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HEALTH RISK ASSESSMENT OF TOXIC METALS AND AFLATOXIN CONTAMINATION IN HOME-MADE AND INDUSTRIAL TARHANAS

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ABSTRACT

Access to adequate and safe food is essential for protecting human health; however, urbanization and industrialization have increased food safety challenges. This study evaluated health risks related to toxic metal and aflatoxin M1 (AFM1) contamination in homemade and industrial tarhana samples produced in different regions of Türkiye. Samples were analyzed using inductively coupled plasma mass spectrometry (ICP-MS), and chronic daily intake (CDI), target hazard quotient (THQ), hazard index (HI), and cancer risk (CR) were 2 calculated and compared with limits set by WHO and USEPA. AFM1 levels were determined by ELISA. All industrial samples exhibited HI values below the safety threshold, whereas three homemade samples showed HI values greater than 1. Cancer risk limits for nickel and chromium were exceeded in some homemade and industrial samples. Additionally, AFM1 levels exceeded Turkish Food Codex limits in 56% of samples. These results indicate that tarhana, particularly homemade products, may pose significant health risks.

Key words: AFM1, tarhana, toxic metal

EV YAPIMI VE ENDÜSTRİYEL TARHANALARDAKİ TOKSİK METALLER VE AFLATOKSİN KONTAMİNASYONUNUN SAĞLIK RİSKİ DEĞERLENDİRMESİ

ÖZ

Yeterli ve güvenli gıdaya erişim insan sağlığı için elzemdir; ancak kentleşme ve sanayileşme bu erişimi giderek karmaşık hale getirmektedir. Bu çalışmada, Türkiye'nin farklı şehirlerinde üretilen ev yapımı ve endüstriyel tarhana örneklerinde toksik metal ve aflatoksin M1 (AFM1) kontaminasyonuna bağlı sağlık riski değerlendirilmiştir. Numuneler ICP-MS yöntemiyle analiz edilmiş; kronik günlük alım (CDI), hedef tehlike katsayısı (THQ), tehlike indeksi (HI) ve kanser riski (CR) hesaplanarak WHO ve USEPA sınırlarıyla karşılaştırılmıştır. AFM1 analizleri ELISA yöntemiyle yapılmıştır. Endüstriyel numunelerin tümünde HI değerleri güvenli sınırların altında bulunurken, üç ev yapımı numunede HI>1 olarak tespit edilmiştir. Nikel ve krom için bazı ev yapımı ve endüstriyel numunelerde kanser riski sınırlarının aşıldığı belirlenmiştir. Ayrıca, numunelerin %56'sında AFM1 düzeyleri Türk Gıda Kodeksi limitlerini aşmıştır. Sonuçlar, özellikle ev yapımı tarhanaların potansiyel sağlık riski taşıyabileceğini göstermektedir.

Anahtar kelimeler: AFM1, tarhana, toksik metal

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INTRODUCTION

Ensuring access to sufficient and safe food is essential for maintaining human health, supporting life, and promoting physical development. However, urbanization, industrialization, and environmental pollution have increasingly complicated the accessibility of safe food in recent years. It is well documented that foods contaminated with biological and chemical hazards, such as bacteria, viruses, and toxic compounds, can lead to a wide spectrum of health problems, ranging from mild gastrointestinal disorders to severe chronic diseases including cancer. According to the World Health Organization (WHO) (2025), approximately 600 million people worldwide suffer from foodborne illnesses each year, underscoring the global burden of food safety.

Among traditional foods, tarhana holds a prominent place in Turkish cuisine due to its high nutritional value and long shelf life. It is produced through the fermentation of wheat flour, yoghurt, salt, tomatoes, peppers, and onions, followed by drying and grinding. The fermentation process, involving lactic acid bacteria from yoghurt and yeasts present in wheat, contributes to the distinctive taste and aroma of tarhana by means of lactic acid and alcoholic fermentation. Moreover, the combination of fermentation and drying techniques not only enhances flavor but also extends the product's durability (Altun, 2015).

In the context of food safety, toxic metals pose a significant threat. Metals are broadly categorized as either essential or non-essential for biological systems. Essential metals are required in trace amounts for physiological functions; however, when their concentrations exceed certain thresholds, they may exert toxic effects. The toxicity of metals depends not only on their concentration in biological tissues but also on factors such as species sensitivity and the specific ionic form of the metal. As a result, regulatory bodies have established maximum allowable limits for metal concentrations in drinking water and foodstuffs, with routine monitoring mandated to ensure consumer safety (Kahvecioğlu et al., 2003).

Another critical contaminant group in food safety is mycotoxins, which are toxic secondary metabolites produced by certain filamentous fungi. These compounds can lead to serious health risks for both humans and animals (Mello et al., 1997). Although nearly 200 fungal species are capable of producing mycotoxins, only about 20-25 of them are frequently encountered in food and feed products. Previous studies have identified the presence of various mycotoxins in milk and dairy products, including aflatoxin M1 (AFM1) and M2, ochratoxin A (OTA), cyclopiazonic acid (CPA), trichothecenes, zearalenone, patulin, and fumonisins (Dağoğlu et al., 1995; Sabuncuoğlu et al., 2008). Aflatoxins, particularly AFM1, have been recognized for their carcinogenic potential, leading the International Agency for Research on Cancer (IARC), under WHO, to classify AFB1 as a Group 1 carcinogen and AFM1 as a Group 2B carcinogen as of June 19, 1993 (Gourama and Bullerman, 1995).

While numerous international studies have evaluated the presence of toxic metals and mycotoxins in food products, there is a notable gap in the literature regarding their simultaneous assessment in tarhana samples in Türkiye. Given the widespread consumption of tarhana, particularly among children and the elderly, it is crucial to investigate its potential contamination with both toxic metals and AFM1. Therefore, the present study aims to analyze tarhana samples for the levels of toxic metals and AFM1 and to evaluate the associated health risks.

MATERIALS AND METHODS

Sample Collection

In this study, a total of 78 tarhana samples were collected for analysis. These comprised three types of widely consumed industrially produced tarhana brands, along with 75 homemade tarhana samples sourced from various cities across different geographical regions of Türkiye. All samples were coded and documented according to ensure traceability.

Sample Preparation

Prior to instrumental analysis, all tarhana samples were finely ground using a laboratory mill to achieve homogeneity. To prevent potential contamination from metal surfaces, all handling procedures, including collection, homogenization, and weighing, were performed using plastic utensils, such as spoons and spatulas. Each sample was individually packaged in labeled polyethylene bags and stored in enclosed cabinets away from light exposure until analysis.

ICP-MS Instrumentation and Calibration

Elemental analysis was performed using an Inductively Coupled Plasma Mass Spectrometry (ICP-MS) system (Thermo Fisher Scientific, iCAP RQ, USA). Before initiating the analyses, the system was calibrated by updating the Tune file, mass calibration, and detector calibration. The ICP-MS was equipped with a quartz nebulizer, spray chamber, torch, injector, and a platinum-

tipped sample and skimmer cone set. The system operated in standard mode, with 40- second injections at room temperature. An automated sampler (Teledyne Cetac Technologies) was used for automated sample introduction. The detailed operating parameters of the ICP-MS are presented in Table 1.

Table 1. Operating parameters of the ICP-MS system

Nebulizer gas flow	0.9636 L/min
Spray chamber temperature	2.7°C
Extraction lens voltage	-150.7 Volts
CCT Focus lens voltage	-2.7 Volts
Plasma power	1550 Watt

Calibration curves were constructed using multi-element standard solutions, and all elements showed high linearity (R^2>0.999). Limits of detection (LOD) were obtained from the ICP-MS software (Qtegra) based on calibration data. Limits of quantification (LOQ) were calculated as 3.3 times the corresponding LOD values, in accordance with commonly accepted analytical approaches (ICH, 2005). The LOD and LOQ values for each element are summarized in Table 2.

Table 2. Limits of detection (LOD) and quantification (LOQ) for the analyzed elements using ICP-MS

Element	LOD (µg.kg^{-1})	LOQ (µg.kg^{-1})
Pb	0.0065	0.021
Cd	0.0016	0.005
As	0.0031	0.010
Cr	0.0448	0.148
Ni	0.0188	0.062
Cu	0.0376	0.124
Al	0.0575	0.190
Fe	0.5146	1.698
Hg	0.0042	0.014

Sample Digestion Procedure

For metal analysis, 400 mg of each ground tarhana sample was accurately weighed using a high-precision analytical balance (OHAUS PR224, USA) and transferred into acid-resistant Teflon digestion vessels. To each vessel, 9 mL of concentrated nitric acid (HNO_3) was added, followed by 1 mL of hydrogen peroxide (H_2O_2) to facilitate oxidative digestion (Milestone Application Note for Acid Digestion). The samples were then subjected to microwave-assisted digestion using a closed-vessel microwave digestion system (Ethos Up, Milestone, Italy). The specific microwave digestion program employed in the study is detailed in Table 3.

Table 3. Microwave digestion program used for sample preparation

Step	Time	T1	Power
1	00:15:00	200°C	1800 W
2	00:15:00	200°C	1800 W

Sample Dilution and Calibration for Elemental Analysis

For elemental quantification, stock solutions were prepared by dissolving the digested tarhana samples in 30 mL of ultrapure water, followed by a 1:200 dilution with additional ultrapure water to achieve the final working solution. Prior to analysis, the ICP-MS system was rinsed with a 2% HNO□ -based washing solution to eliminate potential residues and prevent cross-contamination.

Calibration curves were established using certified multielement standards to determine metal concentration in diluted samples. All calibration procedures were performed according to the manufacturer's recommendations, and calibration parameters and linearity data were obtained (Supplement 1).

Aflatoxin M1 Analysis

For the determination of Aflatoxin M1 (AFM1) content in tarhana samples, 5 g of ground sample was accurately weighed and homogenized with 25 mL of 70% methanol solution. The homogenate was then filtered using Whatman No. 1 filter paper, and the filtrate was collected for analysis (Boshra et al., 2023).

AFM1 levels were measured using a commercial ELISA kit (Elabscience®, Lot No.: LZHKUPWDA8), following

the manufacturer's instructions. Absorbance readings were performed using a Chromate 4300 ELISA reader (Awareness Technology, Inc., Martin Hwy., Palm City, USA). All measurements were conducted under standardized conditions appropriate for the device.

The results were expressed in parts per billion (μg/kg). Data analysis was conducted using a four-parameter logistic regression model, which is standard for ELISA-based quantification and ensures accurate interpolation of concentration values from the calibration curve.

Health Risk Assessment

To evaluate the potential health risks associated with toxic metal exposure through tarhana consumption, risk assessment calculations were performed based on standardized formulas and internationally accepted reference values. The analytical data obtained from the ICP-MS measurements were used as input for the calculations.

1) The Chronic Daily Intake (CDI) of metals was calculated to estimate the average daily intake of toxic metals by an individual consuming tarhana. For this purpose, the reference limits established by the United States Environmental Protection Agency (USEPA) were adopted, as also cited by Osobamiro et al. (2020). The calculation was performed using Formula 1, which is commonly applied in dietary exposure assessments:

$$CDI = (C \times IRi \times EFi \times EDi) / (BWi \times ATn) \quad (1)$$

In this study, a consumption rate (IRi) of 0.02 kg/day (equivalent to 20 g/day) representing the average daily tarhana consumption was used. Body weight (BW) was assumed according to standard adult values commonly used in risk assessments (C: concentration of heavy metals; EDi: exposure duration, years; IRi: ingestion rate, kg/n-day; EFi: exposure frequency, 1 year:365 days; BWi: body weight, kg; ATn: average time exposure, days).

2) Following the calculation of Chronic Daily Intake (CDI) values for each toxic metal detected by ICP-MS, the Target Hazard Quotient (THQ) was calculated using Formula 2. This parameter is commonly used in the USEPA's non-carcinogenic risk assessment framework to determine whether individual metal exposure poses a health risk.

$$THQ = CDI / RFd \quad (2)$$

Interpretation criteria were defined as: THQ≤1: No potential health risk THQ>1: Potential health risk

3) To assess the cumulative non-carcinogenic effects of multiple toxic metals, the Hazard Index (HI) was calculated by summing the individual THQ values for each of the nine toxic metals analyzed. This assessment was performed using Formula 3, and it provides an integrated evaluation of the overall risk level.

$$HI = \Sigma THQ \quad (3)$$

An HI value greater than 1 indicates the potential for combined non-carcinogenic effects.

4) To estimate the potential long-term carcinogenic risk from exposure to specific metals classified as carcinogenic, the lifetime Cancer Risk (CR) was calculated using Formula 4. This assessment was based on the cancer slope factor for ingestion (CSFing) values provided by the USEPA (2011), considering an average lifetime exposure of 70 years. The metals assessed for carcinogenic risk and their corresponding CSFing values are listed in Table 4. The CR values were interpreted within the acceptable risk range of 10^{-6} to 10^{-4}, as defined by the USEPA.

$$CR = CDI \times CSFing$$

Table 4. Reference doses (RfDing) and cancer slope factors (CSFing) used in health risk assessment

USEPA-2011 FAO/WHO-2011	**Ingestion reference dose RfDing (mg. kg^{-1}/day)**	**Ingestion carcinogenic slope factor CSFing (mg. kg^{-1}. /day)$^{-1}$**
Pb	0.004	0.009
Cr	1.500	0.500
As	0.000	1.500
Ni	0.020	170.000
Cd	0.001	0.380
Hg	0.000	0.000
Al	7.000	—

Statistical Analyses

Statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 26.0 (SPSS Inc., Chicago, IL, USA). The Mann-Whitney U test, a non-parametric method, was used to determine statistically significant differences between homemade and industrial tarhana samples. A significance level of $P<0.05$ was considered statistically meaningful in all comparisons.

FINDINGS AND DISCUSSION

The health risk assessment parameters spesifically, CDI, THQ, HI, and CR, were calculated based on the concentrations of Pb, Cd, As, Cr, Ni, Cu, Al, Fe, and Hg detected in all tarhana samples. Additionally, AFM1 levels determined through ELISA were subjected to statistical evaluation. The average values obtained from homemade tarhana samples were compared with those from each industrial tarhana sample as well as their overall mean, and the results were interpreted accordingly. Individual toxic metal concentrations detected by ICP-MS served as the primary input data for the health risk modeling performed (Supplement 2).

The proportional distribution (%) of toxic metal content in homemade (A) and industrial (B) tarhana samples was evaluated relative to reference limit values derived from the FAO/WHO Codex Alimentarius (1995) and relevant literature. This comparison is visually represented in Figure 1, illustrating the extent to which each group adheres to or exceeds these safety thresholds.

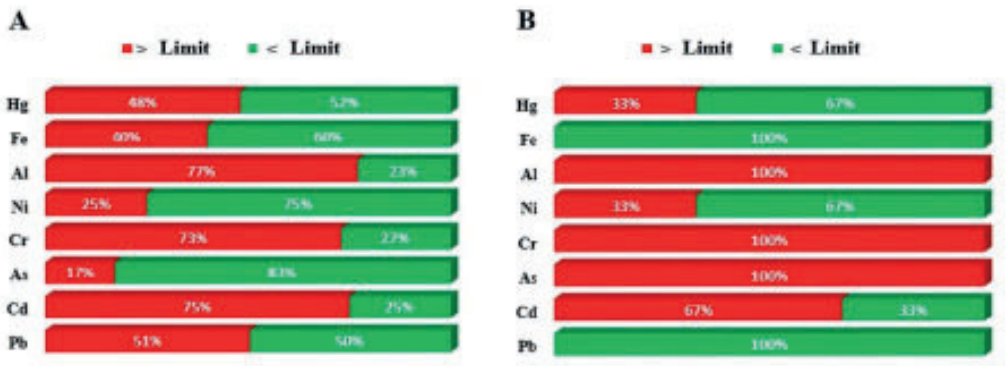


Figure 1. The proportional distribution (%) of toxic metal content in the homemade (A) and industrial (B) tarhana samples

Although several metal concentrations exceeded reference limit values, the health risk assessment parameters (THQ, HI and CR) indicated no significant risk. This apparent discrepancy may be explained by the exposure-based nature of risk assessment models. The THQ and CDI calculations consider factors such as daily consumption rate, exposure frequency, exposure duration, and body weight. In the present study, the assumed daily tarhana consumption (0.02 kg/day) was relatively low, which substantially reduced the estimated metal intake. Therefore, even when certain metal concentrations exceeded reference limit values, the calculated exposure levels remained below the reference doses defined by USEPA, resulting in THQ and HI values below the critical threshold of 1.

In a study conducted in Kahramanmaraş, lead (Pb) concentrations in 10 tarhana samples were reported to be below the limit of 0.20 mg/kg as defined by the Turkish Food Codex (Turgay et al., 2021). Similarly, Yaman and Güçer (1995) investigated vegetables from the Elazığ region and found Pb concentrations as high as 0.73 mg/kg in tomatoes, particularly in samples collected near roads or areas with intensive fertilizer use. In the present study, although the average Pb levels in all tarhana samples exceeded WHO recommended values, they remained within the legal limits set by the TGK. This suggests a potential long-term health concern, particularly considering cumulative exposure, despite formal compliance with national standards.

In terms of cadmium (Cd) contamination, findings from previous international studies show notably low levels: for instance, Chatterjee et al. (2019) reported Cd concentrations below 0.005 mg/kg in mushroom soups in India, while Winiarska-Mieczan et al. (2018) found an average of 0.0007 mg/kg Cd in 27 commercially produced infant soups in Poland, noting a statistically significant variation ($P<0.05$) among samples. Comparatively, in our study, homemade tarhana samples demonstrated higher cadmium contamination levels than industrially produced samples. This difference was statistically significant ($P<0.05$) based on Mann-Whitney U test results, indicating variability in raw materials or preparation environments as a contributing factor.

In one study, the amount of As in 75 milk samples taken from different regions of Türkiye varied between 0.0002-0.05 mg/kg (Şimşek et al. 2000). In other studies, Lee et al. (2006) found 0.08 mg/kg As in sea mustard-based soups and 0.06 mg/kg in beef and mustard soups in Korea, whereas Tchana et al. (2018) reported non-detectable As levels in powdered soups made with soy, mushroom, and moringa in Bangladesh. In our study, 17% of homemade tarhana samples exceeded reference limit values for arsenic, while all industrial tarhana samples contained As levels above the WHO limit. However, despite these exceedances, health risk assessments indicated no significant risk, as THQ<1, HI<1, and CR values remained within the acceptable range of 10^{-6} to 10^{-4}. Furthermore, statistical analysis revealed no significant difference in arsenic content ($P>0.05$, Mann-Whitney U test).

In a study conducted in India, the chromium (Cr) concentration in mushroom soups was reported as 0.0019 mg/kg (Chatterjee et al., 2019). One plausible source of chromium contamination may be the water used in food preparation. In the present study, 73% of the homemade tarhana samples contained Cr levels above the WHO recommended limits, while all industrial samples exceeded these limits. Despite this, the THQ and HI values for Cr remained below 1, indicating no immediate health risk. Nonetheless, the difference in Cr levels between homemade and industrial tarhana samples was found to be statistically significant ($P<0.001$), highlighting potential disparities in raw material sourcing or production practices.

Regarding nickel (Ni), the literature identifies spices, dried fruits, and whole grains as common contributors to Ni content in foods (Cabrera-Vique et al., 2011). Additionally, Reilly (2007) demonstrated that Ni may leach into foods during cooking or storage in stainless steel containers, with concentrations ranging from 0.13 to 0.22 mg/kg within one hour. In a prior study on tarhana, Çiftçi and Karpta (2009) reported an extremely high Ni concentration of 3920 mg/kg, suggesting serious contamination issues. In the current study, Ni concentrations in homemade tarhana exceeded WHO limits in 25% of samples, while 33% of industrial samples also surpassed these standards. A statistically significant difference ($P<0.05$) was found between the two sample groups. Although THQ and HI values for Ni remained below critical thresholds, elevated levels highlight the importance of controlling Ni sources in the production chain.

Aluminum (Al) contamination is also a concern, particularly due to its widespread use in food processing and packaging materials. Chekri et al. (2019) reported an average Al concentration of 0.65 mg/kg in 291 soup and baby food samples in France. Additional studies have shown Al concentrations of 0.93 mg/kg in processed cheese, 0.68 mg/kg in ice cream, and 1.73 mg/kg in chocolate (Biricik et al., 2015). Further, Semwal et al. (2006) found that tomato soup prepared in aluminum cookware contained up to 32 mg/kg of Al, illustrating the metal's ease of migration into food matrices. In our findings, 77% of homemade tarhana samples exceeded WHO aluminum standards, while all industrial samples also surpassed the recommended limits. However, no statistically significant variation was detected between the two groups. Importantly, health risk indicators (THQ<1, HI<1, CR<10^{-6}-10^{-4}) suggest that, despite elevated concentrations, no immediate health risk is posed under typical consumption patterns.

Iron (Fe) concentrations in food products vary significantly depending on the matrix and preparation method. Soylak et al. (2006) reported Fe concentrations ranging from 4.62 mg/kg in tripe soup to 61.7 mg/kg in noodle and lentil soups. Similarly, Olivares et al. (2004) identified an average Fe level of 4.21 mg/kg in chicken soups. In studies specifically focusing on tarhana, Çiftçi and Karpta (2009) found 96 mg/kg, whereas Erbaş et al. (2005) reported 9.7 mg/kg. In the current study, homemade tarhana samples contained Fe concentrations that were 40% above WHO standards, while iron was not detected in any of the industrial samples. Despite this, health risk indicators (THQ<1, HI<1, CR<10^{-6}-10^{-4}) remained within acceptable safety margins. The difference between homemade

and industrial tarhana in terms of Fe content was statistically significant ($P<0.01$), suggesting a possible variation in raw materials such as yogurt or flour sources.

Mercury (Hg) is another toxic metal with significant health implications at elevated levels. İmer and Taşan (2018) reported average mercury levels in various edible oils, with the highest being 10.65 mg/kg in sunflower oil, followed by 0.21 mg/kg in hazelnut oil and 0.03 mg/kg in walnut oil. In our study, 48% of homemade tarhana samples exceeded WHO mercury standards, compared to 33% in industrial samples. Although Hg contamination was more prevalent in homemade samples, no statistically significant difference was observed between the two groups. Furthermore, THQ, HI, and CR values indicated no immediate health risks associated with mercury in either group.

Copper (Cu) levels in foods may vary depending on cookware and food composition. Reboredo et al. (2019) documented high Cu levels (44 mg/kg) in soups containing pumpkin and purslane. Şanlıer and Türközü (2014) highlighted that copper utensils contribute significantly to Cu migration, particularly in acidic or carbonated foods. Meals cooked in copper pots may contain approximately twofold increase Cu compared to those prepared in stainless steel or aluminum cookware. Akbulut (2019) reports that daily Cu intake should be around 2 mg, and toxicity may arise when intake exceeds 15 mg/day. Regulatory thresholds vary, with 1.3 mg/kg in the USA, 1 mg/kg in Canada, and 2 mg/kg in the European Union. When considering 2 mg/kg as a reference limit, homemade tarhana exceeded this value by 45%, and industrial tarhana by 67%. Despite these elevated levels, no statistically significant difference was found between the two groups. Also, health risk assessments indicated no concern (THQ<1, HI<1, CR<10^{-6}-10^{-4}). It is important to note that WHO has not established a definitive limit for Cu, but monitoring remains essential due to its dual nutritional and toxicological roles.

The calculated CDI, THQ, and HI values (Supplement 3) and CR values (Supplement 4) for all toxic metals in tarhana samples provide a detailed overview of possible exposure risks.

In a study conducted on homemade and industrial noodles, THQ<1 and HI<1 were found for the metals Pb, Hg, Cd, As, Cr, Ni, Cu, Al and Fe analyzed in all samples (Yucel and Uyanoglu, 2024). In our study, the Hazard Index (HI), which represents the sum of the THQ for all analyzed metals, was found to be below 1 in all tarhana samples except those containing nickel (Ni). This indicates that the overall non-carcinogenic health risk posed by the nine toxic metals analyzed remains within acceptable limits according to USEPA standards. In particular, while all industrial tarhana samples exhibited HI values below the safety threshold, three homemade samples exceeded the acceptable limit with HI values of 8.23, 2.57 and 1.20, respectively, suggesting local or raw material-related contamination risks.

Cadmium (Cd) is known for its persistent toxicological effects, particularly its nephrotoxicity and capacity for hepatic accumulation; these effects are irreversible once exposure occurs. Furthermore, chronic cadmium intake above regulatory thresholds has been linked to lung and prostate cancers. In this study, however, no cadmium-related CR values exceeded the USEPA threshold in any of the samples analyzed, indicating that while Cd is present, it does not pose a significant carcinogenic risk at the detected concentrations.

Arsenic (As) is a potent toxin, with acute lethal doses reported at 60 mg/kg via food or drinking water, and it presents carcinogenic risks via both ingestion and inhalation routes (Turkish Medical Association, 2016). In our study, no industrial tarhana sample exceeded the arsenic cancer risk limit defined by USEPA. However, in homemade tarhana samples, the CR value for arsenic exceeded this threshold in 11% of the samples (n=8), warranting attention for possible source tracking and control, particularly in water or grain quality.

Chromium (Cr) is classified as a Group I carcinogen by the World Cancer Research Fund / American Institute for Cancer Research (AICR), along with metals such as mercury, cadmium, and vanadium. Chromium exposure, particularly in individuals with respiratory conditions like asthma, has been associated with increased risks of lung and colorectal cancers (Poyraz, 2015). In the present study, 1 industrial tarhana sample (representing 33%) and 25 homemade samples (also 33%) were found to exceed the cancer risk limits for chromium, highlighting its consistent occurrence regardless of production type and pointing to a need for mitigation strategies across both production systems.

Nickel (Ni) is another metal with established links to pulmonary carcinoma, as shown by Howard (2001). Additional studies have identified Ni-related asthma, nasal, and throat cancers in occupationally exposed individuals. Our analysis revealed that 1 industrial sample exceeded the nickel cancer risk limit as defined by USEPA, while 19 homemade tarhana samples (25%)

exceeded this threshold. This suggests a more pronounced contamination risk in domestic production contexts, likely stemming from either raw materials or utensil/processing-related migration.

In a European cohort study involving workers in mercury mines and processing facilities, an increased risk of mortality due to lung, liver, and ovarian cancers was reported among exposed individuals. Similarly, in a separate investigation focusing on workers exposed to inorganic mercury, a higher incidence of lung cancer was observed (Demir, 2021). However, in the present study, CR values associated with mercury exposure were found to be below the threshold established by the USEPA in all tarhana samples, indicating no significant carcinogenic risk from mercury at the detected concentrations.

Evaluation of Mycotoxin Measurements

AFM1 concentrations were analyzed in tarhana samples by ELISA (Supplement 5). The threshold reference value for AFM1 was based on the 0.050 µg/kg limit established in regulation 2.1.12 of the Turkish Food Codex (TGK) (2011) regulation for raw milk, heat-treated milk, and milk used in the production of milk-based products.

Following the identification of the adverse health effects of aflatoxins, particularly AFB1 and its metabolite AFM1, the International Agency for Research on Cancer (IARC), operating under the WHO, classified AFB1 as a Group 1 carcinogen on June 19, 1993 (Karapınar, 2013). In line with global regulatory frameworks, most countries, including Türkiye, have established maximum permissible levels of AFM1 at 0.05 µg/kg in milk and milk-derived products. However, these limit values vary internationally, often influenced by economic considerations. For instance, the European Union and Codex Alimentarius both recognize the 0.05 µg/kg threshold, whereas the United States permits a higher limit of 0.5 µg/kg (Özdemir, 2007).

According to ELISA analysis, AFM1 was detected in 44 out of 78 tarhana samples (56%), while no AFM1 was detected in the remaining 34 samples (44%). In particular, 44 AFM1 positive samples exceeded the TGK safety limit. Among them, 43 samples belonged to the homemade tarhana group (55%), while only one sample (33%) exceeded the limit among industrial tarhanas. The highest recorded AFM1 concentration was 1.011 µg/kg. The distribution of all samples in relation to the TGK threshold for AFM1 is illustrated in Figure 2.

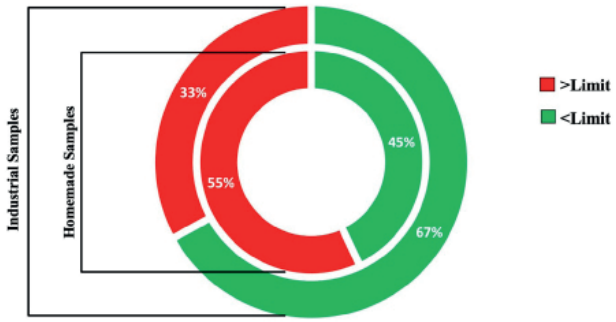


Figure 2. Distribution (%) of tarhana samples according to the TGK limit (0.05 µg/kg) for AFM1

In a study conducted in Pakistan, AFM1 contamination was detected in 11.25% of UHT milk samples and in 33% of raw milk samples (Raza, 2006). According to the results of a review study conducted by Massahi et al., (2023) in a study conducted in Iran to evaluate the contamination level of different milk types, 82.8% of milk samples were found to be infected with AFM1 and the overall mean AFM1 concentration in milk was 159 ± 77 ng/kg.

CONCLUSION

In this study, a total of 78 tarhana soup samples, 75 homemade and 3 industrial, collected from various provinces in Türkiye were evaluated in terms of potential health risks associated with nine toxic metals and AFM1 contamination. The findings indicate that the presence of toxic metals in tarhana may originate from factors such as the raw materials used in production, cooking and drying processes, and metal-containing equipment or storage containers. The concentration of AFM1, on the other hand, is largely attributed to the milk and yogurt components of tarhana. Considering its susceptibility to aflatoxin contamination, appropriate storage conditions must be ensured to maintain food safety.

Although some of the detected metal concentrations remain within acceptable safety limits, their cumulative effects and levels of consumption may pose potential health risks. The metals examined in this study were selected due to their known toxicological significance; however, to achieve a more

comprehensive health risk assessment, future studies should also include a broader range of metals with other toxicological effects. In addition, the limited number of industrial samples (n=3) should be considered when interpreting the comparative results.

It should also be noted that the exposure assessment in this study was based on standard adult body weight values used in risk assessment models. Since children have lower body weight and may consume tarhana regularly as part of their diet, their relative exposure to toxic metals could be higher than that estimated for adults. Therefore, although the calculated THQ, HI, and CR values indicate no significant risk for the adult population, potential health implications for pediatric populations warrant careful consideration. Future studies should consider child-specific exposure scenarios to provide a more comprehensive evaluation of health risks.

Furthermore, comprehensive mycotoxin profiling is needed to better understand and manage contamination risks. Preventive measures should focus particularly on the production and processing stages of milk and dairy-based foods, which are primary contributors to AFM1 presence. For commercial products, some of the critical analyses performed in this study should be adopted as routine safety assessments to ensure product quality and consumer health on a wider scale.

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AUTHOR CONTRIBUTIONS

The authors declare that they have contributed equally to the article. All the authors declare that they have seen/read and approved the final version of the article ready for publication.

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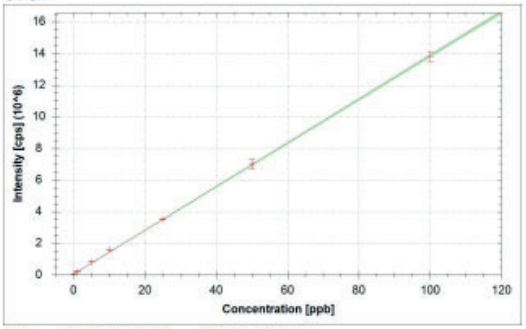
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Nasıl Atıf Yapılır?:
Yücel P, Yücel HN, Uyanoğlu M. (2026) Ev yapımı ve endüstriyel tarhanalardaki toksik metaller ve aflatoksin kontaminasyonunun sağlık riski değerlendirmesi. GIDA (2026) 51 (3) 417-440 doi: 10.15237/gida.GD26014

Supplement 1

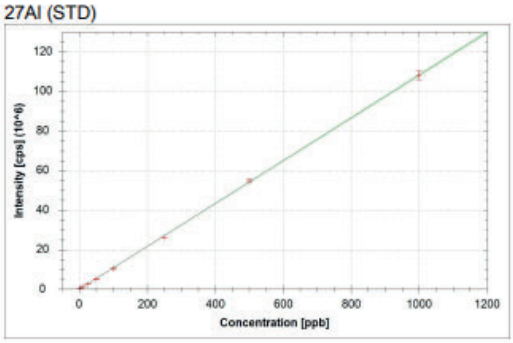
Calibration Charts

52Cr



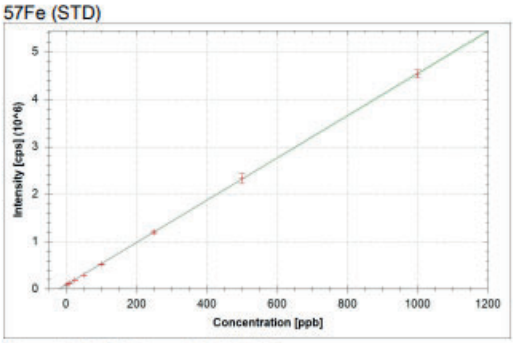
f(x) = 138008.5310*x + 64434.5067
R² = 0.9998
BEC = 0.467 ppb
LoD = 0.0448 ppb

27Al (STD)



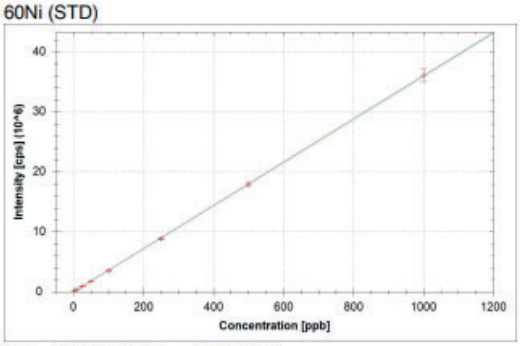
f(x) = 108271.8284*x + 47444.2070
R² = 0.9999
BEC = 0.438 ppb
LoD = 0.0575 ppb

57Fe (STD)



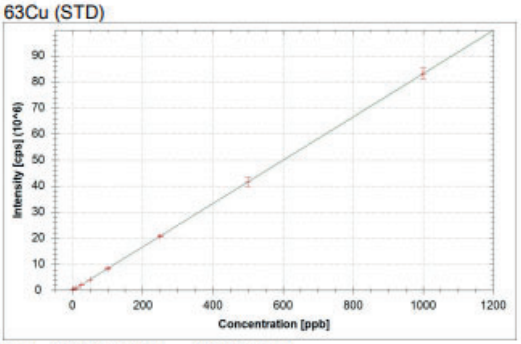
f(x) = 4461.8905*x + 86354.5543
R² = 0.9999
BEC = 19.354 ppb
LoD = 0.5146 ppb

60Ni (STD)



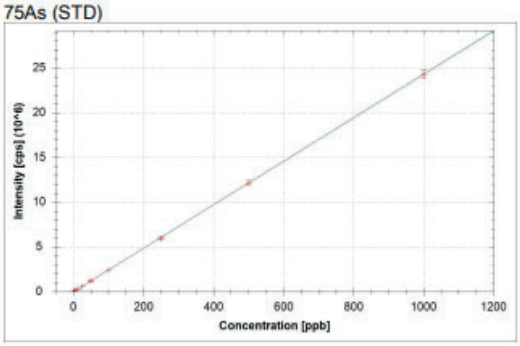
f(x) = 36007.9012*x + 3990.6490
R² = 1.0000
BEC = 0.111 ppb
LoD = 0.0188 ppb

63Cu (STD)



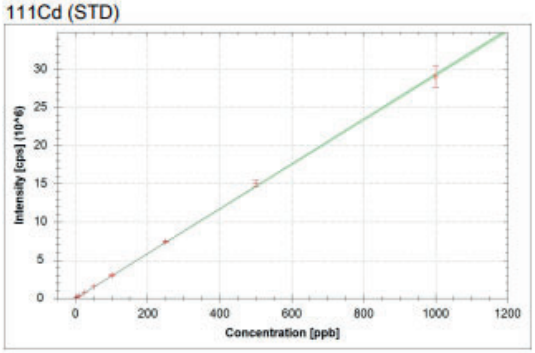
f(x) = 83128.1551*x + 59639.2715
R² = 1.0000
BEC = 0.717 ppb
LoD = 0.0376 ppb

75As (STD)



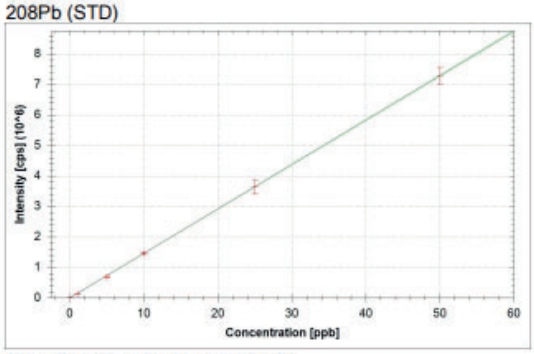
f(x) = 24317.2619*x + 176.6688
R² = 1.0000
BEC = 0.007 ppb
LoD = 0.0031 ppb

111Cd (STD)



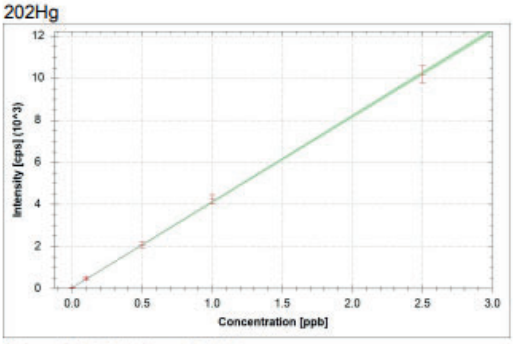
f(x) = 29284.6613*x + 33.3335
R^2 = 0.9997
BEC = 0.001 ppb
LoD = 0.0016 ppb

208Pb (STD)



f(x) = 145805.4510*x + 4567.5271
R^2 = 0.9999
BEC = 0.031 ppb
LoD = 0.0065 ppb

202Hg



f(x) = 4079.9814*x + 33.3335
R^2 = 0.9997
BEC = 0.008 ppb
LoD = 0.0042 ppb

Calibration Standard Solutions

- Chromium standard solution 1000 µg/ml Chem-Lab NV, Belgium
- Mercury standard solution 1000 µg/ml Chem-Lab NV, Belgium
- Multi-element standart solution 100 µg/ml: Ag, Al, As, B, Ba, Bi, Ca, Cd, Co, Cu, Fe, K, Mg, Na, Ni, Pb, Sr, V, Zn Aqueous Analytical Solution, 5% HNO_3 125 ml (d: 1.032 g/ml)

Calibration Standard Analyze

Category	Concentration average (ppb)	Concentration RSD (%)	Standard Concentration (ppb)
^{52}Cr	1.100	9.7	1.000
	5.565	0.7	5.000
	11.164	0.7	10.000
	25.020	0.6	25.000
	50.308	4.7	50.000
	99.695	2.3	100.000
^{27}Al (STD)	1.237	3.1	1.000
	5.489	0.6	5.000
	10.428	3.2	10.000
	23.203	3.0	25.000
	47.155	3.8	50.000
	95.503	3.2	100.000
	241.588	0.4	250.000
	505.302	1.6	500.000
	1,000.082	2.2	1,000.000
^{57}Fe (STD)	0.208	93.5	1.000
	4.852	3.3	5.000
	8.177	6.4	10.000
	23.431	3.2	25.000
	45.800	2.7	50.000
	97.570	2.1	100.000
	248.986	2.7	250.000
	503.774	5.0	500.000
	998.878	1.9	1,000.000
^{60}Ni (STD)	0.960	7.1	1.000
	5.884	3.2	5.000
	10.357	1.2	10.000
	24.902	4.0	25.000
	49.103	1.4	50.000
	97.510	2.8	100.000
	245.647	2.1	250.000
	497.577	2.0	500.000
	1,002.588	3.0	1,000.000
^{63}Cu (STD)	0.587	3.7	1.000
	5.027	2.1	5.000
	10.134	1.9	10.000
	24.720	3.9	25.000
	49.103	1.4	50.000
	99.637	4.1	100.000
	248.974	1.5	250.000
	500.184	4.2	500.000
	1,000.303	2.4	1,000.000
^{75}As (STD)	1.005	3.5	1.000
	4.773	2.5	5.000
	10.007	3.3	10.000
	25.131	1.4	25.000
	50.300	1.8	50.000

	101.002	0.4	100.000
	244.615	3.0	250.000
	501.143	2.2	500.000
	1,000.657	2.1	1,000.000
^{111}Cd (STD)	1.036	4.4	1.000
	5.238	3.1	5.000
	10.626	0.8	10.000
	26.329	0.9	25.000
	52.811	0.9	50.000
	103.484	1.9	100.000
	253.853	1.6	250.000
	514.164	2.5	500.000
	991.425	4.8	1,000.000
^{208}Pb (STD)	0.863	3.1	1.000
	4.707	2.0	5.000
	9.987	3.1	10.000
	24.995	6.6	25.000
	50.300	1.8	50.000
	107.050	1.9	100.000
	265.593	2.3	250.000
	543.207	2.8	500.000
	1,091.620	2.7	1,000.000
^{202}Hg	0.109	18.1	0.100
	0.217	14.7	0.250
	0.499	5.7	0.500
	1.030	5.0	1.000
	1.885	3.9	2.000
	2.488	4.1	2.500

Supplement 2

Toxic metal concentrations detected in each tarhana sample (ppm)

Sample	Pb	Cd	As	Cr	Ni	Cu	Al	Fe	Hg
HM01	1.45	0.14	0.63	6.13	ND	ND	7.95	22.99	0.04
HM02	1.02	0.06	0.48	ND	ND	ND	1.02	65.97	ND
HM03	0.76	0.04	0.38	ND	ND	ND	15.16	11.03	ND
HM04	0.59	0.06	0.26	5.15	ND	8.56	12.11	56.86	ND
HM05	0.40	ND	0.30	ND	ND	6.76	53.88	48.37	ND
HM06	0.28	0.06	0.24	0.18	ND	ND	68.40	36.47	ND
HM07	0.28	0.02	0.22	ND	ND	ND	8.61	24.26	ND
HM08	0.34	ND	0.20	9.46	41.90	5.76	9.01	67.54	ND
HM09	0.20	0.02	0.18	0.04	ND	4.89	612.83	35.29	ND
HM10	0.28	ND	0.18	ND	ND	ND	23.07	39.15	ND
HM11	0.14	0.04	0.16	ND	ND	21.62	30.35	89.23	ND
HM12	0.04	ND	0.12	0.32	ND	3.44	17.07	20.27	0.02
HM13	0.06	ND	0.12	ND	ND	ND	5.74	42.52	ND
HM14	0.22	ND	0.12	0.12	ND	3.26	23.33	25.10	ND
HM15	0.04	0.02	0.10	0.20	ND	1.39	30.44	ND	ND
HM16	ND	0.06	0.06	ND	ND	ND	ND	ND	0.02
HM17	0.02	ND	0.10	0.14	35.48	35.30	ND	ND	ND
HM18	ND	ND	0.10	0.40	ND	4.64	5.15	59.72	0.02
HM19	0.10	0.02	0.14	0.64	ND	6.29	ND	211.43	0.02
HM20	ND	0.02	0.04	0.34	ND	ND	ND	ND	ND
HM21	ND	0.04	0.06	0.56	7.93	8.55	ND	ND	0.04
HM22	0.02	0.04	0.10	4.98	ND	8.75	ND	ND	0.04
HM23	0.48	0.06	0.08	7.11	ND	3.30	5.19	41.31	0.08
HM24	ND	ND	ND	0.71	ND	ND	ND	ND	ND
HM25	ND	0.10	0.04	0.58	ND	3.13	ND	ND	0.04
HM26	ND	0.02	0.02	0.38	ND	0.94	ND	ND	0.04
HM27	0.12	0.12	0.08	0.50	ND	5.25	ND	ND	ND
HM28	ND	0.02	0.04	0.62	ND	ND	ND	ND	ND
HM29	ND	0.02	0.06	ND	ND	ND	13.25	7.93	ND
HM30	ND	0.02	0.10	0.12	23.00	17.83	11.56	80.10	ND
HM31	ND	0.04	0.08	ND	3.80	10.82	8.56	ND	ND
HM32	ND	0.02	0.38	ND	2.44	ND	11.47	ND	0.06
HM33	ND	ND	0.10	0.40	ND	ND	20.50	ND	ND
HM34	ND	0.06	0.12	ND	ND	2.79	19.50	ND	0.04
HM35	0.06	0.02	0.08	0.44	ND	ND	212.54	53.63	0.02
HM36	ND	0.02	0.10	7.44	3.32	6.31	24.15	135.06	ND
HM37	ND	0.02	0.04	7.13	ND	ND	14.41	22.67	0.04
HM38	ND	0.02	0.06	4.49	5.92	ND	24.48	ND	0.04
HM39	ND	0.02	0.02	0.51	ND	ND	49.44	194.56	ND

HM40	ND	0.02	0.04	4.08	ND	ND	5.66	ND	ND
HM41	ND	0.02	0.06	8.48	2.35	ND	6.36	11.65	0.04
HM42	ND	ND	0.06	3.29	1.73	3.23	34.10	27.59	0.02
HM43	ND	0.04	0.04	ND	8.49	ND	18.19	68.65	0.04
HM44	ND	ND	0.08	0.18	ND	ND	19.21	75.56	0.04
HM45	73.19	0.68	0.28	27.39	6.43	220.26	46.02	1894.23	0.04
HM46	0.16	0.14	0.14	0.20	ND	ND	24.02	120.91	0.04
HM47	ND	0.02	0.08	ND	ND	ND	34.12	63.79	ND
HM48	ND	0.02	0.02	0.40	ND	ND	49.89	40.50	0.10
HM49	ND	0.02	0.04	0.38	ND	ND	13.81	33.23	0.06
HM50	ND	ND	0.04	0.24	ND	ND	65.69	29.05	0.06
HM51	ND	0.02	0.10	ND	ND	ND	35.03	50.14	0.04
HM52	0.18	0.06	0.10	0.22	ND	ND	37.67	73.59	0.08
HM53	0.10	0.04	0.12	0.82	ND	ND	53.13	66.63	0.06
HM54	0.06	ND	0.08	6.51	ND	ND	17.17	125.13	0.02
HM55	0.02	ND	0.06	22.74	ND	ND	16.31	160.61	0.02
HM56	0.06	ND	0.10	20.06	10.07	ND	52.45	199.12	0.04
HM57	0.27	0.66	0.08	0.37	ND	6.25	6.86	39.07	ND
HM58	0.10	0.02	ND	6.59	22.61	1.94	0.48	104.84	ND
HM59	0.04	0.02	0.04	22.10	22.93	12.98	22.04	208.75	0.04
HM60	0.06	0.02	0.10	35.61	131.67	81.23	14.11	813.66	ND
HM61	0.08	0.04	0.02	23.24	32.10	46.83	36.10	244.28	0.04
HM62	0.12	0.08	0.02	3.91	ND	31.31	41.73	68.51	ND
HM63	0.18	0.04	ND	0.42	ND	3.92	6.19	63.15	0.02
HM64	0.04	0.02	ND	0.74	ND	6.58	0.98	28.02	ND
HM65	ND	0.02	0.06	0.42	ND	15.54	52.28	39.89	ND
HM66	0.04	0.04	ND	ND	ND	10.31	3.98	79.76	ND
HM67	0.18	0.60	0.04	8.02	ND	3.44	ND	62.19	ND
HM68	0.08	0.04	0.12	1.24	ND	0.54	23.34	84.01	ND
HM69	ND	0.04	ND	0.08	ND	4.36	ND	ND	ND
HM70	ND	0.02	0.02	0.24	ND	ND	ND	23.88	ND
HM71	ND	0.10	0.04	0.36	61.24	36.48	9.05	ND	ND
HM72	0.22	0.02	ND	ND	4.83	2.98	ND	ND	0.02
HM73	ND	ND	0.02	ND	ND	0.45	ND	ND	0.04
HM74	0.04	ND	0.10	0.30	ND	ND	4.03	ND	ND
HM75	ND	ND	ND	ND	ND	ND	ND	ND	0.06
Ind 1	ND	0.04	0.10	0.32	ND	1.16	1.06	ND	0.02
Ind 2	0.18	ND	0.06	0.53	ND	0.75	86.62	ND	ND
Ind 3	ND	0.02	0.14	0.75	3.19	23.88	23.94	ND	ND

ND: Not determined, HM:Homemade, Ind: Indusrial

Supplement 5

Aflatoxin M1 (AFM1) concentrations (ppb)

Sample	AFM_1	Sample	AFM_1
HM01	0.147	**HM32**	-
HM02	-	**HM33**	-
HM03	0.210	**HM34**	0.279
HM04	-	**HM35**	-
HM05	0.315	**HM36**	-
HM06	-	**HM37**	-
HM07	-	**HM38**	0.138
HM08	-	**HM39**	0.354
HM09	-	**HM40**	0.195
HM10	0.264	**HM41**	0.516
HM11	-	**HM42**	-
HM12	0.225	**HM43**	0.171
HM13	-	**HM44**	0.156
HM14	0.192	**HM45**	1.011
HM15	0.471	**HM46**	-
HM16	0.204	**HM47**	-
HM17	0.237	**HM48**	0.168
HM18	-	**HM49**	0.273
HM19	-	**HM50**	-
HM20	0.417	**HM51**	-
HM21	0.417	**HM52**	-
HM22	0.261	**HM53**	-
HM23	0.303	**HM54**	-
HM24	0.192	**HM55**	-
HM25	0.240	**HM56**	-
HM26	0.198	**HM57**	0.228
HM27	-	**HM58**	-
HM28	0.243	**HM59**	0.249
HM29	0.300	**HM60**	-
HM30	0.186	**HM61**	-
HM31	0.189	**HM62**	-

HM63	0.243	**HM71**	0.294
HM64	-	**HM72**	0.192
HM65	0.159	**HM73**	-
HM66	0.717	**HM74**	0.384
HM67	0.171	**HM75**	0.234
HM68	0.237	**Ind 1**	-
HM69	0.138	**Ind 2**	0.189
HM70	0.384	**Ind 3**	-

HM:Homemade. Ind: Indusrial

Supplement 4

Cancer Risk (CR) values calculated for toxic metals whose cancer slope factor for ingestion (CSF_{ing}) values were determined in each tarhana sample

Sample	Pb	Cd	As	Cr	Ni	Hg
HM01	$4.00x10^{-6}$	$1.50x10^{-5}$	$2.69x10^{-4}$	$8.75x10^{-4}$	-	-
HM02	$2.00x10^{-6}$	$7.00x10^{-6}$	$2.06x10^{-4}$	-	-	-
HM03	$2.00x10^{-6}$	$4.00x10^{-6}$	$1.63x10^{-4}$	-	-	-
HM04	$1.00x10^{-6}$	$6.00x10^{-6}$	$1.10x10^{-4}$	$7.36x10^{-4}$	-	-
HM05	$1.00x10^{-6}$	-	$1.28x10^{-4}$	-	-	-
HM06	$1.00x10^{-6}$	$6.00x10^{-6}$	$1.02x10^{-4}$	$2.50x10^{-5}$	-	-
HM07	$1.00x10^{-6}$	$2.00x10^{-6}$	$9.30x10^{-5}$	-	-	-
HM08	$1.00x10^{-6}$	-	$8.40x10^{-5}$	$1.35x10^{-3}$	$2.04x10^{3}$	-
HM09	-	$2.00x10^{-6}$	$7.60x10^{-5}$	$6.00x10^{-6}$	-	-
HM10	$1.00x10^{-6}$	-	$7.70x10^{-5}$	-	-	-
HM11	-	$4.00x10^{-6}$	$6.80x10^{-5}$	-	-	-
HM12	-	-	$5.10x10^{-5}$	$4.50x10^{-5}$	-	-
HM13	-	-	$5.10x10^{-5}$	-	-	-
HM14	$1.00x10^{-6}$	-	$5.10x10^{-5}$	$1.70x10^{-5}$	-	-
HM15	-	$2.00x10^{-6}$	$4.20x10^{-5}$	$2.80x10^{-5}$	-	-
HM16	-	$6.00x10^{-6}$	$2.60x10^{-5}$	-	-	-
HM17	-	-	$4.30x10^{-5}$	$2.00x10^{-5}$	$1.72x10^{3}$	-
HM18	-	-	$4.30x10^{-5}$	$5.70x10^{-5}$	-	-
HM19	-	$2.00x10^{-6}$	$6.00x10^{-5}$	$9.10x10^{-5}$	-	-
HM20	-	$2.00x10^{-6}$	$1.70x10^{-5}$	$4.80x10^{-5}$	-	-
HM21	-	$4.00x10^{-6}$	$2.60x10^{-5}$	$7.90x10^{-5}$	$3.85x10^{-1}$	-
HM22	-	$4.00x10^{-6}$	$4.30x10^{-5}$	$7.11x10^{-4}$	-	-
HM23	$1.00x10^{-6}$	$6.00x10^{-6}$	$3.40x10^{-5}$	$1.02x10^{-3}$	-	-
HM24	-	-	-	$1.02x10^{-4}$	-	-
HM25	-	$1.10x10^{-5}$	$1.70x10^{-5}$	$8.30x10^{-5}$	-	-
HM26	-	$2.00x10^{-6}$	$9.00x10^{-6}$	$5.40x10^{-5}$	-	-
HM27	-	$1.30x10^{-5}$	$3.40x10^{-5}$	$7.10x10^{-5}$	-	-
HM28	-	$2.00x10^{-6}$	$1.70x10^{-5}$	$8.80x10^{-5}$	-	-
HM29	-	$2.00x10^{-6}$	$2.60x10^{-5}$	-	-	-
HM30	-	$2.00x10^{-6}$	$4.30x10^{-5}$	$1.70x10^{-5}$	$1.12x10^{3}$	-
HM31	-	$4.00x10^{-6}$	$3.40x10^{-5}$	-	$1.85x10^{-1}$	-

HM32	-	$2.00x10^{-6}$	$1.64x10^{-4}$	-	$1.19x10^{-1}$	-
HM33	-	-	$4.30x10^{-5}$	$5.70x10^{-5}$	-	-
HM34	-	$6.00x10^{-6}$	$5.10x10^{-5}$	-	-	-
HM35	-	$2.00x10^{-6}$	$3.50x10^{-5}$	$6.30x10^{-5}$	-	-
HM36	-	$2.00x10^{-6}$	$4.30x10^{-5}$	$1.06x10^{-3}$	$1.61x10^{-1}$	-
HM37	-	$2.00x10^{-6}$	$1.70x10^{-5}$	$1.02x10^{-3}$	-	-
HM38	-	$2.00x10^{-6}$	$2.60x10^{-5}$	$6.42x10^{-4}$	$2.88x10^{-1}$	-
HM39	-	$2.00x10^{-6}$	$9.00x10^{-6}$	$7.20x10^{-5}$	-	-
HM40	-	$2.00x10^{-6}$	$1.70x10^{-5}$	$5.83x10^{-4}$	-	-
HM41	-	$2.00x10^{-6}$	$2.60x10^{-5}$	$1.21x10^{-3}$	$1.14x10^{-1}$	-
HM42	-	-	$2.60x10^{-5}$	$4.70x10^{-4}$	$8.39x10^{-2}$	-
HM43	-	$4.00x10^{-6}$	$1.70x10^{-5}$	-	$4.12x10^{-1}$	-
HM44	-	-	$3.40x10^{-5}$	$2.60x10^{-5}$	-	-
HM45	$1.78x10^{-4}$	$7.40x10^{-5}$	$1.20x10^{-4}$	$3.91x10^{-3}$	$3.12x10^{-1}$	-
HM46	-	$1.50x10^{-5}$	$6.00x10^{-5}$	$2.90x10^{-5}$	-	-
HM47	-	$2.00x10^{-6}$	$3.40x10^{-5}$	-	-	-
HM48	-	$2.00x10^{-6}$	$9.00x10^{-6}$	$5.70x10^{-5}$	-	-
HM49	-	$2.00x10^{-6}$	$1.70x10^{-5}$	$5.50x10^{-5}$	-	-
HM50	-	-	$1.70x10^{-5}$	$3.50x10^{-5}$	-	-
HM51	-	$2.00x10^{-6}$	$4.30x10^{-5}$	-	-	-
HM52	-	$7.00x10^{-6}$	$4.30x10^{-5}$	$3.20x10^{-5}$	-	-
HM53	-	$4.00x10^{-6}$	$5.10x10^{-5}$	$1.17x10^{-4}$	-	-
HM54	-	-	$3.40x10^{-5}$	$9.30x10^{-4}$	-	-
HM55	-	-	$2.60x10^{-5}$	$3.25x10^{-3}$	-	-
HM56	-	-	$4.30x10^{-5}$	$2.87x10^{-3}$	$4.89x10^{-1}$	-
HM57	$1.00x10^{-6}$	$7.20x10^{-5}$	$3.30x10^{-5}$	$5.30x10^{-5}$	-	-
HM58	-	$2.00x10^{-6}$	-	$9.41x10^{-4}$	$1.10x10^{0}$	-
HM59	-	$2.00x10^{-6}$	$1.70x10^{-5}$	$3.16x10^{-3}$	$1.11x10^{0}$	-
HM60	-	$2.00x10^{-6}$	$4.30x10^{-5}$	$5.09x10^{-3}$	$6.40x10^{0}$	-
HM61	-	$4.00x10^{-6}$	$9.00x10^{-6}$	$3.32x10^{-3}$	$1.56x10^{0}$	-
HM62	-	$9.00x10^{-6}$	$9.00x10^{-6}$	$5.59x10^{-4}$	-	-
HM63	-	$4.00x10^{-6}$	-	$6.00x10^{-5}$	-	-
HM64	-	$2.00x10^{-6}$	-	$1.05x10^{-4}$	-	-
HM65	-	$2.00x10^{-6}$	$2.60x10^{-5}$	$6.00x10^{-5}$	-	-

HM66	-	$4.00x10^{-6}$	-	-	-	-
HM67	-	$6.50x10^{-5}$	$1.70x10^{-5}$	$1.15x10^{-3}$	-	-
HM68	-	$4.00x10^{-6}$	$5.10x10^{-5}$	$1.77x10^{-4}$	-	-
HM69	-	$4.00x10^{-6}$	-	$1.10x10^{-5}$	-	-
HM70	-	$2.00x10^{-6}$	$9.00x10^{-6}$	$3.40x10^{-5}$	-	-
HM71	-	$1.10x10^{-5}$	$1.70x10^{-5}$	$5.10x10^{-5}$	$2.97x10^{0}$	-
HM72	$1.00x10^{-6}$	$2.00x10^{-6}$	-	-	$2.35x10^{-1}$	-
HM73	-	-	$9.00x10^{-6}$	-	-	-
HM74	-	-	$4.30x10^{-5}$	$4.30x10^{-5}$	-	-
HM75	-	-	-	-	-	-
Ind 1	-	$4.00x10^{-6}$	$4.30x10^{-5}$	$4.60x10^{-5}$	-	-
Ind 2	-	-	$2.60x10^{-5}$	$7.50x10^{-5}$	-	-
Ind 3	-	$2.00x10^{-6}$	$6.10x10^{-5}$	$1.07x10^{-4}$	$1.55x10^{-1}$	-

HM:Homemade. Ind: Indusrial

Supplement 5

Aflatoxin M1 (AFM1) concentrations (ppb)

Sample	AFM_1	Sample	AFM_1
HM01	0.147	**HM32**	-
HM02	-	**HM33**	-
HM03	0.210	**HM34**	0.279
HM04	-	**HM35**	-
HM05	0.315	**HM36**	-
HM06	-	**HM37**	-
HM07	-	**HM38**	0.138
HM08	-	**HM39**	0.354
HM09	-	**HM40**	0.195
HM10	0.264	**HM41**	0.516
HM11	-	**HM42**	-
HM12	0.225	**HM43**	0.171
HM13	-	**HM44**	0.156
HM14	0.192	**HM45**	1.011
HM15	0.471	**HM46**	-
HM16	0.204	**HM47**	-
HM17	0.237	**HM48**	0.168
HM18	-	**HM49**	0.273
HM19	-	**HM50**	-
HM20	0.417	**HM51**	-
HM21	0.417	**HM52**	-
HM22	0.261	**HM53**	-
HM23	0.303	**HM54**	-
HM24	0.192	**HM55**	-
HM25	0.240	**HM56**	-
HM26	0.198	**HM57**	0.228
HM27	-	**HM58**	-
HM28	0.243	**HM59**	0.249
HM29	0.300	**HM60**	-
HM30	0.186	**HM61**	-
HM31	0.189	**HM62**	-

HM63	0.243	**HM71**	0.294
HM64	-	**HM72**	0.192
HM65	0.159	**HM73**	-
HM66	0.717	**HM74**	0.384
HM67	0.171	**HM75**	0.234
HM68	0.237	**Ind 1**	-
HM69	0.138	**Ind 2**	0.189
HM70	0.384	**Ind 3**	-

HM:Homemade. Ind: Indusrial