

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Competing financial interests

The authors have no conflict of interest.

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