




# High Prevalence of Mycotoxigenic Fungi and Aflatoxin B<sub>1</sub> Contamination in Corn and Wheat Grains Grown to Albania: Implications for Food Safety

L. Mato<sup>1</sup>, Z. Damani<sup>2</sup>, J. Spahiu<sup>3</sup>, E. Halimi<sup>4</sup>, B. Seiti<sup>1</sup>, D. Topi<sup>1\*</sup> 

1. University of Tirana, Natural Sciences Faculty, Chemistry Department, Blvd. Zog 1, Tirana, 1,016, Albania

2. Medicine University of Tirana, Medical & Technical Sciences Faculty, Diagnostics and Rehabilitation Department, QSU "Nënë Tereza"; 'Kongresi i Manastirit' str., Tirana, Albania

3. Food and Veterinary Agency, Zona Industriale, Fushë Kosovë, 1,000 Pristine, Kosovo

4. University of Tirana, Natural Sciences Museum, 'Petro Nini Luarasi' str., Tirana, Albania

## HIGHLIGHTS

- Fungi of five genera, *Alternaria*, *Aspergillus*, *Cladosporium*, *Fusarium*, and *Penicillium*, were isolated in corn and wheat from Albania.
- The most abundant resulted the *Penicillium* (77.89%), followed by *Fusarium* (74.73%) and *Aspergillus* genera (72.63%).
- The maximum Aflatoxin B<sub>1</sub> level in corn was found to be 69.12 µg/kg, with an incidence of 88.23%; in contrast, wheat, 0.402 µg/kg, and incidence of 4.91%.
- Referring to the corn consumed as food, 41.18% of samples exceeded the European Union Maximum Residue Level (5 µg/kg), and intended as feed, 32.25% exceeded the European Union Maximum Residue Level (20 µg/kg).
- Estimated Daily Intake indicates that Aflatoxin B<sub>1</sub> chronic exposure from contaminated corn is considerably higher than wheat consumption by Albanians.

## Article type

Original article

## Keywords

Food Safety  
Zea Mays  
Triticum  
Aflatoxin B<sub>1</sub>  
Enzyme-Linked Immunosorbent Assay

## Article history

Received: 6 Nov 2023  
Revised: 13 Jan 2024  
Accepted: 20 Mar 2024

## Acronyms and abbreviations

AF=Aflatoxin  
CFU= Colony Forming Unit  
EDI=Estimated Daily Intake  
ELISA=Enzyme-Linked Immunosorbent Assay  
MRL=Maximum Residue Level

## ABSTRACT

**Background:** Today, mycotoxins are considered critical contaminants in foodstuffs produced by fungi, highlighting the importance of food safety to human health. The toxigenic fungi invasion and mycotoxin production are highly variable and depend on climate, plant, and agronomic practices. Among these, Aflatoxins (AFs) are considered the most potent toxins. This study investigated the fungi presence and AFB<sub>1</sub> contamination in corn and wheat grown in Albania during the 2022 harvesting year.

**Methods:** Wheat samples were collected during the summer, while corn during the autumn, and further analyzed. Mycological contamination assessment applied the Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (VDLUFA) procedures. The AFB<sub>1</sub> levels were measured using the Enzyme-Linked Immunosorbent Assay (ELISA) method. The MATLAB R2016b software was applied to perform statistical analysis. The Estimated Daily Intake on AFB<sub>1</sub> was calculated to evaluate human exposure.

**Results:** The genera *Alternaria*, *Aspergillus*, *Cladosporium*, *Fusarium*, and *Penicillium* were isolated, with higher rates of contamination in corn and the highest frequency *Penicillium* genus (77.89%). The Korça region presented a higher fungal load, 10<sup>4</sup> Colony Forming Unit (CFU)/g in corn. The AFB<sub>1</sub> incidence (88.23%) in corn, was significantly higher than in wheat (4.91%). Additionally, the maximum level in corn was found 69.120 µg/kg, while in wheat, only 0.402 µg/kg. None of the wheat samples, in contrast to the 41.18% of corn samples, exceeded the threshold when referring to the respective Maximum Residue Levels.

**Conclusions:** Our observation indicates a higher rate of AFB<sub>1</sub> contamination in corn than in wheat. The high concentration levels and contamination incidence in corn require targeted interventions to reduce the AFB<sub>1</sub> amounts. Strengthened regulation based on scientific evidence can reduce contamination outbreaks, economic implications, and potential benefits, such as increased consumer trust. Our study indicates that the exposure to AFB<sub>1</sub> originates from corn consumption among the adult population.

© 2024, Shahid Sadoughi University of Medical Sciences. This is an open access article under the Creative Commons Attribution 4.0 International License.

\* Corresponding author (D. Topi)

✉ E-mail: dritan.topi@unitir.edu.al

ORCID ID: <http://orcid.org/0000-0001-7852-5374>

**To cite:** Mato L., Damani Z., Spahiu J., Halimi E., Seiti B., Topi D. (2024). High prevalence of mycotoxigenic fungi and aflatoxin B<sub>1</sub> contamination in corn and wheat grains grown to Albania: implications for food safety. *Journal of Food Quality and Hazards Control*. 11: 59-68.

## Introduction

Trade globalization has emphasized the significance of food and feed safety issues for human and animal health, respectively (Bricher, 2010). Monitoring food contaminants and implementing safety standards are essential tasks carried out worldwide. Consumers are at a higher risk of exposure to food contaminants, including mycotoxins, particularly in developing countries compared to developed countries, due to differences in food safety standards (Nazhand et al., 2020; Patial et al., 2018). Aflatoxins (AFs), Fumonisin (FBs), Deoxynivalenol (DON), Ochratoxin A (OTA), and Zearalenone (ZEN) are the mycotoxins that are most frequently detected. The primary mycotoxin-producing fungi usually belong to the *Aspergillus*, *Fusarium*, and *Penicillium* genera (Luo et al., 2021).

Out of all the identified mycotoxins, AFs are the most toxic and carcinogenic naturally occurring compounds. Among 20 compounds described so far as AFs, AFB<sub>1</sub>, AFB<sub>2</sub>, AFG<sub>1</sub>, and AFG<sub>2</sub> are known to be the most potent toxicants, posing a higher threat to human health (IARC, 2012). The main aflatoxigenic-producing species, *Aspergillus flavus* and *A. parasiticus*, are observed in peanuts, oilseeds, maize, soybeans, and wheat (Liu and Wu, 2010). Manifested only in tropical areas in the past, they presented food safety concerns only at a regional level; nowadays, the AFs contamination is regarded as a global health problem (Alameri et al., 2023; Groopman and Wogan, 2016). Between 2011 and 2021, AFs were involved in 95% of notifications and border rejections, according to the Rapid Alert System for Food and Feed (RASFF) (Owolabi et al., 2023). High temperatures, drought, water activity ( $a_w$ ), storage conditions, and concurrent microbiota affect grains degree of mycotoxin contamination (Pitt et al., 2013).

Fungal contamination can occur from pre- to post-harvest stages. In stored grain, the incidence and prevalence of mycotoxigenic fungi are influenced by the grain type, environmental conditions, and biological factors. Temperature and  $a_w$  are the main ecological factors affecting fungi and mycotoxin levels in stored grains (Mannaa and Kim, 2017). The Hazard Analysis and Critical Control Points (HACCP) approach is applied as a prevention strategy for mycotoxin contamination in the case of grains (Chulze, 2010). AFs mitigation in the post-harvest stage includes physical methods involving the application of sorting, dehulling, wet milling, dry milling, heat treatment, and irradiation; chemical methods contain chemical agents such as adsorbents, acids, and bases; microbiological methods involve intervention with microbiological agents; finally, the methods of genetic engineering rely on the regulatory mechanism of AFs biosynthesis in the *A. flavus* strain (Mahato et al., 2019).

AFs can cause severe public health issues as potent mutagens, immunosuppressants, liver toxins, and

carcinogens (Eaton et al., 2018; Magnussen and Parsi, 2013). Exposure to AFB<sub>1</sub>, in particular, is linked to liver cancer in humans due to its hepatocarcinogenic and hepatotoxic properties (CONTAM et al., 2020). It has been categorized as a Group 1 carcinogenic toxin (IARC, 2012). Reports indicate that AFs can accumulate in various organs, including the kidneys, lungs, heart, and brain (Eaton et al., 2018; Liu and Wu, 2010). Depending on their chemical structure, they display varying degrees of carcinogenicity, mutagenicity, and toxicity, with AFB<sub>1</sub> and AFG<sub>1</sub> being the most harmful. The order of toxicity and carcinogenicity of AFs is AFB<sub>1</sub>>G<sub>1</sub>>B<sub>2</sub>>G<sub>2</sub> (IARC, 2012; JECFA, 2018).

The corn (*Zea mays* L.) and wheat (*Triticum aestivum* L.) cultivation has been one of Albania's most important agricultural activities. The country's favorable climate and fertile soil allow for high yields of maize and wheat grains. Climate change is expected to impact the security of staple crops. The Mediterranean basin, including Albania, will inevitably be affected (Leggieri et al., 2021). Global CO<sub>2</sub> emissions, rising temperatures, and drought in Europe have influenced crop yields and AFs contamination (Perrone et al., 2020).

AFs contamination in corn is a worldwide concern, and recently in southern Europe, with *A. flavus* being the primary species responsible. There exists limited information regarding AFs crop contamination in Albania, belonging to this region, except a study conducted in 2014-2015 uncovered high levels of contamination in maize, ranging from 0.32 to 3,550 µg/kg (Topi et al., 2023). This study aimed to comprehensively examine the fungi and mycotoxin contamination in corn and wheat crops grown in Albania, taking into account the various factors that may contribute to the presence of these harmful substances. Investigating the presence and levels of mycotoxins in these crops is essential to comprehend the potential health risks associated with their consumption in Albanians.

## Materials and methods

### Chemicals and reagents

The solvents, Methanol (MeOH) and Acetonitrile (AcCN) of High-Performance Liquid Chromatography (HPLC)-grade were purchased from Sigma-Aldrich (St. Louis, MO, USA). Deionized water was produced by the Sartorius Arius Mini purification system (Sartorius Italy S.r.l., Varedo, Italy). Microbiological terrains, malt extract, agar, yeast extract, glucose, C, oxytetracycline, and rose bengal were purchased from Sigma-Aldrich (St. Louis, MO, USA). The AFB<sub>1</sub> stock solution standard was purchased by RomerLab (Vienna, Austria). Enzyme-Linked Immunosorbent Assay (ELISA) was performed using MaxSignal® AFB<sub>1</sub> test kit was purchased from PerkinElmer (Waltham, Massachusetts, USA).

### Grain sample collection

Corn (68) and wheat (61) samples were collected throughout the primary producing districts of the nation throughout the 2022 harvesting year. The wheat samples were obtained during the summer, particularly June-July, while the corn sample collection was in the autumn, specifically September-October, to Durrësi, Elbasan, Fieri, and Kavaja. Meanwhile, sampling in the Korça region was proceeded in November due to differences in climate. Located in the western part of the country, Durrësi, Elbasan, Fieri, and Kavaja belong to the identical plateau, alongside the Adriatic sea, a substantial water body of the Mediterranean sea, situated at a very low altitude Above Sea Level (ASL) and characterized by a typical subtropical climate. In contrast, a typical continental climate characterizes the Korça district in the eastern region, at a high altitude of 850 m ASL. The EU regulation 2023/915 sampling procedures were applied during the sample collection to ensure randomization and representativeness (EC, 2023). The samples were then submitted to the Laboratory of Toxic Substances and Biomolecules of the Department of Chemistry for analysis. A random sampling strategy was employed to ensure representation from different geographic regions. A total of 60 farms were randomly selected, collecting samples for each crop commodity. The selection process involved identifying factors such as farm size and crop type. This approach allowed for a comprehensive perception of the overall fungal population while minimizing bias in the sample collection process. Ultimately, the samples were stored in dark conditions under low humidity and at 4 °C until mycological and analytical analyses were completed.

For each sample, 1,000 g of grain was milled using a Perten Lab Mill 120 (PerkinElmer, MA, USA). Finally, a representative flour sample (100 g) was placed in a plastic jar in a dark and dry place at 4 °C (FAO, 2004).

### Mycological analysis

Fungi isolation and identification were performed using the Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (VDLUF) procedures (VDLUF, 2007a, b, c). To begin with, a 20 g sample was ground and added to 180 ml of peptone/water (0.5%). The mixture was then diluted to final concentrations of  $10^{-2}$ ,  $10^{-3}$ , and  $10^{-4}$ . Next, aliquots of 1 ml were taken from each dilution and spread onto parallel plates on a solid medium surface consisting of deionized water (1,000 ml), malt extract (40 g), agar (12 g), yeast extract (2 g), glucose (2 g), marlophen 810 (1 ml), oxytetracycline (60 mg), and Bengal rose (60 mg). The inoculated petri dishes were incubated for three days at 25 °C, kept in a dark and standard atmosphere, and stored at room temperature. The entire process, including the initial incubation period, took around

five days. Eventually, the colonies were counted, and the results were expressed as a mean of the Colony Forming Unit (CFU) in thousands per g of sample ( $10^3$  CFU/g) using equation (1) (VDLUF, 2007a).

$$N = \frac{\sum C}{(V \times n \times d)} \quad (1)$$

Where: N: number of CFU/g of sample;  $\sum C$ : the sum of colon counts on the count plate; V: volume of the dilution transferred into the counting plate, measured in ml; n: number of count plates that may be assessed; and d: the dilution factor.

### AFB<sub>1</sub> analysis

The ELISA screening method for AFB<sub>1</sub> was conducted following the MaxSignal® AFB<sub>1</sub> (#1055-04) of PerkinElmer (Waltham, MA, United States) kit manufacturer instructions was applied to extract wheat and maize samples. In brief, 5.0 g of ground material was placed into a 50 ml conical test tube, adding 25.0 ml of MeOH:H<sub>2</sub>O (70:30 v/v). The mixture was shaken for 10 min using a rack fixed in an orbital shaker IKA Rocker 2D basic (Staufen, Germany). The solution was centrifuged at room temperature at 2,000×g for 10 min in Hettich centrifuge Universal 320R (Tuttlingen, Germany). Subsequently, 300 µl of the acquired supernatant was transferred to a 2 ml tube filled with 900 µl extraction solution C (MeOH/extraction phosphate buffer, 7:23 v/v). Manual vortex was performed to sample for 1 min at maximum speed in Vortex 2, IKA (Staufen, Germany).

The AFB<sub>1</sub> analysis was conducted using the MaxSignal® AFB<sub>1</sub> Kit, which utilizes a competitive ELISA method. This kit includes 96-well microtiter plates that have been sensitized with a monoclonal antibody that targets explicitly AFB<sub>1</sub>. Ultimately, 50 µl of each AFB<sub>1</sub> standard solution (0.1, 1.0, 5.0, 10, 20, 50, 100 ng/ml), arranged in ascending order of concentration, together with the diluted supernatant, were added twice to the wells of the microtiter plate. Afterward, 100 µl of AFB<sub>1</sub>-Horseradish Peroxidase conjugate (HRP) was introduced into each plate well. The plate was agitated for 1 min and placed in an environment with ambient temperature for 30 min. Following incubation, the microtiter well plate was fully emptied, rinsed three times with 250 µl of the 1× wash solution during each rinse, and dried by tapping on a layer of paper towel many times. The unconjugated substance was eliminated during the washing process. After agitating a 100 µl solution of Tetramethylbenzidine (TMB) substrate, for 1 min, was left to react at room temperature for 15 min. To stop the reaction, 100 µl of the enzyme reaction inhibition buffer (stop solution) was added, and the absorbance was measured at 450 nm using a TECAN Microplate reader (Infinite 200 Pro, Nanoquant, Vienna, Austria).

### Quality assurance

The analytical methods were validated based on linearity, Limit of Detection (LOD), Limit of Quantification (LOQ), and percentage of recovery according to the screening and confirmatory methods set by Regulation EC/401/2006 (EC, 2006). For Certified Reference Materials (CRM), the validation parameters were expressed as the sum of 3 replicates for each spiking level.

#### Health risk assessment

Classified as a Group 1 carcinogenic toxin, AFB<sub>1</sub> induce Hepatocellular Carcinoma (HCC) as the main human adverse health effect (IARC, 2012). Risk prediction of developing AFB<sub>1</sub>-induced HCC is based on the Estimation of Daily Intake (EDI) on a chronic basis. In this paper, the AFB<sub>1</sub> exposure in the adult population was assessed by using the daily wheat and corn consumption data extracted by the World Health Organization/Global Environment Monitoring System (WHO/GEMS). Based on each data, the daily consumption of grain and grain-based products was calculated at 350 g/day, with wheat and corn at 345 and 4.9 g, respectively. The EDI values were expressed as ng/kg body weight (bw)/day, referring to 60 kg as adult body weight in equation 2 (CONTAM, 2020).

$$\text{EDI (ng/kg bw/day)} = \frac{\text{consumption (g/day)} \times \text{contamination (ng/day)}}{\text{bw (kg)}} \quad (2)$$

#### Statistical analysis

The statistical analysis was implemented using MATLAB R2016b. The t-test was performed, comparing the mean value with the defined value, considering the null hypothesis

as  $H_0: \mu = \mu_0$ . Also, the t-test was performed to compare the results of AFB<sub>1</sub> contamination among two different crops, considering the null hypothesis as  $H_0: \mu_d = 0$ . The  $p$ -value was calculated using the paired results and compared with the significance level set at 0.05. The mean, standard deviation and the statistical tests was also determined.

## Results

#### Mycological contamination

During the pre- and post-harvest stages, various biological and environmental factors interact complexly, affecting fungal growth and mycotoxin synthesis. According to the findings, the collected wheat and corn samples manifested fungi contamination belonging to different genera, such as *Alternaria*, *Aspergillus*, *Cladosporium*, *Fusarium*, and *Penicillium* (Table 1). The studied samples indicated a similar distribution of mold infection patterns for the three main genera: *Penicillium* spp. (77.89%), *Fusarium* spp. (74.73%), and *Aspergillus* spp. (72.63%). However, for the genera *Alternaria* and *Cladosporium*, contamination was recorded in only 13.68% of samples in each case, displaying a very different result than the data for the three main genera mentioned previously.

Concerning the regions, we detected that the incidence of various genera was not uniform. Five fungi genera were observed in wheat samples from western Albania, characterized by low-altitude geography and a Mediterranean climate. Wheat samples manifested identical contamination patterns (approx. 10<sup>3</sup> CFU/g), regardless of sampling site or mold genera (Table 1).

**Table 1:** The mycological contamination of wheat and corn samples

Fungi	Wheat n=61	Corn n=68	Total n=129
	Incidence (%) <sup>a</sup> Mean/median <sup>b</sup> Max. level ( $\times 10^3$ CFU/g) <sup>c</sup>	Incidence (%) Mean/median Max. level ( $\times 10^3$ CFU/g)	Incidence <sup>d</sup> (%)
<i>Aspergillus</i>	43 (70.5%) 7.43/2.00 34.00	52 (76.5%) 464.2/220.0 1750.0	95 (72.63%)
<i>Penicillium</i>	43 (70.5%) 50.83/6.50 240.00	62 (91.2%) 1,078.38/475.0 5,000.0	105 (77.89%)
<i>Fusarium</i>	43 (70.5%) 9.79/1.00 60.00	56 (82.4%) 363.32/100.0 1000.0	99 (74.73%)
<i>Alternaria</i>	12 (19.7%) 0.75/0.75 1.00	2 (2.90%) 100/100 100	14 (13.68%)
<i>Cladosporium</i>	12 (19.7%) 0.75/0.75 1.00	2 (2.90%) 3.50/3.50 3.50	14 (13.68%)

<sup>a</sup> Number of positive samples/ Incidence(%).

<sup>b</sup> Arithmetic mean/median of positive samples ( $\times 10^3$  CFU/g).

<sup>c</sup> Maximum level observed ( $\times 10^3$  CFU/g).

<sup>d</sup> Total count of positive samples on a specific genus.  
CFU=Colony Forming Unit

Concerning corn contamination, the highest incidence of *Penicillium* sp. referring to the region was recorded in corn samples from the Korça region ( $500 \times 10^4$  CFU/g), followed by *Fusarium* sp. in samples from the Fieri region ( $100 \times 10^4$  CFU/g), and the Korça region ( $80 \times 10^4$  CFU/g). The third-most prevalent mold belonged to the *Aspergillus* genera, with the highest incidence in the Elbasan region ( $26 \times 10^4$  CFU/g), compared to  $20\text{--}24 \times 10^4$  CFU/g in the Fieri, Korça, and Durrësi regions.

To wheat contamination, the *Fusarium* spp., *Aspergillus* spp., and *Penicillium* spp. were identified on the enormous scale, respectively *Aspergillus* genera ( $34 \times 10^3$  CFU/g), followed by *Penicillium* ( $10 \times 10^3$  CFU/g). Regarding the region, the highest contamination levels observed in wheat samples belonged to the Fieri region. Moreover, *Alternaria* genus was present in samples from this region at a level of  $1 \times 10^3$  CFU/g. Interestingly, wheat from the Korça region exhibited a different fungi contamination pattern, with the highest counts recorded for the *Fusarium* genus ( $5 \times 10^2$  CFU/g).

#### AFB<sub>1</sub> contamination

The AFB<sub>1</sub> concentration was determined by calculating the average of two replicates. The mycotoxin presence in winter wheat samples (61) harvested during the summer season and corn (68) harvested in autumn from the 2022 harvesting year was investigated (Table 2). The contamination rate (88.23%) in corn samples was much higher ( $p < 0.05$ ) than in wheat samples (4.91%). A key role is related to climate conditions, with wheat harvested during the summer and corn harvested in autumn. AFB<sub>1</sub> contamination levels in corn varied from 0.389–69.295 µg/kg, with only eight samples not contaminated (11.77%). The AFB<sub>1</sub> contamination in wheat samples was detected in three out of 61 samples, and the maximum value 0.401 µg/kg.

The AFB<sub>1</sub> exposure assessment for Albanians was calculated based on the EDI (ng/kg<sub>bw</sub>/day), which refers to the mean value for wheat and maize consumption (Table 4).

**Table 2:** Aflatoxin B<sub>1</sub> (AFB<sub>1</sub>) in maize and wheat from the harvesting year 2022 (Mean±SD)

	Corn	Wheat
Number of studied samples	68	61
Positive samples	60	3
Incidence (%)	88.23	4.91
Mean value (µg/kg)	17.379±0.161	0.015±0.000
Median value (µg/kg)	0.920±0.017	0.000±0.000
Minimum value (µg/kg)	0.389±0.003	0.221±0.003
Maximum value (µg/kg)	69.295±0.244	0.402±0.001

**Table 3:** Aflatoxin B<sub>1</sub> (AFB<sub>1</sub>) incidence and risk assessment concerning corn application as food Maximum Residue Level (MRL) (5 µg/kg) and feed MRL (20 µg/kg) (EC, 2023)

Interval (µg/kg)	No. of samples (Total number)	Incidence (%)
0	8 (68)	11.76
0-5.00	32 (68)	47.06
Over 5.00 (MRL, food)	28 (68)	41.18
5.00-10.00	2 (68)	2.94
Over 10.00	26 (68)	38.23
Over 20.00 (MRL, feed)	22 (68)	32.35

**Table 4:** Estimating Daily Intake (EDI) of adult Albanians to Aflatoxin B<sub>1</sub> (AFB<sub>1</sub>) from wheat and corn consumption

	Corn		Wheat	
	Mean (ng/g)	Maximum (ng/g)	Mean (ng/g)	Maximum (ng/g)
	17.374	69.295	0.015	0.402
EDI (n.d=0)	1.4112	-	0.0862	-
EDI <sub>max</sub>	-	5.6497	-	2.3047

EDI<sub>max</sub> calculated according to the maximum concentration in maize or wheat samples.

## Discussion

This study presents mycological contamination on two main grains grown in the country while also giving their AFB<sub>1</sub> contamination. Battilani et al. (2016) and Leggieri et

al. (2021) have proposed prediction models on AF corn contamination for southern European countries such as Italy. According to studies, *A. flavus* and *A. parasiticus* are the two primary species associated with AF contamination

in crops. *A. flavus* isolates generally produce AFBs and occasionally Cyclopiazonic Acid (CPA), while most *A. parasiticus* strains produce both AFBs and AFGs but fail to produce CPA. The toxin production in *A. flavus* varies significantly and depends on genotype, substrate, geographic origin, climate change, and agronomic practice (Shabeer et al., 2022).

Global literature data on the contamination of wheat and corn reveal that fungal diseases significantly impede cereal yield, causing yield reduction, estimating 15-20%. In situations as fungal growth and infections are predominant, the losses can escalate to as high as 50% (Rózewicz et al., 2021). High levels of mycological contamination in wheat from Poland was detected. The major fungi genera was *Fusarium* spp. present in 95.5% of samples, *Aspergillus* spp. (81.8%), *Penicillium* spp. (72.3%), *Alternaria* spp. (22.7%) (Čonková et al., 2006). The results are entirely different in the mycological contamination of wheat from northern Africa, with the most common fungi species in wheat, *Eurotium* spp. (62.5%) followed by *Cladosporium* spp. (29.17%), and *Rhizopus* spp. (4.17%), meanwhile, corn revealed higher levels of *Aspergillus* spp. (76.19%), being the most prevalent; however, other genera have a much lower frequency, *Penicillium* spp. (38.10%) or *Fusarium* spp. (19.05%) (Jedidi et al., 2018). Similar to North Africa, the wheat grain from Iran exhibited contamination rates with *Aspergillus* spp. (32.1%), *Alternaria* spp. (26.7%), and *Fusarium* spp. (17.8%), most prevalent (Joshaghani et al., 2013).

Our study indicates a higher rate of AFB<sub>1</sub> contamination in corn compared with wheat ( $p < 0.05$ ). An identical pattern distribution was encountered in both crops for the three main mold genera, *Fusarium*, *Penicillium*, and *Aspergillus*. However, a different situation for the *Alternaria* and *Cladosporium* genera was observed; wheat samples were more likely to be affected than corn, with 19.7 and 2.90%, respectively. In the pre-harvest stage, the main contamination factors are high temperatures, water stresses, and insect damage differently, in the post-harvest stage, temperature and  $a_w$  are the main determining factors (Mahato et al., 2019; Manna and Kim, 2017).

Numerous methods are tested globally to decrease pre-harvest AFs contamination. Recently, using toxigenic strains of *A. flavus* for biological control in agricultural fields has demonstrated significant effectiveness (Bandyopadhyay et al., 2016; Cotty et al., 2007). This method of competitive exclusion, where the toxigenic strains outperform the toxigenic *A. flavus* strains, is considered as the most efficient measure to mitigate the risk of AFs. The efficacy of toxigenic *A. flavus* species as a biocontrol agent has been proven, resulting in a 70 to 99% reduction of AF levels in treated crops (Bhatnagar-Mathur et al., 2015). Monitoring the contamination levels will

provide crucial evidence for the proposed prediction models for aflatoxigenic fungi that grow in temperate regions. This evidence will be necessary for implementing effective strategies to reduce the impact of climate change on agricultural production and food safety in Albania.

Considered one of the most critical contaminants in foodstuffs due to their adverse health effects on humans and animals, EU Regulation No 2023/915 addresses mycotoxin contamination by setting Maximum Residue Level (MRL) for specific contaminants in food (EC, 2023). Climate change, manifested in increased temperatures and extreme weather, has raised the AFB<sub>1</sub> contamination incidence in corn, especially in southern Europe (Piva et al., 2006). In Europe, the hot and dry conditions necessary for *A. flavus* infestation of corn mainly prevail at latitudes below 45° N (Battilani et al., 2016). Not a concern till the end of the 20<sup>th</sup> century (Leggieri et al., 2021; Perrone et al., 2020), the first report on AF corn contamination in Italy was reported in 2003 (Battilani et al., 2016). In southern Europe, climate change scenarios propose an increased probability of AF contamination from low to medium due to a temperature rise of only 2 °C (CONTAM et al., 2020; Luo et al., 2021).

According to the EU Regulation 2023/915, the AFB<sub>1</sub> MRL in corn intended for human consumption (5 µg/kg), the analysed corn samples revealed 28 or 41.18 %, out of 68 samples, were found about this threshold (Table 3). In addition, considering corn as feed, 22 samples, or 32.35 %, presented levels above the MRL (20 µg/kg). In contrast, in European feed, just 2.1% of corn samples exceeded this level (Gruber-Dorminger et al., 2019). The AFB<sub>1</sub> maximum level detected in this commodity was 69.295±0.244 µg/kg. Data from Albania reveal that the AFB<sub>1</sub> occurrence from the 2014 and 2015 harvested seasons, corn samples had a mean value of 464 and 55.7 µg/kg, respectively. AFB<sub>1</sub> contamination in corn samples from 2023 resulted in a much lower prevalence than the 2014 harvesting year but similar to 2015 (Topi et al., 2023).

Seasonal climate differences impact aflatoxin production during plant growth and could explain the pronounced year-to-year variation in mycotoxin levels (Leggieri et al., 2021). Gruber-Dorminger et al. (2019) investigated that, globally, the incidence of AFB<sub>1</sub> in corn was 24%, and a significant percentage (64%) exerting co-contamination by two or more mycotoxins. The data on the European continent indicates that AFB<sub>1</sub> contamination in southern Europe (28.9%) is more common than in other regions (5.9-17.0%) (Gruber-Dorminger et al., 2019). Furthermore, this pattern is present when discussed with corn in China (Sun et al., 2017).

The first AF contamination incidence in the Balkans was reported during the 2013 harvesting season, while different mycotoxins' occurrence in different crops from this region

has been documented during last decade (De Rijk et al., 2015; Gagliu et al., 2018; Janić Hajnal et al., 2017; Kos et al., 2014; Kovač et al., 2022; Pleadin et al., 2015; Topi et al., 2019, 2022, 2023). Crop contamination with mycotoxins is not considered a critical issue, only referring to the adverse effects on human health, but it also endangers the animals' health, as in the case of corn, which is widely applied as feed in livestock (Topi et al., 2022, 2023).

The results on AFB<sub>1</sub> contamination in wheat indicate a better situation, with lower incidence, in comparison with publications from the region, e.g. wheat from Romania (45.4%) (Gagliu et al., 2018), while a similar pattern was observed when compared to the contamination incidence in Serbia (Kos et al., 2014), Croatia (Kovač et al., 2022), and Southern Europe, such as Italy (Alkadri et al., 2014). Considering the global data on contamination level, referred median (1.0 µg/kg), or maximum values (161 µg/kg), our finding indicates a better situation.

The incidence of AFB<sub>1</sub> contamination (88.23%) in corn in our survey denotes a higher incidence compared to the corn from Serbia, 57.2% (Janić Hajnal et al., 2017), Romania, 45.4% (Gagliu et al., 2018), Croatia 31.4% (Pleadin et al., 2015), and 8.7% (Kovač et al., 2022). This difference is further present in comparison with the data from the South Mediterranean, 16% (Abdallah et al., 2017) and 24% globally (Gruber-Dorninger et al., 2019). At maximum levels, this study detected similarity in corn from Serbia, 88.8 µg/kg (Janić Hajnal et al., 2017), Romania, 82.94 µg/kg (Gagliu et al., 2018), but lower value compared to South Mediterranean, 197.5 µg/kg (Abdallah et al., 2017). These studies manifest a considerable variation in corn contamination, with levels ranging from 2,072 µg/kg belonging to the year 2013 in Croatia (Pleadin et al., 2015), up to 4,822 µg/kg (Topi et al., 2023). The global survey data, including China, reveal that in our study, the occurrence levels are higher (Gruber-Dorninger et al., 2019; Jiang et al., 2019).

The AFB<sub>1</sub> incidence (4.9%) in wheat displays the same pattern as data from two countries, Croatia and Serbia, where an incidence range of 0-19% was reported (Kos et al., 2014; Kovač et al., 2022; Pleadin et al., 2015), but different in case of Romania, 45.4% (Gagliu et al., 2018). The maximum level in wheat samples is 0.402 µg/kg) was much lower than the data in AFB<sub>1</sub> contamination from this commodity in the region, Croatia, 5.41 µg/kg (Pleadin et al., 2015) or 16.20 µg/kg (Kovač et al., 2022), Romania 82.94 µg/kg (Gagliu et al., 2018); the Mediterranean area, 66.7 µg/kg (Serrano et al., 2012), and globally, 161 µg/kg (Gruber-Dorninger et al., 2019).

In positive samples, concentrations ranged from 0.223-0.402 µg/kg, with a mean of 0.015±0.000 µg/kg, indicating no wheat samples exceeded the MRL (2 µg/kg). Considering the region, the contaminated samples related

to the Fieri region, geographically part of the western plain, with a typical Mediterranean climate (Table 1). Similar contamination rates are identified with reported data from 2014 and 2015, indicating 6.0 and 0.0%, respectively (Topi et al., 2023).

Considering the significant differences in AFB<sub>1</sub> contamination levels among corn and wheat, The climate conditions are considered as the main factor, especially in the pre-harvesting stage, when wheat commodities cropped in the summer. In contrast, corn harvesting during the autumn imposes higher exposure to climate factors, which favors fungi growth.

Regarding the amount of AFB<sub>1</sub> in corn, after performing a t-test in two samples with size n=68 elements, as the *p*-value is smaller than the significance level  $\alpha=0.05$ , we reject the null hypothesis and accept the alternative hypothesis in both cases ( $p_1=0.0001$  and  $p_2=0.0001$ ). Also, after comparing two independent samples, 1 and 2, we again reject the null hypothesis for the equality of the two means, as the *p*-value is smaller than the significance level ( $p=0.001$ ). While, regarding the amount of AFB<sub>1</sub> in wheat, the results are the opposite of corn. So, after performing a t-test in two samples with size n=61 elements, as the *p*-value is greater than the significance level  $\alpha=0.05$ , we can't reject the null hypothesis in both cases ( $p_1=0.092$  and  $p_2=0.091$ ). Also, after comparing two independent samples, 1 and 2, again, we can't reject the null hypothesis for the equality of the two means, as the *p*-value is greater than the significance level ( $p=0.098$ ).

Cereals constitute an essential part of Albanians' daily consumption of approx. 350 g grain and grain-based products, wheat comprises 445 g, and corn 5 g (Héraud et al., 2013). Considering mean values of AFB<sub>1</sub> in wheat and corn during this harvesting year, it was found that the highest exposure in adult Albanians originated from corn consumption, EDI, 1.411 ng/kg<sub>bw</sub>/day in comparison with wheat consumption of 0.086 ng/kg<sub>bw</sub>/day. Meanwhile, considering the maximum AFB<sub>1</sub> levels detected in corn and wheat, these values demonstrate that consumption has a higher risk for adults, 5.650 and 2.304 ng/kg<sub>bw</sub>/day, respectively. This value is triple higher as compared to data from the literature (Udovicki et al., 2021). This investigation indicates that a more detailed consumption survey is required to perform.

## Conclusions

This paper analyzes mycotoxigenic contamination in corn and wheat harvested in Albania in 2022. The AFB<sub>1</sub> values indicate that the contamination rate of corn commodities is a substantial issue. None of the wheat samples exceeded the MRL set by the European Union. In contrast, 41.18% of corn samples were higher than the MRL of 5 µg/kg intended for use as food, and 32.25%

exceeded the MRL of 20 µg/kg as well. The research reveals a small occurrence of AFB<sub>1</sub> contamination in the wheat grain. The study provides substantial data for the assessment of hazards. Measuring the frequency of AFB<sub>1</sub>, the central AF of interest, includes health institutions and organizations with information regarding the likelihood of adverse health consequences for consumers. Regulatory authorities can employ these data to prioritize surveillance of mycotoxin contamination in the nation's main crops and recommend appropriate measures based on the identified risks. They must collaborate with farmers to implement appropriate agricultural practices, storage techniques, and other preventive measures to prevent crop contamination. Additionally, this partnership should encompass the formulation of suggestions. Regulatory bodies must effectively address growing concerns, particularly in the ever-changing food industry, due to the impacts of climate change. The EDI indicates that the adult population's exposure mainly originates from wheat while identifying higher values than data from neighboring countries.

#### Author Contributions

L.M. and J.S. worked on formal analysis and validation methods; L.M. wrote the manuscript; D.T. and Z.D. designed the study, manuscript review, and editing; B.S. and E.H. engaged in resources, data curation, and visualization; D.T. funding acquisition and involved in supervision. All authors read and approved the final manuscript.

#### Conflicts of Interest

The authors declare no conflict of interest.

#### Acknowledgments

This study received financial support from the Albanian National Agency for Scientific Research and Innovation (NASRI) grant R&D\_2022/17.

#### Ethical Consideration

The authors conducted this study according to the Code of Ethics approved by the Senate of the University of Tirana. It is part of the first author's Ph.D. thesis.

#### Funding

This study received financial support from the Albanian National Agency for Scientific Research and Innovation (NASRI) grant R&D\_2022/17.

#### References

Abdallah M.F., Girgin G., Baydar T., Krska R., Sulyok M. (2017).

- Occurrence of multiple mycotoxins and other fungal metabolites in animal feed and maize samples from Egypt using LC-MS/MS. *Journal of Science of Food and Agriculture*. 97: 4419-4428. [DOI: 10.1002/jsfa.8293]
- Alameri M.M., Kong A.S.-Y., Aljaafari M.N., Al Ali H., Eid K., Al Sallagi M., Cheng W.-H., Abushelaibi A., Erin Lim S.-H., Loh J.-Y., Lai K.-S. (2023). Aflatoxin contamination: an overview on health issues, detection and management strategies. *Toxins*. 15: 246. [DOI: 10.3390/toxins15040246]
- Alkadri D., Rubert J., Prodi A., Pisi A., Mañes J., Soler C. (2014). Natural co-occurrence of mycotoxins in wheat grains from Italy and Syria. *Food Chemistry*. 157: 111-118. [DOI: 10.1016/j.foodchem.2014.01.052]
- Bandyopadhyay R., Ortega-Beltran A., Akande A., Mutegi C., Atehnkeng J., Kaptoge L., Senghor A.L., Adhikari B.N., Cotty P.J. (2016). Biological control of aflatoxins in Africa: current status and potential challenges in the face of climate change. *World Mycotoxin Journal*. 9: 771-789. [DOI: 10.3920/WMJ2016.2130]
- Battilani P., Toscano P., Van Der Fels-Klerx H.J., Moretti A., Camardo Leggieri M., Brera C., Rortais A., Goumperis T., Robinson T. (2016). Aflatoxin B1 contamination in maize in Europe increases due to climate change. *Scientific Reports*. 6: 24328. [DOI: 10.1038/srep24328]
- Bhatnagar-Mathur P., Sunkara S., Bhatnagar-Panwar M., Waliyar F., Kumar Sharma K. (2015). Biotechnological advances for combating *Aspergillus flavus* and aflatoxin contamination in crops. *Plant Science*. 234: 119-132. [DOI: 10.1016/j.plantsci.2015.02.009]
- Bricher J.L. (2010). Ensuring global food safety—a public health priority and a global responsibility. In: Boisrobert C.E., Stjepanovic A., Oh S., Lelieveld H.L. (Editors). Ensuring global food safety. Academic Press, Cambridge, Massachusetts, USA. pp: 1-4.
- Chulze S.N. (2010). Strategies to reduce mycotoxin levels in maize during storage: a review. *Food Additives and Contaminants: Part A*. 27: 651-657. [DOI: 10.1080/19440040903573032]
- Čonková E., Laciaková A., Štyriak I., Czerwiecki L., Wilczyńska G. (2006). Fungal contamination and the levels of mycotoxins (DON and OTA) in cereal samples from Poland and East Slovakia. *Czech Journal of Food Sciences*. 24: 33-40. [DOI: 10.17221/3291-CJFS]
- Cotty P.J., Antilla L., Wakelyn P.J. (2007). Competitive exclusion of aflatoxin producers: farmer driven research and development. In: Vincent C., Goettel N., Lazarovits G. (Editors). Biological control: a global perspective. CAB International, London, UK. pp: 241-253. [DOI: 10.1079/9781845932657.0241]
- De Rijk T.C., Van Egmond H.P., Van Der Fels-Klerx H.J., Herbes R., De Nijs M., Samson R., Slate A.B., Van Der Spiegel M. (2015). A study of the 2013 western European issue of aflatoxin contamination of maize from the Balkan area. *World Mycotoxin Journal*. 8: 641-651. [DOI: 10.3920/WMJ2015.1903]
- Eaton D.L., Beima K.M., Bammler T.K., Riley R.T., Voss K.A. (2018). Hepatotoxic mycotoxins. In: McQueen C.A. (Editor). Comprehensive toxicology, 3<sup>rd</sup> Edition. Elsevier, Oxford, U.K. pp: 483-521. [DOI: 10.1016/B978-0-12-801238-



- 3.64337-4]
- ESFA Panel on Contaminants in the Food Chain (CONTAM), Schrenk D., Bignami M., Bodin L., Chipman J.K., Mazo J.D., Grasl-Kraupp B., Hogstrand C., Hoogenboom L., Leblanc J.-C., Nebbia C.S., Nielsen E., et.al. (2020). Risk assessment of aflatoxins in food. *EFSA Journal*. 18: 6040. [DOI: 10.2903/j.efsa.2020.6040]
- European Commission (EC). (2006). Commission regulation (EC) No 401/2006 of 23 February 2006 laying down the methods of sampling and analysis for the official control of the levels of mycotoxins in foodstuffs. *Office Journal of European Union*. L 70: 12-34. (Accessed 28 August 2023).
- European Commission (EC). (2023). Commission regulation (EU) 2023/915 of 25 April 2023 on maximum levels for specific contaminants in food and repealing Regulation (EC) No 1881/2006. *Office Journal of European Union*. L 119: 103-157. (Accessed 28 August 2023).
- Food and Agriculture Organization (FAO). (2004). Worldwide regulations for mycotoxins in food and feed in 2003. FAO Food and Nutrition Paper 81. Rome, Italy. URL: <https://www.fao.org/3/y5499e/y5499e00.htm>.
- Gagiu V., Mateescu E., Armeanu I., Dobre A.A., Smeu I., Cucu M.E., Oprea O.A., Iorga E., Belc N. (2018). Post-harvest contamination with mycotoxins in the context of the geographic and agroclimatic conditions in Romania. *Toxins*. 10: 533. [DOI: 10.3390/toxins10120533]
- Groopman J.D., Wogan G.N. (2016). Aflatoxins: a global public health problem. In: Caballero B., Finglas P.M., Toldrá F. (Editors). *Encyclopedia of food and health*. Elsevier, Oxford, U.K. pp: 68-72. [DOI: 10.1016/B978-0-12-384947-2.00015-5]
- Gruber-Dorninger C., Jenkins T., Schatzmayr G. (2019). Global mycotoxin occurrence in feed: a ten-year survey. *Toxins*. 11: 375. [DOI: 10.3390/toxins11070375]
- Héraud F., Barraij L.M., Moy G.G. (2013). GEMS/food consumption cluster diets. In: Moy G., Vannoort R.W (Editors). *Total diet studies*. Springer, New York. pp: 427-434. [DOI: 10.1007/978-1-4419-7689-5\_43]
- International Agency for Research on Cancer (IARC). (2012). Chemical agents and related occupations. A review of human carcinogens. IARC monographs on the evaluation of carcinogenic risks to humans. 100F. Lyon, France. URL: [www.ncbi.nlm.nih.gov/books/NBK304416/](http://www.ncbi.nlm.nih.gov/books/NBK304416/).
- Janić Hajnal E., Kos J., Krulj J., Krstović S., Jajić I., Pezo L., Šarić B., Nedeljković N. (2017). Aflatoxins contamination of maize in Serbia: the impact of weather conditions in 2015. *Food Additives and Contaminants: Part A*. 34: 1999-2010. [DOI: 10.1080/19440049.2017.1331047]
- Jedidi I., Soldevilla C., Lahouar A., Marín P., González-Jaén M.T., Said S. (2018). Mycoflora isolation and molecular characterization of aspergillus and fusarium species in Tunisian cereals. *Saudi Journal of Biological Sciences*. 25: 868-874. [DOI: 10.1016/j.sjbs.2017.11.050]
- Jiang D., Li F., Zheng F., Zhou J., Li L., Shen F., Chen J., Li W. (2019). Occurrence and dietary exposure assessment of multiple mycotoxins in corn-based food products from Shandong, China. *Food Additives and Contaminants: Part B*. 12: 10-17. [DOI: 10.1080/19393210.2018.1503341]
- Joint Expert Committee on Food Additives (JECFA). (2018). Safety evaluation of specific contaminants in food: prepared by the eighty-third meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA). WHO Food Additives Series, Rome, Italy, 74, pp: 3-280.[URL: <https://www.who.int/publications/i/item/9789241660747>]
- Joshaghani H., Namjoo M., Rostami M., Kohsar F., Niknejad F. (2013). Mycoflora of fungal contamination in wheat storage (silos) in Golestan province, north of Iran. *Jundishapur Journal of Microbiology*. 6: e6334. [DOI: 10.5812/jjm.6334]
- Kos J.J., Škrinjar M.M., Mandić A.I., Mišan A.Č., Bursić V.P., Šarić B.M., Janić Hajnal E.P. (2014). Presence of aflatoxins in cereals from Serbia. *Food and Feed Research*. 41: 31-38. [DOI: 10.5937/FFR1401031K]
- Kovač M., Bulaić M., Nevistić A., Rot T., Babić J., Panjičko M., Kovač T., Šarkanj B. (2022). Regulated mycotoxin occurrence and co-occurrence in Croatian cereals. *Toxins*. 14: 112. [DOI: 10.3390/toxins14020112]
- Leggieri M.C., Toscano P., Battilani P. (2021). Predicted aflatoxin B<sub>1</sub> increase in Europe due to climate change: actions and reactions at global level. *Toxins*. 13: 292. [DOI: 10.3390/toxins13040292]
- Liu Y., Wu F. (2010). Global burden of aflatoxin-induced hepatocellular carcinoma: a risk assessment. *Environmental Health Perspective*. 118: 818-824. [DOI: 10.1289/ehp.0901388]
- Luo S., Du H., Kebede H., Liu Y., Xing F. (2021). Contamination status of major mycotoxins in agricultural products and foodstuff in Europe. *Food Control*. 127: 108120. [DOI: 10.1016/j.foodcont.2021.108120]
- Magnussen A., Parsi M.A. (2013). Aflatoxins, hepatocellular carcinoma and public health. *World Journal of Gastroenterology*. 19: 1508-1512. [DOI: 10.3748/wjg.v19.i10.1508]
- Mahato D.K., Lee K.E., Kamle M., Devi S., Dewangan K.N., Kumar P., Kang S.G. (2019). Aflatoxins in food and feed: an overview on prevalence, detection and control strategies. *Frontiers in Microbiology*. 10: 2266. [DOI: 10.3389/fmicb.2019.02266]
- Mannaa M., Kim K.D. (2017). Influence of temperature and water activity on deleterious fungi and mycotoxin production during grain storage. *Mycobiology*. 45: 240-254. [DOI: 10.5941/MYCO.2017.45.4.240]
- Nazhand A., Durazzo A., Lucarini M., Souto E.B., Santini A. (2020). Characteristics, occurrence, detection, and detoxification of aflatoxins in foods and feeds. *Foods*. 9: 644. [DOI: 10.3390/foods9050644]
- Owolabi I.O., Karoonuthaisiri N., Elliott C.T., Petchkongkaew A. (2023). A 10-year analysis of RASFF notifications for mycotoxins in nuts. Trend in key mycotoxins and impacted countries. *Food Research International*. 172: 112915. [DOI: 10.1016/j.foodres.2023.112915]
- Patil V., Asrani R.K., Thakur M. (2018). Foodborne mycotoxicosis: pathologies and public health impact. In: Holban A.M., Grumezescu A.M. (Editors). *Handbook of food bioengineering, foodborne diseases*. 15. Academic Press, Cambridge, Massachusetts, USA. pp: 239-274.
- Perrone G., Ferrara M., Medina A., Pascale M., Magan N. (2020). Toxicogenic fungi and mycotoxins in a climate change scenario: ecology, genomics, distribution, prediction and prevention of

- the risk. *Microorganisms*. 8: 1496. [DOI: 10.3390/microorganisms8101496]
- Pitt J.I., Taniwaki M.H., Cole M.B. (2013). Mycotoxin production in major crops as influenced by growing, harvesting, storage and processing, with emphasis on the achievement food safety objectives. *Food Control*. 32: 205-215. [DOI: 10.1016/j.foodcont.2012.11.023]
- Piva G., Battilani P., Pietri A. (2006). Emerging issues in southern Europe: aflatoxins in Italy. In: Barug D., Bhatnagar D., Van Egmond H.P. Van Der Kamp J.W., Van Osenbruggen W.A., Visconti A. (Editors). *The mycotoxin factbook*. Food and Feed Topics; Wageningen Academic Publishers, Wageningen, The Netherlands. pp. 139-153.
- Pleadin J., Vulić A., Perši N., Škrivanko M., Capek B., Cvetnić Ž. (2015). Annual and regional variations of aflatoxin B1 levels seen in grains and feed coming from Croatian dairy farms over a 5-year period. *Food Control*. 47: 221-225. [DOI: 10.1016/j.foodcont.2014.07.017]
- Różewicz M., Wzyńska M., Grabiński J. (2021). The most important fungal diseases of cereals—problems and possible solutions. *Agronomy*. 11: 714. [DOI: 10.3390/agronomy11040714]
- Serrano A.B., Font G., Ruiz M.J., Ferrer E. (2012). Co-occurrence and risk assessment of mycotoxins in food and diet from Mediterranean area. *Food Chemistry*. 135: 423-429. [DOI: 10.1016/j.foodchem.2012.03.064]
- Shabeer S., Asad S., Jamal A., Ali A. (2022). Aflatoxin contamination, its impact and management strategies: an updated review. *Toxins*. 14: 307. [DOI: 10.3390/toxins14050307]
- Sun X. D., Su P., Shan H. (2017). Mycotoxin contamination of maize in China. *Comprehensive Review in Food Science and Food Safety*. 16: 835-849. [DOI: 10.1111/1541-4337.12286]
- Topi D., Babic J., Jakovac-Strajn B., Tavčar-Kalcher G. (2023). Incidence of aflatoxins and ochratoxin A in wheat and corn from Albania. *Toxins*. 15: 567. [DOI: 10.3390/toxins15090567]
- Topi D., Spahiu J., Rexhepi A., Marku N. (2022). Two-year survey of aflatoxin M<sub>1</sub> in milk marketed in Albania and human exposure assessment. *Food Control*. 136: 108831. [DOI: 10.1016/j.foodcont.2022.108831]
- Topi D., Tavčar-Kalcher G., Pavšič-Vrtač K., Babič J., Jakovac-Strajn B. (2019). *Alternaria* mycotoxins in grains from Albania: alternariol, alternariol monomethyl ether, tenuazonic acid, and tentoxin. *World Mycotoxin Journal*. 12: 89-99. [DOI: 10.3920/WMJ2018.2342]
- Udovicki B., Tomic N., Spirovic Trifunovic B., Despotovic S., Jovanovic J., Jacxsens L., Rajkovic A. (2021). Risk assessment of dietary exposure to aflatoxin B<sub>1</sub> in Serbia. *Food and Chemical Toxicology*. 151: 112116. [DOI: 10.1016/j.fct.2021.112116]
- VDLUF (2007a). Standard operating procedure for identifying bacteria, yeasts, moulds, and dematiaceae as product-typical and spoilage-indicating microorganisms in feeds. In VDLUF Method Book III Suppl. No. 7 (chap. 28.1.3., 11). VDLUF, Darmstadt, Germany.
- VDLUF (2007b). Standard operation procedure for the enumeration of microorganisms using solid culture media. In VDLUF Method Book III Suppl. No. 7 (chap. 28.1.1., 14). VDLUF, Darmstadt, Germany.
- VDLUF (2007c). Standard operation procedure to enumerate bacteria, yeasts, moulds, and Dematiaceae. In VDLUF Method Book III Suppl. No. 7 (chap. 28.1.2., 18). VDLUF, Darmstadt, Germany