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Determination of Fumonisin Levels in Flour and Tarhana Samples from Different Provinces of Türkiye

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ABSTRACT Fumonisins are toxic secondary metabolites synthesized by fungi belonging to the genus *Fusarium*. These compounds are frequently detected in cereal-derived food products and are considered important contaminants because they can compromise food hygiene and quality, thereby posing a potential concern for public health. This study aimed to determine fumonisin levels in samples of various cereal flours and tarhana, a traditional fermented cereal-based product widely consumed in Türkiye, typically prepared from wheat flour, yogurt, vegetables, and spices. Samples were collected from three provinces in Türkiye-Afyonkarahisar, Denizli, and Uşak-and analyzed using the ELISA method. A total of 80 samples were analyzed, including wheat (n=31), corn (n=12), barley (n=9), rye (n=6), chickpea (n=2) flours, and tarhana (n=20). Fumonisin contamination was detected in 12.5% of the samples (n=10), with concentrations ranging from 15.6 to 39.6 mg/kg, exceeding the maximum limits set by the Turkish Food Codex. The highest incidence was observed in corn flour (58.3%), followed by rye (33.3%) and barley (11.1%) flours. The remaining 87.5% of samples were below the detection limit. These results emphasize the need for continuous monitoring and strict control to ensure the safety and quality of cereal products in Türkiye. In addition, no fumonisin contamination was detected in any of the tarhana samples analyzed, suggesting that tarhana may be relatively safe with respect to fumonisin risk.

Keywords: *Cereal flour, ELISA, Fumonisin, Public health, Tarhana.*

ÖZ

Türkiye'nin Farklı İllerinden Alınan Un ve Tarhana Örneklerinde Fumonisin Düzeylerinin Belirlenmesi

Fumonisinler, *Fusarium* cinsine ait mantarlar tarafından sentezlenen toksik ikincil metabolitlerdir. Bu bileşikler sıklıkla tahıl bazlı gıda ürünlerinde tespit edilir ve gıda hijyenini ve kalitesini bozarak halk sağlığı için potansiyel bir endişe kaynağı oluşturabildikleri için önemli kirleticiler olarak kabul edilirler. Bu çalışma, çeşitli tahıl unları ve Türkiye'de yaygın olarak tüketilen, tipik olarak buğday unu, yoğurt, sebze ve baharlardan hazırlanan geleneksel fermente tahıl bazlı bir ürün olan tarhana örneklerinde fumonisin düzeylerini belirlemeyi amaçlamıştır. Örnekler, Türkiye'nin üç ilinden (Afyonkarahisar, Denizli ve Uşak) toplanmış ve ELISA yöntemi kullanılarak analiz edilmiştir. Buğday (n=31), mısır (n=12), arpa (n=9), çavdar (n=6), nohut (n=2) unları ve tarhana (n=20) olmak üzere toplam 80 örnek analiz edilmiştir. Örneklerin %12.5'inde (n=10) fumonisin kontaminasyonu tespit edilmiş olup, konsantrasyonlar 15.6 ile 39.6 mg/kg arasında değişmekte ve Türk Gıda Kodeksi tarafından belirlenen maksimum limitleri aşmaktadır. En yüksek görülme sıklığı mısır ununda (%58.3), ardından çavdar (%33.3) ve arpa (%11.1) unlarında gözlemlenmiştir. Geri kalan %87.5'lik numuneler tespit limitinin altında kalmıştır. Bu sonuçlar, Türkiye'deki tahıl ürünlerinin güvenliği ve kalitesinin sağlanması için sürekli izleme ve sıkı kontrolün gerekliliğini vurgulamaktadır. Ayrıca, analiz edilen tarhana örneklerinin hiçbirinde fumonisin kontaminasyonu tespit edilmemiştir; bu da tarhananın fumonisin riski açısından nispeten güvenli olabileceğini düşündürmektedir.

Anahtar Kelimeler: *ELISA, Fumonisin, Halk sağlığı, Tahıl unu, Tarhana.*

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INTRODUCTION

Cereals and cereal-based products are among the most traditional and important sources of energy and nutrients worldwide (Yazar and Kokini 2025). Their high nutritional value is primarily attributed to their rich content of dietary fibers (e.g., beta-glucan, arabinoxylan, and resistant starch), proteins, minerals, vitamins, and phytoestrogens with antioxidant properties. Evidence suggests that these functional components may reduce the risk of non-communicable diseases such as cancer, cardiovascular disorders, and obesity. Consequently, cereals have gained widespread use in bakery, dietetic, infant, and breakfast-related products (Khatoon and Maity 2025).

Despite their nutritional benefits, cereals are susceptible to contamination by chemical food safety hazards, particularly mycotoxins. Mycotoxins are toxic secondary metabolites produced by fungal genera such as *Aspergillus*, *Penicillium*, *Fusarium*, *Alternaria*, and *Claviceps* (Tsouloufi 2024). Of these, the Fusarium species are of great concern due to their ability to grow rapidly on grains in favorable temperature and moisture conditions, causing food spoilage and toxic accumulation. *Fusarium verticillioides* and *Fusarium proliferatum* are recognized as major fumonisin-producing species, alongside others such as *F. napiforme, F. anthophilum, F. dlamini,* and *F. nygamai* (Navale et al. 2022; Reinhold et al. 2024).

Fumonisins are classified into four groups (A, B, C, and P), with group B fumonisins being the most relevant in terms of toxicology and frequency of occurrence. The main representatives of this group are Fumonisin B1 (FB_1), B2 (FB_2), B3 (FB_3), and B4 (FB_4), with FB_1 being the most prevalent. Although fumonisins are not considered genotoxic, mutagenic, or teratogenic (EFSA 2018; Andrade 2023), they exert neurotoxic and immunotoxic effects through disruption of lipid metabolism, particularly by strongly inhibiting sphingolipid biosynthesis. This mechanism can result in necrotic brain lesions (Khan et al. 2024; Szabo et al. 2025). Epidemiological studies further indicate a higher incidence of esophageal cancer in regions where fumonisin-contaminated maize is widely consumed (Schieszl et al. 2025).

Fumonisins have been detected in a wide range of foodstuffs, including maize and maize-derived products (Ma and Guo 2025), rice, millet, beans, sorghum, wheat noodles, pickled red pepper, black-eyed peas, asparagus, soybeans, garlic, onion, black radish, black tea, sage, linden and chamomile flowers, mint, nettle, figs and peanuts (Karbancıoğlu-Güler and Heperkan 2009; Kanabus et al. 2025), and even milk and eggs from animals fed contaminated feed. Their distribution within maize kernels is heterogeneous, with higher concentrations in the outer layers, resulting in lower levels in processed products such as corn flour and semolina (Castells et al. 2008).

Although FB_1 is heat-stable, like other mycotoxins, partial degradation can occur at elevated temperatures. For instance, in a study by Humpf and Voss (2004), heating contaminated maize products at 190 °C for 60 minutes reduced fumonisin content by 60.0-80.0%, while treatment at 220 °C for 25 minutes completely eliminated fumonisins. Due to their toxicological significance, many countries have established maximum permissible levels for fumonisins. In the European Union, the combined maximum levels of FB_1 and FB_2 are set at 4000 µg/kg in unprocessed maize and range between 200 and 1000 µg/kg in maize-based foodstuffs (European Commission 2023). In Türkiye, the Turkish Food Codex Contaminants Regulation specifies limits of 4000 µg/kg in unprocessed maize, 1000 µg/kg in maize and maize-based foods intended for direct consumption, 800 µg/kg in maize-based breakfast cereals and snacks, 2000 µg/kg in maize flours not intended for consumers, 1400 µg/kg in other milled maize products, and 200 µg/kg in baby foods (Tarım ve Orman Bakanlığı 2023).

In Türkiye, wheat, maize, rye, and chickpea flours are widely produced and consumed. Moreover, tarhana-a traditional fermented cereal-based product prepared from wheat flour, semolina, or mixtures thereof with yogurt, vegetables, and herbs-represents a culturally significant staple food consumed across all age groups. Despite its popularity, little is known about the potential risk of fumonisin contamination in tarhana, particularly given its complex production process and widespread consumption. Considering both the public health implications and the lack of existing data, this study aimed to investigate the presence and levels of fumonisins in various flour types and tarhana samples collected from three provinces in Türkiye (Afyonkarahisar, Denizli, and Uşak). By addressing this gap, the study provides valuable insights into food safety risks associated with traditional cereal-based products and contributes to the development of more effective monitoring and regulatory strategies.

MATERIAL AND METHODS

Sample Collection

A total of 80 food samples were collected from three provinces of Türkiye (Afyonkarahisar, Denizli, and Uşak) between October and December 2023. Of these, 60 were flour samples (31 wheat flour, 12 corn flour, 9 barley flour, 6 rye flour, and 2 chickpea flour) and 20 were tarhana samples obtained from Denizli. All samples were purchased from different commercial producers in local open markets.

Sample Preparation

All flour and tarhana samples were finely homogenized prior to analysis. Fifty grams of each flour sample were finely ground, and 5 g subsamples were weighed into separate containers. To each subsample, 25 mL of extraction solution (70.0% methanol, 4.0% NaCl, and distilled water) was added. The mixture was homogenized for 3 minutes and subsequently filtered through Whatman No. 1 filter paper. From the filtrate, 50 µL was transferred into a new tube and diluted with 950 µL of distilled water (1:20 dilution). After mixing, 50 µL of the diluted extract was used for analysis.

ELISA Assay

Fumonisin extraction and quantification were performed using the Celer FUMONISINO commercial ELISA kit (Tecna, Eurofins Technologies, Italy; Code No: MF100/101), following the manufacturer's instructions. This kit is designed for the detection of FB_1, FB_2, and FB_3 in cereals and cereal-based products. The microtiter plate is pre-coated with anti-fumonisin antibodies. During the assay, fumonisins in the samples and standards compete with the immobilized antigen for antibody binding sites. Subsequently, enzyme conjugate and substrate reagents are added to facilitate color development. The optical density (OD) values of the samples are inversely proportional to fumonisin concentration. Quantification was achieved by comparing sample OD values with those of the calibration curve generated using fumonisin B1 standards. The calibration curve employed in the quantitative assessment is presented in Figure 1.

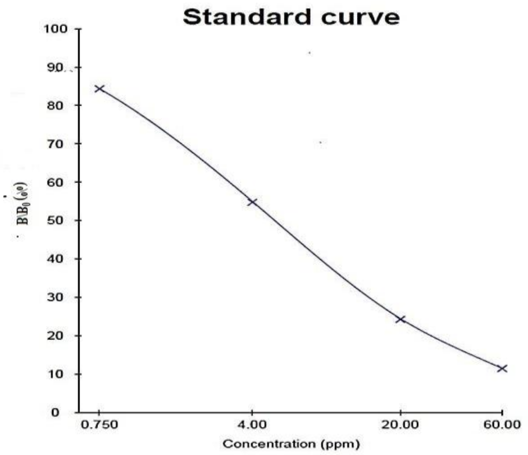

Figure 1: Standard calibration curve for fumonisin concentration measurement.

B/B0: Standard (or sample) absorbance/Standard 0 ppm (B0) absorbance X 100

During the assay setup, one well was assigned for each standard and sample. Into each premixing well, 100 µL of enzyme conjugate and 50 µL of either standard solution (0, 0.75, 4, 20, and 60 ppm) or sample extract were added. Using a micropipette, 100 µL aliquots were transferred three times from each premixing well into the corresponding anti-fumonisin antibody-coated microwells. The plate was incubated at room temperature for 10 minutes. Following incubation, the liquid was discarded, and all wells were washed three times with washing buffer. The plate was inverted, and residual droplets were removed by tapping firmly on absorbent paper. Subsequently, 100 µL of development solution was added to each well, mixed briefly by rotation, and incubated at room temperature for 10 minutes. The reaction process was stopped by adding 50 µL of stop solution to each well. Then, absorbance values were determined at 450 nm using a microplate reader within 60 minutes.

The percentage absorbance of each sample was calculated using the formula:

% Absorbance=Absorbance of sample or standard/Absorbance of 0 ppm standard (B0) ×100

The values obtained were multiplied by the dilution factor (20). The detection limit of the kit was 0.75 mg/kg.

Statistical Analysis

All data obtained from the experiments were processed using Microsoft Excel 2019. Results are expressed as mean values ± standard deviation (SD). For categorical data, the Chi-Square Test of Independence was applied to evaluate potential associations between sample type and fumonisin occurrence. In cases where expected cell counts were below 5, Fisher's Exact Test was additionally performed to confirm the robustness of the results. Statistical significance was considered at $p<0.05$.

RESULTS

The fumonisin concentrations in different flour types and tarhana samples are presented in Table 1. Overall, fumonisins were detected in 13.0% of the flour samples. Contamination was most frequent in corn flour (58.0%), followed by rye flour (33.0%) and barley flour (11.0%). The mean concentrations of fumonisins in positive corn, barley, and rye samples were 28.5, 16.4, and 18.9 mg/kg, respectively. As shown in Table 1, fumonisin contamination was observed in corn, barley, and rye flours, but not in wheat, chickpea, or tarhana samples. A Chi-Square Test of Independence (2×6) confirmed a significant association between flour type and fumonisin positivity (χ^2=33.016, df=5, $p<0.001$, Cramér's V=0.642). Because some expected cell counts were below 5, a Fisher's Exact Test (corn vs. other flours) was conducted, which confirmed corn flour as a high-risk category (OR≈30.33, $p<0.001$).

Table 2 presents the range of fumonisin concentrations and contamination percentages across flour types and tarhana samples. In total, 10 samples exceeding the maximum acceptable limit of the Turkish Food Codex (12.5%) were detected. The distribution of fumonisin-positive flour samples per province is presented in Table 3. As regards corn flour, the highest percentage of positive samples was detected in Denizli province (100%) and the lowest in Uşak (25.0%). As regards barley and rye flours, the highest percentage of positive samples was observed in Denizli (33.3% and 50.0%, respectively).

DISCUSSION AND CONCLUSION

The presence of fumonisins in cereals and cereal products is an important food safety hazard worldwide. Previous studies conducted in Türkiye and other countries have detected fumonisins in cereals and cereal products (Table 4), including different flour types (wheat, corn, barley, rye, and soy, etc.). In this study conducted with different flour types and tarhana samples, 10 out of 80 samples (12.5%), 7 of which were corn flour (58.3%), 2 of which were rye flour (33.3%), and 1 of which were barley flour (11.1%), were contaminated with fumonisin in the range of 16.7-39.6 mg/kg, 15.6-22.1 mg/kg, and 16.04 mg/kg respectively, even though 31 wheat flour (0%), 2 chickpea flour (0%) and 20 (0%) tarhana samples were all found to be fumonisin negative. Ocak and Bostan (2010) reported that 56.0% of corn flour samples obtained from Istanbul were contaminated with fumonisin in the range of 257-5580 µg/kg. They also stated that 25.0% of these samples were above the legal limit. In a study conducted with different flour types, 18 out of 135 samples (13.3%), 16 of which were corn flour (100%) and 2 of which were rye flour (11.1%), were contaminated with fumonisin in the range of 0-103 µg/kg and 670-1684 µg/kg, respectively, while 82 wheat flour (0%) and 19 barley flour (0%) samples were all found to be fumonisin negative (Kaya and Tosun 2013). In İzmir, fumonisin was detected in 45 (78.9%) of 57 corn and corn-based samples (Bakırcı 2014). Our findings aligned with these reports show contamination primarily in corn and rye flour, while wheat flour samples remained fumonisin-free.

A review of the literature revealed no studies investigating fumonisin contamination in tarhana samples, either in Türkiye or internationally. In the present study, 20 tarhana samples were analyzed, and all were found to be negative for fumonisin contamination.

In contrast, no fumonisin contamination was detected in the wheat flour, chickpea flour, or tarhana samples analyzed in this study. While these findings suggest a lower risk associated with these products, caution should be exercised in their interpretation. In particular, the very

Table 1: Fumonisin levels in different flour types and Tarhana samples.

Samples (n)	Number of samples n (%)		Concentration (mg/kg)		Positive samples
	Positive	Negative	Minimum	Maximum	Mean±SD
Wheat flour (31)	0 (0)	31 (100)	-	-	-
Corn flour (12)	7 (58.3)	5 (41.7)	16.7	39.6	28.5±8.15
Barley flour* (9)	1 (11.1)	8 (88.9)	-	16.04	16.4±0.00
Rye flour (6)	2 (33.3)	4 (66.7)	15.6	22.1	18.9±3.24
Chickpea flour (2)	0 (0)	2 (100)	-	-	-
Tarhana (20)	0 (0)	20 (100)	-	-	-

Mean: The arithmetic mean of the measured values.

SD (Standard Deviation): It indicates the extent to which the data are dispersed around the mean.

*The standard deviation (SD) value of 0.00 for barley flour reflects the presence of only a single positive sample; therefore, no variability could be calculated.

Table 2: Fumonisin range of concentrations and respective contamination percentages in different flour types and Tarhana samples.

Samples (n)	<15 mg/kg n (%)	15-30 mg/kg n (%)	30-45 mg/kg n (%)
Wheat flour (31)	31 (100)	-	-
Corn flour (12)	5 (41.7)	4 (33.3)	3 (25.0)
Barley flour (9)	8 (88.9)	1 (11.1)	-
Rye flour (6)	4 (66.7)	2 (33.3)	-
Chickpea flour (2)	2 (100)	-	-
Tarhana (20)	20 (100)	-	-
Total (80)	70 (87.5)	7 (8.75)	3 (3.75)

Table 3: Distribution of fumonisin levels by province.

Sample type	Number of samples	Province					
		Afyonkarahisar		Denizli		Uşak	
		Number of samples n (%)		Number of samples n (%)		Number of samples n (%)	
		Positive	Negative	Positive	Negative	Positive	Negative
Wheat flour	31	0 (0)	10 (100)	0 (0)	1 (100)	0 (0)	10 (100)
Corn flour	12	2 (50.0)	2 (50.0)	4 (100)	0 (0)	1 (25.0)	3 (75.0)
Barley flour	9	0 (0)	3 (100)	1 (33.3)	2 (66.7)	0 (0)	3 (100)
Rye flour	6	0 (0)	2 (100)	2 (50.0)	2 (50.0)	-	-
Chickpea flour	2	-	-	0 (0)	2 (100)	-	-
Tarhana	20	-	-	0 (0)	20 (100)	-	-

"-": No sample was taken from that province.

Table 4: Fumonisin incidence in different flour types and locations.

n	n_1 (%)	Flour type	Fumonisin levels(min-max)	Location	References
25	14 (56.0)	Corn flour	257-5580 µg/kg	İstanbul, Türkiye	Ocak and Bostan 2010
135	82 (0) 19 (0) 18 (11.1) 16 (100)	Wheat flour Barley flour Rye flour Corn flour	- - 0-103 µg/kg 670-1684 µg/kg	Türkiye	Kaya and Tosun 2013
57	45 (78.9)	Corn and corn-based products	118-9589.4 µg/kg	İzmir, Türkiye	Bakırcı 2014
52	46 (88.4)	Corn flour	Mean 140 µg/kg	South Africa	Sydenham et al. 1991
14 12	9 (64.3) 0 (0)	Corn flour Wheat flour	1.3-15.6 µg/kg -	USA	Pestka et al. 1994
18	16 (88.9)	Corn flour	250-1000 µg/kg	USA	Pohland 1996
14	14 (100)	Corn flour	0.5-8.8 µg/kg	People's Republic of China	Groves et al. 1999
9	9 (100)	Corn flour	0.56-4.93 µg/kg	Brazil	Machinski and Valente-Soares 2000
60	60 (100)	Corn flour	590-19230 µg/kg	Brazil	Bittencourt et al. 2005
90	90 (100)	Corn flour	892-6307 µg/kg	Argentina	Castells et al. 2008
41	41 (100)	Corn flour	50.0-1300 µg/kg	Portugal	Martins et al. 2008
17 11	9 (52.9) 1 (9.1)	Corn flour Soy flour	58.2-600 µg/kg 56.4-56.4 µg/kg	Serbia	Matic et al. 2009
16	13 (81.3)	Wheat flour	0-400 µg/kg	People's Republic of China	Sun et al. 2011
23	8 (35.0)	Corn flour	0.8-2.4 µg/kg	Argentina	Lerda 2017
48 48 48	38 (80.0) 29 (60.0) 17 (36.0)	Corn Corn flour Corn bread	820-29760 µg/kg 660-14360 µg/kg 590-12400 µg/kg	Honduras	Cabrera-Meraz et al. 2021
6881	5986 (87.0)	Corn	1390-170300 µg/kg	Mexico Central America	Odjo et al. 2022
53	40 (75.5)	Corn	4-6456 µg/kg	India	Navale and Vamkudoth 2025

n: Number of samples, n_1: Positive samples.

small sample size (n=2) for chickpea flour limits the statistical reliability of this observation and prevents drawing definitive conclusions. This limitation should be considered when interpreting the absence of contamination in this subgroup.

Statistically, although the Chi-square and Fisher's Exact tests confirmed a significant association between flour type and fumonisin formation, the study lacked prior power analysis and formal sample size determination. This could affect the robustness and generalizability of statistical inferences. Additionally, the presence of small subgroup sizes can reduce statistical power and increase the likelihood of Type II error (β). Therefore, future studies should incorporate appropriate sample size calculations and more balanced sampling strategies to strengthen the validity of the findings.

Fumonisins, which are frequently detected in corn and corn-based products in particular, have been shown to cause pulmonary edema, kidney and liver toxicity in mammals. Additionally, they may contribute to an increase in the incidence of esophageal cancer in people who consume high amounts of corn and corn products contaminated with *Fusarium* species. It is recommended to minimize fumonisin levels in grain and grain products to prevent economic losses as well as the possible risks of fumonisins on animal and human health (Yalçın and Kart 2018).

Studies from other countries have reported variable fumonisin contamination levels (Table 4). Sydenham et al. (1991) analyzed 52 corn flour samples in South Africa. Fumonisin was detected in 46 of these samples (88.4%) with an average concentration of 140 µg/kg. Pestka et al. (1994) reported that 64.3% of corn flour samples in the USA contained fumonisin in the range of 1.3-15.6 µg/kg, and in another study conducted in the same country by Pohland (1996), 88.9% of corn samples contained fumonisin in the range of 250-1000 µg/kg. In studies in Brazil, where a total of 69 corn flour samples were analyzed, 100% were found to be contaminated with fumonisin (Machinski and Valente-Soares 2000; Bittencourt et al. 2005). Similarly, studies on the presence of fumonisin in corn flour samples in different countries found that all 145 analyzed samples (100%) were contaminated (Groves et al. 1999; Castells et al. 2008; Martins et al. 2008). Matic et al. (2009) analyzed 17 corn flour and 11 soy flour samples in Serbia. It was revealed that 9 (52.9%) of the corn flour samples and 1 (9.1%) of the soy flour samples were contaminated with fumonisin at levels of 58.2-600 µg/kg and 56.4-56.4 µg/kg, respectively. In addition, as a result of studies conducted on the presence of fumonisin in corn flour samples in Argentina and Honduras, it was reported that 35.0% (in the range of 0.8-2.4 µg/kg) and 60.0% (660-14360 µg/kg) were contaminated, respectively (Lerda 2017; Cabrera-Meraz et al. 2021). In a study conducted by Sun et al. (2011) determining fumonisin levels in wheat flour samples, they found that 13 (81.3%) were contaminated in the range of 0-400 µg/kg. These results differ from our study results when it is evaluated that all 31 wheat flour samples analyzed in our study were not contaminated with fumonisin. According to research conducted on corn samples in different countries, fumonisin was found positive in 38 (80.0%) in Honduras, 5986 (87.0%) in Mexico and 40 (75.5%) in India (Cabrera-Meraz et al. 2021; Odjo et al. 2022; Navale and Vamkudoth 2025).

Several factors influence the formation of fumonisins in cereals and cereal products, particularly geographical differences and seasonal conditions, which vary across countries. In addition, the hygienic quality of the raw materials used and the production period play important roles. Various species of *Fusarium* are significant plant pathogens that infect corn and several other crops, resulting in diseases such as ear blight, root rot, and stem injury (Badiwe et al. 2025; Navale and Vamkudoth 2025).

This study investigated fumonisin contamination in different flour types and tarhana. Overall, 12.5% of the samples tested positive for fumonisins. As a potent mycotoxin, fumonisin represents a significant public health concern that should not be overlooked. Several factors influence the formation of mycotoxins in food; the most important of these are environmental conditions (e.g., temperature and humidity), storage environments, and the type of food product in question (Bereziartua et al. 2025).

Fungal contamination in corn grains represents a major concern due to the potential production of toxic mycotoxins that compromise food safety and quality. The findings of this study revealed a considerable likelihood of fumonisin presence in maize samples, with certain samples surpassing the allowable regulatory limits. These results highlight the importance of early screening for mycotoxin-producing fungi and the implementation of ongoing surveillance systems to prevent adverse and potentially irreversible health effects in humans and animals.

Cereals and cereal products are staple foods worldwide, and fumonisin contamination remains a persistent threat across different flour types. The high contamination levels reported in many studies highlight the need for strict control and preventive measures.

Preventive strategies should begin at the raw material production stage. Cereals must be thoroughly dried to inhibit mold growth and should not be stored under hot and humid conditions. Regular monitoring of fumonisin levels is essential, and producers should be educated on hygienic practices to ensure safer production environments. Implementing these measures will contribute to reducing fumonisin contamination and safeguarding both food quality and public health.

To our knowledge, this is the first study to investigate fumonisin contamination in tarhana, a traditional fermented cereal-based food widely consumed in Türkiye. The absence of fumonisins in all tarhana samples analyzed is a reassuring finding, suggesting that either the raw materials used or the fermentation and drying processes may reduce fumonisin risk. This result contributes valuable new insights into food safety risks associated with traditional cereal-based products and highlights the need for continued surveillance across diverse food categories.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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AUTHOR CONTRIBUTIONS

Idea/Concept: ÖÇ, UA, DAA
Supervision/Consultancy: ZG, RK
Data Collecting and/or Processing: AS, FK, TL
Analysis and/or Interpretation: ÖÇ, UA, DAA, AS, FK, TL
Writing the Article: ÖÇ, UA, DAA
Critical Review: ÖÇ, UA, DAA, ZG, AS, FK, RK, TL

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