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Indicators for early identification of re-emerging mycotoxins

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ABSTRACT

The aim of this study was to select the most important indicators for early identification of re-emerging mycotoxins in wheat, maize, peanuts and tree nuts. The study was based on a holistic approach and, consequently, potential indicators were evaluated not only from the food production chain but also from other influential sectors. The study comprised a literature review followed by an expert judgement study. The expert study consisted of a series of individual interviews and a workshop. It used a panel of 25 experts from the Netherlands. The selected indicators for the model commodity wheat included relative humidity, temperature, transport and storage conditions, crop rotation, crop variety, tillage practice, and drying of the kernel. For maize, peanuts and tree nuts, the first three indicators were found to be most important. The results of this study will be used in the development of models for early identification of re-emerging mycotoxins in wheat, maize, peanuts and tree nuts. Such models may be useful for risk managers from feed and food industry and/or governmental authorities to facilitate pro-active feed and/or food safety management.

1. Introduction

Within the European Union many efforts are being made to set up and improve management of food-borne emerging health risks by using pro-active, anticipating and forward-looking approaches. An emerging risk is defined as a risk resulting from a *newly identified hazard* to which a significant exposure may occur or from an unexpected new or increased significant exposure and/or susceptibility to a *known hazard* (which is then called a 're-emerging risk') [1]. Traditionally, the identification and control of food-related hazards that present a (potential) risk to human health focus on known hazards and the relevant food production system. However, in addition, a more pro-active and broader approach is necessary to also identify emerging hazards and, ultimately, prevent them from actually becoming a risk. Using the so-called holistic approach, first presented by the OECD [2] and further elaborated upon, among other, in the European projects PERI-APT [3], EMRISK [4] and SAFE FOODS [5–7], such a broader approach should not only focus on the specific food supply chain, but also consider its host environment. An illustration of the host environment of the production chain – with its influential sectors (areas of disciplines) – is presented in Fig. 1. For the identification of emerging hazards in the food supply chain, indicators can be derived from the various influential sectors. An indicator is defined as a signal that indicates (directly or indirectly) the possibility of the occurrence of a (re-)emerging hazard [1,3,4].

An important case of food-borne emerging hazards to human health is the presence of mycotoxins in various harvest crops used for feed and food production. Mycotoxins are toxic secondary metabolites produced by fungi that colonize crops in the field or post-harvest. Over one hundred different mycotoxins have been described and new ones are being identified [8]. The consumption of contaminated crops, or food products made thereof, may pose a potential threat to human health [8–10]. Health effects caused by mycotoxins are diverse and include, among other, growth disorders, immunomodulation, carcinogenicity, and mutagenicity [11,12]. Emerging mycotoxin hazards may arise from unidentified new form(s) of a (group of) known mycotoxin(s), not well-known mycotoxins, and increased occurrence of known mycotoxins. The latter, i.e., the re-emerging mycotoxin hazards, seem to be important—in addition to newly identified mycotoxins. In the period 2003–2006 about 30–35% of the notifications received through the European Union Rapid Alert System for Feed and Food (RASFF) concerned known mycotoxins (see http://europa.eu.int/comm/food/food/rapidalert/index_en.htm). In this period, about 90–95% of the notifications on mycotoxins concerned aflatoxins; notifications on fumonisins and ochratoxin A were also rather frequent. In the Netherlands, the maximum limits for the toxins aflatoxins, ochratoxin A, fumonisins and deoxynivalenol (DON) were exceeded in 2007 [13].

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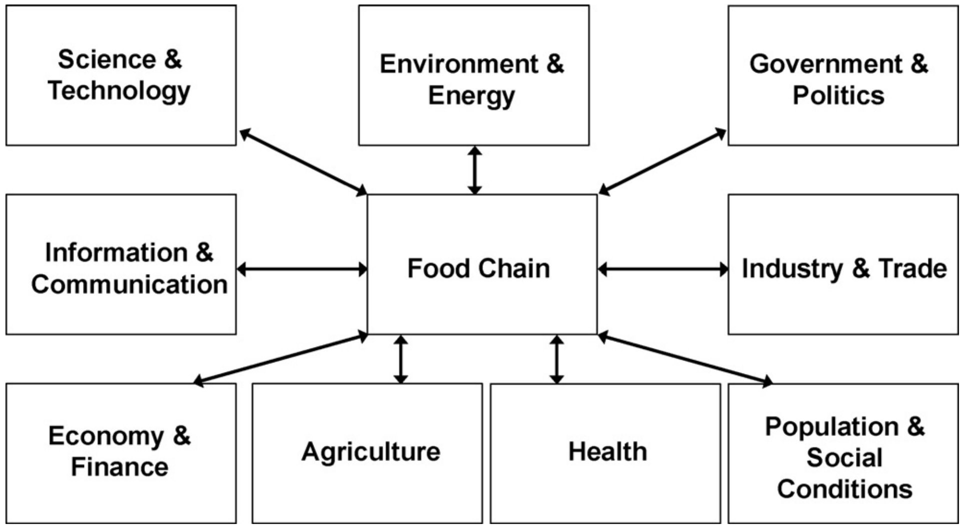

Fig. 1. Concept for the food chain's host environment (adapted from Noteborn et al. [3] and Noteborn [4]).

In order to control mycotoxin contamination of harvest products, several models have been developed that aimed at predicting the occurrence of specific (known) mycotoxins in a particular commodity. Such models have been developed, among other, for DON in wheat in Canada [14] and in the Netherlands [15,16], and for DON and zearalenone in wheat in Italy [17]. For maize in Italy also predictive models have been developed for both fumonisin [18] and aflatoxin B_1 [19]. In Canada, a preliminary model for the toxins DON and fumonisin in maize has been developed [20]. These predictive models are mainly based on meteorological and agronomic parameters known to affect the occurrence of the particular toxin(s). However, many more factors from inside as well as outside the food production chain are, to a more or lesser extent, relevant for the occurrence of re-emerging mycotoxin hazards.

The aim of the current study was to select the most important indicators for early identification of re-emerging mycotoxin hazards in wheat, maize, peanuts and tree nuts, by evaluating all potential indicators, applying a holistic approach. Wheat and maize were chosen as commodities as these are the most important crops grown in the European Union; peanuts and tree nuts were chosen because the majority of the RASFF notifications between 2003 and 2006 concerned these food items (http://europa.eu.int/comm/food/food/rapidalert/index_en.htm). The study comprised a literature review followed by an expert judgement study. The results, i.e., the most important indicators, will be used for the development of models for early identification of the presence of re-emerging mycotoxins in wheat, maize, peanuts and tree nuts. MYCONET, another European study, focused on the selection of indicators and the development of a conceptual model for emerging (including new, not well-know and known) mycotoxins produced by *Fusarium* species in wheat [21–23].

2. Materials and methods

2.1. Study design

The study comprised a literature review to list all potential indicators from the food and feed supply chain and its influential sectors (Fig. 1), followed by expert consultation aimed at selecting the most important ones. The literature review covered, among other, publications on field and experimental studies, predictive models, and management and prevention strategies. It resulted in a gross list of 163 potential indicators (presented in [24]). Next, a background document was prepared for setting up and executing the expert judgement study. It consisted of information on the holistic approach, a selection of the most relevant re-emerging mycotoxins in wheat, maize, peanuts and tree nuts, and the gross list of indicators.

Expert judgement was elicited by a two-stage approach: a series of in-depth interviews followed by a workshop. This approach enabled combining the main advantages of these two expert judgement techniques, particularly individual response and group interaction.

2.2. Individual interviews

2.2.1. Preparation

The aim of the interviews was to obtain argued judgements from individual experts on the main influential sectors with their main indicators to identify re-emerging mycotoxins in wheat, maize, peanuts and tree nuts. The latter two food items were considered as one group, hereafter referred to as 'nuts'. A fixed interview format consisting of open questions was defined beforehand. Twenty Dutch experts were invited for the interviews. The selection of the experts was such that all influential sectors (Fig. 1), except health, would be covered by the expertise of the experts. The sector health was not included as it is related to the potential health risks posed by exposure to mycotoxins, rather than to the presence of these toxins in crops (our study focus). Experts were identified based on participant lists of previous and running projects on emerging risks [3–5], the project team's network, and suggestions from the approached experts. Prior to the interviews, the experts were sent background information on the study, including its aim and design.

2.2.2. Interviews

The experts from one organization were interviewed together as they were expected to complement each other's expertise. Each interview was led by two or three persons from the project team. At the start of the interview, the holistic approach was explained to the expert. Then, the expert was asked to indicate the main influential sectors for identification of re-emerging mycotoxins in the three commodities, and to name the influential sectors that fell within his expertise. Next, the expert was asked to select relevant indicators within each of the main influential sectors identified, and to explain the rationale for selection. After the individual interview, each expert (or couple) received a written report of the interview. Each report included a list of the influential sectors and indicators (within each sector) mentioned by the expert. The expert was asked to add missing influential sectors and/or indicators, if any. Then, the expert was requested to prioritize the importance of the indicators identified for each of the three commodities, using four semi-quantitative categories from 0 (unimportant) to 3 (highly important). In addition, he was asked to select the five most important indicators, taking into account all three commodities simultaneously. If two experts (from one organization) were interviewed at the same time, they were asked to respond to the report together.

2.2.3. Analyses

The information obtained in the interviews was stored and analysed using a Microsoft Office Excel datasheet (see http://office.microsoft.com/). Data were analysed per interview (not per expert). The relative rankings (per interview) of the indicators were grouped into four classes using a scale from 0 (unimportant) to 3 (highly important). Next, for each indicator the ranks were summed over the interviews. All interviews were equally weighted. This resulted in an overall score per indicator, indicating its relative importance per commodity. The frequency with which each indicator was selected in the interviews within the top five indicators was calculated as well. From these results the overall 10 main indicators were derived based on (1) the extent to which the indicators were mentioned (as being important) by the experts, (2) the ranking of the indicators for the three commodities, and (3) the extent to which the indicators were listed in the top five. The set of 10 main indicators was used as the starting point for the workshop.

2.3. Workshop

After completion of the series of individual interviews, a workshop was organized with the experts. The ultimate aim of the workshop was to arrive at consensus on the most important indicators for identification of re-emerging mycotoxins. The workshop focused on wheat as model commodity. The aim of the workshop consisted of the following objectives:

1. To further reduce the set of 10 main indicators resulting from the series of interviews.
2. To define the selected most important indicators (reduced set) in more detail.
3. To identify interactions between the selected indicators.
4. To reach consensus on the most important indicators and relevant interactions.

For the workshop, 27 experts from the Netherlands were selected such that expertise on the main influential sectors and the set of 10 main indicators, resulting from the series of interviews, would be covered. Furthermore, experts were selected such that various backgrounds, including risk management/risk assessment and food industry/government, would be represented at the workshop. Prior to the workshop, the experts were sent background information on the project and the workshop objectives. The workshop started with an explanation of the overall results from the series of interviews, including the set of 10 main indicators. The rest of the workshop consisted of an individual ranking task, discussions in subgroups, and a plenary feedback session. In the ranking task, the individual experts were asked to rank the 10 main indicators on a scale from 1 (least important) to 10 (most important) according to their relative importance. Next, the total score for each indicator was calculated by adding up the individual experts' scores for the particular indicator. Thereafter, group interaction within subgroups was used to further select the most important indicators. Two subgroups of a nearly equal number of experts were formed. The subgroups were asked to select the most important indicators, based on the ranking results, and to add missing indicators, if any. The aim of the consecutive discussion in the subgroups was to further define the selected most important indicators (reduced set) in more detail, and to identify important interactions between the selected indicators. At the end of the workshop a plenary feedback session was held in which the two subgroups presented their results. An overall group discussion was then held with the aim to reach final consensus among the panel of experts on the most important indicators, their definitions and relevant interactions between indicators.

3. Results

3.1. Expert panel

Seventeen experts from 13 organizations participated in the interviews. This resulted in 13 interviews: four with governmental (related) organizations, four with researchers, and five with feed and food industry representatives. Most experts had expertise, in their opinion, on the influential sectors food chain (10 interviews); agriculture (8 interviews); industry and trade (8 interviews), and government and politics (6 interviews). Overall, each influential sector was covered by two or more interviews.

Fourteen experts attended the workshop, six of whom had participated also in the interviews. Out of the 14 participants, 4 were from government (related) bodies, 5 from research organizations, and 5 from the (feed and food) industry. The two subgroups consisted of 7 persons each, with experts from industry and government not attending the same subgroup.

3.2. Individual interviews

The main influential sectors as indicated in the interviews included: agriculture (13 interviews), environment and energy (12 interviews), food chain (11 interviews), and industry and trade (9 interviews). The five other influential sectors were considered less important, as they were indicated as an important influential sector in only three or fewer interviews. The full list of indicators mentioned during the interviews included approximately 130 indicators. All of these could be classified into one of the nine influential sectors; the other influential sectors were judged not to be relevant.

Twenty-one indicators – from seven different influential sectors – were mentioned in more than 25% of the interviews (Table 1). Among these, indicators mentioned in more than 50% of the interviews were: humidity/drought, temperature, storage conditions, changes in eating patterns, transport conditions, tillage practice, and regulations with respect to mycotoxins. The various indicators were ranked in order of importance per commodity, in ten interviews for wheat, eight for maize and nine for nuts. Table 1 also shows the results of this ranking, expressed by the total scores for the various indicators. For all three commodities, the three indicators that ranked highest were: humidity/drought, temperature, and storage conditions. These three indicators were followed by tillage practice for wheat, and transport conditions for maize and nuts. The top five most important indicators were indicated by the experts in ten of the thirteen interviews. Fig. 2 presents the indicators that were mentioned in the top five in two or more interviews. Of these, humidity/drought was selected most (seven interviews), followed by temperature (five interviews), storage conditions (four interviews) and crop variety (three interviews).

By combining the different analyses of importance of the indicators, the ten main indicators for all three commodities were identified (Table 2). In this way all indicators were selected that had been mentioned in more than 50% of the interviews and/or in the top five rankings of two or more interviews, in combination with

Table 1
Most frequently mentioned indicators (>25% of the interviews) for early identification of re-emerging mycotoxins in wheat, maize and nuts, with percentage of interviews (n = 13), as well as total score of each indicator per commodity.

Influential sector/Indicator	Percentage interviews[a]	Total score per indicator and per crop (with rank)[b,c]		
		Wheat	Maize	Nuts
Food chain				
Traceability	38	9	9	12
Mixing	31	7	7	6
Transport conditions	**62**	12	12 (4)	15 (4)
Storage conditions	**77**	20 (3)	17 (1)	20 (1)
Agriculture				
Scale of production	46	10	11	13
Tillage practice	**54**	16 (4)	10	2
Crop variety	46	14	8	2
Genetically modified crops	31	7	7	1
Crop rotation	46	13	7	0
Irrigation and drainage	31	7	7	9
Use of pesticides	31	7	8	6
Harvest conditions	31	10	11	10
Environment and energy				
Humidity/drought	**77**	23 (1)	17 (1)	19 (2)
Temperature	**77**	22 (2)	16 (3)	18 (3)
Industry and trade				
Global trade	38	8	6	6
Changes in trade flows	31	5	4	4
Other markets (e.g., biofuel)	31	3	2	0
Government and politics				
Regulations with respect to mycotoxins	**54**	14	11	12
Communication and information				
Information flows	46	6	6	10
Education within food production chain	46	12	10	13
Population and social conditions				
Changes in eating pattern	**69**	10	11	8

[a] Percentages >50 are printed bold.
[b] Based on 10 interviews for wheat, eight interviews for maize and nine interviews for nuts.
[c] The ranking of the four indicators with the highest score is in parentheses.

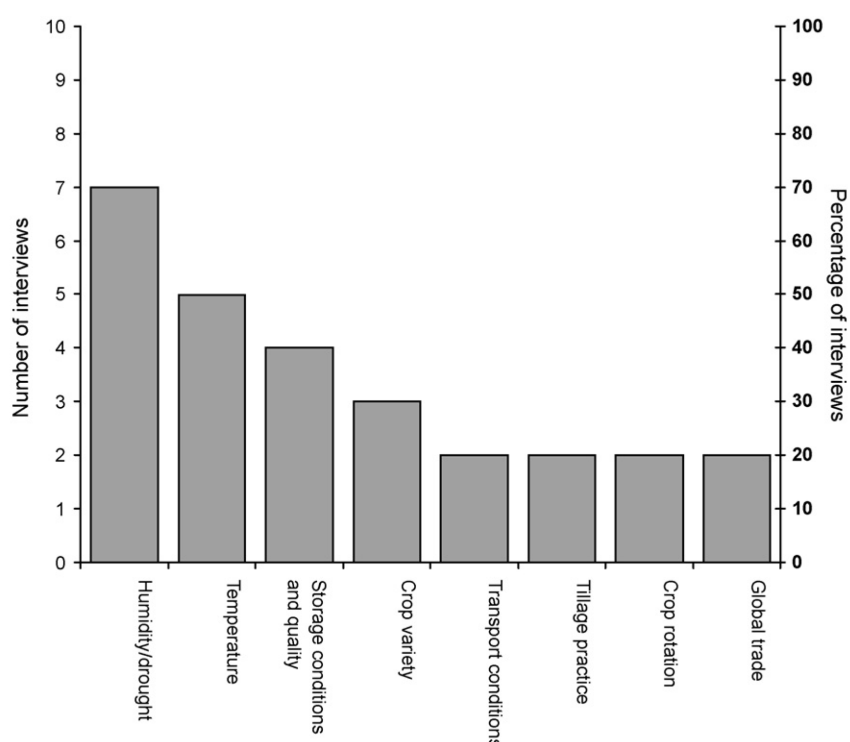

Fig. 2. Number of interviews in which the experts classified the particular indicators in the top five of most important indicators.

Table 2
The 10 main indicators for identification of re-emerging mycotoxins in wheat, maize and nuts, as well as total score and relative ranking (based on total score) per indicator for wheat, as judged by individual experts (during workshop).

Indicator	Total score[a]	Ranking
Humidity (relative)/drought	128	1
Temperature	97	2
Crop rotation	93	3
Tillage practice	83	4.5
Storage conditions	83	4.5
Crop variety	80	6
Transport conditions	66	7
Global trade	37	8
Regulations with respect to mycotoxins	33	9
Changes in eating patterns	14	10

[a] Maximum score is 130.

the indicators that were ranked highest per crop. From the ten main indicators, the experts considered the two weather-related indicators humidity/drought and temperature, and storage conditions more important than the seven other ones. For several indicators differences appeared in the results from the various analyses. Crop variety, crop rotation and global trade were mentioned among the top five indicators but not in more than 50% of the interviews. Of these, crop variety was ranked highest for wheat. In addition, changes in eating patterns and regulatory matters with respect to mycotoxins were mentioned in more than 50% of the interviews but not among the top five indicators.

3.3. Workshop

3.3.1. Individual ranking

The results from the experts' individual ranking of the ten main indicators for wheat are presented in Table 2. Humidity/drought was evaluated as the most important indicator for identification of re-emerging mycotoxins in wheat, followed – in order of importance – by temperature and crop rotation. Tillage practice, storage conditions, and crop variety were similar in importance, followed by transport conditions. The other indicators were judged to be less relevant.

3.3.2. Group discussion

In both subgroups, group interaction to select the most important indicators resulted in consensus on the following most important indicators: humidity/drought (which after discussion was named 'relative humidity'), temperature, crop rotation, crop variety, tillage practice and storage conditions. One subgroup selected drying of the kernel to be an additional indicator. Moreover, this subgroup also selected transport conditions, but integrated with the indicator storage conditions, as transport could be seen as a form of temporary storage. During the overall feedback session of the workshop, consensus was reached by the entire group on both aspects. The definitions of the various indicators as well as the potential interaction terms identified showed to be comparable for the two subgroups. Consensus on these aspects was reached within the total group. Table 3 presents the results, i.e., the seven most important indicators together with their definitions. The following potential interactions between the selected indicators (with rationale) were identified:

1. Relative humidity × temperature: temperature is only relevant when relative humidity is conditioning.
2. Crop rotation × tillage practice: tillage is especially relevant with maize as pre-crop (crop that was grown before the current crop).
3. Transport and storage conditions × drying of the kernel: if kernels are not dried properly, transport and storage conditions are more important.

4. Discussion

The study presented in this paper used a holistic approach [3–7] to select the most important indicators for early identification of re-emerging mycotoxins. Correspondingly, experts with a variety of backgrounds and expertise in the various influential sectors were consulted. Taking this broad (holistic) point of view ensured that a wide range of indicators from all influential sectors were evaluated for their relevance for identification of re-emerging mycotoxins in wheat, maize, peanuts and tree nuts. This resulted in approximately 130 potential indicators – covering the nine relevant influential sectors – initially mentioned in the interviews and in the seven most important indicators for identification of re-emerging mycotoxins in wheat eventually defined in the workshop.

The two-stage design chosen in the expert study, including a series of individual in-depth interviews followed by a workshop, was a very useful approach for the current subject of interest. During the individual interviews, the holistic approach for emerging risk identification could be explained to the experts, if necessary. Also, experts were asked for their individual response and for the rationales of their judgements. Due to time constraints, the workshop focused on wheat as a model commodity, rather than all three commodities covered in the interviews. The workshop made it

Table 3
The seven most important indicators for identification of re-emerging mycotoxins in wheat, together with their description.

Indicator	Description
1. Relative humidity	Relative humidity (RH) during crop growth. Ideally, RH is expressed as leaf wetness (moisture on the surface of the leaf). Precipitation (in combination with temperature) and irrigation normally are used as alternative. For RH, three time windows during crop growth are important: the period around/at flowering, two weeks before harvest, and delayed harvest
2. Temperature	Temperature during crop growth. Temperature is only relevant in case humidity is conditioning (thus, in combination with humidity). Consequently, the same three windows as defined for relative humidity are also important for temperature
3. Crop rotation	The crop that is grown on the field prior to wheat and/or in previous year(s). Growing maize before wheat or wheat before wheat increases the possibility of the occurrence of mycotoxins. Especially maize before wheat is a potential risk factor
4. Crop variety	Susceptibility/resistance of the used variety to mycotoxin-producing fungi. Resistance levels are variable (not absolute), and not always clearly defined and also not stable over time. Recommended varieties vary among countries
5. Tillage practice	Tillage practice used before the crop is sown. Tillage practices may include: no tillage, medium tillage, deep-tillage (and burning). Tillage practices vary among countries. In the Netherlands, burning is prohibited and deep-ploughing is not used because of erosion.
6. Drying of the kernel	In the EU, a moisture content <15% of the grain is recommended during storage, and therefore proper drying before storage is often necessary
7. Storage (and transport) conditions	In case grain moisture content is kept at or below 15% mycotoxins will not be formed. Moisture contents above 15% pose a risk for the formation of mycotoxins, and also favour the growth of other fungi. Presence of pests and/or insects as well as high fluctuations in outside temperature could lead to a local increase in moisture content. The moisture content of the grain at the start of transportation or storage is therefore important but can be controlled by proper drying after harvest. Kernel damage can be relevant when moisture content increases

possible to have group interaction to discuss similarities and differences in experts' opinions. This group interaction finally resulted in consensus on the seven most important indicators, together with their definitions and interactions, for identification of re-emerging mycotoxins in wheat. A total of 25 persons, covering a wide range in expertise and fields of interests, participated in the entire expert study. So consulting additional experts is believed not to lead to changes in the results for wheat.

Although a holistic approach was followed in this study, the seven main indicators for wheat all belonged to the influential sectors food supply chain, agriculture, environment (weather), and energy, and not to influential sectors that are less directly related to the formation of mycotoxins (Fig. 1). This could, partly, be explained by our study focusing on re-emerging mycotoxins. It was expected that indicators from other influential sectors, such as industry and trade or health, would have been judged more important in case the study focus also had included potential health risks and/or unidentified or poorly characterized mycotoxins.

Another study that focused on selection of indicators for emerging mycotoxins in wheat (including new, not well-known and known toxins) resulted in an identical list of seven indicators judged to be most important [16,22]. Apparently, the most important indicators for both re-occurring known mycotoxins in wheat and (the entire group of) emerging *Fusarium* mycotoxins in wheat are perceived not to differ substantially. The results of expert consultation regarding the seven most important indicators for wheat (Table 3) also agreed very well with findings from epidemiological studies and predictive mathematical models on known mycotoxins in wheat in various other countries. Therefore, these results – retrieved by consulting Dutch experts – are considered to be valid throughout Europe. Preliminary results from a field survey in the UK showed that region, pre-crop (maize), tillage practice, and varietal resistance affected the occurrence of mycotoxins produced by *Fusarium* spp. in wheat [25]. In Canada, the content of DON in wheat was found to be affected by year – which was attributed to weather conditions – followed by crop variety and preceding crop, but no effect was found from tillage practice [26]. An effect of the pre-crop and maize variety on DON accumulation in wheat was also reported from a field survey conducted in the period 1997–2000 [27]. In the DONcast model, weather variables related to rainfall and temperature in three different periods around heading were used to predict the DON content in wheat [14]. In a later version of this prediction model, agronomic variables were incorporated, including wheat variety, tillage practice, and pre-crop [20]. In a neural network model for the prediction of the DON content of wheat, weather data and preceding crop were included as predictive variables [28]. Predictive models for DON in winter wheat in the Netherlands included variables related to weather in different periods of the growing season as well as region, wheat resistance level and the use of fungicides [15,23]. As data on other agronomic variables was lacking, the effects of these variables could not be analysed. From field surveys in Canada on the content of DON and fumonisin B_1 of maize, these two mycotoxins were found to be mostly associated with (maize) hybrid and year effects caused by weather, and/or geographical differences [29]. Additionally, an effect of the preceding crop was found, with higher incidences of DON and fumonisin B_1 occurring, if maize was grown after wheat compared with maize after maize. The importance of the indicators related to post-harvest conditions (i.e., transport and storage conditions, drying of the kernel) have been stressed in literature as well [8]. The experts' rationales for the selection of the main indicators coincided well with factors reported, such as drying of the kernel to less than 15% moisture content and absence of storage pests that can produce metabolic water and heating [30].

Based on the interviews it is highly presumable that out of the seven main indicators selected for wheat, the three indicators relative humidity, temperature, and storage and transport conditions could also be used for the identification of re-emerging mycotoxins in maize, peanuts and tree nuts, as these indicators were ranked highest for these commodities in the interviews (Table 1). The other four main indicators for wheat (crop rotation, crop variety, tillage practice and drying of the kernel), as selected in the workshop, are all mentioned as important issues in the code of practice for the prevention and reduction of mycotoxins in cereals (including maize) and peanuts [31,32]. These indicators may, therefore, also be valuable for identification of re-emerging mycotoxins in these commodities (maize and peanuts). The code of practice for prevention and reduction of aflatoxins in tree nuts only mentions crop variety as an important issue [33]. Since tree nuts are grown in orchards, crop rotation and tillage practice are not relevant. To verify the selected indicators and identify additional indicators (if necessary) for identification of re-emerging mycotoxins in maize, peanuts and/or tree nuts, more data and/or expert judgement will be needed. The interview results could hereby used as a starting point. Based on these results, additional indicators might include scale of production and education. During the workshop, the indicator changes in eating patterns and regulations with respect to mycotoxins were judged to be related to the potential health risks of mycotoxins, rather than occurrence of these toxins. As we focused on mycotoxin presence, these indicators were found not to be relevant for the three commodities.

Although most of the indicators were found important for all commodities considered, it was recognized that they do not affect the occurrence of different mycotoxins in the same way. Therefore, as a next step, risk categories within each of the selected indicators, together with their impact, should be defined for the most relevant re-emerging mycotoxins in wheat, maize, peanuts and tree nuts. These next steps in the development of models for early identification of re-emerging mycotoxins in the different commodities are currently being taken [24]. Such models may be used by risk assessors and risk managers to anticipate the potential presence of mycotoxins by, for example, adjusting sampling strategies or by giving advice along the food chain. For industrial stakeholders, these models may also be helpful in purchase decisions or strategies to improve the quality of the commodities used for feed and food production.

5. Conclusions

Based on literature and expert judgement, the seven most important indicators for identification of re-emerging mycotoxins in wheat include: relative humidity, temperature, transport and storage conditions, crop rotation, crop variety, tillage practice, and drying of the grain. Potential interactions were identified between relative humidity and temperature, between crop rotation and tillage practice, and between drying of the grain and transport and storage conditions. The first three indicators are also highly important for maize, peanuts and tree nuts. The relevance of additional indicators for identification of re-emerging mycotoxins in these crops needs further investigation. The results of this study will be used as input into models for early identification of the presence of re-emerging mycotoxins in wheat, maize, peanuts and tree nuts. Such models may help risk managers in their decision-making processes.

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