MycoTWIN

Worldwide Mycotoxin Management via Co-Creation of Innovative Strategies

CLIMATE CHANGE AND MYCOTOXINS: AN INCREASING THREAT TO FOOD SAFETY

Ilknur Demirtas, PhD

TUBITAK MRC, Life Sciences

Food Safety and Quality Research Group

22nd NMI Directors Meeting, 2023

About The Scientific and Technological Research Council of Türkiye, Marmara Research Center (TUBITAK MRC)

TUBITAK MRC

- One of the leading research centers in Türkiye,
- With its customer-oriented approach, it offers original solutions to public, private and military agencies and institutions.
- TUBITAK MRC comprises several research centers and institutes carrying out applied research in various scientific domains.
- Basic research, applied research and development, technology transfer, innovation, system and facility construction, national standard and norm-setting, professional consulting, and training activities.

Material Technologies

Life Sciences

Climate Change and Sustainability

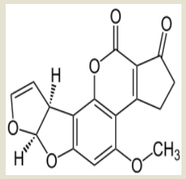
Energy Technologies

Mycotoxins

- Secondary metabolites produced by plant pathogenic fungi such as ***Aspergillus***, ***Penicillium***, ***Fusarium***, ***Claviceps*** and ***Alternaria***.
- Different adverse effects on human health, such as, carcinogenicity, mutagenicity, teratogenicity, cytotoxicity, neurotoxicity, nephrotoxicity, immunosuppression and estrogenic effects (Silva A.S., et al., 2019).
- Affect approximately **25% of the world's food crops**.
- Currently, 400 mycotoxins have been reported.

Aflatoxin (AF)

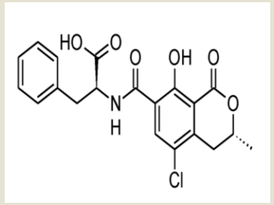
- Aflatoxin B_1, B_2, G_1, G_2, M_1 and M_2 are the most studied.
- AFB1 is considered as the most toxic aflatoxin.
- Aflatoxins often develop during storage, though contamination of food and feed material can also occur in the field.
- Found on agricultural crops such as maize, peanuts, cottonseed and tree nuts, dried fruits and cereals.



Aflatoxin B_1

Ochratoxin A (OTA)

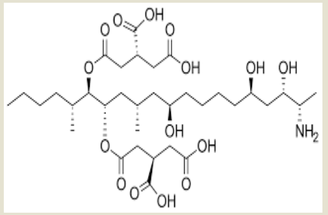
- OTA is one of the mycotoxins most commonly isolated from the environment.
- OTA is produced under storage conditions that would favor mold growth.
- It is regularly detected in cereals, coffee, nuts, cocoa, wine, beer, spices and milk, but also occur in other foodstuffs.
- OTA is potentially carcinogenic to humans (Group 2B).



OTA

Fusarium mycotoxins

- Fumonisins (FUMs), zearalenone (ZEN), deoxynivalenol (DON), and T-2/HT- 2 toxin.
- Mainly contaminate cereals.
- Fumonisin B_1 (FB_1) is the most toxic.
- Drought stress followed by warm, wet weather during flowering seem to be relevant for FUM production.



Fumonisin B_1

Factors affecting the occurance of mycotoxin contamination in the food chain

Planting

*Crop variety

*Seed treatment

*Planting date

*Tillage practices

*Previous crop

Environmental factors

*Temperature

*Water stress

*Insect/bird damage

Harvesting

*Harvest date

*Crop maturity

*Temperature

*Crop moisture

Storage

*Temperature

*Moisture

*Aeration

*Forage consolidation

*Storage length

Transport

*Temperature

*Moisture

Delivery to animals

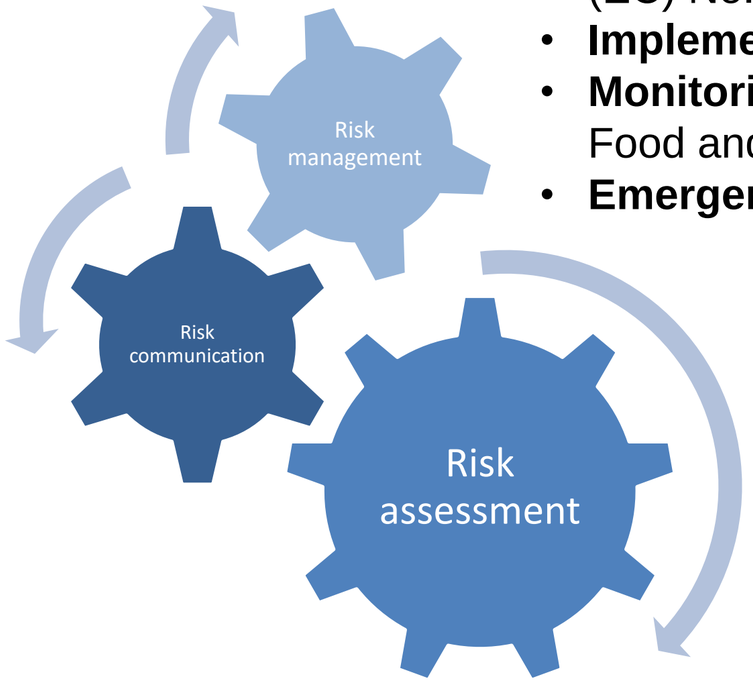
*Mycotoxin contamination in feed

Adapted from CAST, 2003; Simion V., Bogdan A.T.,..Recent Researches in Energy and Environment, doi:978-960-474-274-5

Mycotoxin Risk Analysis

> Not moulds but their toxins are problematical for animals as well as for humans. They accumulate in grains and cause enormous economic losses. Therefore, it is crucial to identify and deactivate these mycotoxins in time.
>
> **Professor Dr. Rudolf Krska**

- **Transparent information sharing**
- **Education and awareness**
- **Labelling**



- **Setting regulatory limits** (Commission Regulation (EC) No. 1881/2006).
- **Implementation of Good Practices** (GAP and GMP)
- **Monitoring and surveillance** (Rapid Alert System for Food and Feed (RASFF)
- **Emergency responses**

- **Hazard identification**
- **Hazard characterization**
- **Exposure assessment**
- **Risk characterization**

CLIMATE CHANGE AND FOOD SAFETY: MYCOTOXINS

Climate change is real.

It’s happening and it’s global.

To get an idea about what’s at stake just look at your plate.

Food is profoundly affected by climate change from how it’s produced and what we can grow in the first place.

How climate change and mycotoxins are interconnected:

1. Increasing temperatures

Rising temperatures in **temperate regions** may see arise in fungal damage.
As temperatures rise, more fungal species will move into previously unoccupied regions at higher latitudes, increasing the risk of aflatoxin contamination, particularly in **maize and groundnuts**.

2. Altered precipitation patterns

Drought causes stress in plants, making them more vulnerable to fungal diseases.
Flooding will disrupt storage facilities and standing crops, raising the risk of mycotoxins.

3. Extended growing seasons

Extended growing seasons could potentially affect the usual timing of crop maturity, making them more vulnerable to mycotoxin contamination. ***Aspergillus*** and ***Fusarium*** may survive and thrive for an extended period of time, increasing the risk to maize, wheat, and rice.

4. Changes in fungal distribution

Climate change can alter the geographic distribution of fungi.
Fusarium graminearum, found mainly in **warmer central** and **southern Europe**, has been reported to emerge as the dominant Fusarium species in **northern Europe** by replacing the more common ***F. Culmorum*** (Moretti, etc. 2019)

CAST. Mycotoxins: Risks in plant, animal, and human system. Council for Agricultural Science and Technology: Ames IA; 2003

Modelling, predicting and mapping the emergence of aflatoxins in cereals in the EU due to climate change (EFSA MODMAP-AFLA)

The patterns of AF occurance in maize, wheat and rice under climate change scenarios +2 °C, and +5 °C over the next century in Europe have been modelled.

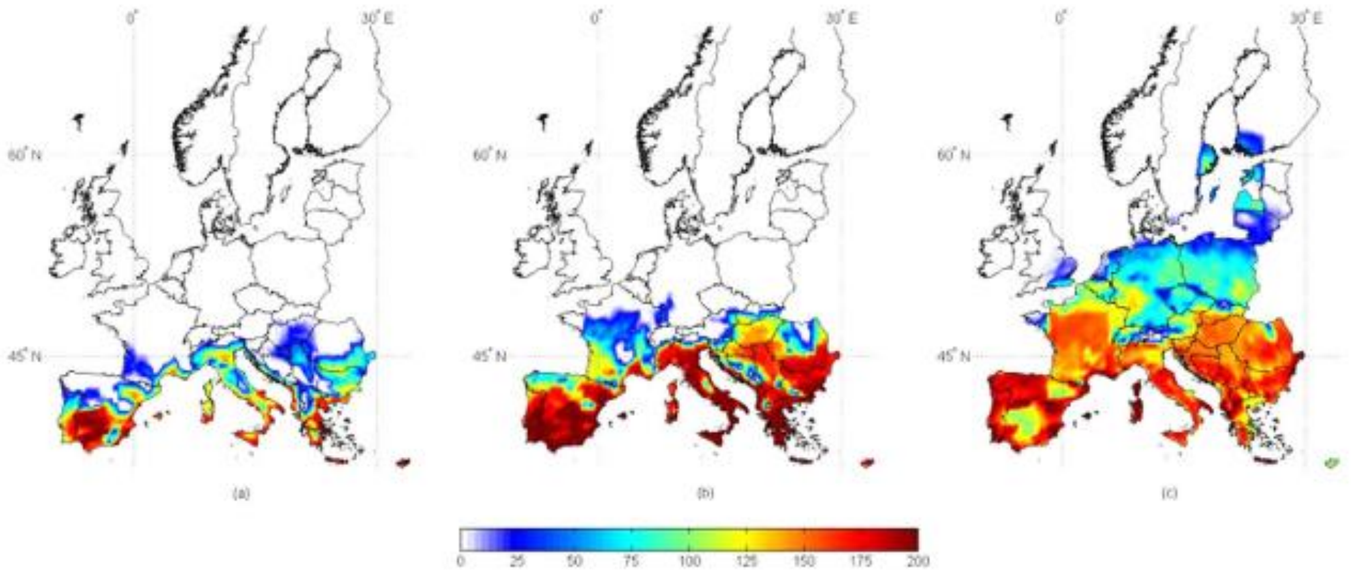


Figure 1. Mapping of AF contamination risks in maize under three climate scenarios (current, +2 °C, and +5 °C) in Europe.

- **AFB_1** is likely to become a major food safety issue in maize, especially in Eastern Europe, the Balkan Peninsula and the Mediterranean regions under a **+2°C scenario**.

- In the **+ 5 °C scenario**, levels of contamination are predicted to be lower but risks are expected to be **wider and enlarge towards northern EU countries**.

- Very low risk of contamination in wheat.

- No contamination expected in rice crops.

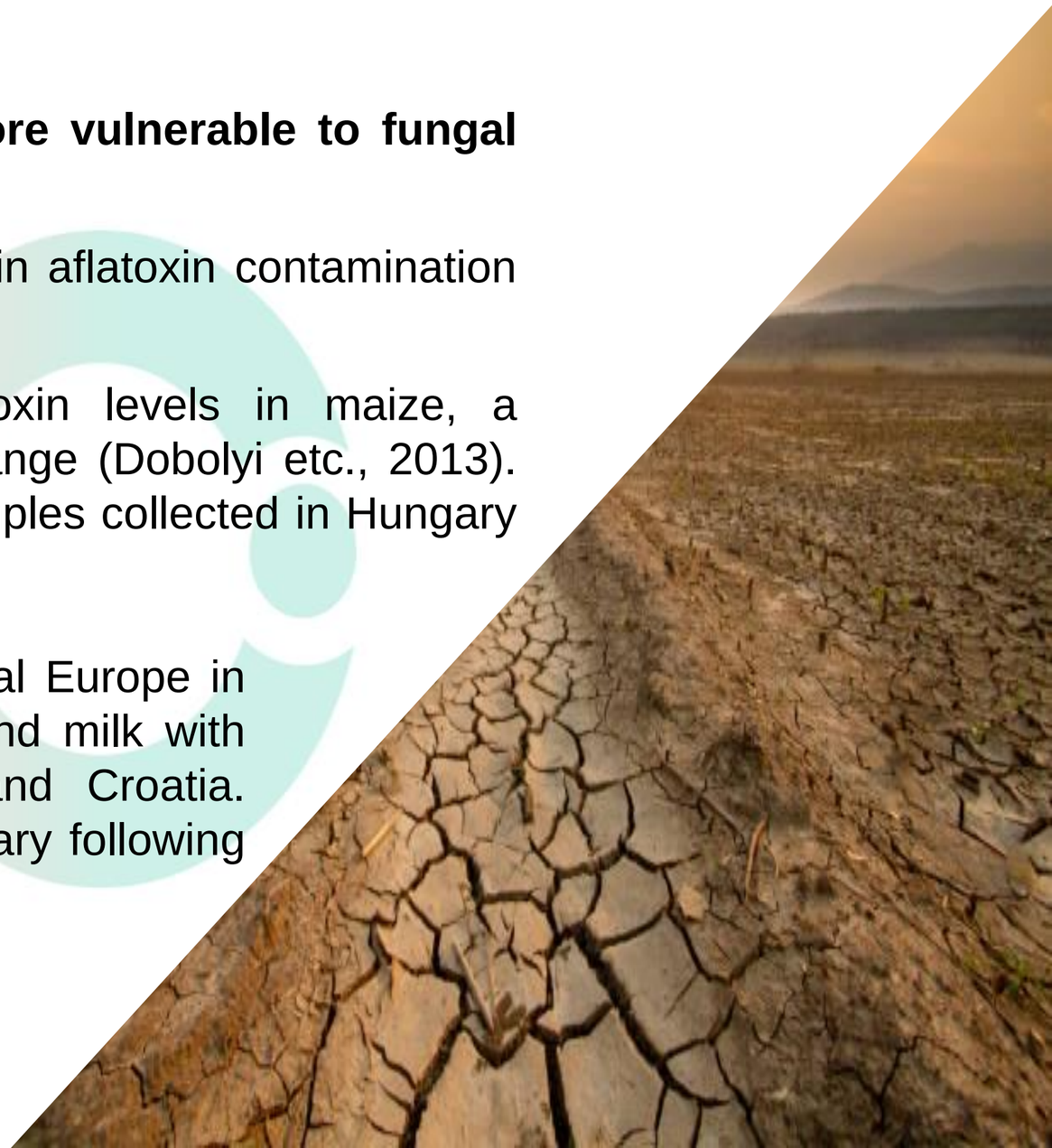
Scientific report submitted to EFSA, MODMAP-AFLA, 2012, 1-72.

Climate change impacts on mycotoxins: Elevated temperatures

- Given the current climate change trends, the maize sector in the United States could experience increased and more frequent losses due to AF contamination (Mitchell etc. 2012).
- Modeling studies suggest that the primary regions for maize production located between the Tropics of Cancer and Capricorn could be **unsuitable for cultivation** in future climate change scenarios.
- The cooler regions in Northern Europe and North America could potentially become suitable for **maize cultivation**. (Ramirez-Cabral, Kumar, and Shabani in 2017).

Climate change impacts on mycotoxins: Precipitation changes

- **Drought causes stress in plants, making them more vulnerable to fungal infections.**
- In 2012, Serbia faced an extensive drought, resulting in aflatoxin contamination affecting nearly 70% of the maize harvest for that year.
- Hungary has witnessed a noticeable rise in aflatoxin levels in maize, a phenomenon attributed to the influence of climate change (Dobolyi etc., 2013). Mycotoxin levels in 4.8% of cereal and mixed feed samples collected in Hungary exceeded the European Union accepted limit of AFB_1.
- The extreme weather conditions experienced in Central Europe in 2012 resulted in significant contamination of maize and milk with AFs, creating major issues in Serbia, Romania, and Croatia. Additionally, AFs were found in maize kernels in Hungary following the 2012 harvest (Baranyi etc. 2015).



Climate change impacts on mycotoxins: Changes in Fungal Distribution

International Journal of
Environmental Research and Public Health

MDPI

Concept Paper

Thermophilic Fungi to Dominate Aflatoxigenic/Mycotoxigenic Fungi on Food under Global Warming

Robert Russell M. Paterson * and Nelson Lima

CEB—Centre of Biological Engineering, Campus de Gualtar, University of Minho, 4710-057 Braga, Portugal; nelson@ie.uminho.pt
* Correspondence: russell.paterson@deb.uminho.pt; Tel.: +351-253-601-599

Academic Editor: Marcello Iriti
Received: 16 December 2016; Accepted: 13 February 2017; Published: 17 February 2017

Abstract: Certain filamentous fungi produce mycotoxins that contaminate food. Mycotoxin

- As per the research by Paterson and Lima, the fundamental concept regarding the impact of climate change on mycotoxins involves the movement of heat-resistant molds (for example, *A. flavus*) from tropical areas to regions currently characterized by temperate climates.
- The emergence of novel mycotoxin-commodity combinations is a growing concern, as it enables new fungal genotypes with greater aggressiveness and enhanced mycotoxin production (Moretti and Logrieco, 2015).
- Compared to the past when *Fusarium* and *Aspergillus* mycotoxins were predominantly found in southern Europe, *Fusarium* mycotoxins are expected to shift to northern Europe, while *Aspergillus* species will mainly be observed in southern and central Europe.

Further Research and Prevention Strategy

Implement Climate-Resilient Agriculture

- Develop and adopt agricultural practices that are more resilient to changing climate conditions.
- The adaptation and implementation of the principles of good agriculture (GAP) and good manufacturing practices (GMP).

Monitoring and Early Warning Systems

- Implement monitoring and early warning systems to detect mycotoxin contamination in crops.
- This can help reduce the risk of mycotoxin exposure to humans and animals.

Climate Change Mitigation

- Efforts to reduce greenhouse gas emissions and mitigate climate change can indirectly benefit mycotoxin management by helping to stabilize climate conditions.

Research and Training

- Invest in research to better understand the complex interactions between climate change and mycotoxins.
- Training and educational programs can also raise awareness among farmers and food producers about the risks associated with mycotoxins and how to manage them.

Enhancing Research and Innovation Capacity of TUBITAK MAM Food Institute on Management of Mycotoxigenic Fungi and Mycotoxins (ID:952337)

The **general objective** of MycoTWIN is strengthening research in the field of mycotoxigenic fungi and mycotoxins in an institute from a widening country (TUBITAK) by linking it with two internationally-leading research institutions; **Consiglio Nazionale Delle Ricerche (CNR-ISPA)** and **Universitat De Valencia (UV)**.

i) Biodiversity and molecular identification of toxigenic fungi
- Toxigenic *Fusarium*, *Aspergillus/Penicillium, Alternaria* species

ii) Rapid tests and advanced analysis techniques for mycotoxins
- Regulated mycotoxins in European Union
- Emerging mycotoxins
- Modified mycotoxins
- Biomarkers for exposure assessment
- Multi mycotoxin analysis
- Reference materials for multi-mycotoxins

iii) Management of toxigenic fungi and mycotoxins in agro-food chain
- Pre-harvest mycotoxin management
- Safe use of mycotoxin contaminated biomasses
- Post-harvest mycotoxin management in the crops: Dried fruits (raisin, dried fig), vinefruit, nuts (hazelnut, peanut, pistachio, almond), cereal(wheat), spice (red pepper)
- Innovative management tools: Decision support systems, agro-climatic modelling
- Effect of climate changes

Enhancing Research and Innovation Capacity of TUBITAK MAM Food Institute on Management of Mycotoxigenic Fungi and Mycotoxins (ID:952337)

Short-term on-site trainings

Technical visits

Info days **Workshops**

Summer schools

Expert visits

Open days

Conferences

Working group meetings

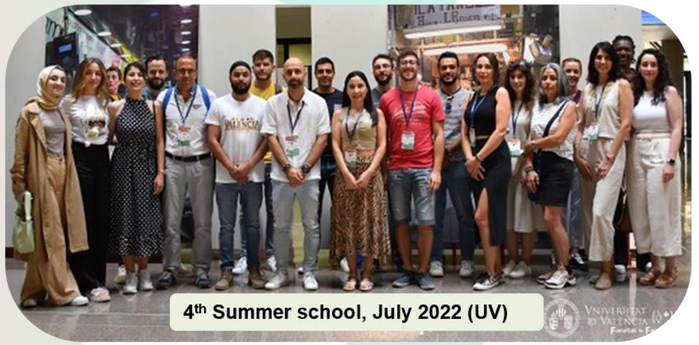
Round table group meetings

1st & 2nd Summer schools, October 2022 (CNR-ISPA)

Technical visit, October 2023 (Fontsalem, Spain)

2nd Short-term visit, June-July 2022 (CNR-ISPA)

Technical visit, January 2023 (Balsu, Turkey)



4th Summer school, July 2022 (UV)

3rd Short-term visit, May-July 2022 (UV)

8th Summer school, July 2023 (UV)

1st Short-term visit, June-July 2022 (CNR-ISPA)

Smart Applications Research Center for Food Supply Security (SMARTFOOD)

The Project's goal is to establish a research facility to create advanced research, development, and technological diffusion through various disciplines to produce agricultural and food safety solutions.

Controlled-environment agriculture

The development of automation systems that ensure the best conditions for plant growth by controlling light, temperature, humidity, and CO_2 levels

Smart applications in agricultre

The development of technologies such as remote sensing, imaging, GPS/GIS, and artificial intelligence to enhance agriculture's efficiency and sustainability

Sustainable and zero-waste solutions

The development of gereen and environmentally friendly technologies for the production of biofertilizers, proteins, and bioactive products from agriculture and food waste

Drought-resistant crops

The development of technologies aimed at conserving water sources

Alternative food sources

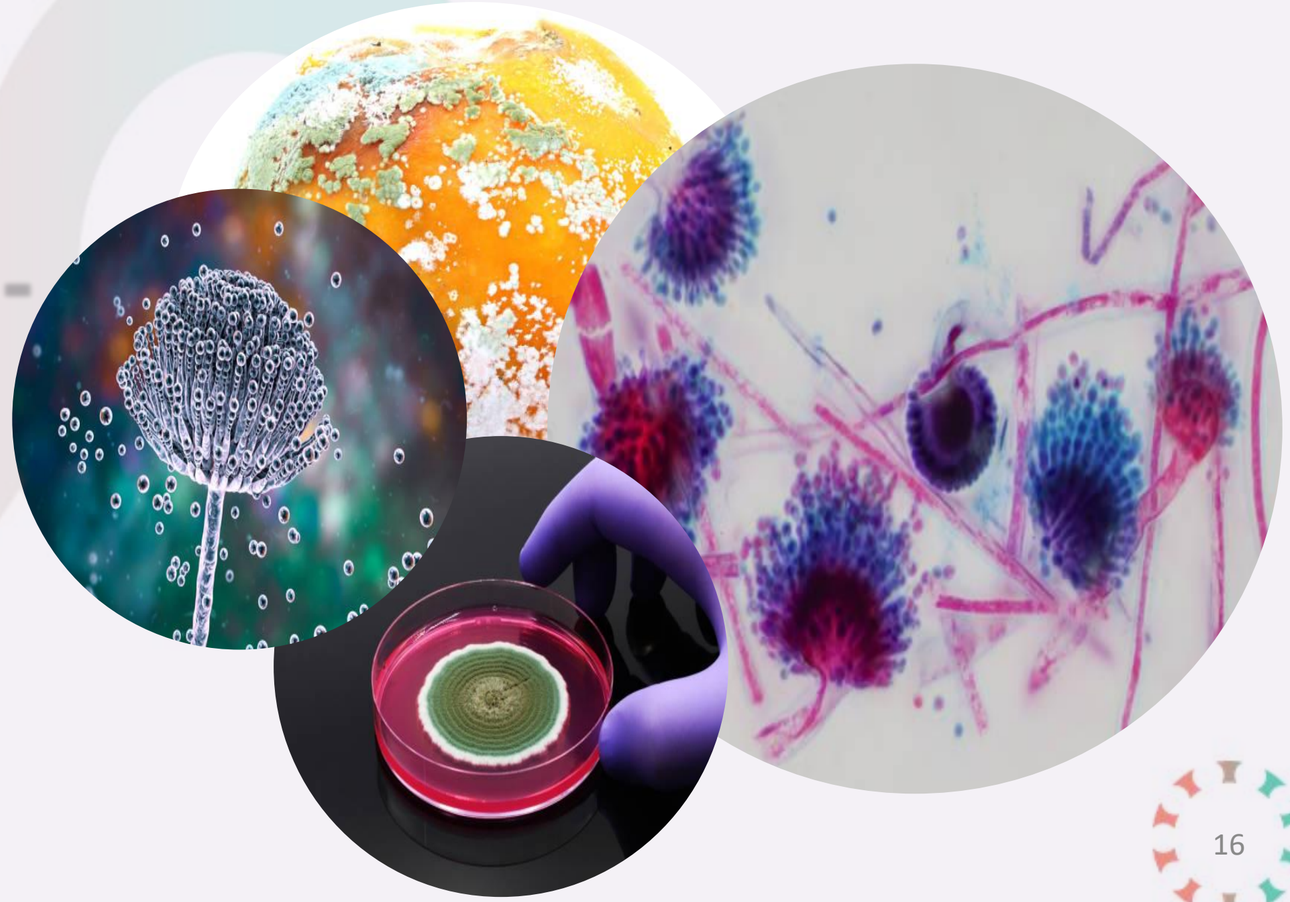
The exploration of novel and sustainable food sources, especially new protein source alternatives

Production of Analytical Mycotoxin Standards

The aim of the project is to produce high-quality mycotoxin standards (98%) for analytical purposes, ensuring the availability of accurate and reliable reference materials for the detection and quantification of mycotoxins in various applications.
Project is based on process and technologies validated on a laboratory scale (TRL 4-5) and pre-commercial (**TRL 6-7**) analytical standards will be developed.

Analytical mycotoxin standards

- Aflatoxin B_1
- Aflatoxin B_2
- Aflatoxin G_1
- Aflatoxin G_2
- OTA
- Deoksinivalenol (DON)
- Zearalenon (ZEN)
- Fumonisin B_1
- Fumonisin B_2
- Patulin



Development of a National Mycotoxin Early Warning System Utilizing Climate and Image Data

To create a system that can provide early warnings and predictions related to mycotoxin contamination, leveraging climaThis system intends to enhance food safety and security by allowing for proactive measures to mitigate mycotoxin risks in agricultural products, particularly in relation to climate and environmental conditions te and image data. (Funded by TUBİTAK ARDEB 1003 Project code: 123O644).

Advantages

- National Mycotoxin Early Warning System will **provide an unprecedented, data-driven tool, leveraging accurate and dependable information, to forecast the potential risks of mycotoxigenic fungi in the field** prior to the planting or seeding season.
- A substantial effort will be dedicated to enhancing our country's capability to **mitigate the primary food safety concern, which is mycotoxin contamination in maize**.
- Contribute significantly to the prevention of **risks associated with climate change.**

Team..

Dr. Hayrettin Özer
Food Safety and Quality Research Group Leader
Chemist

Dr. İlknur Demirtaş
Chemist

Ceyda Pembeci Kodolbaş
Biologist

Dr. Özlem Aslan
Food Engineer

Dr. E. Aytunga Kibar
Food Engineer

Dr. N. Aslı Öncü
Microbiologist

Elif Yener, PhD candidate
Food Engineer

Gökçe Gürün, MSc Student
Food Engineer

To conclude..

- The effects of climate change are becoming more and more apparent with each passing year.
- Climate change can influence the occurrence and severity of mycotoxin contamination in crops, posing challenges for food and feed safety.
- Climate change has given rise to new and modified mycotoxins, creating challenges in risk analysis and standard setting due to the **lack of suitable reference materials**.
- **A strict control system** will need to be put in place for crops that are vulnerable to aflatoxin contamination in currently temperate regions.
- **Mitigation and adaptation strategies** are needed to address effects of climate change on mycotoxins and protect both human and animal health.

Thank you..

References & Contact

- Baranyi, N.; Kocsubé, S.; Varga, J. 2015. Aflatoxins: Climate change and biodegradation. *Curr. Opin. Food Sci.*, *5*, 60–66.
- CAST, 2003; Simion V., Bogdan A.T.,..Recent Researches in Energy and Environment.
- CAST. Mycotoxins: Risks in plant, animal, and human system. Council for Agricultural Science and Technology: Ames IA; 2003.
- Dobolyi, C., Sebo˝ K, F., Varga, J., Kocsubé, S., Szigeti, G., Baranyi, N., Szécsi, Á., Tóth,B., Varga, M., Kriszt, B., Szoboszlay, S., Krifaton, C. & Kukolya, J. 2013. Occurrence of aflatoxin producing *Aspergillus flavusisolates* in maize kernel in Hungary*. Acta Alimentaria*, 42(3): 451–459.
- EFSA. 2012. Scientific report: Modelling, predicting and mapping the emergence of aflatoxins in cereals in the EU due to climate change (MODMAP-AFLA).
- EFSA. 2020: EN-1757. *Mycotoxin mixtures in food and feed: holistic, innovative, flexible risk assessment modelling approach.*
- FAO. 2020. *Climate Change: Unpacking the burden of food safety*. Food safety and quality series No. 8. Rome. https://doi.org/10.4060/ca8185en
- Mitchell NJ, Bowers E, Hurburgh C, Wu F. 2016. Potential economic losses to the US corn industry from aflatoxin contamination. Food Additives & Contaminants. Part A, *Chemistry, Analysis, Control, Exposure & Risk Assessment*. 33(3):540-550.
- Moretti, A., Logrieco, A.F. Climate change effects on the biodiversity of mycotoxigenic fungi and their mycotoxins in preharvest conditions in Europe. In *Climate Change and Mycotoxins*; Botana, M.J., Sainz, L.M., Eds.; Walter de Gruyter GmbH: Berlin, Germany, 201
- Moretti, A., Pascale, M., Logrieco, A.F. 2019. Mycotoxin risks under a climate change scenario in Europe. *Trends Food Sci. Technol. 84*, 38–40.
- Paterson R.R.M., Lima N: 2017. Thermophilic fungi to dominate aflatoxigenic/mycotoxigenic fungi on food under global warming. *Int J Environ Res Public Health*, 14(2), 199.
- Ramirez-Cabral, N.Y.Z., Kumar, L. & Shabani, F. 2017. Global alterations in areas of suitability for maize production from climate change and using a mechanistic species distribution model (CLIMEX). Scientific Reports, 7(1): 5910.
- Russell, R., Paterson M., Lima N. 2010. How will climate change affect mycotoxins in food? *Food Research International*, 43, 1902-1914.
- Scientific report submitted to EFSA, MODMAP-AFLA, 2012, 1-72.

Contact:
Dr. Hayrettin Ozer, hayrettin.ozer@tubitak.gov.tr
Dr. Ilknur Demirtas, ilknur.demirtas@tubitak.gov.tr

https://www.mycotwin.eu/
https://mam.tubitak.gov.tr/en