

OPINION ARTICLE

## Lessons learned from 16 editions of the World Mycotoxin Forum 50 years after the first international conference on mycotoxins

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### Abstract

On-going research and interdisciplinary networking among scientists and stakeholders are still needed for the development of affordable and practical tools for farmers and food processors to efficiently manage the risk of mycotoxin contamination along food and feed chains. In order to facilitate appropriate actions, thematic interlaboratory projects have been initiated, professional networking-organisations have been founded, dedicated journals have been started and mycotoxin conferences have been organised. The World Mycotoxin Forum (WMF) has established itself as a leading international networking conference series on mycotoxins where food and feed industry representatives meet with representatives from government, food authorities, food and feed industry and with people from universities and other research institutions from around the world. The WMF has gradually moved from food and feed related technological topics to international and regulatory issues and to mitigation strategies based on fungal and plant genetics, big data based decision support tools and sustainable solutions in view of climate change. Over all these years, the conclusions made from each WMF have been summarised by the general conference chair(s) as the 'top 5 lessons learned' on the last day of each conference. 50 years after the first international conference on mycotoxins organised by IPUAC in 1972, this article has compiled all 'top 5 lessons learned' presented at the 16 editions of the WMF and joint WMF/IUPAC events organised between 2001 and 2022. Since the first international conference on mycotoxins, much progress has been made in the prevention, reduction and control of mycotoxins. However, continuous attention and further efforts are still needed in order to tackle the complex issues of mycotoxin contamination especially in view of climate change and other global challenges on the horizon.

### Keywords

scientific conference – dissemination – mycotoxin history

## 1 Introduction

Agriculture and food industries continue to be vulnerable to the complex problems of contamination with mycotoxins. The discovery of aflatoxins in the early 1960s can be considered the official birth of the perception of mycotoxins in food. At that time, more than 100,000 young turkeys died in England after being fed mouldy peanut meal from Brazil. The intensive search for toxic substances to reveal the cause of this so-called turkey X disease (Blount, 1961; Pickova *et al.*, 2021) eventually led to the discovery of aflatoxins, which were named after their first known producer, *Aspergillus flavus*. In the meanwhile, global warming (Medina *et al.*, 2015) and extreme weather events make the occurrence of the wide range of toxic secondary metabolites of fungi even more unpredictable. It has recently been estimated that up to 80% of food items of plant origin worldwide are contaminated with mycotoxins (Eskola *et al.*, 2020). The spectrum of adverse health effects ranges from nausea, vomiting, and weight loss to infertility and liver cancer. Significant economic losses are associated with the impact of mycotoxins on human health, animal welfare and productivity, and both domestic and international trade (Pitt and Miller, 2017; Wu and Mitchell, 2016). Affordable and practical tools for farmers and food processors along the food and feed chains are still required to efficiently reduce the risk of mycotoxin contamination of crops, feeds and foods. As a result of the turkey X disease, international organisations got involved with mycotoxins. Later thematic inter-laboratory projects were initiated, professional networking-organisations were founded, legal measures were established, dedicated journals, such as the World Mycotoxin Journal were started and mycotoxin conferences have been held.

## 2 From the first mycotoxin conference to the World Mycotoxin Forum series

The first international conference on mycotoxins was organised by the International Union of Pure and Applied Chemistry (IUPAC) under the title Symposium on the Control of Mycotoxins, in 1972, a dozen of years after the discovery of the aflatoxins in Kungälv near Göteborg, Sweden (IUPAC, 1972). A selection of the lectures was published in a special edition of Pure and Applied Chemistry and these proceedings give us an interesting insight in the state-of-knowledge as it existed 40 years ago (Krogh, 1973). Papers largely focused on

aflatoxins, although some papers related to *Fusarium* toxins. Analytical methods based on thin layer chromatography (TLC), with some interest for rapid methods (e.g. hyperspectral bright greenish-yellow fluorescence (BGYF) imaging of aflatoxin contaminated corn kernels and the use of mini-columns). The need for the availability of standards was also emphasised at this first IUPAC conference on mycotoxins. Much research on carry-over of aflatoxins and first attempts for decontamination procedures were described. Hans van Egmond (Van Egmond and Krska, 2012) reports that the main attention was on the control of mycotoxins due to the understanding already back then that eradication was not possible. 'Problems due to mycotoxins would keep us busy', as succinctly described in the title of Leo Goldblatt's lecture: Learning to live with mycotoxins. Based on recent Rapid Alert System for Food and Feed (RASFF) reports we can see, that some 40 years later mycotoxin issues are still with us to a considerable extent. The EU's RASFF system reported 5,045 and 439 notifications for mycotoxin contamination in food and feed products, respectively, imported by EU countries from 2010 to 2019 (Alshannaq *et al.*, 2021; Krska *et al.*, 2022).

Besides other related conferences, in 2001 a new series of conferences started, the so-called World Mycotoxin Forum (WMF), an initiative of Helena B. Bastiaanse and Daniel Barug from Bastiaanse Communication in Bilthoven, the Netherlands. They have been the organisers of all WMFs so far. Whereas IUPAC conferences have been mostly directed towards attendees from academia, research institutions and government agencies with a strong focus on (applied) chemistry, the WMF has striven to get more involvement from industry and issues such as prevention has achieved a more prominent place. In 2010 the idea to merge the 2 conferences in 2012 (WMFmeetsIUPAC) was well-received by IUPAC, also because it appeared difficult to continue the IUPAC series independently. In 2022, 50 years after the first international symposium on mycotoxins (organised by IUPAC), a total of 25 WMF and/or IUPAC conferences have been organised (Table 1). Over the same period of time (1972-2022), an impressive number of 102,575 Science Citation Indexed (SCI) papers (search 'mycotox\*' in all fields) and 33,855 papers (search 'mycotox\*' in abstract, title and keywords) have been published according to Scopus (Figure 1), which testifies to the massive scientific effort in mycotoxin research.

TABLE 1 WMF, IUPAC and WMFmeetsIUPAC conferences on mycotoxins from 1972 till 2023<sup>1</sup>

Conference	Year	Town	Country	Number of participants <sup>2</sup>
IUPAC	1972	Kungälv/Göteborg	Sweden	unknown
IUPAC	1974	Pullawy	Poland	unknown
IUPAC	1976	Paris	France	unknown
IUPAC	1979	Lausanne	Switzerland	unknown
IUPAC	1982	Vienna	Austria	unknown
IUPAC	1985	Pretoria	South Africa	unknown
IUPAC	1988	Tokyo	Japan	unknown
IUPAC	1992	Mexico City	Mexico	unknown
IUPAC	1996	Rome	Italy	unknown
IUPAC	2000	Guarujá	Brazil	unknown
WMF	2001	Noordwijk	The Netherlands	175
WMF	2003	Noordwijk	The Netherlands	186
IUPAC	2004	Washington DC	USA	300
WMF	2005	Noordwijk	The Netherlands	197
WMF	2006	Cincinnati	USA	222
IUPAC	2007	Istanbul	Turkey	580
WMF	2008	Noordwijk	The Netherlands	239
WMF	2010	Noordwijkerhout	The Netherlands	263
WMFmeetsIUPAC	2012	Rotterdam	The Netherlands	330
WMF	2014	Vienna	Austria	358
WMFmeetsIUPAC	2016	Winnipeg	Canada	373
WMF	2018	Amsterdam	The Netherlands	391
WMFmeetsIUPAC	2019	Belfast	Northern Ireland/UK	399
WMF	2020	Bangkok	Thailand	259
WMF	2022	Parma	Italy	401
WMF	2023	Antwerp	Belgium	

1 Some of these conferences also covered phycotoxins and/or plant toxins). In total, 12 IUPAC and 13 WMF conferences (3 of which as WMFmeetsIUPAC events) have been organised so far.

2 unknown = unknown to the authors, to the best of our knowledge the data are not available.

Documents by year

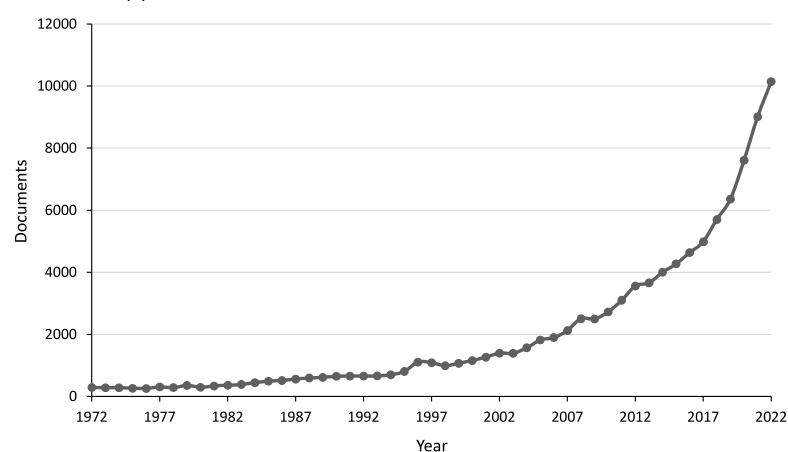


FIGURE 1 102,575 of Science Citation Indexed papers have been published in the area of mycotoxins between 1972 and 2022 according to Scopus (search 'mycotox\*' in all fields).

### 3 (Top 5) Lessons learned from the World Mycotoxin Forum

For more than 20 years the WMF with its 13 editions (plus 3 on-line events) has been a leading international meeting series on mycotoxins dedicated to assembling the world's best minds across the spectrum of integrated strategies ensuring the safety and security of the food and feed supply chain. The WMF has been bringing together holistic conference programmes covering the latest challenges and solutions in mycotoxin management and has been targeted at everyone working in the mycotoxin space – researchers, food and feed industry, laboratories, policy makers, and enforcement agencies from around the world. Presentations and discussions have been taken place in plenary meetings, parallel sessions, poster sessions, young scientist sessions and company pitches, workshops and demonstrations including case studies and industry updates covering a wide range of topics. Towards the end of each WMF, the individual session chairs provided their conclusions on the respective scientific sessions to the general conference chairs who further summarised and condensed the information received. Finally, the so-called 'top 5 lessons learned' at the WMF (called 'answers/things learned until 2012) were presented by the general conference (co-)chairs during the closing session of the conference. From 2001 to 2018, the WMF was 10 times (co-)chaired by Hans van Egmond. Hans also served as editor-in-chief of the World Mycotoxin Journal for many years and retired from the Business Unit Contaminants and Toxins at the RIKILT Institute of Food Safety, Wageningen University and Research Centre, the Netherlands in 2015. From 2012 till 2018 the WMF was co-chaired by Rudolf Krska and Hans van Egmond. Since 2019 the authors of this article Rudolf Krska and Chris Elliott have been serving as general conference (co-)chairs. Especially during the last decade, the 'top 5 lessons learned' presented by the general conference (co-)chairs has become a highly recognised and very popular conference summary. Thousands of views on various media platforms, such as LinkedIn, testify to this recognition. In the following, the major topics and 'top 5 lessons learned' from each WMF conference starting with 2001 in Noordwijk in the Netherlands are presented.

#### *The 1<sup>st</sup> WMF, Noordwijk, the Netherlands, May 14-15, 2001*

The first WMF was presented as 'The international networking conference for the food and feed industry' (Figure 2). Since 2010, the 6<sup>th</sup> WMF, this head-

line has been amended to 'The international networking conference for the food and feed industry, regulatory authorities and science', thus, including authorities and science/universities. Contrary to other mycotoxin related conferences back then, the WMF considered itself mainly as a platform for industry and included many presentations from industrial partners. The top 5 lessons learned – back then presented as 'things learned' were rather short and simple:

1. There is a lot of attention on regulatory/enforcement issues, and
2. A substantial focus on supply chain management.
3. Major emphasis is on prevention and decontamination.
4. In the analytical arena, sampling issues, antibody-based techniques, biosensors, and near infrared spectroscopy are increasingly important.
5. The future: ... further conferences!

#### *The 2<sup>nd</sup> WMF, Noordwijk, the Netherlands, February 17-18, 2003*

The second WMF was dedicated to specific food and feed issues from around at the world and various case studies were presented. The peer-reviewed papers presented at this WMF were published in the book 'Meeting the mycotoxin menace' (Barug *et al.*, 2004). The top 5 lessons learned were:

1. Plant breeding is an important tool to prevent mycotoxins.
2. Biocontrol of aflatoxins in peanuts as an important reduction strategy.
3. FAO/WHO risk assessment for mycotoxins.<sup>1</sup>
4. Increasing activities in the exploration of multi-toxin LC-MS (liquid chromatography coupled to mass spectrometry) as a powerful analysis technique.
5. Prospect: use of omics tools to reveal mechanism of plant resistance.

In his plenary lecture on *Mycotoxins – current issues in USA*, Deepak Bhatnagar (USDA) pointed out that the economic costs of crop losses from just three mycotoxins (aflatoxins, fumonisins and deoxynivalenol) is estimated to exceed 900 million US\$.

<sup>1</sup> Remark by the authors of this paper: A safety evaluation of certain mycotoxins in food was carried out during the 56<sup>th</sup> meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 2001 (WHO/FAO, 2001).



FIGURE 2 The announcement of the first World Mycotoxin Forum in Noordwijk, the Netherlands, 2001.

***The 3<sup>rd</sup> WMF, Noordwijk, the Netherlands, November 10-11, 2005***

The peer-reviewed papers presented at the third WMF were published in the book 'The mycotoxin factbook' (Barug *et al.*, 2006). At this WMF, the International Society of Mycotoxicology was formally launched by a consortium of international experts 'in order to more effectively disseminate knowledge and skills on toxigenic fungi and mycotoxins' (ISM, 2023). The top 5 lessons learned at the 3<sup>rd</sup> WMF were:

1. Applications of forecasting models (especially of DONcast<sup>®</sup>).
2. Aerosol mycotoxins in indoor air.
3. Measurement uncertainty; standardisation of activities in mycotoxin determination.
4. On the horizon: use of GMOs as a strategy to prevent mycotoxins.
5. Special emphasis on the risks of mycotoxins in the context of human nutrition and animal feeding.

***The 4<sup>th</sup> WMF, Ohio, Cincinnati, USA, November 6-7, 2006***

For the first time, the WMF went overseas. The top 5 lessons learned from the fourth WMF in Ohio were:

1. Ample attention for risks and regulations.
2. Impact of regulations on economy and industry.
3. Mycotoxin contamination in organic food chains.
4. Development and use of biomarkers for mycotoxin exposure.
5. Aquaculture and mycotoxins: a rising threat?

***The 5<sup>th</sup> WMF, Noordwijk, the Netherlands, November 17-18, 2008***

Back in Europe, the focus of the fifth WMF was on emerging problems in the food and feed chains. The top 5 lessons learned were:

1. Model for identification of emerging risks.
2. Effective: Europe's Rapid Alert System for Food and Feed.
3. Plant resistance to fungal infection and mycotoxin production.
4. The unpredictable: co-exposure of mycotoxins.
5. Analytically: transcriptomics as a tool to determine trichothecenes and molecularly imprinted polymers (MIPs) for enrichment.

***The 6<sup>th</sup> WMF: Noordwijkerhout, the Netherlands, November 8-10, 2010***

At the sixth conference of the series, the WMF broadened its scope to include plant and marine biotoxins. The top 5 lessons learned were:

1. Global warming and toxin-producing mycobiota.
2. EFSA's approach for the assessment of mycotoxin-detoxifying agents.
3. Workplace-related risks from mycotoxin exposure.
4. Antibody-based multiplexing analysis methods.
5. Insect sniffing: an alternative way to detect mycotoxins.

***The 7<sup>th</sup> WMF: Rotterdam, the Netherlands, November 5-9, 2012***

The last IUPAC conference on mycotoxins, which also included phycotoxins, was organised in Istanbul back

in 2007. Hence, five years later, an effort was made to organise the seventh WMF as a joint event with IUPAC. As a result, the 'WMFmeetsIUPAC' symposium 2012 was held in Rotterdam, the town with the biggest harbour in Europe. During this conference special attention was laid on (applied) chemistry and on a sampling workshop at the Rotterdam harbour on the occasion of an incoming ship filled with groundnuts from Brazil, which were tested for aflatoxins. The top 5 lessons learned were:

1. Expect the unexpected (the 'black swans' in the mycotoxin arena).
2. Sampling of dust as a means for rapid analysis of grains.
3. Importance of Proficiency testing of LC-MS/MS multi-methods.
4. 'Masked mycotoxins': analysis, occurrence and the need for toxicological data.
5. Genomics as a tool for a better understanding of plant-fungi interactions.

#### *The 8<sup>th</sup> WMF, Vienna, Austria, November 10-12, 2014*

A major emphasis of the eighth WMF was on 'mycotoxin control and the systems approach' to address the need to reduce mycotoxins through integrated approaches to control mycotoxin contamination along the whole food and feed supply. This WMF was organised in conjunction with the 1<sup>st</sup> World Plant Toxin Forum (WPTF) which dealt with plant toxins.

Due to the enthusiasm of the session chairs, who were for the first time involved to assist the general conference (co-)chairs, the top 5 lessons learned, started to become more detailed:

1. Changing weather conditions (climate change) require adaptations in crop management, land use and agricultural practices to manage the risk of mycotoxins in major staple crops.
2. Effective pre- and post-harvest management systems are key in reducing mycotoxins and crop loss. Such schemes require an integrated approach taking into account observations at the cellular/molecular level as well as on countryside scale.
3. Regulations should not aim to restrict access to feed and food but should be an incentive to introduce the necessary changes in crop management, land use and agricultural practices to manage the risk of mycotoxins in major staple crops worldwide.
4. Rapid high throughput screening of mycotoxins at critical control points on-site is now feasible and attractive but account shall be taken of adequate sampling.

5. Mass spectrometry based metabolomics enables to recognise changes in the plant metabolome after treatment with trichothecenes, which is important to understand plant-pathogen interactions in a functional genomics context – as a basis for improved resistance breeding.

#### *The 9<sup>th</sup> WMF, Winnipeg, Canada, June 6-9, 2016*

The ninth WMF went again overseas and was for the first time organised in Canada. Due to the success of the seventh WMF, this event was again organised as a 'WMFmeetsIUPAC' event. Moreover, the 9<sup>th</sup> WMF was organised in conjunction with the 2<sup>nd</sup> World Plant Toxin Forum (WPTF). However, due to a lack of attendance, the decision was made not to organise another WPTF.

During the WMF in Winnipeg, several perspectives were expressed on 'mycotoxins in a changing world' with representatives from IUPAC, FDA, EFSA, FAO and ILSI who disclosed their views. Among many other topics, the focus of this conference was on the co-occurrence of mycotoxins including their modified forms and the need to consider a wide range of secondary fungal metabolites in exposure assessment. Moreover, the clear trend towards ICT based tools including novel handheld devices was discussed in detail. As a result of very detailed discussions, the top 5 lessons learned from this joint WMF-IUPAC symposium in Winnipeg were again rather comprehensive:

1. We are living in a changing world as we face changing technology, climate change, changing mycotoxin patterns, diverse dietary patterns, etc. As a result, large collaborative projects have been launched with increasing involvement of Asia and Africa, food authorities and international. Economic and human health costs can be equated but the methods for assessment are arbitrary.
2. Food authorities recognise mycotoxin co-occurrence as a priority in exposure assessment. However, different modes of action are a major challenge for toxicological evaluations
3. Improved analytics include (a) new on-line FAO sampling tool to visualise effects of sampling plan parameters on the risk, (b) advanced mass spectrometric methods to check for co-occurring (masked) fungal secondary metabolites, (c) new approaches for biomarker analysis (including blood spot analysis) provide new insights into the exposure to mycotoxins, (d) omics based technologies are becoming an important data source for improved risk assessment and for understanding

plant-fungi interactions as a basis for sustainable prevention strategies.

4. Success stories and new promising techniques: (a) biocontrol: expanding application of atoxigenic *Aspergillus* strains in Africa has dramatically reduced aflatoxin contamination of maize, (b) novel compounds including natural products inhibit toxin production in the plant and mitigate the physiological impact on intestinal tissue, (c) the use of hyperspectral imaging or near infrared (NIR) spectroscopy as non-invasive analytical techniques, e.g. for sorting, (d) novel ICT based tools incl. handheld devices and the provision of on-line data via apps.
5. Going beyond field-to-fork: new integrated approaches consider the entire cycle including the lifecycle of fungi and their interaction with host and environment but also waste management, alternative energy at the end of the chain. Effective regulations to avoid adverse health effects have to impact the whole chain.

***The 10<sup>th</sup> WMF, Amsterdam, the Netherlands, March 12-14, 2018***

‘Taking mycotoxin control to the next level’ was the header of the tenth WMF edition. This tenth conference also marked the last conference of a series of ten WMF editions (co-)chaired by Hans van Egmond. His co-chair Rudolf Krska thanked him, also on behalf of Bastiaanse Communication and the mycotoxin community, for his outstanding contributions in mycotoxin research and for having been a great and inspiring WMF chair over all these years. Top 5 lessons learned from the 10<sup>th</sup> WMF were:

1. Integrated solutions are crucial for the efficient control and reduction of mycotoxins along food and feed chains.
2. Effective intervention strategies are required to reduce mycotoxins taking into account climatic variation and extreme weather conditions.
3. There is a need for further development, exploration and harmonised safety assessment of detoxifiers across the continents.
4. Omics approaches are effective tools for understanding the interaction between living organisms and for disclosing biological pathways.
5. Integrated solutions are crucial for the efficient control and reduction of mycotoxins along food and feed chains.

***The 11<sup>th</sup> WMF, Belfast, Northern Ireland, UK, October 14-16, 2019***

Due to the success of the seventh and ninth conference, also the eleventh WMF edition was organised as a ‘WMFmeetsIUPAC’ event. The focus of this symposium was on ‘Looking beyond horizons’. The top 5 lessons learned were:

1. It’s time to shift from plant-pathogen interaction to the plant-microbiome-pathogen triangle.
2. The ILSI Europe Practical Guidance to Mitigation of Mycotoxins provides ‘easy to use’ information on food.
3. Still more research is needed on the uptake, metabolism and excretion of mycotoxins, in particular for humans.
4. More research is required on multiple exposures and their effects on health.
5. We need to focus more on the whole process of mycotoxin analysis, not just the detection technology.

***The 12<sup>th</sup> WMF, Bangkok, Thailand, January 13-15, 2020***

For the first time and just before the COVID-19 pandemic, the WMF was organised in Asia. The so-called ‘WMFmeetsAsia’ conference emphasised the importance of ‘sharing knowledge and experience across boundaries’. The top 5 lessons learned were:

1. South-East-Asia remains at high risk of aflatoxin contamination with changing contamination levels and considerable co-contamination.
2. Minimising mycotoxin contamination is not only about technology. Hence, behavioural changes and sustained efforts on a daily basis are needed.
3. Ensuring safety and security of the entire food supply chain for a growing world population is required.
4. Climate change makes the occurrence of mycotoxins increasingly unpredictable.
5. There is a great demand for novel integrated strategies to control, reduce and detoxify (co-)occurring mycotoxins in foods and feeds in a sustainable, economic environment.

During the COVID-19 pandemic, three so-called virtual WMF pre-conferences on different topics were organised:

*Virtual WMF pre-conference on the Human exposome, October 12, 2021 (chaired by Sarah de Saeger, Ghent University, Belgium)*

The top 5 lessons learned from this rather unique virtual mycotoxin event dealing with the human exposome were:

1. It is of great importance to study the exposome as a non-genetic driver of human health and disease and the development of low-grade gut inflammation.
2. New concepts and sensitive methods needed, such as exposomics, adductomics, non-targeted biomonitoring and stable isotope assisted LC-HRMS based metabolomics.
3. Validation of biomarker analysis is needed, not only from an analytical point of view but also to verify the relationship between the concentration of selected biomarkers and the effect of the studied mycotoxin on humans.
4. There is a massive lack of authentic standards for biomarkers and for the identification of xenobiotics (as a basis for reliable testing).
5. The human exposome is vast, highly dynamic and driven by lifestyle and season.

*Virtual WMF pre-conference on Animal Health, November 11, 2021 (chaired by Isabelle Oswald, Institut National de la Recherche Agronomique, Toulouse, France)*

The top 5 lessons learned from this virtual event with a focus on the impact of mycotoxins on animal health were:

1. Both gut health and immunity are significantly compromised by the ingestion of individual mycotoxins (and mixtures) in livestock and fish.
2. The impact of (emerging) (co-)occurring mycotoxins on microbiota and on the enteric nervous system needs to be further investigated.
3. A new effect of a well-known mycotoxin (i.e. zearalenone as metabolic disruptor) and old mycotoxins as new threats (i.e. ergot alkaloids and their bioactive epimers) have been revealed. Hence, further studies and risk assessment are needed.
4. Aquaculture: many mycotoxins are detrimental to fish but there is a lack of knowledge on toxicity and the occurrence of mycotoxins in fish feed.
5. More research is needed to assess the full impact of (low dose) mycotoxin exposure on animal health and the resulting economic consequences.

*Virtual WMF pre-conference on analysis, February 1, 2022 (chaired by Rudolf Krska, University of Natural Resources and Life Sciences, Vienna – BOKU, Austria)*

The top 5 lessons learned from this pre-conference with an emphasis on analytical methods for the determination of mycotoxins were:

1. The use of technical replicates for validation, as suggested by most guidelines, underestimates measurement uncertainty. It is therefore recommended to rather use a range of individual samples ideally from different lots.
2. Determination of mycotoxins in aquatic ecosystems shall be further investigated but requires ultra-sensitive LC-MS/MS based methods.
3. Hyperspectral imaging, NIR and fluorescence spectroscopy have shown good promise for non-destructive (indirect) detection of mycotoxins in grains and nuts.
4. General indicators of low quality maize, such as insect damage or discoloration, are useful features for optical speed sorting of clean and aflatoxin/fumonisin contaminated kernels.
5. Revolutionary developments in mid IR photonic technologies, including on chip devices, show great potential to determine mycotoxins in grains.

*The 13<sup>th</sup> WMF, Parma, Italy, June 16-18, 2022*

After the worst of the COVID-19 pandemic, a major purpose of the thirteenth WMF was to finally reconnect and to discuss the latest developments of the last 3 years. The top 5 lessons learned were:

1. Big data-based monitoring, supported by machine learning contributes to improved decision support tools including a more accurate forecasting of mycotoxin formation on the field.
2. The negative impact of low levels of mycotoxins on livestock productivity and environmental sustainability need to be fully quantified. The potential of insects to provide valuable proteins combined with the potential for the detoxification of mycotoxins needs to be further explored (= 'mitigation through our friends, the bugs').
3. The effect of mycotoxins as a predisposing factor in the pathogenesis of viral/bacterial diseases and in vaccine and therapy failure is still unclear.
4. The effect of food processing on the fate of mycotoxins at industrial scale (bread, pizza ...) has become state-of-the art with more activities to come.
5. Chronic low-dose exposure of multiple mycotoxins can potentially lead to synergistic effects and



human carcinogenesis. More studies on the relationship of mycotoxins and gut microbiota are required – taking into consideration the potential shift of exposure through greener diets.

#### 4 Conclusions

At the first international conference on mycotoxins organised by IUPAC in 1972, papers focused largely on the control, carry-over and decontamination of mycotoxins. Although the emphasis was on aflatoxins, some papers related to *Fusarium* toxins. The great need for the availability of standards was also pointed out in this first IUPAC conference on mycotoxins and TLC was the mostly employed method (Krogh, 1973). 29 years later, the first WMF was organised in 2001. In total, 16 WMF events have been organised since, 13 of which as physical events including 10 WMFs and 3 joint WMF-IUPAC conferences ('WMFmeetsIUPAC'). Three virtual WMF pre-conferences were organised during the pandemic. The WMF started in the Netherlands and soon spread its wings across Europe, USA, Canada and Thailand with an average turnout of some 300 participants (Table 1) from all over the world. Over the last 50 years, many other highly recognised international conferences were organised by the International Society for Mycotoxicology (ISM, 2023) or the Society for Mycotoxin Research (Society for Mycotoxin Research, 2023), but also by the FAO (FAO, 1977) – next to the beforementioned IUPAC events (IUPAC, 1972). Whereas the focus of these conferences has been on fundamental and applied research carried out by mycotoxin researchers, the WMF established itself as an international networking conference series on mycotoxins where food and feed industry representatives meet with representatives from government, food authorities, food and feed industry and with people from universities and other research institutions from around the world.

The WMF has gradually been expanded from food and feed related technological issues, such as sampling and analysis, prevention, control and reduction to e.g. international and regulatory issues, the role of emerging mycotoxins in food and feed industry and improved human exposure assessment. Over all these years, the conclusions made from each WMF have been summarised by the general conference chair(s) as the 'top 5 lessons learned' on the last day of each conference. 50 years after the first international conference on mycotoxins organised by IUPAC, this article has compiled all 'top 5 lessons learned' presented at the WMF and

'WMFmeetsIUPAC' events organised between 2001 and 2022. As can be seen from this collection of lessons learned, there is a number of burning challenges still unresolved, such as proper sampling, effective biocontrol for aflatoxin reduction and improved plant resistance and forecasting. In addition, there is a wide range of new developments and research questions arising, such as the identification and use of suitable biomarkers to evaluate the human exposure to mycotoxins, the efficacy of detoxifiers in animal husbandry, the LC-MS based determination of – ideally the entire spectrum of – emerging mycotoxins and the use of omics-based tools for the improved understanding of the plant-microbiome-pathogen interaction triangle. From a more global perspective, South East Asia and Sub-Saharan Africa remain at high risk of aflatoxin contamination and considerable co-contamination have been addressed in large projects which have been launched. However, more resources to support important research are still needed to tackle the mycotoxin menace especially in the Global South.

New challenges include climate change which impacts on the increasingly unpredictable (co-)occurrence of toxigenic fungi and related mycotoxins. In order to mitigate the issue, there is a great demand for integrated solutions for the control and reduction of mycotoxins along the food and feed chains including proper waste management and safe use options for contaminated batches such as the production of biofuels.

Latest developments in mycotoxin research include the consideration of the entire human exposome and the validation of appropriate biomarkers for the accurate study of human exposure to mycotoxins. In the area of aquaculture it was found that many mycotoxins are detrimental to fish. However, there is a lack of knowledge on the toxicity and occurrence of mycotoxins in fish feed. More research is also needed to assess the full impact of (low dose) mycotoxin exposure on animal health and the resulting economic and sustainability consequences. Chronic low-dose exposure of multiple mycotoxins can potentially lead to synergistic effects and human carcinogenesis. In addition, more studies on the relationship of mycotoxins and gut microbiota are crucial – taking into consideration the potential shift of exposure through greener diets.

An important lesson learned in the analytical area is the usage of technical replicates – as suggested by most guidelines – for validation purposes, which, however, leads to an underestimation of the measurement uncertainty. For rapid screening/pre-analysis of grains and nuts, hyperspectral imaging, NIR and fluorescence spec-

troscopy have shown good promise for non-destructive (indirect) detection of mycotoxins. In the future, big data-based monitoring, supported by machine learning will increasingly contribute to improved decision support tools, including the more accurate forecasting of mycotoxin formation on the field.

Lessons learned from 16 editions of the World Mycotoxin Forum (including 3 virtual events) 50 years after the first international conference on mycotoxins document a lot of progress in the prevention, reduction and control of mycotoxins. The WMF conference series has demonstrated the importance of such gatherings – not only because of the ‘lessons learned’ but also for the international exchange between industry, food authorities, international organisations and the academia. However, continuous attention and further research efforts are still needed in order to achieve more effective and sustainable mitigation and control measures for mycotoxins and to minimise exposure of humans and animals around the world and especially in the Global South. It is very clear that the issue of mycotoxins has become even more relevant in times of climate change and other global challenges, topics which will continue to be discussed in future WMF gatherings. This is why we are very much looking forward to many more WMFs to come, such as the 14<sup>th</sup> WMF which will be held in Antwerp, Belgium in October 2023.

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### Authors' contribution

Conceptualization, RK and CE; methodology, RK; writing-original draft preparation, RK; writing-review and editing, RK and CE. Both authors have read and agreed to the published version of the manuscript.

### Conflict of interest

The authors have declared no conflict of interest.

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