Mycotoxins in foods: challenges, trends and innovations

Joanne Chan Sheot Harn
Centre Director (National Centre for Food Science)

Hong Kong Food Safety Seminar for Trade 2025
4th December 2025

Singapore Food Agency

- Formed on 1 April 2019 under the Ministry of Sustainability & the Environment
- Bringing together all food-related resources and capabilities from multiple agencies in Singapore government to achieve holistic management “from farm to fork”.

Vision: Safe Food for All

Mission: To ensure and secure a supply of safe food

www.sfa.gov.sg

National Centre for Food Science (NCFS)

The **NCFS** is the scientific foundation of Singapore's food safety system, providing key capabilities in food safety testing, development of scientific expertise, assessment of foodborne exposure risks, and monitoring of emerging food safety risks.

5 Key Pillars:

1. Critical Food Safety Testing Capabilities	2. Translational Science Research	3. Exposure Science	4. Risk Assessment and Communications	5. International Scientific Partnerships & Engagements

- **World Organisation for Animal Health Collaborating Centre for Food Safety**
- **WHO Collaborating Centre for Food Contamination Monitoring**
- **ASEAN Food Reference Laboratories**
  (1) Pesticide Residues (2004) (2) Mycotoxins (2004)
  (3) Environmental Contaminants (2014) (4) Marine Biotoxins & Scombrotoxin (2019)

SFA's **first Mobile Lab**

Mycotoxins in the food chain

Toxic secondary metabolite naturally produced by fungi when they colonises food in the field and during storage.

Ingestions by animals and humans can cause a wide range of negative effects, such as impaired reproduction, digestive disorders, carcinogenicity and reduced performance.

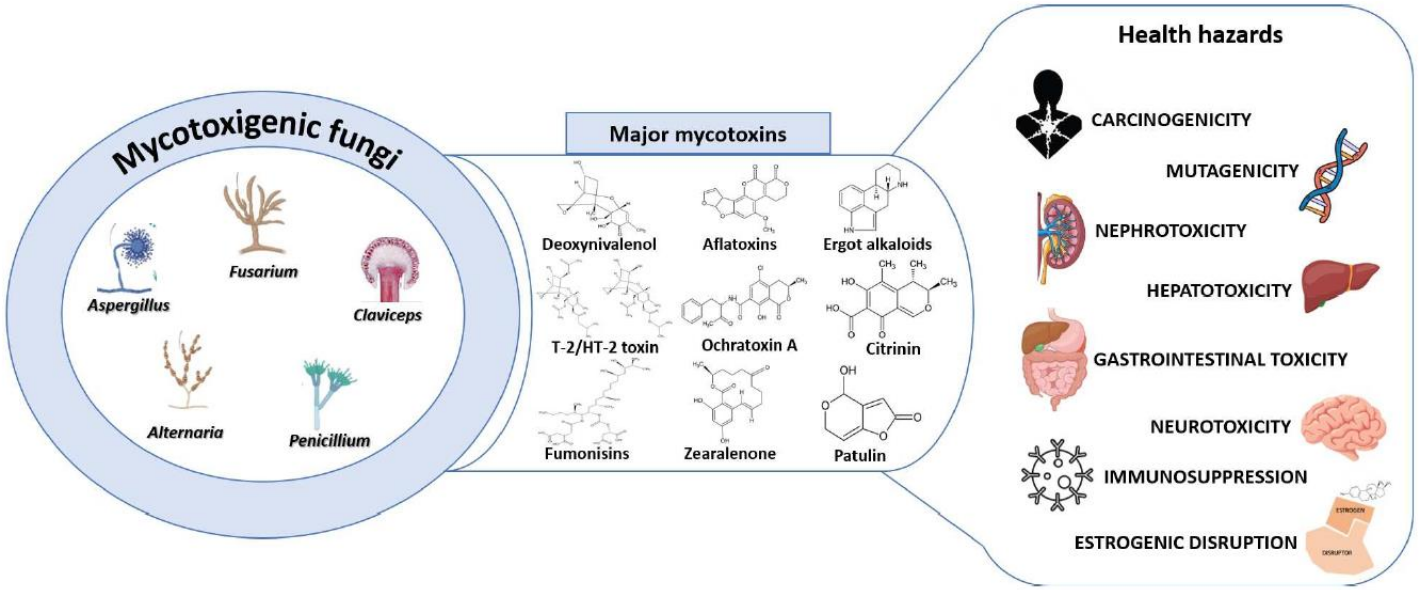


Figure 1. Schematic representation of the toxicological impact of major mycotoxins.

Singapore Food Agency

*Reference : Sharma, V. et al. ACS Food Sci. Technol.**2021**, 1(10), 1717–1739 and K*.T., M.; J., Šangut, I., *Toxins* **2025**, *17*, 515

Mycotoxins in the food chain

Mycotoxin contamination can occur at any point in the food and feed production and food chain. Three fungal genera dominate mycotoxin production: **Aspergillus, Fusarium and Penicillium** and >300 mycotoxins have been found with 6 of them consistently found in food. They are Aflatoxins, Trichothecenes, Zearalenone, Fumonisins, Ochratoxins and Patulin.

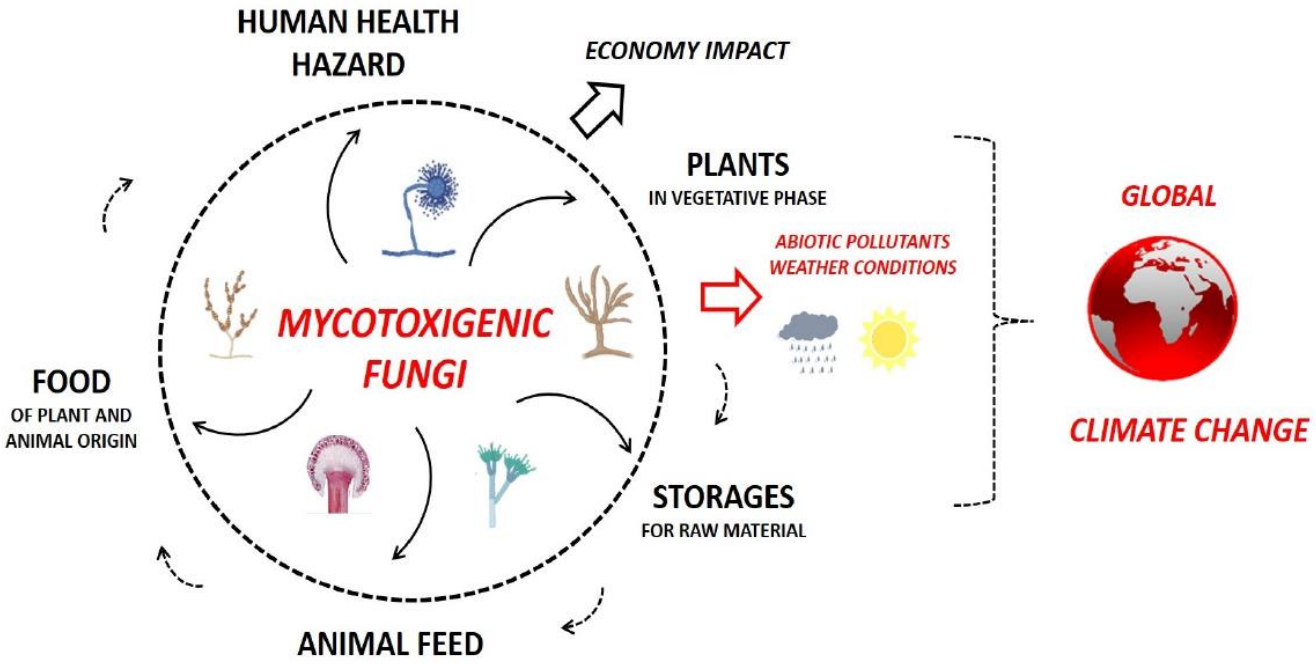


Figure 2. Scheme of mycotoxin contamination cycle and its influencing factors, adapted from [1].

Singapore Food Agency

Reference : Raghda et el. Journal of Future Foods 2-2, 2022, pp.91-202 and K.T., M.; J., Šangut, I., *Toxins* **2025**, *17*, 515.

Impact of climate change on mycotoxin production

Climate is a key driver of mycotoxigenic fungi colonization and mycotoxin production.

Recent studies have shown that water activity, temperature, Carbon Dioxide and light all have a significant effect on growth, development and mycotoxin production of mycotoxigenic fungi

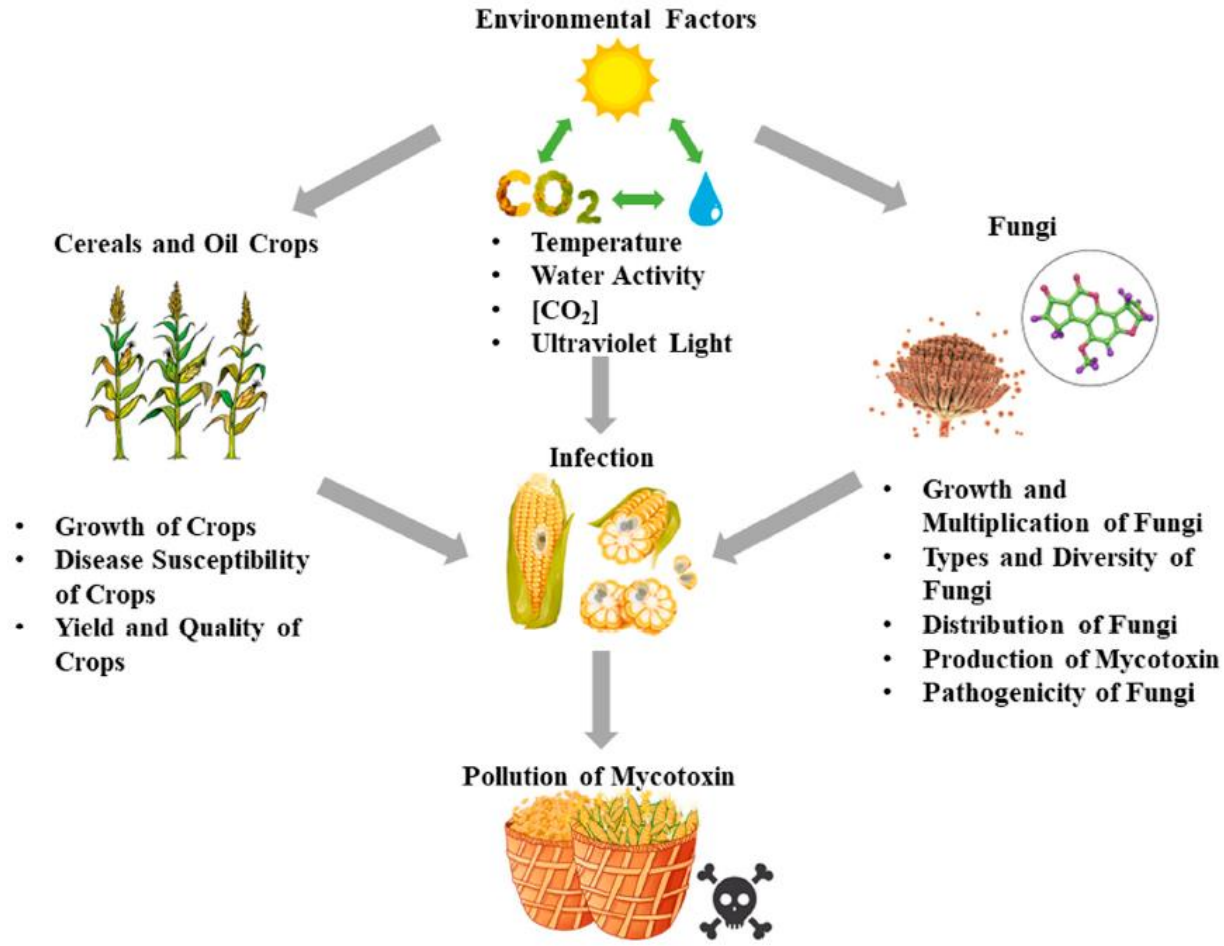


Figure 2. Impact of environmental factors on toxin contamination.

Singapore Food Agency

Reference : Zhang, C.; Qu, Z.; Hou, J.; Yao, Y. , *Microorganisms* **2024**, *12*, 567.

Mycotoxins in the food chain

Mycotoxins	Related moulds	Most prone food products to be contaminated	Symptoms/toxicology	References
Aflatoxins	*Aspergillus parasiticus*, *A. nomius*, and *A. flavus*	**Grain, cherries, strawberries, groundnut, raspberries, maize, peanuts, maize, cotton, pearl millet, sorghum, pistachios, chillies, cassava, oil seeds, spices, and dried fruits**	Depressed immune response, liver tumours, Liver necrosis, reduced growth, carcinogenic, hepatotoxic, mutagenic, teratogenic, vomiting, and pulmonary convulsions	Liu et al. (2006)
Cyclopiazonic acid	*A. flavus*, *A. oryzae*, *A. versicolor*, *A. tamarii*. *P. patulum*, *P. verrucosum*, *P. camembertii*, *P. cyclopium*, *Penicillium griseofulvum*, and *P. puberulum*	**Peanuts, maize, cheese etc.**	Neurotoxin, cytotoxicity, weight loss, immunotoxicity, diarrhea, muscle, nausea, viscera necrosis, and convulsions	Gonçalez et al. (2008)
Deoxynivalenol, Vomitoxin, Zearalenone	*Fusarium graminearum* and *F. subglutinans*	**Wheat, maize, oats, maize, rice, sorghum, and barley**	Diarrhoea, vomiting, decreased weight gain, feed refusal, infertility, hepatotoxic, genotoxic, immune- toxic, hemato-toxic, and oestrogenic effect	Nakagawa et al. (2011)
Fumonisn B1 and Fumonisn B2	*F. moniliforme* and *F. verticillioides*	**Maize, rice, and wheat**	Porcine pulmonary edema, equine leukoencephalomalacia, kidney disease, liver tumor, hepatotoxic, nephrotoxic, cytotoxic, and oesophagal cancer	Topi et al. (2021)
Trichothecenes	*F. culmorum*, *Trichoderma*, *F. graminearum*, *F. poae*, *Cephalosporium*, and *Trichothecium*	**Wheat, oats, and maize**	Food toxic aleukia, necrosis, oral lesion in broiler chickens, weight loss, vomiting, diarrhoea haemorrhages, growth retardation, cartilage tissue damage, fever, dizziness, fever, and neurotoxic.	Jimenez and Mateo (1997)
Ochratoxin	*A. ochraceus*, *P. verrucosum*, and *A. carbonarius*	**Wheat, spices, grapes, and coffee**	Various poultry symptoms; porcine nephropathy, genotoxicity, immunotoxicity, embryotoxicity teratogenicity, neurotoxicity, protein, RNA, and DNA synthesis inhibitor	Iqbal et al. (2018)
Patulin and Citrinin	*P. expansum*	**Apple, orange, grapes, and related products**	Kidney damage, nephrotoxic, immunotoxicity, teratogenic, hepatotoxic, and foetotoxic	Saxena et al. (2008); Oteiza et al. (2017)
Sterigmatocystin	*A. parasiticus*, *A. versicolor*, *A. flavus*, *A. nidulans*, *A. rugulosus*, *A. rubber*, *A. chevalieri*, *P. camembertii*, *A. amsyelodami*, *P. griseofulvum*, *P. communer*	**Maize, rice, wheat, and hay**	Carcinogenic, mutagenic, immunotoxicity, cytotoxicity, diarrhea, nausea, and weight loss.	Iqbal et al. (2018)
Alternaria toxins: alternariol, tenuazonic acid and others	*Alternaria* species	**Grains, oil seeds, spices, and various fruits and vegetables**	Cytotoxic, genotoxic, teratogenic, mutagenic, fetotoxic, and dermal toxicity	Dong et al. (2019)

Singapore Food Agency

Reference : Pandey et all. *Front. Sustain. Food Syst.*, *2023*, 7:1162595, doi: 10.3389/fsufs.2023.1162595 .

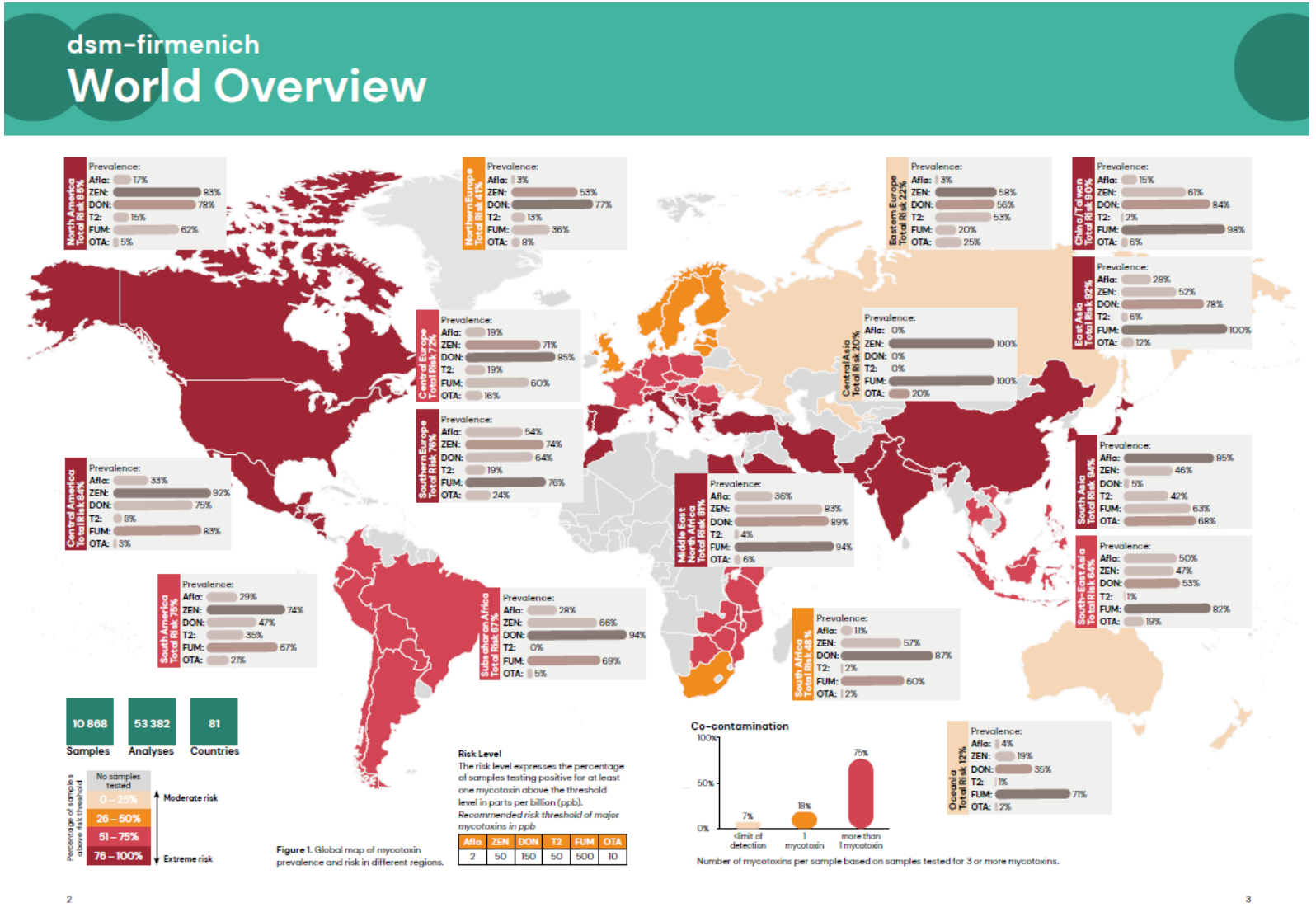
Global mycotoxin survey on exposure risk for livestock

Mycotoxins Survey from Jan to Jun 2025

10,868 feed samples
81 countries
53,383 analyses

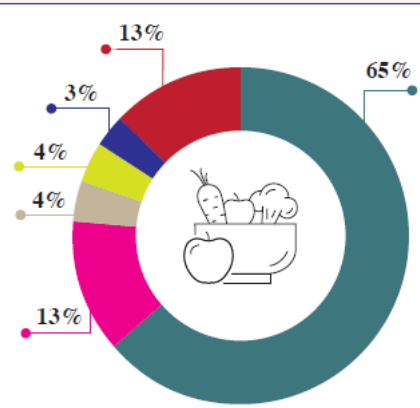
Widespread and persistent occurence of mycotoxins in feed ingredients across the globe

- Deoxynivalenol, zearalenone and fumonisin are most frequently detected in America, South Asia, China
- Aflatoxins is detected in 85% of samples in South Asia



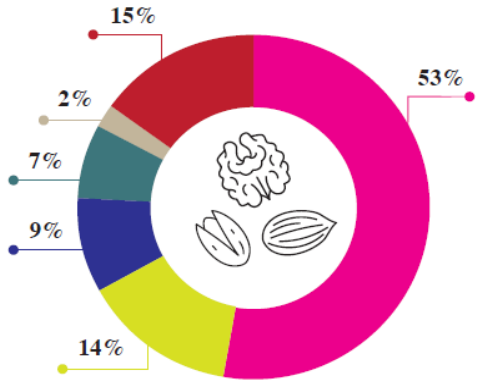
Reference : DSM-Firmenich World Mycotoxin Survey Report

The 2024 mycotoxin Landscape in Europe



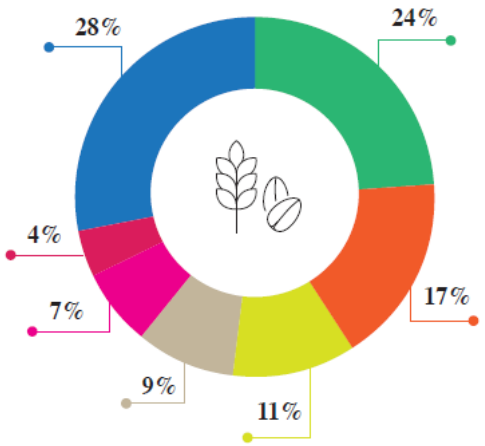
Graph 4: Most common issues reported for fruit and vegetables products in the ACN in 2024.

- **Pesticide residues** (chlorpyrifos, acetamiprid)
- **Mycotoxins** (aflatoxins, ochratoxin A)
- **Labelling issues**
- **Pathogenic micro-organisms** (Norovirus, *Salmonella*)
- **Metals** (cadmium, lead)
- **Others** (environmental pollutants, process contaminants, etc)



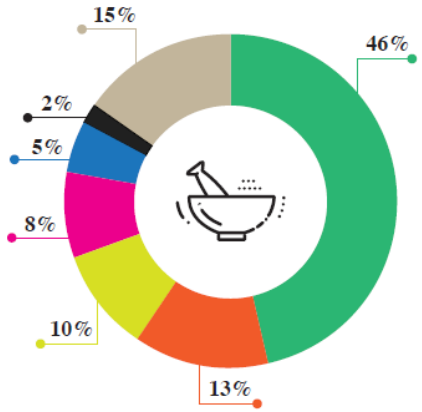
Graph 5: most common issues reported for nuts and nut products in the ACN in 2024.

- **Mycotoxins** (aflatoxins, ochratoxin A)
- **Pathogenic micro-organisms** (*Salmonella*, *Listeria*)
- **Absence of health certificate(s)**
- **Pesticide residues** (chlorpyrifos, chlorate)
- **Natural toxins** (pyrrolizine alkaloids, opium alkaloids)
- **Others** (allergens, novel foods, biological contaminants)



Graph 7: most common issues reported for cereals and bakery products in the ACN in 2024

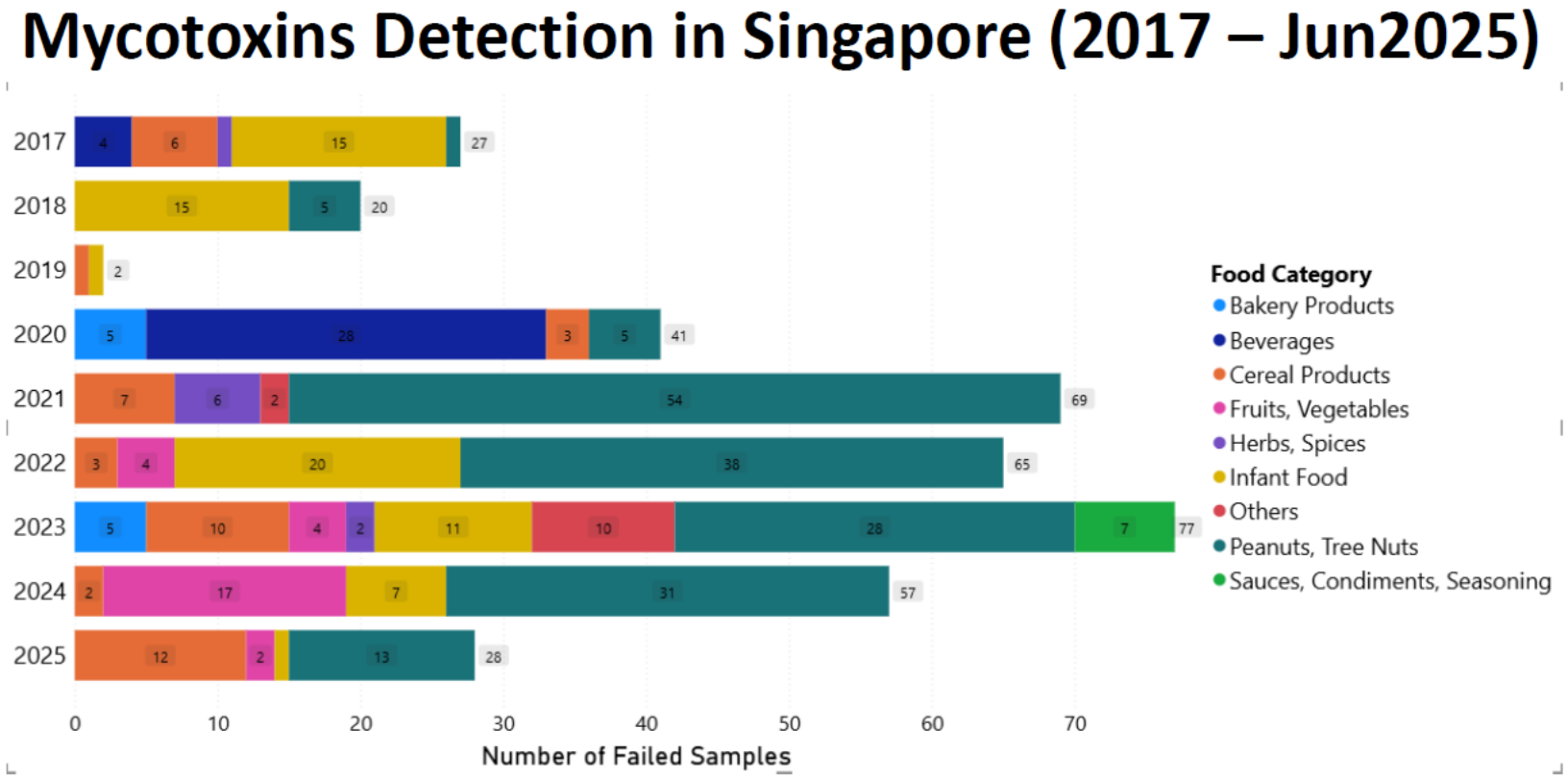
- **Pesticide residues** (chlorpyrifos, acetamiprid, thiamethoxam)
- **Labelling issues** (best before date, incorrect language)
- **Mycotoxins** (aflatoxins and ochratoxin A)
- **Allergens**
- **Foreign bodies**
- **Food additives and flavourings** (titanium dioxide (E171))
- **Others** (natural toxins, unapproved substances, process contaminants)



Graph 8: most common issues reported in the ACN for herbs and spices products in 2024

- **Pesticide residues** (chlorpyrifos, acetamiprid, carbendazim)
- **Natural toxins** (pyrrolizidine alkaloids)
- **Pathogenic micro-organisms** (*Salmonella*, *Bacillus cereus*)
- **Mycotoxins** (aflatoxins, ochratoxin A)
- **Labelling issues**
- **Environmental pollutants** (polycyclic aromatic hydrocarbons)
- **Others** (foreign bodies, novel foods, allergens)

The evolving mycotoxin landscape in Singapore



Highest failure in: (1) Aflatoxin B&G, (2) Patulin, (3) Ochratoxin A

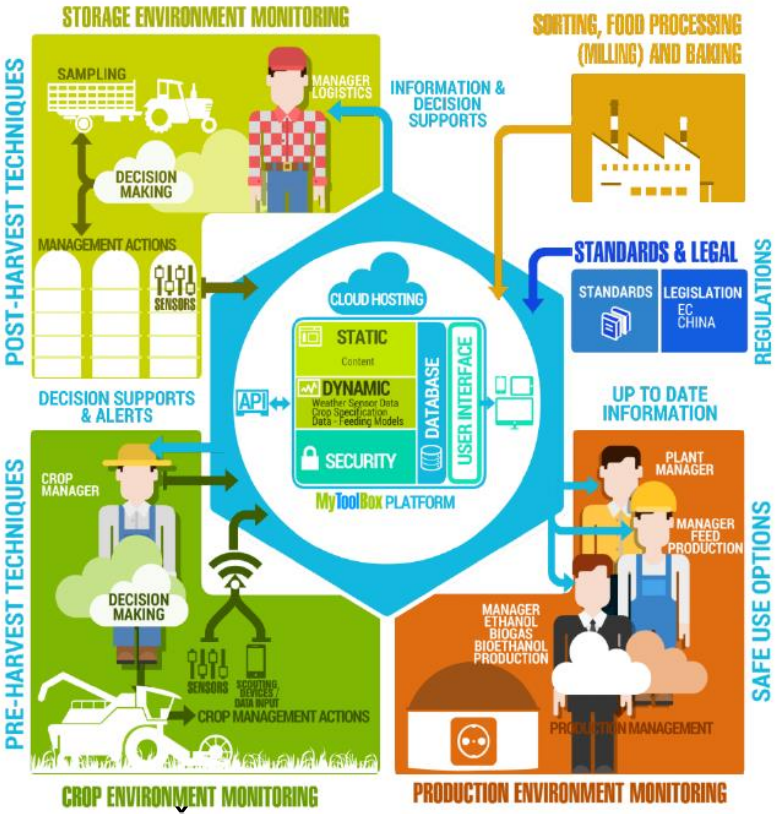
Peanuts, tree nuts are highest risk food commodities

Approaches for mycotoxin management by regulators

At the regulatory level, food safety agency work with key stakeholders by putting in place horizon scanning programme, food surveillance programmes to monitor food and feed contamination, enforcing regulations, recalling contaminated food crops as well as implementing risk communication.

Innovative approaches for mycotoxins mitigation

EC project, **MyToolBox** with 23 partners from 11 countries between 2016-2020 to minimize and reduce mycotoxins contamination along the entire food chain. The management practices were integrated into an e-tool to assist decision making for all actors in the supply chain



M.; J., Šangut, I., *Toxins* **2025**, *17*, 515

EU project, **FoodSafeR Digital Hub** build international food network through information sharing - proactive early warning and detection systems for rapid identification of problems, innovations in science and technology and big data and AI to reduce food safety risks and strengthen policies.

Reference : L.JF, E. CN, W. M, E. C, M. O, Uyttendaele M, Yongning W, Wang S, Okoth S, Lindsay J, Rawn DFK, Chan SH, Zhang K, Lattanzio VMT, Wu F, Bandyopadhyay R, Dupouy E, Wearne S, Godefroy S, Suman M and Krska R (2025) A FoodSafeR perspective on emerging food safety hazards and associated risks. *Front. Sustain. Food Syst.* 9:1646792.

Approaches for mycotoxins mitigation by industry

At the food industry level, good pre-harvest measures (crop rotation, proper soil cultivation, use of appropriate fertilizers, seed material, sowing techniques, crop breeding and selection)

and good post harvest measures (physical, chemical or biological methods for mycotoxin decontamination and detoxification, proper storage condition) can reduce mycotoxin contamination in food crop.

Figure 3. Control methods of mycotoxin contamination in grain and oil crops.

Innovative Approaches for Mycotoxins mitigation

Recent strategies and emerging methods aimed at preventing fungal growth and mycotoxin contamination in food matrices

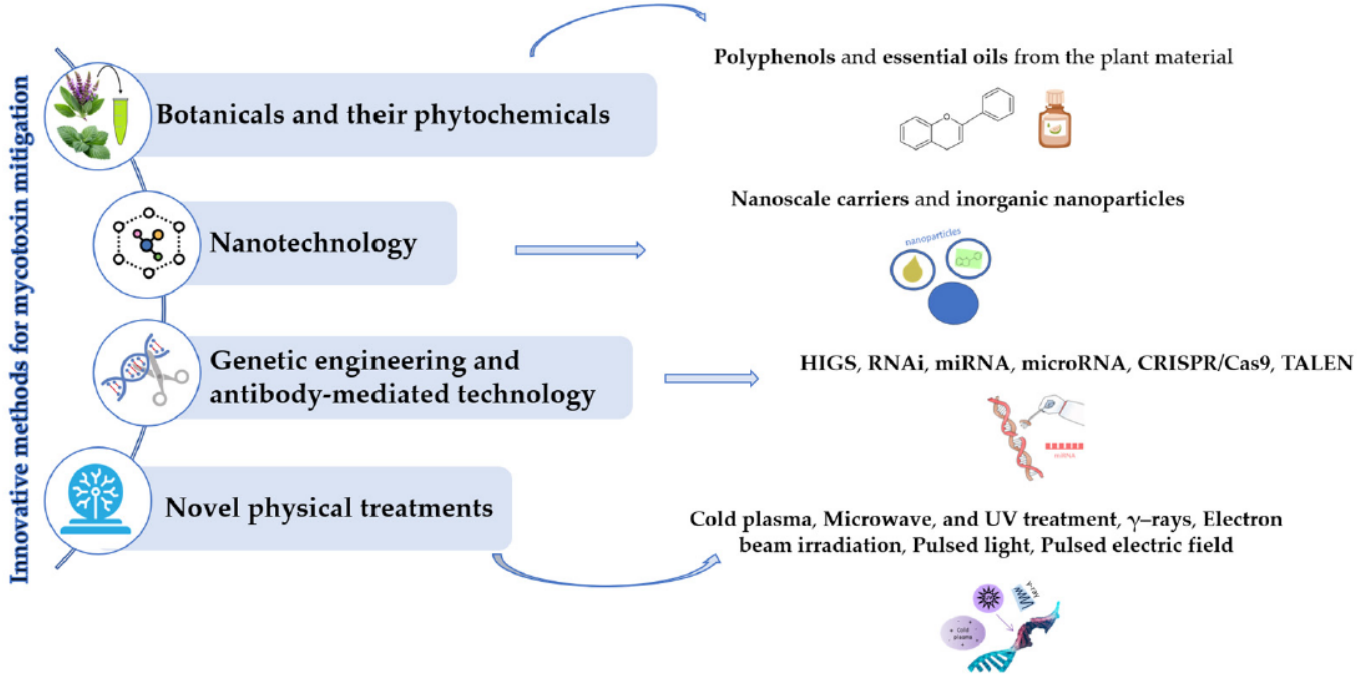


Figure 3. Schematic overview of current innovative methods for mycotoxin mitigation.

Reference : M.; J., Šangut, I., *Toxins* **2025**, *17*, 515

Conclusion

- Mycotoxins pose significant threats to human, animal and plant health with economic impact
- Mycotoxins can develop at any point along the food chain
- Climate change can potentially exacerbate the threat by altering fungal behaviour and distribution in crops, increasing risk of exposure to these toxins
- A integrative, interdisciplinary approach is required to mitigate risk of mycotoxins

Thank you