National Institute
for Public Health
and the Environment

Report 320111002/2008

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A holistic approach

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RIVM Report 320111002/2008
RIKILT Report 2008.004
PRI Report 186

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A holistic approach

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This research has been performed within Work Package 2 of the SAFE FOODS project (task 2.10.3) within the framework of EU 6th Framework Programme, Research Program 9.4.1 ('New food safety risks') of the Dutch Food and Consumer Product Safety Authority, and Strategic Research Program 'Food Safety' (theme 6) of the Dutch Ministry of Agriculture, Nature and Food Quality.

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Abstract

Development of a model to assess the occurrence of mycotoxins in wheat, maize and nuts using a holistic approach

The most important factors for the prediction of the occurrence of mycotoxins in food include weather conditions (such as temperature and atmospheric humidity), agricultural factors (such as crop rotation and soil cultivation) and factors within the food chain (such as crop drying and storage conditions). Mycotoxins are toxic chemical compounds produced by fungi that can occur in various foodstuffs. The National Institute for Public Health and the Environment (RIVM) and Wageningen University and Research Centre (Wageningen UR) have developed a blueprint of a model to assess the risk of occurrence of re-emerging mycotoxins in wheat, maize and nuts. In order to protect consumers against mycotoxins, it is essential to detect any possible contamination with fungi at the earliest possible stage. Governmental organizations and the commercial sector can use the proposed model as an early detection tool.

During the development of the model, an investigation was necessary to determine which factors, both inside and outside the food chain, could be used as indicators for the presence of mycotoxins. This investigation included interviews and a workshop with experts from various fields related to this subject. These insights have led to the development of a conceptual ‘traffic light’ model that indicates the risk of occurrence of mycotoxins with color signals; red indicates high risk, yellow medium risk, and green low risk. The prediction capacity of the conceptual model will be further investigated in a follow-up study.

Key words: mycotoxins, food, emerging risks, indicators, model

Rapport in het kort

Ontwikkeling van een model om de aanwezigheid van mycotoxinen op tarwe, maïs en noten in te schatten volgens een holistische benadering

De belangrijkste factoren om de aanwezigheid van mycotoxinen in voedingsmiddelen te kunnen voorspellen zijn: weersomstandigheden (zoals temperatuur en luchtvochtigheid), landbouwkundige factoren (zoals gewasrotatie en grondbewerking) en factoren in de voedselketen (zoals het drogen van de gewassen en opslagcondities). Mycotoxinen zijn giftige chemische stoffen die door schimmels worden geproduceerd en in verschillende voedingsmiddelen terecht kunnen komen. Het Rijksinstituut voor Volksgezondheid en Milieu (RIVM) en Wageningen Universiteit en Researchcentrum (Wageningen UR) hebben een conceptmodel ontwikkeld waarmee de aanwezigheid van mycotoxinen op tarwe, maïs en noten kan worden geschat. Om consumenten tegen mycotoxinen te kunnen beschermen is het noodzakelijk om een mogelijke besmetting met schimmels zo vroeg mogelijk te ontdekken. Overheidsorganisaties en het bedrijfsleven kunnen het model als hulpmiddel hierbij gebruiken.

Bij de ontwikkeling van dit conceptmodel is onderzocht welke factoren binnen en buiten de voedselketen gebruikt kunnen worden als indicatoren voor de aanwezigheid van mycotoxinen op tarwe, maïs en noten. Hiervoor zijn interviews en een workshop met deskundigen uit verschillende invalshoeken gehouden. Met deze inzichten is een concept ‘stoplicht’-model ontwikkeld dat de mate van het risico op de aanwezigheid van mycotoxinen aangeeft door middel van een rood (hoog risico), geel (gemiddeld risico) of groen (laag risico) signaal. In een vervolgstudie zal het voorspellende vermogen van het conceptmodel verder worden onderzocht.

Trefwoorden: mycotoxinen, voeding, opkomende risico’s, indicatoren, model

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Contents

Summary

This report describes the development of a blueprint of a model to assess the risk of occurrence of re-emerging mycotoxins in wheat, maize, peanuts and tree nuts. This model may be used by risk assessors, risk managers and industrial stakeholders to anticipate on the potential presence of mycotoxins by proactive risk management strategies or by adjusting purchasing strategies.

Various fungi and mycotoxins can occur on wheat, maize, peanuts and tree nuts. To select the most relevant mycotoxins for which the model should be developed, the occurrence, intake and toxicity of the different mycotoxins in each of the four commodities was evaluated. DON, OTA, T-2 and HT-2 seem to be the most important mycotoxins in wheat and maize, while aflatoxins seem to be the most important mycotoxins in peanuts, tree nuts and maize.

For the development of the model, a holistic approach was used in which not only indicators related to the food production chain, but also indicators from influential sectors outside the food production chain were studied. Based on a literature survey and an expert study, consisting of in-depth interviews and a workshop, relevant indicators for the model were identified. Fourteen experts with expertise on various influential sectors participated in the interviews, resulting in an overall selection of ten important indicators for all commodities. The workshop focused on wheat and consensus was reached on the seven most important indicators for the risk of occurrence of re-emerging mycotoxins in wheat, the definitions for these indicators and sub-indicators and the interrelationships between these (sub-)indicators.

The indicators and sub-indicators as defined for wheat during the workshop were critically reviewed for their predictive value for maize, peanuts and tree nuts, based on the results of the interviews and additional literature research. Additional indicators and sub-indicators were defined for maize, peanuts and tree nuts. Overall, the most relevant indicators for the four commodities are temperature and (relative) humidity, crop variety, crop rotation, tillage, drying of the kernel, storage and transport conditions, insect damage and blanching of nuts. Some of these indicators (rotation, tillage, and blanching of nuts) are not relevant for all commodities.

For all indicators, measurable sub-indicators (model parameters) were defined such as ‘sensitivity towards fungal contamination’ as a sub-indicator for ‘crop variety’. For these (sub-)indicators different risk categories were defined to facilitate inclusion in the model. Depending on the indicator, two (‘red’ and ‘green’) or three (‘red’, ‘yellow’ and ‘green’) risk categories were defined referring to a, respectively, ‘high’, ‘intermediate’ and ‘low’ risk of occurrence of mycotoxins. The risk categories are separated from each other by threshold values that are referred to as ‘cut-off values’ in this report. Since the most favorable conditions are different for the various mycotoxins, cut-off values were defined in such a way that it is expected that conditions that are most favorable for the most relevant mycotoxins in the specific commodity can be distinguished from less favorable and unfavorable conditions. Interrelationships between parameters were included in the risk categories. Furthermore, relative importance scores were assigned to each (sub-)indicator for each commodity.

A blueprint of a ‘traffic light model’ was developed for the risk of occurrence of mycotoxins in each of the four commodities (wheat, maize, peanuts and tree nuts). By including different risk categories, cut-off values and importance scores for each commodity, this model was specified for each commodity. In this model, the user can insert input on the various sub-indicators, leading to a classification for the

occurrence of mycotoxins into a low (green), intermediate (yellow) or high (red) risk. Depending on the cut-off values of the different risk categories, the user input for each indicator will fall into one of these risk categories, leading to a score of 0 (green), 1 (yellow) or 2 (red). These scores together with the importance factors given to the different (sub-)indicators, determine the output signal.

Also, possible data sources for the indicators of the model are listed in the current report. Before this conceptual model can be used as a model to assess the risk of occurrence of re-emerging mycotoxins in wheat, maize and nuts, a performance assessment is necessary. To enable implementation of the model for governmental stakeholders, an infrastructure should be established to obtain sufficiently detailed information on all indicators included in the (conceptual) model. Some industrial stakeholders may already have data available on most of these indicators for various purposes.

1 Introduction

Many efforts are undertaken in the European Union to improve the risk management of food-borne emerging risks by using pro-active, forward-looking approaches. A distinction can be made between emerging risks related to 1) a significant exposure to a hazard not recognized earlier, and 2) a new or increased exposure to a known hazard (which is then called a 're-emerging risk'). To control (re-)emerging risks pro-actively, it is necessary to explore a broader area of disciplines which are related to or influence the food production chain, rather than analysing solely the relevant food supply chain. Inspired by the OECD report 'Emerging Risks in the 21st Century' (OECD, 2003), a holistic approach has been developed and elaborated upon in several research projects (Noteborn et al., 2005; Noteborn, 2006; Van der Roest et al., 2007). In 2004 and 2005, a holistic approach was applied on mycotoxins in a project sponsored by the Dutch Food and Consumer Safety Authority (VWA). A preliminary inventory was made of relevant indicators in the food supply chain for fungal growth and mycotoxin production in various commodities. Furthermore, the available data sources of these indicators were identified (Park and Bos, 2007). Within task 2.10.3 of the SAFE FOODS project, which is funded by the 6th framework program of the EU, a model to assess the risk of occurrence of (re-)emerging mycotoxins in wheat, maize and nuts is developed using a holistic approach. From 2006 onwards, these activities on mycotoxins were combined. From 2007 onwards, activities within a project on mycotoxins financed by the Dutch Ministry for Agriculture, Nature and Food Quality (LNV), were also included.

The current report describes the development of a blueprint of a model to assess the risk of occurrence of re-emerging mycotoxins in wheat, maize and nuts using a holistic approach. Wheat and maize were selected because these commodities are used as model commodities in various other Work Packages of the SAFE FOODS project. Nuts were selected because the VWA frequently encounters peanuts, pistachios, dried figs and to a lesser extent hazelnuts that are contaminated with excessive levels of aflatoxin B1 and total aflatoxin. In addition, the most common notifications of mycotoxin hazards received by the EU RASFF (Rapid Alert System for Food and Feed) system in the last couple of years concern aflatoxin contamination of nuts (mainly pistachios, peanuts and hazelnuts). The aim of the model is restricted to assess the presence of re-emerging (i.e. known) mycotoxins and not the related health risk. For emerging (i.e. not yet known) mycotoxins, it will be difficult to identify specific indicators and develop a model, but the indicators for re-emerging mycotoxins will probably also be valuable for emerging mycotoxins.

First, a literature search was performed to define the most relevant mycotoxins and to establish a gross list of indicators that may be relevant for the occurrence of mycotoxins on wheat, maize and nuts (described in chapters 2 and 3). Thereafter, an expert study consisting of a series of in-depth expert interviews followed by a workshop was performed to define the most important indicators that can be used in the model (chapter 4). The results of the interviews and the workshop were used to develop a blueprint of a model to assess the presence of re-emerging mycotoxins on wheat, maize, peanuts and tree nuts (chapter 5). In chapter 6, data sources that are currently available to and used by governmental and industrial stakeholder are described and possible additional data sources for the indicators that were included in the blueprint of the model are discussed. Before this conceptual model can be used to assess the risk of occurrence of re-emerging mycotoxins in wheat, maize and nuts, a performance assessment is necessary, by means of analyzing a sufficient number of historical and/or ‘real-time’ cases of mycotoxin contamination. Also, the data sources for the different indicators have to be filled out into more detail.

2 Identification of most relevant mycotoxins

To select the most relevant mycotoxins for which the model should be developed, the occurrence of mycotoxins in several product categories was evaluated based on notifications on mycotoxins received by the EU's RASFF (Rapid Alert System for Food and Feed). Also the daily intake (exposure) and the toxicity of the main mycotoxins in wheat, maize and nuts were evaluated based on literature reviews (see below).

2.1 Overview RASFF mycotoxin hazards

Under the RASFF system, members, such as national food control authorities, are obliged to notify any measures regarding to food safety, such as recalls of food and feed products and arrestment of imported consignments not complying with food legislations. As set out in the General Food Law (EU regulation 178/2002/EC), RASFF is hosted by the EFSA. The European Commission publishes weekly overviews of RASFF alert and information notifications on its website. In addition, it publishes annual reports of the notifications. These annual reports provide an overview of the numbers of notifications and the categories of food products and hazards that they pertained to. In addition, each annual report highlights peculiar developments within the particular year (Kleter, submitted). The annual reports and the weekly overviews of RASFF notifications are available through the RASFF website (http://europa.eu.int/comm/food/food/rapidalert/index_en.htm).

In 2006, 31% of the original notifications received through the RASFF system concerned mycotoxins (877 notifications) (RASFF, 2007). This is comparable with the number and percentage of original notifications in 2003 (805 notification; 35%), 2004 (881 notifications; 34%) and 2005 (993 notifications, 31%) (RASFF, 2004; 2005; 2006).

In Table 2.1 a breakdown of the RASFF notifications on mycotoxins in 2006 by mycotoxin and product category is given. In general, similar numbers of mycotoxin contaminations within the different products categories were observed in 2003, 2004 and 2005. About 90-95% of the notifications on mycotoxins in 2003 - 2006 concerned aflatoxin. Most of these notifications concerned pistachio nuts primarily originating from Iran. Aflatoxins were also regularly reported in peanuts and derived products originating from China, Brazil, Argentina, India, Egypt and Ghana (peanut butter). Furthermore, many notifications in 2006 (but also in 2003, 2004, and 2005) were mainly related to Ochratoxin A (OTA) and to a lesser extent patulin and fumonisins. In 2006, the OTA notifications concerned mainly fruits and vegetables (especially dried vine fruit) (27), coffee and coffee products (12), cereals and cereal products (11) and herbs and spices (4).

Table 2.1 The number of RASFF notifications on mycotoxins in 2006 for the main mycotoxins within several product categories [Source: RASFF, 2007].

	Animal nutrition	Cereal products	Coffee	Baby food	Fruit and vegetables	Herbs and spices	Fruit juices	Nut and nut products	Total
Aflatoxins	4	5	1	0	69	37	0	684	800
Fumonisins	0	14	0	1	0	0	0	0	15
Ochratoxin A	0	11	12	0	27	4	0	0	54
Patulin	0	0	0	1	1	0	5	0	7
Zearalenone	1	0	0	0	0	0	0	0	1
Total	5	30	13	2	97	41	5	684	877

2.2 Literature review

In addition to the RASFF notifications, several literature reviews on (the occurrence of) mycotoxins were consulted, including two reviews conducted within the SAFE FOODS project by UNICATT (Prandini, submitted a; submitted b; Pitt, 2000a; Pitt et al., 2000b; Doohan et al., 2003; Logrieco et al., 2003). From these reviews, several relevant mycotoxins occurring in wheat, maize and nuts and the different fungi which can produce these mycotoxins were identified. An overview of fungi and mycotoxins occurring in wheat, maize and nuts is given in the table underneath.

Table 2.2 An overview of fungi and mycotoxins occurring in wheat, maize and nuts.

Fungi	**Mycotoxin***	**Remarks**
Wheat		
F. graminearum, F. culmorum and closely related species	DON, ZEA, NIV	The major source of DON and NIV is *F. graminearum,* a species endemic in wheat and other cereals throughout the world.
F. sporotrichioides, *F. acuminatum* and *F. poae*	T-2	T2 occurs occasionally in wheat, especially in northern temperate climate.
Penicillium verrucosum	OTA	Associated with northern European barley and wheat, does not appear to be common elsewhere.
A. alutaceus (formerly known as *A. ochraceus*)	OTA	Although isolated from a wide range of cereals, records are rather infrequent.

Fungi	Mycotoxin*	Remarks
Maize		
F. verticillioides (F. moniliforme) (and closely related species like *F. proliferatum* and *F. subglutinans*)	FB1, FB2, FB3 (and to a lesser extent MON, BEA and FUP)	Maize is the only significant source of these compounds.
F. graminearum, F. culmorum and closely related species	DON, ZEA, NIV,	Under natural conditions these mycotoxins do not occur solitary.
F. sporotrichioides, *F. acuminatum* and *F. poae*	T-2 HT-2	T2 occurs occasionally in maize, especially in northern temperate climate.
A. flavus (and *A. parasiticus)*	AFB1 (and to a lesser extent AFB2, AFG1 and AFG2)	*A. flavus* is the dominant species in maize and tree nuts.
A. alutaceus (formerly known as A. ochraceus)	OTA	*A. alutaceus* is common in peanuts and maize. Although OTA is isolated from a wide range of cereals, records are rather infrequent.
Peanuts		
A. parasiticus (and A. flavus)	AFB1, AFG1 (followed by AFB2 and AFG2)	*A. parasiticus* is the dominate species in peanuts.
A. alutaceus (formerly known as A. ochraceuss), A. niger, and *A. gluacus.*	OTA	*A. alutaceus* is a common in peanuts and maize.
Tree nuts		
A. flavus (and A. *parasiticus)*	AFB1 (and to a lesser extent AFB2, AFG1 and AFG2)	*A. flavus* is the dominant species in maize and tree nuts.
A. niger, A. gluacus, and *A. alutaceus (formerly known as A. ochraceuss),* and other related species	OTA	

* AFB1 = Aflatoxin B1; BEA = beauvericin; DON = deoxynivalenol; FB1 = Fumonisin B1; FUP = Fusaproliferin; MON = moniliformin; NIV = nivalenol; OTA = Ochratoxin A; T-2 = T-2 toxin; ZEA = zearalenone

In 2001 the SCOOP (Scientific Co-operation on Questions relating to Food) task 3.2.10 'Collection of occurrence data of *Fusarium* toxins in food and assessment of dietary intake by the population of EU Member States' was established. The task was divided in three subtasks (zearalenone, fumonisins and trichothecenes) (Schothorst and Van Egmond, 2004). Within this study thirteen countries were asked to provide information on the exposure of the population to *Fusarium* toxins in their country. Twelve countries provided data on trichothecenes and 9 countries on zearalenone and fumonisins. Table 2.3 summarizes this information. The database covered altogether 44959 analyses on 16 *Fusarium* mycotoxins. Positive samples ranged from 0% (verrucarol) to 57% (deoxynivalenol) of all samples (Gareis et al., 2003).

Table 2.3 Overview on ***Fusarium*** toxin occurrence data submitted by the countries participating in the SCOOP project [Source: Gareis et al., 2003].

Fusarium toxin	Countries	Number of samples	Positive samples
Type B trichothecenes			
DON	11	11022	57%
NIV	7	4166	16%
3-acetyldeoxynivalenol	6	3721	8%
15-acetyldeoxynivalenol	3	1954	20%
Fusarenon X	3	1872	10%
Type A trichothecenes			
T-2	8	3490	20%
HT-2	6	3032	14%
T-2 Triol	2	1389	6%
Neosolaniol	2	1323	1%
Diacetoxyscirpenol	3	1886	4%
Monoacetoxyscirpenol	1	853	1%
Verrucarol	1	121	0%
ZEA	9	5018	32%
Fumonisins			
FB_1	9	3863	46%
FB_2	6	1010	42%
FB_3	1	239	36%
	Sum:	44959	

Table 2.4 presents a summary of food categories most frequently contaminated with *Fusarium* mycotoxins. Cereals ranked first and among them maize and wheat showed the highest level of contamination with *Fusarium* mycotoxins.

Table 2.4 Summary of food groups most frequently contaminated with ***Fusarium*** mycotoxins [Source: Gareis et al., 2003].

Fusarium toxin	Main food items/food groups contaminated (percentage of positive samples)
Type B trichothecenes	
DON	maize (89%), wheat* (61%)
NIV	maize (35%), oats (21%), wheat* (14%)
3-Acetyldeoxynivalenol	maize (27%), wheat (8%)
Type A trichothecenes	
T-2	maize (28%), wheat (21%), oats (21%)
HT-2	oats (41%), maize (24%), rye** (17%)
ZEA	maize (79%), maize milling fractions (51%), maize based products (53%), wheat (30%), wheat milling fraction (24%), wheat based products (11%), baby food (23%)
Fumonisins	
FB1	maize (66%), maize flour (79%), maize based products (31%), maize flakes (46%), wheat (79%)
FB2	maize (51%)

* Wheat and wheat flour ** Rye and rye flour

Dietary intakes were calculated from 12 (trichothecenes), 9 (zearalenone) and 7 (fumonisins) countries. An overview of the calculations of mean dietary intakes as percentages of the TDI (tolerable daily intake) values is given in Table 2.5 (Gareis et al., 2003). The calculated average dietary intake values for most *Fusarium* toxins were found to be considerably below the (temporary) TDI-values. Higher intakes (as percentage of the (temporary) TDI values) were observed for the group of infants. Intakes higher than the TDI were noted for the sum of T-2 toxin and HT-2 toxin for both adults and infants.

Table 2.5 Range of average dietary intakes* calculated as percentage of the TDI values [Source: Gareis et al., 2003].

Mycotoxin	TDI (µg/kg bw/day)	Population (% TDI)	Adults (% TDI)	Infants (% TDI)
DON	1	0.8 - 33.8	14.4-46.1	11.3-95.9
NIV**	0.7	4.2 - 11.1	0.8-8.25	3.7-22.6
T-2 + HT-2**	0.06	18.3 - 250	61.7-171.7	26.7-563.3
ZEA**	0.2	13.4	5.3-14.5	3-27.5
FB1 + FB2	2	0.8 - 13.2	0.1-14.1	22.3

* Mean food consumption and mean occurrence data ** Temporary TDI

Gareis et al. (2003) demonstrated that *Fusarium* mycotoxins are widely distributed in the food chain in the EU. The major sources are products made from cereals, in particular wheat and maize. While the dietary intakes of *Fusarium* toxins are often less than the TDI values for the respective toxin for the entire population and adults, they are close to or even exceed in some cases the TDI values for risk groups like infants and children.

The results of similar SCOOP tasks on OTA were reported in 1997 and 2002 (EC, 1997 and 2002). From these assessments of dietary intake of OTA by the population of EU Member States it can be concluded that the main food items/ food groups contaminated with OTA in 2000 were rye and derivatives, cocoa and products, dried fruits, millet, cereal and products, baby food, and wheat and derivatives (EC, 2002). Respectively 61, 67, 70, 71, 73, 81, and 88% of the tested samples of these food products/food groups were tested positive for OTA. The calculated average dietary intake values for OTA were in most cases below the TDI-value suggested by the SCF (5 ng/kg bw/day). The estimated average dietary intakes ranged between 23-73% of the TDI for the whole population of the different countries, between 23-53% of the TDI for adults, and between 38-96% of the TDI for children.

The occurrence in food and dietary intake of aflatoxins were evaluated the Scientific Panel on Contaminants in the Food Chain (CONTAM) of the EFSA. The main food items contaminated with aflatoxins in 2000-2006 were tree nuts, groundnuts, spices, figs and other dried fruits, maize and other cereals, crude vegetable oil and cocoa beans. The number of samples with total aflatoxin levels of 4 µg/kg or less varied from 78.5% for Brazil nuts to 100% for baby foods (EFSA, 2007). The EFSA calculated the dietary intake of aflatoxins using mean occurrence data and mean consumption data based on the current situation for adults. All occurrence values were truncated at the current EU Maximum Limits for adults. For groundnuts, nuts, dried fruit, cereals and processed products thereof intended for direct human consumption or as an ingredient in foodstuffs, maximum levels of 4 µg/kg for total aflatoxins (aflatoxins B1 +B2 + G1 + G2) and 2 µg/kg for aflatoxin B1 (AFB1) have been fixed. For spices corresponding levels have been set to 10 µg/kg for total aflatoxins and 5 µg/kg for AFB1. The mean estimates of exposure to total aflatoxins in the European Member States ranged between 0.35 and 0.84 ng/kg body weight per day for lower bound (aflatoxin concentrations below the limit of detection (LOD) were entered as zero) and between 0.69 and 1.93 ng/kg body weight per day for upper bound estimates (aflatoxin concentrations below the LOD were entered as the actual value of LOD).

Aflatoxins are genotoxic carcinogens, for which it is generally assumed that there is no threshold dose below which no tumour formation would occur. Therefore, it is recommended that exposure to aflatoxins should be as low as reasonably achievable (EFSA, 2007).

2.3 Conclusions

Based on the occurrence, intake and toxicity of the different mycotoxins in wheat and maize, DON, OTA, T-2 and HT-2 seem to be the most important mycotoxins, especially when children are taken into account. In addition, also aflatoxins are important mycotoxins in maize. For nuts, aflatoxins are the most relevant mycotoxins. An overview of the most important mycotoxins found in Table 2.6. For these mycotoxins a model will be developed to assess the risk of occurrence in wheat, maize and nuts.

Table 2.6 Overview of most important mycotoxins per commodity.

Commodity	**Mycotoxin**
Wheat	DON OTA T-2 HT-2
Maize	DON OTA T-2 HT-2 AFB1 (AFG1, AFB2 and AFG2)
Nuts	AFB1, AFG1, AFB2 and AFG2

3 Literature search on relevant indicators

3.1 Relevant indicators

Relevant indicators for the risk of occurrence of the most important mycotoxins (see Table 2.6) in wheat, maize and nuts include indicators from the food supply chain as well as from the host environment. In the PERIAPT project, several influential sectors from the host environment were identified (Noteborn et al., 2005). In the EMRISK project, these influential sectors were further refined and the resulting influential sectors are shown in Figure 3.1.

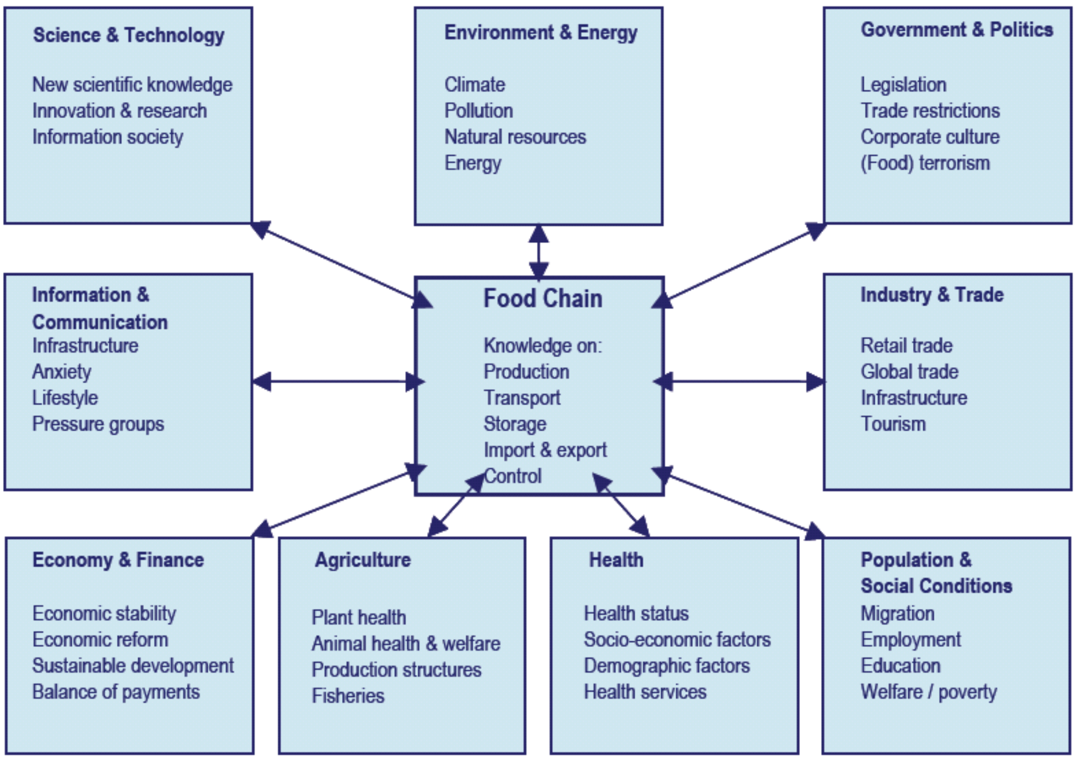

Figure 3.1 Influential sectors in the host environment of the food supply chain regarding emerging risks (from Noteborn et al., 2006).

In the current project, a gross list of indicators for the presence of (re-)emerging mycotoxins in wheat, maize, peanuts and tree nuts was made (see the table in Annex 1). This table is arranged according to the influential sectors shown in Figure 3.1. However, since the aim of the model that will be developed will be to assess the presence of mycotoxins on wheat, maize and nuts and not to assess the related health risk, the influential sector 'Health' was excluded in the current project. Several information sources were used to establish this gross list, and these are described shortly below.

In the EMRISK project, a list of 270 initial indicators for identification of emerging risks in general was produced based on inputs of ongoing initiatives elsewhere (i.e. FAO, WHO, SANCO etc.) and results of workshops organised with issue and/or field experts (Noteborn et al., 2006). For the current project, these indicators were reviewed for their relevance to fungal growth and mycotoxin production and the relevant ones are listed in Annex 1.

In a previous RIVM project commissioned by the VWA (Park and Bos, 2007), a preliminary inventory of relevant indicators for fungal growth and mycotoxin production was already made based on data from Good Agricultural, Storage and Manufacturing Practices guidelines, Hazard Analysis and Critical Control Point (HACCP) programs, existing early warning systems, case studies, literature reviews and personal communication with experts. These indicators are also used in the current project.

Additional indicators were identified from several literature reviews (Hussein and Brasel, 2001; Van Maanen and Xu, 2003) and publications on monitoring, management and prevention strategies (CAC, 2004; CAC 2005; Queensland Government 2007).

Information on several currently available models predicting the occurrence of fungi and mycotoxins in wheat and maize (and wheat and maize based products) was reviewed within task 2.10.1 and 2.10.2 of Work Package 2 of the SAFE FOODS project by Prandini et al. (submitted b). Several additional models are described by De la Campa et al. (2005) and Xu (2003). These models are generally region specific and (partly) loss their predictive value outside the region for which they were developed. Since the aim of this project is to develop a more general model, these models themselves are not directly useful for this purpose. However, the indicators of these models can be used in the development of a more general model and are therefore also included in the table in Annex 1. These indicators are predominantly of meteorological origin (e.g. temperature, rainfall, and relative humidity), sometimes in combination with agricultural information (e.g. growth stages of the crops). Furthermore, some additional indicators for wheat and maize were derived from several other publications (Vigier et al., 2001; Munkvold, 2003; Nordby et al., 2004; EMAN, 2006; Aldred and Magan, 2004; Schrödter, 2004).

For peanuts and tree nuts, information obtained from several monitoring, management and prevention strategies and some predictive models for aflatoxin contamination in nuts were used to select relevant indicators for the risk of occurrence of mycotoxins in nuts (Bayman et al., 2002; Boutrif et al., 1998; Henderson et al., 2000; Rachaputi, 2002; Turner, 2005).

All indicators identified for wheat, maize, peanuts and tree nuts are listed in the table in Annex 1.

3.2 Interrelations between indicators

Because of the strong interrelationship of many indicators, these relations were made more visible by combining them into two schemes, one scheme for the indicators of mycotoxin growth on the crop in the field (pre-harvest; Figure 3.2) and another scheme for mycotoxin growth on crop during processing and storage (post-harvest; Figure 3.3). Those indicators that are closely related to the product (primary indicators; e.g. temperature) are positioned in the inner circle of the scheme, closest to the centre of the scheme (mycotoxin in crop). Secondary indicators (those that might influence the primary indicators like pesticides or economy) are positioned in the outer circle of the scheme. To keep the scheme comprehensive, the more distantly related indicators are not presented separately but are represented by boxes of their influential sector outside the outer circle.

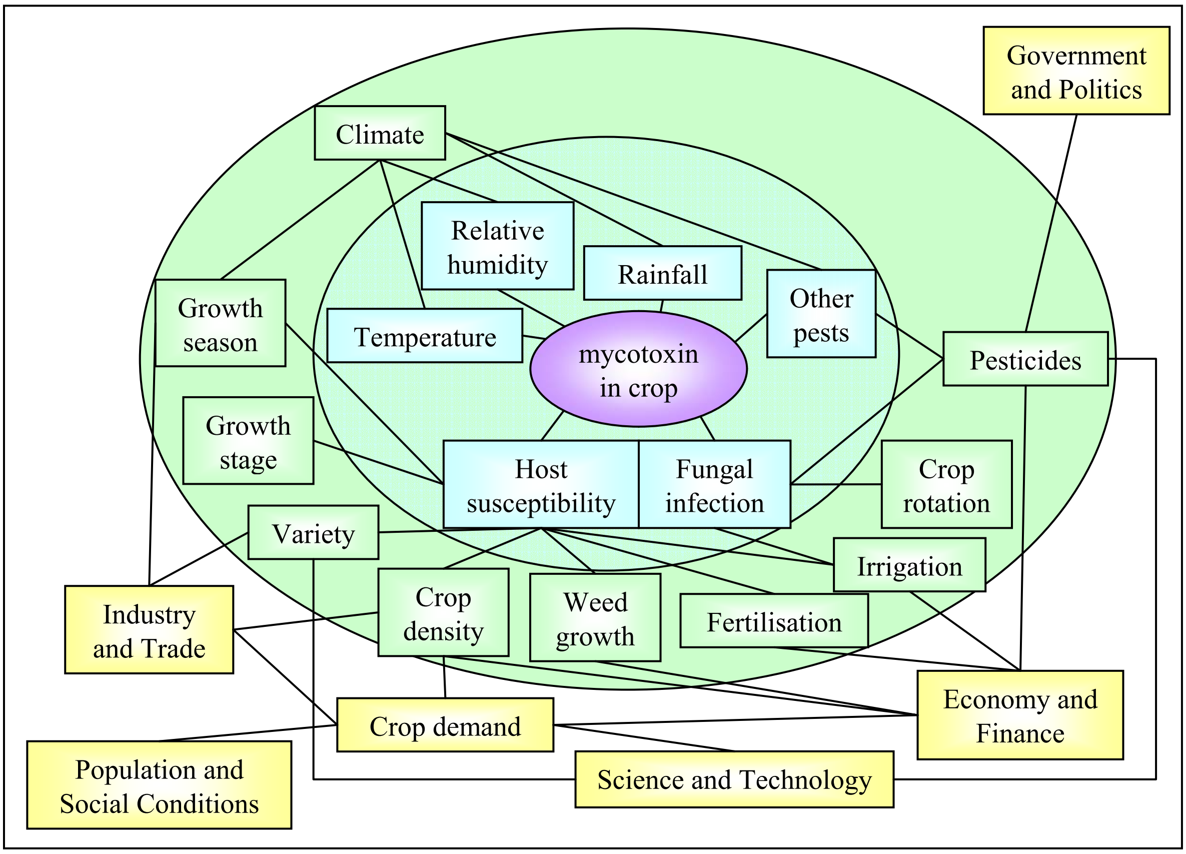

Figure 3.2 **Indicators of mycotoxin growth on crop in field (pre-harvest) and their interrelationships** (primary indicators are positioned in the inner circle, while secondary indicators and influential sectors are positioned in the outer circles of the scheme).

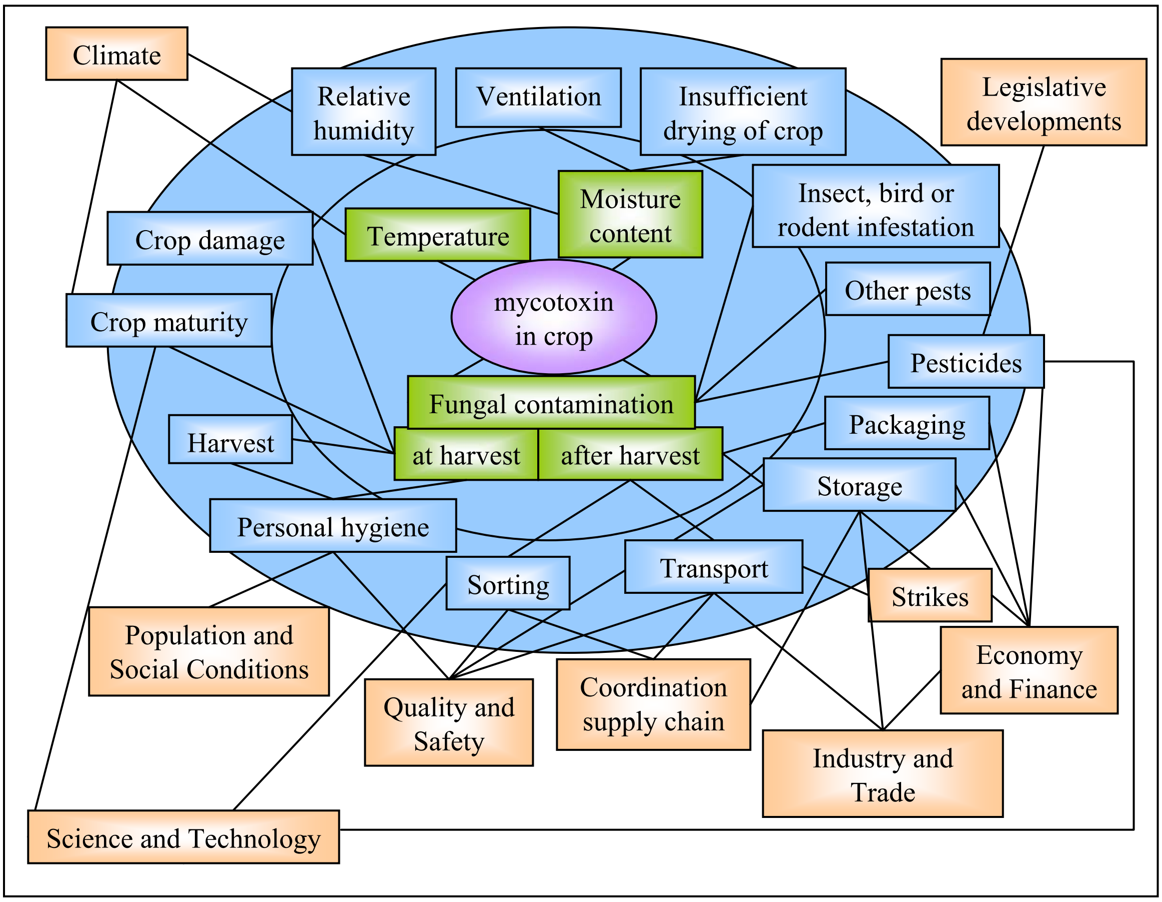

Figure 3.3 **Indicators of mycotoxin growth on crop during processing and storage (post-harvest) and their interrelationships** (primary indicators are positioned in the inner circle, while secondary indicators and influential sectors are positioned in the outer circles of the scheme).

Another way of putting the indicators into perspective is by 'backtracking' the different stages the product or crop has gone through before it becomes available for consumption. This is the usual procedure after a contamination of mycotoxins in food items is discovered. First information on the country of origin and transport conditions of the food item is gathered and studied. When a certain food item that is usually mainly imported from one country is suddenly mainly imported from other countries, this may indicate possible changes in mycotoxin contamination of this food item due to differences in general conditions within these countries which may or may not favour the occurrence of mycotoxins in this food item. Figure 3.4 gives an overview of the indicators important in this backtracking.

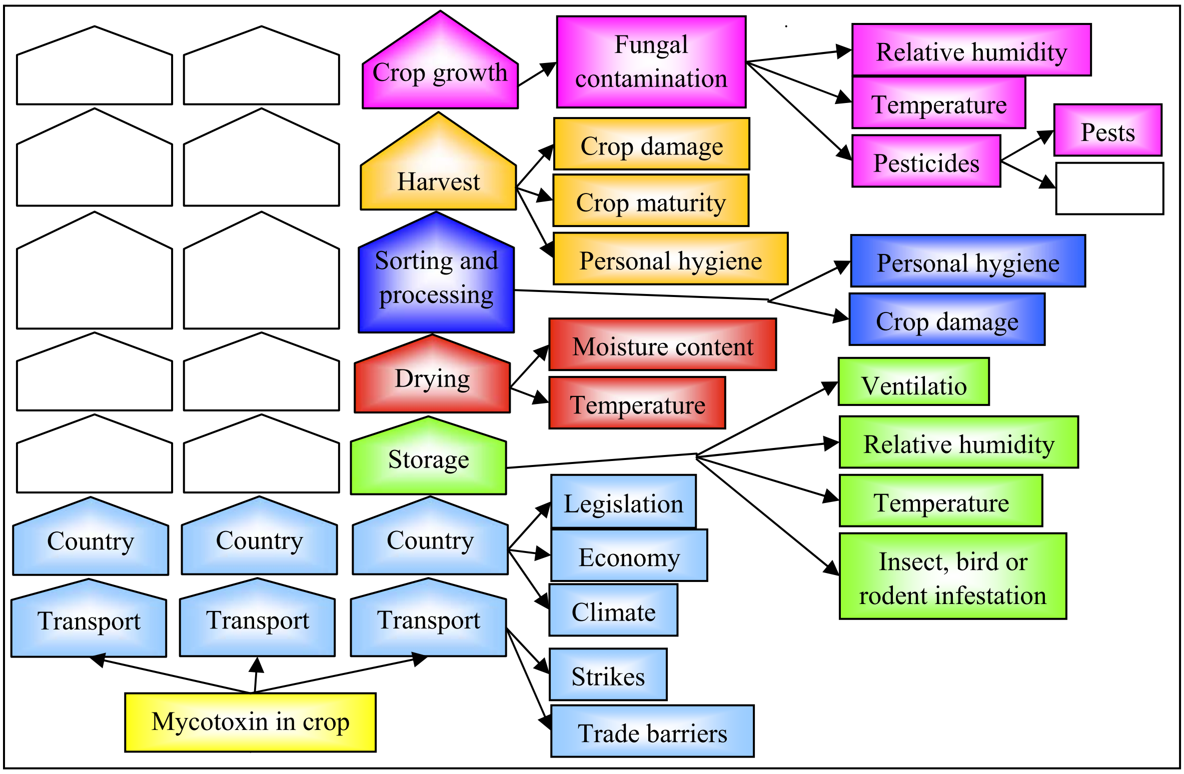

Figure 3.4: Indicators of mycotoxin growth on crop by 'backtracking' the different stages the product or crop has gone through before it becomes available for consumption.

3.3 Conclusions

In the models that are currently available in literature to predict the occurrence of known fungi and mycotoxins, predominantly meteorological indicators (e.g. temperature, rainfall, and relative humidity) were found, sometimes in combination with agricultural information (e.g. growth stages of the crops). From the monitoring, management and prevention strategies described in literature, mainly indicators originating from the food supply chain could be derived. In addition to these indicators, several indicators from the other influential sectors (derived from the EMRISK report) may also be relevant to assess the presence of mycotoxins on various crops and may be useful in a model (see Annex 1). Furthermore, based on the literature search it is evident that the indicators are highly interrelated and interrelationships between indicators have to be taken into account when developing a model to assess the risk of occurrence of re-emerging mycotoxins.

4 Review and selection most relevant indicators

4.1 Introduction

To select the most important indicators to assess the risk of occurrence of re-emerging mycotoxins in wheat, maize and nuts, a series of in-depth interviews was held, followed by a workshop. In-depth interviews were chosen instead of a written questionnaire, since holistic approaches are rather complex and during an in-depth interview, the holistic way of thinking can be explained better than with a written questionnaire. Also, more detailed insight in the expert judgments on the indicators and their rationales can be obtained. During the group discussions of the workshop, the differences in expert opinions were discussed to try to obtain consensus among the experts.

4.2 Interviews

4.2.1 Approach

4.2.1.1 Set-up expert interviews

The series of expert interviews was aimed to identify the main influential sectors and the main indicators for the presence of mycotoxins on wheat, maize and nuts. During the interviews, the experts were first asked to identify the most important influential sectors and to indicate which influential sectors are within their expertise. Thereafter, the experts were asked to think about indicators within the different influential sectors. The gross list of indicators (Annex 1) was not used in the interviews, so that the experts would not be hampered by this prior knowledge, which made it possible to identify new indicators and rephrase indicators already identified. However, the list was used by the interviewers to be able to give examples, if necessary.
Afterwards, the experts received a report on their interview, and were asked to rank the importance of the indicators that were mentioned by them. They were asked to do so for wheat, maize and nuts, separately, and to select the five most important ones. The questionnaire used in the interviews can be found in Annex 2.

4.2.1.2 Selection of experts

The selection of experts was such that every influential sector listed in Annex 1 would be covered by several experts. Experts were selected based on the expert database of the SAFE FOODS project, on the list of participants of previous emerging risks projects (EMRISK, PERIAPT), on suggestions by the VWA, and on suggestions of experts interviewed during the current project.

4.2.1.3 Data analysis

To get insight in the importance of the indicators for the three crops wheat, maize and nuts, the experts were asked to rank the indicators for each crop with an importance score of 1 – 4 (1 = very important, 2 = reasonably important, 3 = slightly important, 4 = irrelevant). For the data analysis, the score 1 (very important) got the value 3, the score 2 (reasonably important) the value 2, the score 3 (slightly important) the value 1 and the score 4 (irrelevant) the value 0. For each indicator, the values obtained in all interviews were summed per crop and also for all three crops together. In addition, the experts were asked to select the five most important indicators ('top 5'). The frequency that each indicator was selected in the top 5 was calculated. All data from the interviews were analyzed per interview (also if an interview was held with two experts at the same time).

4.2.2 Results

4.2.2.1 Experts

In total, 13 interviews have been conducted with in total 17 experts. Figure 4.1 gives an indication of the extent to which each influential sector is covered by the area of expertise of the consulted experts per interview, based on their own judgement. For each influential sector, it is indicated how many interviews were conducted with experts with knowledge on this influential sector. All experts had knowledge on at least two influential sectors. All influential sectors were covered by at least two interviews. A list with the consulted experts and their areas of expertise can be found in Annex 3.

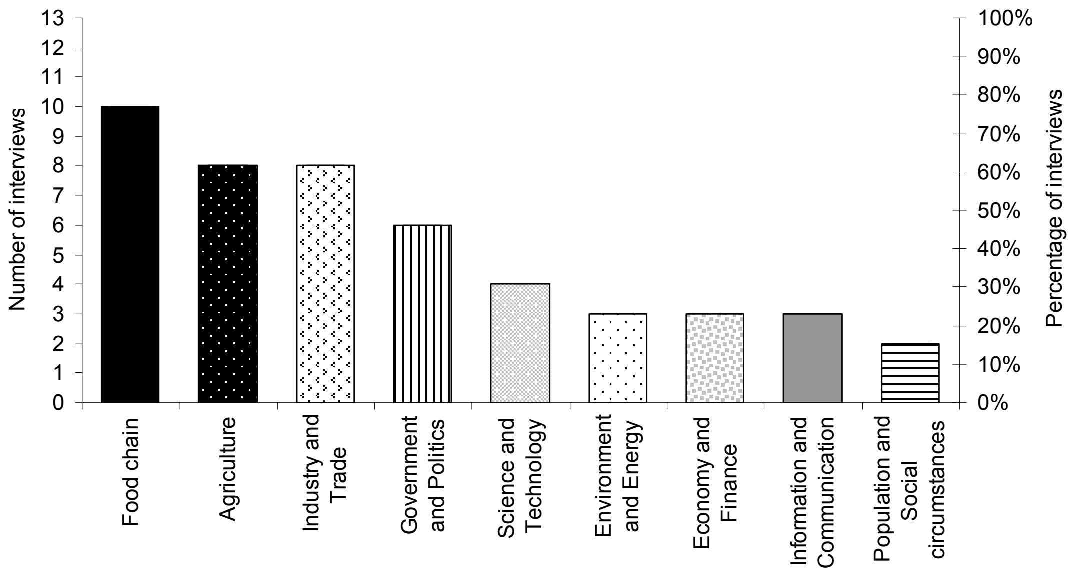

Figure 4.1 Number of interviews with experts with knowledge on the different influential sectors.

4.2.2.2 Influential sectors

All indicators mentioned by the experts could be classified within one of the influential sectors already identified. In one expert interview, 'disasters' (with indicators such as 'food scarcity' and 'war') was suggested as an additional influential sector. However, after further discussing these indicators, they were considered to be covered by the existing influential sector 'Population and Social conditions). Therefore, no new influential sectors were identified. Figure 4.2 indicates the percentage of the interviews in which the different influential sectors were regarded as an important sector. The most important influential sectors were 'Agriculture', 'Environment and Energy' (more specifically 'Climate'), 'Food Chain' and 'Industry and Trade'.

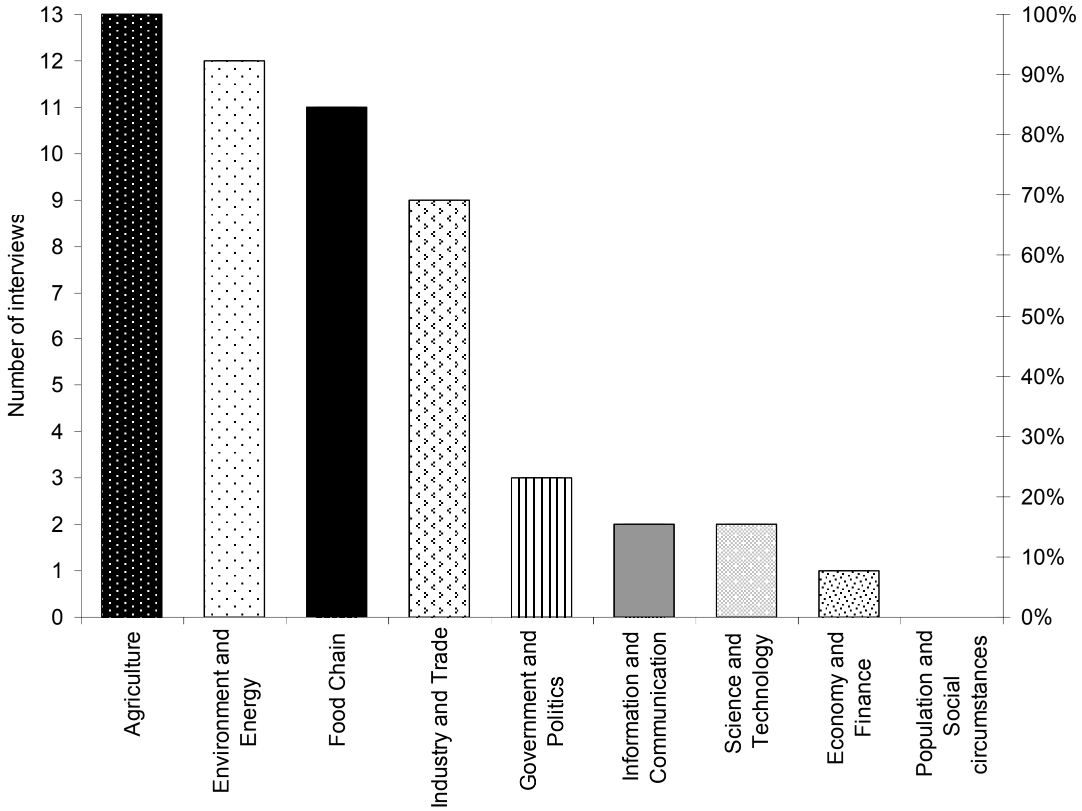

Figure 4.2 Number of interviews in which the experts regarded the indicated influential sector important.

4.2.2.3 Indicators

A list of all indicators that were mentioned during the interviews can be found in Annex 4. In Table 4.1, the indicators that were mentioned in >25% of the interviews are listed. In the second column of Table 4.1, the percentage of interviews in which the different indicators were mentioned is given. For each indicator, the importance scores obtained in all interviews in which the indicator was mentioned, were summed per crop (see the third column ‘Total score in interviews per crop’) and also for all three crops together (see the last column ‘Total score for all crops’). Since the experts were asked to give these scores only to those indicators they had mentioned themselves, these total scores are much lower than the maximum score possible (which would add up for wheat to a maximum of 10 interviews x maximum score of 3 = 30, for maize to a maximum of 8 x 3 = 24 and for nuts to a maximum of 9 x 3 = 27). Based on the percentage of interviews in which each indicator is mentioned, the most important indicators (mentioned in >50% of the interviews) are: storage conditions and quality, humidity/drought, temperature, changes in consumption patterns, transport conditions, tillage policy and regulations with respect to mycotoxins. Based on the total score the most important indicators for all three crops (total score > 35) are: humidity/drought, storage conditions and quality, temperature, changes in consumption pattern, regulations with respect to mycotoxins, transport conditions and education within food production chain. Differences between the crops were that the indicators tillage policy, crop variety and crop rotation scored relatively high in wheat and maize, but low for nuts (see Table 4.1).

Table 4.1 Overview of the most frequently mentioned indicators and their importance scores as judged by the experts in the interviews.

Indicator	Percentage of interviews*	Total score in interviews per crop			Total score for all crops **
Number of interviews	**n = 13**	**Wheat (n=10)**	**Maize (n=8)**	**Nuts (n=9)**	
Influential sector: Food Supply Chain					
Traceability	38%	9	9	12	30.0
Mixing	31%	7	7	6	20.0
Transport conditions	**62%**	12	12	15	**39.0**
Storage conditions and quality	**77%**	20	17	20	**57.0**
Influential sector: Agriculture					
Agriculture small/large scale production	46%	9.5	10.5	13	32.5
Tillage policy	**54%**	16	10	2	28.0
Crop variety	46%	14	8	2	24.0
Genetically modified crops	31%	7	7	1	15.0
Crop rotation/pre-crop	38%	13	7	0	20.0
Irrigation and drainage	31%	7	7	9	23.0
Use of pesticides	31%	7	8	6	21.0
Harvest conditions	31%	10	11	10	31.0
Influential sector: Climate and Energy					
Humidity/drought	**77%**	23	17	19	**59.0**
Temperature	**77%**	22	16	18	**56.0**
Influential sector: Industry and Trade					
Global trade	38%	8	6	6	20.0
Changes in trade flows	31%	5	4	4	13.0
Other market (biofuel)	31%	3	2	0	5.0
Influential sector: Economy and Finance					
Influential sector: Government and Politics					
Regulations with respect to mycotoxins	**54%**	14	11	12	**37.0**
Influential sector: Communication and Information					
Information flows (e.g. RASFF, but also to consumers)	46%	6	6	10	22.0
Education within food production chain	46%	12	10	13	**35.0**
Influential sector: Science and Technology					
Influential sector: Population and Social conditions					0.0
Changes in consumption pattern	**69%**	10	11	8	29.0

* percentages above 50% are printed bold
** scores above 35 are printed bold

Next to assigning an importance score to each of the indicators, the experts were also asked to select the five most important indicators ('top 5'). Figure 4.3 gives an overview of these most important indicators, including in how many interviews these indicators were listed in the top five. This result is based on 10 interviews, since in the remaining interviews no answer to this question was given. In 7 of the 10 interviews, humidity/drought was in the top five of most important indicators. Furthermore, temperature, storage conditions and quality, crop variety, transport conditions, tillage policy, crop rotation, and global trade were in the top five of two or more interviews. These indicators belong to the influential sectors 'Environment and Energy', 'Agriculture', 'Food Chain', and 'Industry and Trade'. Please note that Figure 4.3 can not be directly compared to the results in Table 4.1, since Figure 4.3 reflects the results the top five and Table 4.1 reflects the results of the importance scores that were assigned to all indicators mentioned.

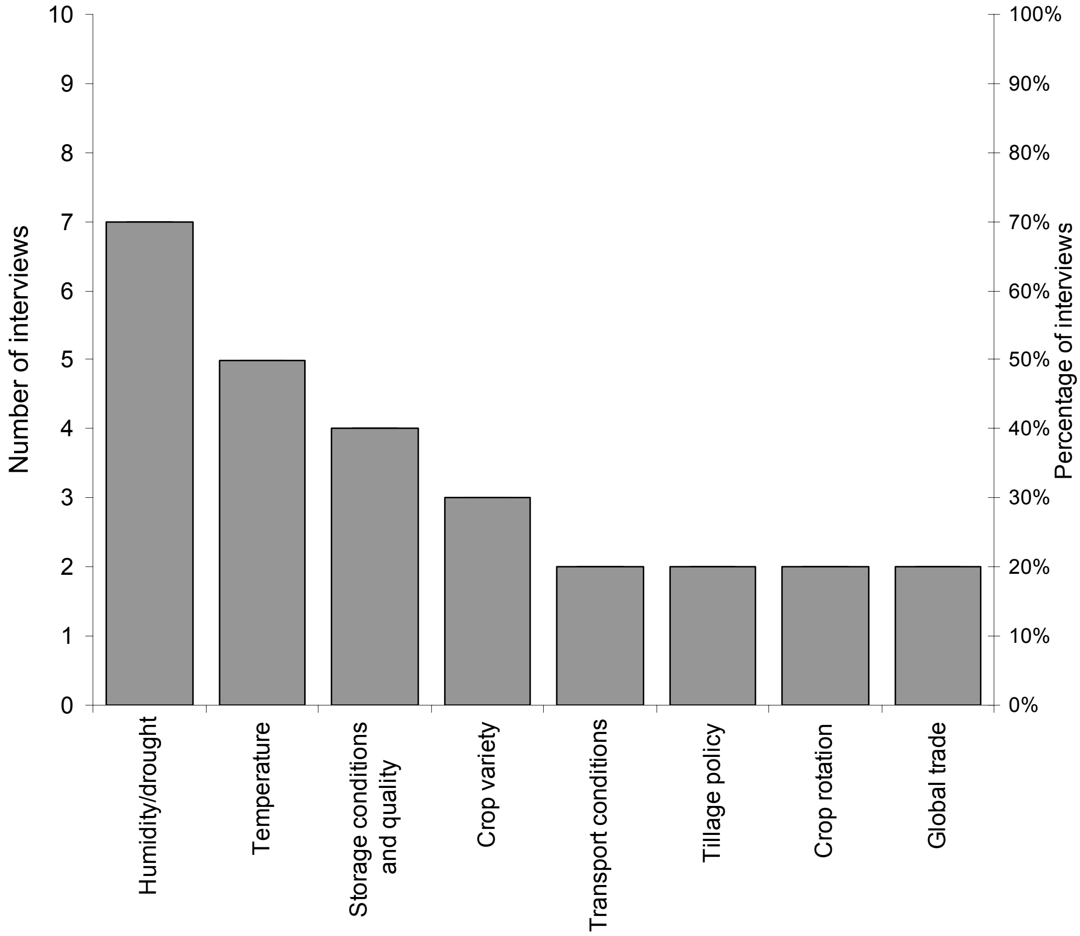

Figure 4.3 Number of interviews in which the experts classified the different indicators in the top five of most important indicators.

Based on the percentage of interviews in which the different indicators were mentioned, the importance scores, and the percentage of interviews in which the different indicators belonged to the top 5, the 10 most important indicators were selected. Table 4.2 provides a description of these most important indicators. The indicator ‘changes in consumption patterns’ (see Table 4.2) is an important indicator according to the results of the interviews. This indicator, however, seems to be more related to the health risk of mycotoxins than to the risk of mycotoxin contamination in various commodities.

Table 4.2 Description of the most important indicators based on the interview results.

Indicator	Explanation
Humidity/drought	Air/soil humidity, rain and drought during the different stages of the crop (flowering, harvest etc.).
Temperature	High temperatures in winter, large day-night temperature differences in spring, early and/or warm summers.
Storage conditions and quality	Examples of such conditions are time, storage per farmer versus storage in cooperation’s, separate storage of suspected lots and temperature and humidity.
Crop variety	Choice of for example resistant, short or GMO varieties.
Transport conditions	Examples of such conditions are time, size shipping company, temperature, moist, ventilation and measures to prevent condensation.
Tillage policy	No tillage policy or deep ploughing.
Crop rotation	Growing similar/dissimilar types of crops on the same parcel in sequential seasons.
Global trade	Trade of crops among many different countries of various parts of the world.
Changes in consumption patterns	Differences in eating patterns of certain products.
Regulations with respect to mycotoxins	European and national limits for mycotoxins in different products in importing and exporting countries.

4.2.3 Conclusions

Based on Figure 4.2, it can be concluded that the most important influential sectors are ‘Agriculture’, ‘Environment and Energy’, ‘Food chain’ and ‘Industry and Trade’.
Experts were asked to assign importance scores to the indicators they mentioned during the interview and also to list the five most important indicators. An analysis of the most important indicators was performed based on a) the extent to which the indicators are mentioned in the different interviews (Table 4.1), b) the ranking of these indicators for the different crops (Table 4.1), and c) the extent to which the indicators were listed in the top five in the different interviews (Figure 4.3). When comparing the results of these different analyses, some differences are observed. Global trade is an important indicator according to the top five results, whereas based on the extent to which the indicators were mentioned and the ranking of the indicators with importance scores, global trade is not among the most important indicators. In addition, changes in consumption patterns and regulations with respect to mycotoxins are found to be important indicators based on the extent to which the indicators were mentioned and the ranking of the indicators with importance scores, but not when using the top 5 method. Taking the different analyses together, the 10 most important indicators were identified (Table 4.2) with ‘humidity/drought’ and ‘temperature’ being more important than the other eight indicators. These results were used as a starting point for the workshop (see next section).

4.3 Workshop

4.3.1 Approach

4.3.1.1 Objectives

The overall aim of the workshop was to arrive at consensus upon the most important indicators for identification of (re-)occurrence of mycotoxins. The workshop focused on wheat as a model commodity. The aim of the workshop was broken down into the following objectives:

- to further reduce the set of 10 main indicators identified in the interviews;
- to define the selected most important indicators in more detail;
- to identify potential interactions between the selected indicators;
- to obtain consensus upon the most important indicators and relevant interactions.

4.3.1.2 Selection of experts

The selection of experts was aimed to include experts with expertise in the relevant influential sectors, i.e. 'Agriculture', 'Environment and Energy', 'Food chain' and 'Industry and Trade' (as determined in section 4.2). Furthermore, the experts were selected on the basis of their backgrounds, aiming to include experts from risk management, risk assessment and feed and food industry. Several experts that participated in the interviews were invited, together with additional experts.

4.3.1.3 Set-up of workshop

After a short introduction in which the aim of the workshop was explained, the results of the expert interviews were presented, including the set of 10 most important indicators based on the interviews. The participants were asked to individually rank these indicators from 1 – 10 according to their relative importance for wheat. After this individual task, the experts were divided into 2 groups, each group consisting of experts with various backgrounds. In each group the results on the ranking of the indicators were discussed aiming to reach consensus on the most important ones and to add any missing indicators. These most important indicators were defined in more detail and interactions with other important indicators were identified. The last part of the workshop consisted of a plenary feedback session, in which the results of the two group discussions were presented and an overall discussion was held on potential differences in the outcomes.

4.3.2 Results

4.3.2.1 Experts

In the workshop, fourteen experts with expertise in the relevant influential sectors (based on the results of the interviews) participated, with 4 persons from industry, 5 persons from risk management and 5 persons from risk assessment (a list of participants is included as Annex 5).

4.3.2.2 Selection of indicators

Table 4.3 presents the results from the experts' individual scoring of the 10 most important indicators (resulting from the series of interviews). As can be seen from this Table, humidity was evaluated to be the far most important indicator to assess the risk of the occurrence of mycotoxins in wheat, followed – in order of importance – by temperature and crop rotation. Then, three other indicators were judged to be nearly as important, being tillage, storage conditions and quality, and crop variety. The other indicators were judged to be less important. The indicator 'changes in consumption patterns' was selected as an important indicator according to the results of the interviews. However, during the workshop, this indicator was considered not to be important in assessing mycotoxin contamination in various commodities, since this indicator is more related to the health risk of mycotoxins than to the risk of occurrence of mycotoxins in various commodities.

Table 4.3 Results ranking of top 10 indicators interviews during workshop.

Ranking	Indicator	Total scores*
1	Humidity/drought	128
2	Temperature	97
3	Crop rotation	93
4.5	Tillage policy	83
4.5	Storage conditions and quality	83
6	Crop variety	80
7	Transport conditions and quality	66
8	Global trade	37
9	Regulations with respect to mycotoxin limits	33
10	Changes in consumption patterns	14

* Thirteen participants filled in the ranking, and gave 10 points to the most important indicator and 1 point for the least important indicator (maximum score 130)

During the discussion on selecting the most important indicators and identification of missing indicators in both the subgroups, several experts stressed that indicators will differ for different mycotoxins and/or fungi. Therefore, it was decided to allow discussion on various toxins but to focus on those toxins that can be produced by *Fusarium* species in wheat. In both subgroups of experts, consensus was reached on the following most important indicators: relative humidity, temperature, crop rotation, crop variety, tillage policy and storage and transport conditions. Both subgroups considered ‘transport’ as prolonged ‘storage’ and therefore the indicators ‘storage conditions and quality’ and ‘transport conditions and quality’ were merged into one new indicator, being ‘storage and transport conditions’. In addition, in one subgroup, the indicator ‘drying of the kernel’ was indicated as an additional indicator.

4.3.2.3 Further definition of indicators

The most important indicators were further defined in both subgroups by determining what information (measurement) is needed and when (how often) this information should be obtained. Afterwards, these definitions were discussed in the plenary feedback session. The outcome of this part of the plenary session is presented in Table 4.4.

Table 4.4 Most important indicators as defined during the workshop.

Indicator	Description
Relative humidity	Relative humidity during wheat cultivation. Ideally, relative humidity should be expressed as leaf wetness. Since this is difficult to monitor, rainfall (in combination with **temperature**) and irrigation could be used as an alternative. For relative humidity, three time windows during cultivation of wheat are important, being the period around/at flowering, two weeks before harvest, and delayed harvest.
Temperature	Temperature (sun shine) during wheat cultivation. Temperature is only relevant in combination with humidity. Therefore, the same three time windows as mentioned for relative humidity are important.
Crop rotation	The crop that is grown previously/during the previous year(s). Growing maize before wheat or wheat before wheat increases the possibility of occurrence of mycotoxins. Especially maize before wheat is a risk factor.
Crop variety	The cultivar/variety of crop. The susceptibility of the used cultivar/variety for mycotoxin producing fungi is important. Resistance levels are variable (not absolute), not always clearly defined and not stable over time. Recommended varieties vary between countries.
Tillage policy	The tillage policy that is used before the crop is planted. Levels for tillage may include: no tillage, mediate tillage, deep-tillage (and burning). Tillage policies vary between countries. In the Netherlands, burning is prohibited and deep-ploughing not used (due to erosion).
Drying of the kernel	The extent to which the kernel is dried before storage. In the EU, a moisture content < 15% in the kernel is recommended during storage, and therefore proper drying before storage is often necessary.
Storage (and transport) conditions	The conditions and quality of the storage (and transport) of the commodities, including relative humidity, temperature, protection against pests and/or insects, etc. The water content of the kernel can be measured and temperature differences in the storage facility can be monitored.

4.3.2.4 Interactions between indicators

Several potential interactions between the indicators were identified:

- Relative humidity and temperature during cultivation (temperature is only important in combination with humidity).
- Storage conditions and drying (when kernels are not dried properly, the storage conditions are more important).
- Crop rotation and tillage policy (especially when maize is pre-crop, ploughing is important).

4.4 Conclusions

On the basis of the results of the expert study, consisting of a series of in-depth interviews and a workshop, the most important indicators for the risk of occurrence of re-emerging mycotoxins produced by *Fusarium* fungi in wheat include humidity, temperature, crop rotation, crop variety, tillage policy, drying, and storage and transport conditions. In total 25 experts participated in the expert study. Since during the workshop, consensus was reached on the most important indicators, it is not to be expected that consulting additional experts will change this list of most important ones. The indicators were defined for re-emerging mycotoxin, but it is to be expected that these indicators will also have predictive value, to some extent, for emerging mycotoxins. Emerging mycotoxins are addressed in more detail in the European MYCONET project (Van der Fels-Klerx et al., 2008). The indicators were further defined during the workshop by specifying what information (measurement) is needed and when (how often) this information should be obtained. Significant interactions were identified between relative humidity and temperature during cultivation; crop rotation and tillage policy; and drying and storage conditions. The results of both the interviews and the workshop are used as input into a risk model for the assessment of the risk of occurrence of mycotoxins in the three commodities.

5 Development of the model

5.1 Set-up of the model

5.1.1 Introduction

The ability to anticipate on the presence of mycotoxins on products such as wheat, maize and nuts requires observation of the correct indicators and efficient communication along the food production chain. To anticipate on this re-emerging risk, a blueprint of a model was developed to assess the risk of occurrence of mycotoxins on wheat, maize and nuts (peanuts and tree nuts).

The aim of this model is to assess the presence of mycotoxins on wheat, maize, peanuts and tree nuts (the raw commodities) and not to assess the related health risk. Furthermore, the aim of the model is to assess the risk of occurrence of re-emerging (i.e. known) mycotoxins and not of emerging (not yet identified) mycotoxins. For emerging (i.e. not yet known) mycotoxins, it will be difficult to identify specific indicators and develop a model. However, many indicators used in the model for re-emerging mycotoxins will probably also have a predictive value for emerging mycotoxins. Emerging mycotoxins will be addressed in more detail in the European project MYCONET (Van der Fels-Klerx et al., 2008).

The model may be used by risk assessors/risk managers to anticipate on the potential presence of mycotoxins by proactive risk management strategies such as adjusting sampling strategies, giving advice along the food chain or obliging certain data to be provided for each lot that enters the country. For industrial stakeholders this model may be useful for purchasing strategies or other strategies to improve the quality of the purchased commodities.

In Figure 5.1, a decision tree is shown that indicates when the model that will be developed, may be used to determine sampling strategies. For some commodities, legislation enforces control. EC decision 2006/504 describes which fraction of certain commodities originating from certain countries should be sampled when entering the European Union (EU, 2006b). In these cases, sampling should be performed according to the respective legislation. For several countries, models are described that assess the presence of (certain) mycotoxins on (certain) commodities well (> 80% certainty) (e.g. DONCAST, available at: http://www.ontarioweathernetwork.ca/DONcast.cfm). These models are very valuable in assessing the presence of certain mycotoxins in a specific region and therefore, these regional models may be preferred over the new generic model that will be developed. When no legal monitoring is required and no reliable regional model is available, the new model that will be developed could be used to determine the sampling strategy (Figure 5.1).

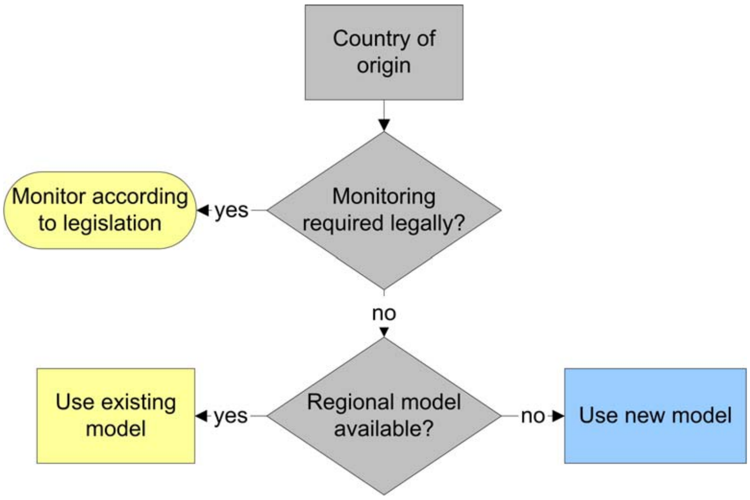

Figure 5.1 Decision tree to determine when the new model can be used in determining the sampling strategy.

Similar decision trees can be drawn for other risk management strategies or for example for optimizing purchasing strategies for industrial stakeholders. This new predictive model will be based on the indicators and the interrelations between the indicators that were defined in the workshop (see chapter 4). Two possible set-ups for the predictive model will be discussed in the next sections, being a 'traffic light' model and a 'decision tree' model.

5.1.2 'Traffic light model'

In the EMRISK report, a 'traffic light model' is described as tool to predict (re-)emerging risks (Noteborn et al., 2006). In Figure 5.2, an example of a traffic light model is given. In a 'traffic light model' relevant indicators are monitored continuously or are measured at (a) certain time point(s). These indicators can be qualitative, semi-quantitative or quantitative Each indicator has several alert values (red, yellow, green). The more indicators have a yellow or red alert value, the higher the risk on a certain effect is. Next to the alert value, several other factors including urgency factors (U-factors) (included in Figure 5.2), importance factors (I-Factors) (not included in Figure 5.2) and relationship factors (R-factors) (not included in Figure 5.2) are mentioned as possible additional factors in this 'traffic light model'. The urgency factor refers to the speed with which assessment actions should be taken. The higher the urgency factor the more urgency should be given to risk management actions in this approach. The importance factor reflects that the indicators are not all equally important. The relationship factor accounts for the relationship that can exist between indicators. Two indicators may for example have a synergistic effect (Noteborn et al., 2006). For the current purpose, the advantage of this 'traffic light model' is that the outcome of the model is based on the values of all indicators taking into account that some indicators are more important than others by the use of importance factors.

Nature	Features	Alert value	UF*	Examples
Qualitative	Yes No	Red Green	5 1	Bad Good
Semi-quantitative	Too low or too high Low or high Normal	Red Yellow Green	5 3 1	<25 or > 300 % 25-50 % or 150-300 % 50-150 %
Quantitative	Out of wide range Within wide range Within normal range	Red Yellow Green	5 3 1	> x ± 6 s.d. = x ± 6 s.d. = x ± 3 s.d.

Figure 5.2 Example of a 'traffic light' model including urgency factors [Source: Noteborn et al., 2006]. * UF = urgency factor.

5.1.3 Decision tree model

Another possibility is a 'decision tree model' (see Figure 5.3). In a decision tree model, the outcome of each indicator indicates the next step in the model until a decision point is reached (in the model in Figure 5.3 this decision point could be 'high risk on mycotoxin contamination' or 'low risk on mycotoxin contamination'). The main advantage of this model for the current purpose is that in some cases a decision can already have been achieved with information on one or two indicator(s). However, for the current purpose, this advantage is not that large, since it is never known beforehand how many indicators are necessary to arrive at a decision point. A disadvantage of this model is that it is difficult to include interrelations between indicators in the model.

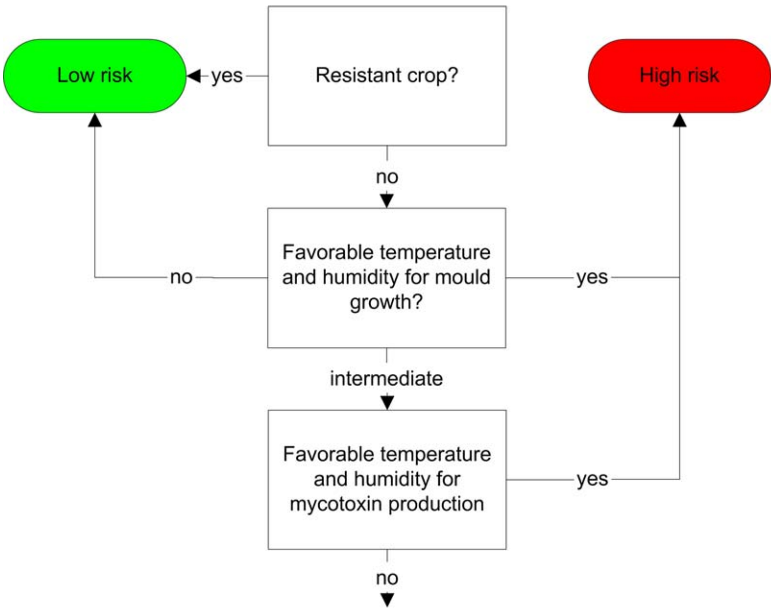

Figure 5.3 Example of a 'decision tree' model for risk on mycotoxin contamination.

5.1.4 Set-up of the model - approach

For the current purpose, the ‘traffic light model’ was used as a starting point, since it was expected that a) most reliable results will be obtained using all indicators and taking into account that some of them are more important than others and b) some interrelated indicators might need to be evaluated together (see also sections 3.2 and 4.3.2.4). During the discussion on the most important indicators in the workshop, several experts stressed that the choice for the indicators will differ for different commodities, mycotoxins and/or fungi and that for example optimal weather circumstances will vary for different mycotoxins and/or fungi. During the development of the model, it was attempted to design a blue-print of a model that can be used for different fungi, mycotoxins on all four commodities (wheat, maize, peanuts and tree nuts). This blue-print can be specified for a certain (fungi/mycotoxin in a) commodity by inclusion of different indicators, with different importance factors and by defining the risk categories differently per commodity/fungi/mycotoxin.

For wheat, during the workshop the main indicators were defined in more detail, leading to several sub-indicators e.g. ‘water content of the kernel’ and ‘temperature differences in the storage facility’ as sub-indicators for the indicator ‘storage and transport conditions’. For the other commodities (maize, peanuts and tree nuts), the indicators and sub-indicators defined in the workshop for wheat were critically reviewed for their predictive value for these commodities. Based on the results of the interviews and based on additional literature research additional indicators and sub-indicators were defined for maize, peanuts and tree nuts. During the interviews, peanuts and tree nuts were discussed together, but due to their differences in growth (trees versus plants), these commodities are now discussed separately.

For the (sub-)indicators that were defined for the different commodities, different risk categories were defined to facilitate inclusion in the model. Depending on the indicator, two (‘red’ and ‘green’) or three (‘red’, ‘yellow’ and ‘green’) risk categories were defined with ‘red’ referring to high risk of occurrence of mycotoxins, ‘yellow’ referring to intermediate risk of occurrence of mycotoxins and ‘green’ referring to low risk of occurrence of mycotoxins. The risk categories are separated from each other by threshold values that are referred to as ‘cut-off values’ in this report. For all commodities the definition of the cut-off values and the corresponding risk categories are described in section 5.2. These risk categories and the corresponding cut-off values are based on the interpretation of available data (obtained from literature, from the interviews, from the workshop or from other expert judgements) by the project members. Further validation of these risk categories and the corresponding cut-off values using a sufficient amount of data is needed.

Furthermore, to each (sub-)indicator, an importance factor was attributed per commodity, based on expert judgements (obtained during the interviews and workshop), existing models, or the judgement of the project members. These importance scores are listed in section 5.3. Further validation of these importance factors using a sufficient amount of data is needed as well.

In addition, as discussed in section 3.2 and during the workshop (section 4.3.2.4) several interrelationships between indicators exist. In the model, these interrelations are included in the risk categories (e.g. if intermediate tillage is performed, the risk category is yellow, but if intermediate tillage is performed and maize is pre-crop, the risk category is red).

Urgency factors are not yet included in the model. In a later stage, urgency factors may be included in the model, since this may be valuable for several proactive risk management strategies such as giving advice along the food chain or for the determination of purchasing strategies by industrial stake holders.

5.2 Definition of risk categories and interrelations of the indicators

5.2.1 Temperature and relative humidity during cultivation

5.2.1.1 General

Relative humidity and temperature during cultivation (pre-harvest) are two indicators that are highly interrelated and therefore these indicators will be discussed together in this section. For all commodities (wheat, maize, peanuts and tree nuts), the respective (sub-)indicators relating to relative humidity and temperature will be described in the next sections.

Table 5.1 Favourable temperature and water activity for fungal growth and the production of mycotoxins

Fungus Species	**Fungal growth or mycotoxin**	**Optimum temperature (ºC)**	**Water activity (a_w)**	**Reference**
DON + T-2 + HT-2 producing fungi				
F. graminearum	fungal growth	25	>0.88	JECFA, 2001a
	fungal growth	24-26	>0.9	FAO, 2001
	fungal growth	24-28		Doohan et al., 2003
	DON	25-28	0.97	Doohan et al., 2003
F. culmorum	fungal growth	21	>0.87	JECFA, 2001a
F. proliferatum	fungal growth	30	>0.925	Doohan et al., 2003
F. verticillioides and F. proliferatum	DON	11	0.90	Murphy et al., 2006
F. sporotrichioides	fungal growth	22.5 – 27.5	>0.88	FAO, 2001
	T-2 + HT-2	20-25	0.99	Doohan et al., 2003
OTA producing fungi				
A. ochraceus	fungal growth	moderate	>0.8	JECFA, 2001b
	fungal growth	25-31	>0.79	FAO, 2001
	OTA	25-28		FAO, 2001
	OTA	30	0.98	Murphy et al., 2006
A. carbonarius	fungal growth	high	<0.82	JECFA, 2001b
	OTA	15-20	0.85-0.90	Murphy et al., 2006
A. niger	fungal growth	35-37	various	JECFA, 2001
P. verrucosum	fungal growth	<30	<0.80	JECFA, 2001b
	fungal growth	0-31	>0.80	FAO, 2001
	OTA	0-31	>0.86	FAO, 2001
	OTA	25	0.90-0.98	Murphy et al., 2006
Aflatoxin producing fungi				
A. parasiticus	fungal growth	30	>0.83	FAO, 2001
	aflatoxins	33	0.99	Murphy et al., 2006
	aflatoxins	28	>0.87	FAO, 2001
A.flavus	fungal growth	30	0.82-0.99	FAO, 2001
	aflatoxins	20-30		FAO, 2001
	aflatoxins	33	0.99	Murphy et al., 2006

To facilitate the derivation of cut-off values for the (sub-)indicators, in Table 5.1, the results of literature searches on optimal temperature and humidity conditions for fungal growth and/or the production of mycotoxins are listed for the most relevant mycotoxins as identified in section 2.3. In most literature, humidity is expressed as the water activity (a_w), which is defined as the vapor pressure of water in a product divided by that of pure water at the same temperature. Therefore, pure distilled water has a water activity of exactly one and a_w has no unit.

5.2.1.2 Wheat

In literature, several regional predictive models for mycotoxin formation on wheat are described that include parameters on relative humidity and temperature. Table 5.2 summarizes some threshold values for relative humidity and temperature used in these models. Since these models are regional models, these threshold values can not be extrapolated to other regions. However, they do give an indication which ranges in relative humidity and temperature are favourable for the occurrence of mycotoxins in wheat.

Table 5.2 Literature overview of threshold values related to temperature and/or relative humidity for the occurrence of mycotoxins in wheat.

Mycotoxin	Indicators	Country	Reference
FHB*	FHB incidence increased with number of 2 d periods with rain (≥0,2 mm) and RH > 81% on the first and ≥ 78% on second day. FHB incidence decreased with days with maximum daily temperatures >26ºC or <9ºC.	Argentina	Moschini et al., 2001
DON	FHB increased with rain >5 mm and decreased with temperatures < 10ºC (4-7 days before heading), increased with rain >3mm and with temperatures > 32ºC (3-6 days after heading), FBH increased with rain > 3 mm (7-10 days after heading)	Canada	Hooker et al., 2002
DON, ZEA	Sequences of rainy days, air temperature, relative humidity, rainfall, wetness duration, and free water in the host tissue (a_w)	Italy	Rossi et al., 2003a; 2003b
DON, T-2, HT-2	Tmax ≥17ºC, Tmin≥10ºC Humidity at noon ≥ 75% Rainfall during 24 h ≥1 mm	Norway	Nordby et al., 2004

* FHB: *Fusarium* Head Blight

Since optimum humidity and temperature conditions differ for the various fungi and mycotoxins that can occur in wheat (see Table 5.1), it is difficult to define general cut-off values which are valid for all mycotoxins. Therefore cut-off values were defined in such a way that it is expected that the conditions that are most favorable for most of the mycotoxins can be distinguished from less favorable and unfavorable conditions. Based on Table 5.1, Table 5.2, the results of the workshop (see chapter 4) and unpublished data from the Netherlands two sub-indicators were defined related to relative humidity and temperature. A high humidity (relative humidity > 80% or > 5 mm rain per day) is a risk factor for the occurrence of mycotoxins. For most of the mycotoxins occurring in wheat, this is especially the case in combination with a high temperature (>20°C). Therefore, the two sub-indicators are:

(a) the number of days with a relative humidity > 80% or > 5 mm rain and a temperature > 20°C in the two-weeks period around flowering and two weeks before harvest
(b) the number of days with a relative humidity > 80% or > 5 mm rain and a temperature ≤ 20°C in the two-weeks period around flowering and two weeks before harvest,

with (a) having a stronger influence on than the outcome of the model than (b).

By including the two weeks before harvest period into this indicator, weather conditions that may increase the risk on mycotoxin contamination due to delayed harvest are accounted for in the model. The risk category of the both indicators, will be:

- green when a = 0 days and 0 ≤ b ≤ 2 days,
- yellow when 0 < a ≤ 2 days or b > 2 days,
- red when a > 2 days.

These risk categories and the corresponding cut-off values need further validation.

5.2.1.3 Maize

For maize, no predictive models that include threshold values for relative humidity and temperature are described in literature. It is difficult to define general cut-off values which are valid for all mycotoxins occurring in maize, because many fungi and mycotoxins with different optimum humidity and temperature conditions (see Table 5.1) can occur in maize. Based on the values of Table 5.1, together with the data from the predictive models for wheat (Table 5.2), for maize the same sub-indicators related to relative humidity and temperature were defined as for wheat (see 5.2.1.2). In addition the sub-indicator drought stress is included, since this is an important indicator for aflatoxin contamination in maize (Blaney, 2007). The three sub-indicators are therefore:

(a) the number of days with a relative humidity > 80% or > 5 mm rain and a temperature > 20°C in the two-weeks period around flowering and two weeks before harvest
(b) the number of days with a relative humidity > 80% or > 5 mm rain and a temperature ≤ 20°C in the two-weeks period around flowering and two weeks before harvest,
(c) ‘days of drought stress’ (further definition of drought stress is necessary).

with (a) having a stronger influence on than the outcome of the model than (b).

By including the two weeks before harvest period into this indicator, weather conditions that may increase the risk on mycotoxin contamination due to delayed harvest are accounted for in the model. The risk category of the both indicators, will be:

- green when a = 0 days and 0 ≤ b ≤ 2 days and c = 0 days,
- yellow when 0 < a ≤ 2 days or b > 2 days or 0 < c ≤ 20 days,
- red when a > 2 days or c> 20 days.

These risk categories and the corresponding cut-off values need further validation.

5.2.1.4 Peanuts

For peanuts, the most important mycotoxins are aflatoxins. In literature several quantitative indicators for the occurrence of aflatoxins in peanuts are described. Two main indicators are soil and air temperature and kernel moisture according to Queensland Government (2007). Soil and air temperatures between 22 and 35 °C increase the risk of aflatoxin infection of peanuts (Queensland Government, 2007). Although fungi generally grow better when the humidity is high, drought stress during the pre-harvest period may increase mycotoxin production, by reducing the kernel moisture in the field, leading to a longer period in which the kernel moisture is favourable for aflatoxin production (15 – 30%) (see Figure 5.4) (Queensland Government, 2007). Kernel moisture in a range around 15 –

30% for more than 7 – 14 days can be used as an indicator for an increased risk of aflatoxin contamination. It can occur either pre-harvest (when end-of-season drought increases the time period in which the kernel moisture is between 15-30%) or post-harvest (when pods are dried too slowly or inadequately).

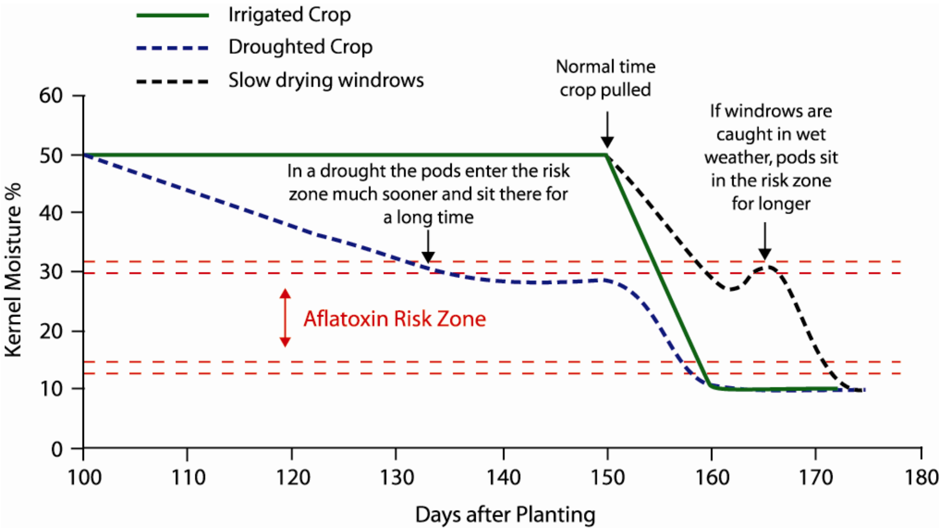

Figure 5.4 Kernel moisture content risk zone [Adapted from Queensland Government, 2007].

In a model described by Henderson et al. (2000), three quantitative indicators related to relative humidity and temperature were used: length of drought stress period, mean soil temperature, and accumulated heat units (AHU). Drought stress was the number of consecutive days of drought conditions; mean soil temperature was the mean temperature of the soil during this period, and accumulated heat units were defined as the daily accumulation of heat above 25 °C during the drought period. This value was calculated by the following equation: AHU = (mean soil temperature – 25) x length of drought stress period.

Based on these data and the information from Table 5.1, for peanuts three sub-indicators related to relative humidity and temperature were defined, being

(a) 'days with a relative humidity > 70% and a temperature > 22°C before harvest',
(b) 'days with a relative humidity > 70% and a temperature ≤ 22°C before harvest',
(c) 'days of drought stress' (further definition of drought stress is necessary).

For all indicators, the risk categories are:

- green when a = 0 days and 0 ≤ b ≤ 7 days and c = 0 days,
- yellow when 0 < a ≤ 7 days or b > 7 days or 0 < c ≤ 20 days,
- red (when a > 7 days or c > 20 days).

This should be investigated using a data set before the exact cut-off values and time windows for these indicators can be defined. Pre-harvest kernel moisture could also be an indicator, but this is probably difficult to monitor, and is therefore not included in the model.

5.2.1.5 Tree nuts

For tree nuts, the most important mycotoxins are aflatoxins. In literature predictive models for the occurrence of aflatoxin in tree nuts have not been described. Warm, humid climate and drought stress are mentioned in several publications as important risk factors for aflatoxin contamination of tree nuts (Bayman et al., 2002; Boutrif et al., 1998; CAC, 2005). *Aspergillus flavus/A. parasiticus* cannot grow or produce aflatoxins at water activities less than 0.7, relative humidity below 70% and temperatures below 10ºC, whereas under stress conditions such as drought aflatoxin contamination is likely to be high (CAC, 2005).

Based on these data and the information from Table 5.1, three sub-indicators related to relative humidity and temperature were defined for tree nuts:

(a) 'days with a relative humidity > 70% and a temperature ≥ 22°C',
(b) 'days with a relative humidity > 70% and a temperature ≤ 22°C',
(c) 'days of drought stress'.

The sub-indicator 'days of drought stress', needs to be defined more specifically in the validation stage of the model. For all indicators, the risk categories are:

- green when a = 0 days and 0 ≤ b ≤ 7 days, and c = 0 days,
- yellow when 0 < a ≤ 7 days or b > 7 days or 0 < c ≤ 30 days,
- red when a > 7 days or c > 30 days.

This should be investigated using a data set before the exact cut-off values and time windows for these indicators can be defined. Pre-harvest kernel moisture could also be an indicator, but this is probably difficult to monitor, and is therefore not included in the model.

5.2.2 Crop rotation

An important risk factor for infection with mycotoxin producing fungi could be the presence of contaminated crop debris of the preceding crop in the field. Therefore, the consecutive culture of crops that are hosting the same mycotoxin producing fungi should be avoided. This is important for wheat, maize and peanuts. For the culture of (amongst others) wheat and maize, the Code of Practice of the European Union recommends a crop rotation schedule which avoids growing the same crop in a field in two consecutive years and that avoids cultivation of wheat and maize in rotation with each other. It is suggested to use crops such as potato, other vegetables, clover and lucerne, as pre-crops for wheat and maize (CAC, 2003) and maize should be excluded as a pre-crop for other cereals (Blonk et al., 2000). It has been shown that cultivation of the crop 3 years previous to the current crop has no effect on the formation of *Fusarium* head blight (FHB) in wheat, while the crop 2 years previous to the current crop has only a minor effect (Schaafsma et al., 2001). The continued cultivation of peanuts on the same land or the rotation of peanuts with other *A. flavus* or *A. parasiticus* fungi host crops such as maize will increase the probability of infection and aflatoxin contamination, due to the presence of inoculums in the soil (Queensland Government, 2007; CAC, 2004). For tree nuts, crop rotation is not relevant, since tree nuts are grown in orchards without crop rotation.

As crop rotation could influence the formation of mycotoxins in wheat, maize and peanuts, the preceding crop in the year before will be used as an indicator for these commodities. For wheat and maize, three risk categories are used:

- red when maize is pre-crop,
- yellow when wheat is pre-crop,
- green when an other crop is pre-crop.

For peanuts two risk categories will be used:
- red when maize or peanuts are pre-crop,
- green when another crop is pre-crop.

5.2.3 Tillage policy

The production of mycotoxins by fungi can be influenced by the soil management (tillage) strategies. Three types of soil cultivation were described by Edwards et al. (2004): (a) deep ploughing, where the top 10–30 cm of soil are inverted, (b) minimum tillage, where the crop debris is mixed with the top 10–20 cm of soil, and (c) no-tillage, meaning the seed is directly drilled into the previous crop stubble with minimum disturbance to the soil structure. Although tillage is not for all fungi and mycotoxins important, some fungi (spores) can survive on debris and in the soil when conditions are favorable and therefore deep ploughing could considerably reduce chances on fungi infection of the next crop. When minimum tillage or no-tillage is applied, the growth conditions for the spores are more favorable and there will be an increased chance of the infection of the roots, leaves and ear of the next crop. For wheat, maize and peanuts, soil cultivation (tillage) strategies are especially important (Kennisakker, 2007). However, due to erosion problems, no-tillage practices are required in several regions. Also burning off the stubble can reduce the survival of the fungi, but this is forbidden in the Netherlands and many other countries.
For tree nuts, tillage is not an important indicator, since in orchards were tree nuts are grown no-tillage is performed. However, for nuts it is important that after harvest, the nuts remaining on the trees and litter and crop debris from harvest operations are removed (CAC, 2005). However, this factor is not included in the decision model.

Tillage will be used as an indicator for wheat, maize and peanuts. Three risk categories are defined for tillage. For wheat, maize and peanuts, the risk categories are:
- green when deep ploughing is performed,
- yellow when intermediate ploughing is performed,
- red when no ploughing is performed or when intermediate ploughing is performed and maize is pre-crop.

5.2.4 Drying

In order to avoid mycotoxin formation or outgrow of fungi during the storage it is important that wheat and maize granules, peanuts and tree nuts have a sufficiently low moisture level before storage. For wheat and maize, generally, a moisture level of less than 15% is regarded as a suitable moisture level according to the Code of Practice of the European Union (CAC, 2003). If it is not possible to harvest the grain with a suitable moisture content, it is necessary to dry the grain as quickly as possible. This is especially important for maize, with its high water content of 30% at harvest (Schrödter, 2004). For peanuts, poor post-harvest drying methods (in windrows and artificial driers) can result in uneven drying, which may lead to increased aflatoxin contamination in storage. Further, both under- or over-drying can significantly affect seed quality (especially splits, blanchability, off-flavours and seed germinability). Kernel moistures around 15 -30% for more than 7 to 14 days increase the risk of aflatoxin contamination. This may occur when wet weather affects windrowing and/or when pods are inadequately dried. Peanuts should be dried in such a manner that damage to the peanuts is minimized and should only be stored after they have been dried down to a moisture level below 10 or 12.5%. This is necessary to prevent further growth of a number of fungal species in peanuts (CAC, 2004; Queensland Government, 2007). Tree nuts should be dried as soon as possible after hulling to a safe moisture level (below 6%). De-hulled nuts that are allowed to sun-dry are at a greater risk of becoming contaminated during the drying process as a result of fungal growth and/or damage by pests.

Mechanical driers should be available and used to reduce the potential of further aflatoxin contamination in regions where steam or aqueous solutions are traditionally used to facilitate de-hulling, and segregation of defective nuts (CAC, 2005; Boutrif, 1998).
Drying of the crops until a suitable moisture level is reached is important for wheat, maize, peanuts and tree nuts. For all commodities, the moisture content in the kernel at the beginning of the storage will be used as an indicator. Risk categories defined for wheat and maize are:
- green when moisture content ≤ 13%,
- yellow when moisture content is between 13-15%,
- red when moisture content > 15%.

For peanuts and tree nuts, two risk categories ('green' and 'red') were defined:
- green when moisture content ≤ 10% (for peanuts) or ≤ 6% (for tree nuts),
- red when moisture content > 10% (for peanuts) or > 6% (for tree nuts).

5.2.5 Storage and transport conditions

During the workshop two important sub-indicators for storage and transport conditions were defined for mycotoxin formation on wheat. These were temperature differences within the day (difference in day and night temperature) and the relative humidity in the storage facility. During storage, large differences in temperature can cause condensation and increase the risk on fungi growth and mycotoxin production. For wheat and maize, the EU advices to measure the temperature of the stored grain at several fixed time intervals during storage. A temperature increase of 2-3°C in the storage facility may indicate microbial growth and/or insect infestation EU, 2006a). Also steep rises and falls in outside temperature may cause condensation in the storage containers if ventilation is suboptimal. Furthermore, the humidity in the kernel at the end of the storage/transport period may be used as an indicator for wheat and maize.
For peanuts, the post-harvest storage is the phase that can contribute most to the aflatoxin problem in peanuts. The water activity, which varies with moisture content and temperature, should be carefully controlled during storage. Since *A. flavus/A. parasiticus* cannot grow or produce aflatoxins at water activities less than 0.7, the relative humidity should be kept below 70%. Temperatures between 0 and 10 °C are optimal for minimizing deterioration and fungal growth during long time storage. A temperature rise may indicate microbial growth and/or insect infestation (CAC, 2004). For tree nuts, the relative humidity should be kept below 65 to 70% and the temperature between 0ºC and 10ºC (for pistachios it should be 0ºC) to minimize fungal growth during storage (CAC, 2005; Boutrif et al., 1998).

For all commodities, the number of days with temperature differences outside the storage facility within the day > 10 °C (g) and the days with temperature differences inside the storage facility within the day > 3 °C (h) will be used as sub-indicators for storage and transport conditions with the risk categories:
- green when g=0 days and h=0 days,
- yellow when 0 < g ≤ 3 days and 0 < h ≤ 3 days,
- red when g > 3 days or h > 3 days.

For all commodities, the humidity in the kernel during the storage and transport phase (i) will be used as another sub-indicator. For wheat and maize, the risk categories are:
- green when i ≤ 13%,
- yellow when 13 < i ≤ 15,
- red when i > 15%.

For peanuts and tree nuts, relative humidity (j) and temperature (k) during storage are two additional sub-indicators that will be used in the model. For peanuts the risk category will be:

- green when i ≤ 10% and (j ≤ 70% or k ≤ 10°C),
- red when i > 10% or (j > 70% and k > 10 °C).

For tree nuts the two risk categories will be:

- green when i ≤ 6% and (j ≤ 65% or k ≤ 10°C),
- red when i > 6% or (j > 65% and k > 10 °C).

5.2.6 Crop variety

The susceptibility towards mycotoxin producing fungi of the crop variety that is cultivated is an important indicator for all commodities. For wheat and maize, it is recommended to use only seed varieties which are recommended for use in a particular area of a country to diminish mycotoxin contamination (CAC, 2003). In some countries it is possible to cultivate varieties which are (partially) resistant to fungi infection and insect pests. For peanuts it is recommended to use the peanut cultivars that have been adapted to the region that are recommended by the appropriate plant breeding authorities or agricultural extension services. Also for peanuts, it is possible to cultivate varieties that are less susceptible to various factors such as insect attack and microbial and fungal attack that can have an impact on the safety and quality of the peanuts produced. A cultivar should be selected that is suitable for a particular growing season and mature at the end of the rainy season so that post-harvest field drying can be done under favorable conditions (CAC, 2004). For tree nuts it is also advised to use species that are less susceptible to various factors (e.g., frost, microbial and fungal diseases), if available (CAC, 2005).

For wheat, maize, peanuts and tree nuts, the susceptibility towards mycotoxin producing fungi of the variety that is cultivated is an important indicator and will be included in the model. For all commodities, the risk categories are:

- green for low susceptibility,
- yellow for intermediate susceptibility,
- red for high susceptibility.

In future, these categories may be further defined based on crop resistance numbers.

5.2.7 Insect damage

Although 'insect damage' was not included in the top 10 indicators of the interviews and is not discussed in the workshop, it is an important indicator for maize, peanuts and tree nuts according to the literature. The EU (2006a) indicates that there is no evidence that insect control has any effect on *Fusarium* head blight of cereals in general, but that for maize the control of insects can reduce the incidence of *Fusarium* ear rot and the resulting fumonisin content of maize. In addition, it was indicated that the relationship between mycotoxins and insect damage makes it additionally difficult to predict the occurrence of mycotoxins in maize as compared to wheat (Schaafsma and Hooker, 2007). For peanuts, cultivation and crop protection practices lowering the incidence of soil insects, mites, and nematodes should help in reducing aflatoxin contamination (CAC, 2004). For tree nuts, growers should determine insects and other pests that are commonly found in their region that might attack tree nuts causing them to be more susceptible to fungal infections that can lead to aflatoxin production (CAC, 2005).

For maize, peanuts and tree nuts, insect damage (as determined by visual inspection) is a risk factor for mycotoxin contamination and will be included as an indicator in the model. The three risk categories for this indicator are:

- green for low insect damage,
- yellow for intermediate insect damage,
- red for high insect damage.

5.2.8 Blanching of nuts

During the interviews it was stressed that for peanuts and tree nuts, blanching of the nuts is effective in reducing the aflatoxin contamination, while on the other hand, when the blanching is done inadequately, the risk on mycotoxin contamination of a certain lot may be considerably higher. Blanching used in conjunction with gravity tables and manual or electronic sorting is very efficient in removing aflatoxin-contaminated kernels. Colour sorting, combined with blanching have been shown to reduce aflatoxin contamination by as much as 90% (CAC, 2003).

Therefore, for peanuts and tree nuts, blanching quality (as determined by visual inspection) will be used as an indicator in the model. For both commodities the risk categories are:

- green for high quality,
- yellow for intermediate quality,
- red for low quality.

5.3 Relative importance of the different indicators

An importance factor was assigned to each (sub-)indicator for all commodities, based on expert judgements (obtained during the interviews and workshop), existing models, and the judgement of the project members. In Table 5.3, all indicators (without the corresponding sub-indicators) are listed.

Hooker et al. (2002) describe that 73% of the variation in the concentration of DON in winter wheat can be explained by weather variables. Furthermore, De la Campa et al. (2005) indicate that 82% of the variation in fumonisin accumulation in grain can be explained by (listed in order of importance) weather, insect damage, hybrid and the use of Bt hybrids. Henderson et al. (2000) describe the development of a genetic algorithm/backpropagation neural network hybrid (GA/BPN) that predicts aflatoxin contamination levels in peanuts based on environmental data. This GA/BPN was evaluated by comparing predictions against observed or target values for the training, test and validation data sets, leading to R^2 values of 0.77, 0.70 and 0.51, respectively. However, this last model is based on measurements in peanuts that were grown in environmentally controlled stands, which makes it difficult to assess their predictive value for peanuts grown in the field.

The first two models are regional models that focus on one (type of) mycotoxin and therefore, temperature and relative humidity ranges are very specific for that (type of) mycotoxin in that region. Therefore, in the current (more general) model, a lower percentage of the outcome of the model was attributed to temperature and relative humidity.

For the current model, the importance factors were attributed such that temperature and relative humidity are responsible for about 40% of the outcome of the model for all commodities (see Table

5.3). Depending on the commodity, drying is responsible for about 15% (wheat and maize) or 20% (peanuts and tree nuts), followed by storage and transport conditions (divided into temperature and humidity), crop variety and insect damage which were all are responsible for about 5% or 10% of the outcome of the model. The relative importance of tillage and crop rotation varied between 0 and 15% of the outcome of the model the four commodities.

Table 5.3 Importance factors (IF) for wheat, maize, peanuts and tree nuts for all indicators.

Indicator	Wheat	Maize	Peanuts	Tree nuts
	IF (%)	IF (%)	IF (%)	IF (%)
Temperature and relative humidity	8 (38)	8 (38)	8 (38)	8 (38)
Crop rotation	2 (10)	2 (10)	1 (5)	0 (0)
Tillage	3 (14)	3 (14)	1 (5)	0 (0)
Drying	3 (14)	3 (14)	4 (19)	4 (19)
Storage and transport conditions: temperature	1 (5)	1 (5)	2 (10)	2 (10)
Storage and transport conditions: humidity	1 (5)	1 (5)	2 (10)	2 (10)
Crop variety	2 (10)	2 (10)	1 (5)	1 (5)
Insect damage	1 (5)	1 (5)	1 (5)	2 (10)
Blanching of nuts	0 (0)	0 (0)	1 (5)	1 (5)
Total	21 (100)	21 (100)	21 (100)	21 (100)

5.4 Detailed model for wheat, maize and nuts

Using the relevant (sub-)indicators (see section 5.2), their risk categories and corresponding cut-off values (see section 5.2) and their importance factors (see section 5.3), a blueprint of a traffic light model was designed. This blueprint includes all (sub-)indicators that were defined for at least one of the commodities. For commodities in which one of the (sub-)indicators is not used, an importance factor of 0 is attributed to this (sub-)indicator. In Tables 5.4-5.7, this model is specified for each commoditie by filling in the respective cut-off values and importance factors. This model is a generic model, and is not (yet) specified for different mycotoxins.

The first two columns of these tables include a description of the indicators and sub-indicators. The third column 'description input' describes the unit or possible values of the user input (column four). The fourth column 'user input' needs to be filled in by the user or may ideally be automatically derived from an electronic information source, depending on the situation that needs to be evaluated. In Tables 5.4-5.7, some random input values are filled in to show an example in which the input of the different indicators lead to different risk categories. The risk categories (green, yellow and red) and the corresponding cut-off values are described in the fifth column. The sixth column 'score' indicates the resulting risk category of the indicator given the user input. The risk category 'green' refers to a low risk (score=0), 'yellow' refers to intermediate risk (score =1) and 'red' refers to a high risk (score=2). The seventh column consists of the importance factors that were attributed to each indicator (see 5.3). The score for each indicator is multiplied by its importance factor, resulting in a total score (shown in the grey column) for each indicator. In the last column, the maximum total score that could be obtained for each indicator is given. This maximum total score is obtained by multiplying the maximum score possible (which is 2 for all indicators) with the importance factor).

The total scores and the maximum total scores are summed up and are shown at the bottom of the grey column 'total score' and the colum 'maximum total score', respectively. The overall score in the last row is the sum of the total scores expressed as a percentage of the sum of the maximum total scores for all indicators. This percentage is divided into three different categories, including 'green' (low risk of occurrence of mycotoxins, 0-33% of total score), 'yellow' (intermediate risk of occurrence of mycotoxins, 34-66% of total score) and 'red' (high risk of occurrence of mycotoxins, 67-100% of total score).

When using the model, it may be possible that user input is missing (i.e. data for certain indicators can not be obtained). In certain cases, even when the input for several indicators is missing, the overall score can already indicate a high risk of occurrence of mycotoxins, especially when the indicator 'temperature and relative humidity' gives its maximum score (14). Another option is to adjust the model by for example attributing a default score to each indicator that will be used when no user input is given. This option should be investigated during the performance assessment of this model. Furthermore, it is important to note that this model is a conceptual model and is not (yet) validated. Therefore, the numbers used in this model are estimated based on literature studies, expert opinions, and judgements of the project members. Before the exact cut-off values, time windows and importance factors for the indicators can be defined, a performance assessment for this model, using a sufficient amount of data, is needed.

Table 5.4 Model to assess the risk of occurrence of mycotoxins in wheat[a]

Indicator[b]		Description (sub-)indicator[b]	Description input[c]	User Input[d]	Cut off value[b]	Score[e]	Importance factor[f]	Total score[g]	Maximum total score[h]
Temperature and (relative) humidity	a	days with (relative humidity > 80% OR > 5 mm rain) AND > 20°C **in the two weeks period around flowering and two weeks before harvest**	number of days	3	a > 2	2	8	16	16
	b	days with (relative humidity > 80% OR > 5 mm rain) AND ≤ 20°C **in the two weeks period around flowering and two weeks before harvest**	number of days	0	0 < a ≤ 2 OR b > 2				
	c	days of drought stress	number of days		a = 0 AND 0 ≤ b ≤ 2				
Crop rotation	d	crop grown the year before growing **wheat**	maize wheat peanuts other	maize	maize wheat other	2	2	4	4
Tillage	e	tillage policy	no intermediate deep ploughing	no	no OR (intermediate when d = maize) intermediate deep ploughing	2	3	6	6
Drying	f	humidity in kernel before storage	percentage	2	f > 15 13 < f ≤15 f ≤ 13	0	3	0	6
Storage and transport conditions: temperature	g	days with outside temperature differences within one day > 10°C	number of days	2	g> 3 OR h > 3 0 < g ≤ 3 AND 0 < h ≤3 g=0 AND h=0	1	1	1	2
	h	days with inside temperature differences > 3°C	number of days	0					
Storage and transport conditions: humidity	i	humidity in kernel during storage	percentage	16	i >15 13< i ≤15 i ≤ 13	2	1	2	2
	j	relative humidity during storage	percentage						
	k	temperature during storage	°C						
Crop variety	l	susceptibility for fungal contamination	high intermediate low	low	high intermediate low	0	2	0	4
Insect damage	m	crop damage	high intermediate low	low	high intermediate low	0	1	0	2
Blanching of nuts	n	quality of blanching	low intermediate high		low intermediate high	0	0	0	0
Sum of (maximum) total scores[i]								29	42
Overall score[j]		≥ 66% 33 ≤ x < 66% < 33%			high intermediate low			69%	

a Please note that this model is a conceptual model and is not (yet) validated. Therefore, the numbers used in this model are estimated based on literature studies and expert opinions and are estimated by the project members. Before the exact cut-off values, time windows and importance factors for the indicators can be defined, further validation of this model, using a sufficient amount of data, is needed. In the column 'user input' a fictive score is shown.

b For a more detailed description of the (sub-)indicators and cut-off values see section 5.2.

c The unit or the possible values of the user input. For quantitative indicators the unit (e.g. number of days, % or °C) is given. For semi-quantitative or qualitative indicators the possible values (e.g. high, intermediate, low) are given.

d The input that is filled in by the user of the model or that is automatically derived from an electronic information source. This input varies depending on the situation that needs to be evaluated. In this table some random input values are filled for explanatory purposes.

e The resulting risk category of each indicator given the user input. The risk category red (score=2) refers to a high risk, yellow (score=1) to an intermediate risk, and green (score=0) to a low risk of mycotoxin contamination of the commodity.

f The relative importance of the (sub-)indicators as described in section 5.3.

g The score multiplied by the importance factor.

h The maximum total score that could be obtained for each indicator (the maximum score possible (red=2) multiplied by the importance factor).

i The sum of the total scores of all indicators and the sum of the maximum scores of all indicators.

j The sum of the total scores divided by the sum of the maximum total scores of all indicators, expressed as a percentage and divided into three categories. The risk category red (66-100%) refers to a high risk, yellow (33-65%) to an intermediate risk, and green (0-32%) to a low risk of mycotoxin contamination of the commodity.

rivm

Table 5.5 Model to assess the risk of occurrence of mycotoxins in maize[a]

Indicator[b]		Description (sub-)indicator[b]	Description input[c]	User Input[d]	Cut off value[b]	Score[e]	Importance factor[f]	Total score[g]	Maximum total score[h]
Temperature and (relative) humidity	a	days with (relative humidity **> 80%** OR **> 5 mm rain**) AND **> 20°C in the two weeks period around flowering and two weeks before harvest**	number of days	0	a > 2	0	8	0	16
	b	days with (relative humidity **> 80%** OR **> 5 mm rain**) AND **≤ 20°C in the two weeks period around flowering and two weeks before harvest**	number of days	1	0 < a ≤ 2 OR b > 2				
	c	days of drought stress	number of days	0	a = 0 AND 0 ≤ b ≤ 2				
Crop rotation	d	crop grown the year before growing **maize**	maize wheat peanuts other	maize	maize wheat other	2	2	4	4
Tillage	e	tillage policy	no intermediate deep ploughing	no	no OR (intermediate when d = maize) intermediate deep ploughing	2	3	6	6
Drying	f	humidity in kernel before storage	percentage	14	f > 15 13 < f ≤ 15 f ≤13	0	3	0	6
Storage and transport conditions: temperature	g	days with outside temperature differences within one day > 10 °C	number of days	2	g> 3 OR h > 3 0 < g ≤ 3 AND 0< h ≤ 3 g = 0 AND h = 0	2	1	2	2
	h	days with inside temperature differences > 3° C	number of days	4					
Storage and transport conditions: humidity	i	humidity in kernel after storage	percentage	16	i > 15 13 < i ≤ 15 i ≤13	2	1	2	2
	j	relative humidity during storage	percentage						
	k	temperature during storage	°C						
Crop variety	l	susceptibility for fungal contamination	high intermediate low	low	high intermediate low	0	2	0	4
Insect damage	m	crop damage	high intermediate low	low	high intermediate low	0	1	0	2
Blanching of nuts	n	quality of blanching	low intermediate high		low intermediate high	0	0	0	0
Sum of (maximum) total scores[i]								14	42
Overall score[j]		≥ 66% 33 ≤ x < 66% < 33%			high intermediate low			33%	

a Please note that this model is a conceptual model and is not (yet) validated. Therefore, the numbers used in this model are estimated based on literature studies and expert opinions and are estimated by the project members. Before the exact cut-off values, time windows and importance factors for the indicators can be defined, further validation of this model, using a sufficient amount of data, is needed. In the column 'user input' a fictive score is shown.

b For a more detailed description of the (sub-)indicators and cut-off values see section 5.2.

c The unit or the possible values of the user input. For quantitative indicators the unit (e.g. number of days, % or °C) is given. For semi-quantitative or qualitative indicators the possible values (e.g. high, intermediate, low) are given.

d The input that is filled in by the user of the model or that is automatically derived from an electronic information source. This input varies depending on the situation that needs to be evaluated. In this table some random input values are filled for explanatory purposes.

e The resulting risk category of each indicator given the user input. The risk category red (score=2) refers to a high risk, yellow (score=1) to an intermediate risk, and green (score=0) to a low risk of mycotoxin contamination of the commodity.

f The relative importance of the (sub-)indicators as described in section 5.3.

g The score multiplied by the importance factor.

h The maximum total score that could be obtained for each indicator (the maximum score possible (red=2) multiplied by the importance factor).

i The sum of the total scores of all indicators and the sum of the maximum scores of all indicators.

j The sum of the total scores divided by the sum of the maximum total scores of all indicators, expressed as a percentage and divided into three categories. The risk category red (66-100%) refers to a high risk, yellow (33-65%) to an intermediate risk, and green (0-32%) to a low risk of mycotoxin contamination of the commodity.

Table 5.6 Model to assess the risk of occurrence of mycotoxins in peanuts[a]

Indicator[b]		Description (sub-)indicator[b]	Description input[c]	User Input[d]	Cut off value[b]	Score[e]	Importance factor[f]	Total score[g]	Maximum total score[h]
Temperature and (relative) humidity	a	days relative humidity **> 70%** AND **> 22°C before harvest**	number of days	9	a>7 OR c>20	2	8	16	16
	b	days relative humidity **> 70%** AND **≤ 22°C before harvest**	number of days	8	0 < a ≤ 7 OR b>7 OR 0 < c ≤ 20				
	c	days of drought stress	number of days	1	a = 0 AND 0 < b ≤ 7 AND c = 0				
Crop rotation	d	crop grown the year before growing **peanuts**	maize wheat peanuts other	maize	maize or peanuts other	2	1	2	2
Tillage	e	tillage policy	no intermediate deep ploughing	no	no OR (intermediate when d = maize/peanuts) intermediate tillage deep ploughing	2	1	2	2
Drying	f	humidity in kernel before storage	percentage	7	f > 10 f ≤10	0	4	0	8
Storage and transport conditions: temperature	g	days with outside temperature differences within one day > 10 °C	number of days	2	g > 3 OR h > 3 0 < g ≤ 3 AND 0< h ≤ 3	1	2	2	4
	h	days with inside temperature differences within one day > 3 °C	number of days	0	g = 0 AND h = 0				
Storage and transport conditions: humidity	i	humidity in kernel during storage	percentage	0	i > 10 OR (j > 70 AND k > 10)	0	2	0	4
	j	relative humidity during storage	percentage	0	i ≤ 10 AND (j ≤ 70 OR k ≤ 10)				
	k	temperature during storage	degrees celsium	0					
Crop variety	l	susceptibility for fungal contamination	high intermediate low	low	high intermediate low	0	1	0	2
Insect damage	m	crop damage	high intermediate low	low	high intermediate low	0	1	0	2
Blanching of nuts	n	quality of blanching	low intermediate high	no	low intermediate high	2	1	2	2
Sum of (maximum) total scores[i]								24	42
Overall score[j]		≥ 66% 33% ≤ x < 66% < 33%			high intermediate low			57%	

a Please note that this model is a conceptual model and is not (yet) validated. Therefore, the numbers used in this model are estimated based on literature studies and expert opinions and are estimated by the project members. Before the exact cut-off values, time windows and importance factors for the indicators can be defined, further validation of this model, using a sufficient amount of data, is needed. In the column 'user input' a fictive score is shown.

b For a more detailed description of the (sub-)indicators and cut-off values see section 5.2.

c The unit or the possible values of the user input. For quantitative indicators the unit (e.g. number of days, % or °C) is given. For semi-quantitative or qualitative indicators the possible values (e.g. high, intermediate, low) are given.

d The input that is filled in by the user of the model or that is automatically derived from an electronic information source. This input varies depending on the situation that needs to be evaluated. In this table some random input values are filled for explanatory purposes.

e The resulting risk category of each indicator given the user input. The risk category red (score=2) refers to a high risk, yellow (score=1) to an intermediate risk, and green (score=0) to a low risk of mycotoxin contamination of the commodity.

f The relative importance of the (sub-)indicators as described in section 5.3.

g The score multiplied by the importance factor.

h The maximum total score that could be obtained for each indicator (the maximum score possible (red=2) multiplied by the importance factor).

i The sum of the total scores of all indicators and the sum of the maximum scores of all indicators.

j The sum of the total scores divided by the sum of the maximum total scores of all indicators, expressed as a percentage and divided into three categories. The risk category red (66-100%) refers to a high risk, yellow (33-65%) to an intermediate risk, and green (0-32%) to a low risk of mycotoxin contamination of the commodity.

Table 5.7 Model to assess the risk of occurrence of mycotoxins in tree nuts[a].

Indicator[b]	Description (sub-)indicator[b]		Description input[c]	User Input[d]	Cut off value[b]	Score[e]	Importance factor[f]	Total score[g]	Maximum total score[h]
Temperature and (relative) humidity	a	days relative humidity **> 70%** AND **> 22°C before harvest**	number of days	0	a>7 OR c>30 0 < a ≤ 7 OR b>7 OR 0 < c ≤ 30 a=0 AND 0 < b ≥ 7 AND c=0	0	8	0	16
	b	days relative humidity **> 70%** AND **≤ 22°C before harvest**	number of days	7					
	c	days of drought stress	number of days	0					
Crop rotation	d	crop grown the year before growing **tree nuts**	maize wheat peanuts other		maize or peanuts other	0	0	0	0
Tillage	e	tillage policy	no intermediate deep ploughing		no OR (intermediate when d = maize/peanuts) intermediate tillage deep ploughing	0	0	0	0
Drying	f	humidity in kernel before storage	percentage	5	f > 6 f ≤ 6	0	4	0	8
Storage and transport conditions: temperature	g	days with outside temperature differences within one day > 10 °C	number of days	0	g > 3 OR h > 3 0 < g ≤ 3 AND 0< h ≤ 3 g = 0 AND h = 0	1	2	2	4
	h	days with inside temperature differences within one day > 3 °C	number of days	2					
Storage and transport conditions: humidity	i	humidity in kernel during storage	percentage	5	i > 6 OR (j > 65 AND k > 10) i ≤ 6 AND (j ≤ 65 OR k ≤ 10)	2	2	4	4
	j	relative humidity during storage	percentage	88					
	k	temperature during storage	degrees celsium	15					
Crop variety	l	susceptibility for fungal contamination	high intermediate low	low	high intermediate low	0	1	0	2
Insect damage	m	crop damage	high intermediate low	low	high intermediate low	0	2	0	4
Blanching of nuts	n	quality of blanching	no intermediate high	no	no intermediate high	2	1	2	2
Sum of (maximum) total scores[i]								8	40
Overall score[j]		≥ 66% 33 ≤ x < 66% < 33%			high intermediate low			20%	

a Please note that this model is a conceptual model and is not (yet) validated. Therefore, the numbers used in this model are estimated based on literature studies and expert opinions and are estimated by the project members. Before the exact cut-off values, time windows and importance factors for the indicators can be defined, further validation of this model, using a sufficient amount of data, is needed. In the column 'user input' a fictive score is shown.

b For a more detailed description of the (sub-)indicators and cut-off values see section 5.2.

c The unit or the possible values of the user input. For quantitative indicators the unit (e.g. number of days, % or °C) is given. For semi-quantitative or qualitative indicators the possible values (e.g. high, intermediate, low) are given.

d The input that is filled in by the user of the model or that is automatically derived from an electronic information source. This input varies depending on the situation that needs to be evaluated. In this table some random input values are filled for explanatory purposes.

e The resulting risk category of each indicator given the user input. The risk category red (score=2) refers to a high risk, yellow (score=1) to an intermediate risk, and green (score=0) to a low risk of mycotoxin contamination of the commodity.

f The relative importance of the (sub-)indicators as described in section 5.3.

g The score multiplied by the importance factor.

h The maximum total score that could be obtained for each indicator (the maximum score possible (red=2) multiplied by the importance factor).

i The sum of the total scores of all indicators and the sum of the maximum scores of all indicators.

j The sum of the total scores divided by the sum of the maximum total scores of all indicators, expressed as a percentage and divided into three categories. The risk category red (66-100%) refers to a high risk, yellow (33-65%) to an intermediate risk, and green (0-32%) to a low risk of mycotoxin contamination of the commodity.

5.5 Discussion

A blueprint of a model was developed to assess the risk of occurrence of mycotoxins on wheat, maize, peanuts and tree nuts. For each commodity, the model was specified by defining the relevant (sub-)indicators, the risk categories (and corresponding cut-off values) and importance scores. Interrelationships between parameters were included in the risk categories. However, for certain (sub-)indicators, it is not possible to fully derive the cut-off values based on the literature data available. In addition, not enough information is available to assign solid importance factors to the different indicators. Therefore these cut-off values and importance factors need to be evaluated during a performance assessment of the model, with the use of a suitable data set. During the performance assessment, it should be determined which indicators/sub-indicators can be filled in using existing knowledge or available data sources, and whether the model can estimate the mycotoxin contamination accurately even when several indicators can not be filled in due to lack of data.

6 Identification of data sources

This chapter describes for which indicators of the proposed model information is available for the different end-users of the model (governmental users and industry). Open access/public data sources were identified based on the results of the interviews and the workshop, literature searches and web searches. In addition, the relevant open access/public data sources described in Park and Bos (2007) were selected. Furthermore, an inventory was made of the information and the data sources that are currently available for a governmental stakeholder (the Dutch Food and Consumer Product Safety Authority, VWA) and two industrial stakeholders that were interviewed.

6.1 Open access data sources

6.1.1 Data sources for indicators related to climate

Weather forecast services are widely available for practically every location in the world, such as for example The Royal Netherlands Meteorological Institute (KNMI) and MeteoConsult (part of MeteoGroup) in the Netherlands. The site of the The Royal Netherlands Meteorological Institute (KNMI) provides daily meteorological data for ten locations in the Netherlands, including average, minimum and maximum temperature, average relative humidity and amount and duration of precipitation (http://www.knmi.nl/).
MeteoGroup provides meteorological data, ranging from worldwide ground observations, to raw global model forecasts and weather predictions for any location worldwide. Furthermore, they can offer a wide range of information and services for agriculture, including detailed forecasts including temperature, relative humidity, and precipitation, and that they can provide models that translate meteorological information into advanced planning tools for farmers. MeteoGroup also supplies significant meteorological datasets that can be used as input into modelling systems (Website MeteoGroup; www.meteogroup.com).
The World Climate Service is a joint enterprise of Weather Ventures Ltd. and ZedX, inc., in collaboration with MeteoConsult in the Netherlands and its affiliates throughout Europe. Against payment, it provides analysis of seasonal trends and outlooks for the entire world. Products include periodic newsletters and a website providing probabilistic seasonal forecasts of temperature and precipitation for selected geographical regions or the entire world. The World Climate Service Website provides monthly updates of forecasts for each of the next six months in probabilistic formats for six continents or geographical areas (North America and Central America; South America; Europe and the Middle East; Africa; Asia; Australia and Oceania). Premium services include user-decision aids specifying probabilities of occurrence of user-defined events and climatological analyses tailored to user requirements. The World Climate Service will also provide its services in forms designed and branded by users under conditions to be negotiated individually (Park and Bos, 2007).

Several worldwide or local information sources could potentially be used as data source for the sub-indicators belonging to ‘relative humidity and temperature’. Both Meteogroup and the World Climate Service offer, against payment, tailor-made services that may enable incorporation of their meteorological data in the predictive model for mycotoxins.

6.1.2 Data sources for indicators related to agriculture

6.1.2.1 General

MARS (Monitoring Agriculture through Remote Sensing techniques) is a long term project of the Directorate General Joint Research Center (JRC) of the European Commission. The main goal of the MARS-project is to monitor weather and crop conditions during the current growing season and to estimate final crop yields for Europe by harvest time. Main activities within this project include measures to combat fraud related to the implementation of the Common Agricultural Policy as central theme and crop and yield monitoring. After registration, maps of weather indicators and maps and time profiles of crop indicators are freely available on the MARS website.

The Global Information and Early Warning System on Food and Agriculture (GIEWS) of the FAO provides information on food production and food security for every country in the world. The system's goal is to provide policymakers and policy-analysts with the most up-to-date and accurate information available on all aspects of food supply and demand. GIEWS warns of imminent food crises, so that timely interventions can be planned and suffering avoided. It provides regular bulletins on food crop production and markets at the global level and situation reports on a regional and country-by-country basis. For these publications, many sources of information on weather and other natural conditions for agriculture, as well as on economic, social and political factors are used. With respect to the indicators related to mycotoxin occurrence, information on weather conditions (including floods, dry spells and rainfall), pests and diseases can be obtained, especially for those countries facing widespread and serious food emergencies (Website GIEWS: http://www.fao.org/giews/english/about.htm).

6.1.2.2 Tillage policy and crop rotation

For tillage policy and crop rotation, the most direct information could be obtained from the farmers of a certain lot. For industrial users of the model, it may be possible to request such data as a prerequisite for the purchase of certain crops. For governmental users, these data may not be readily available. Since several (parts of) countries have no till or minimum till policies due to problems with erosion, it may be possible to make a database based on governmental information for those countries in which the user of the model is interested. The same may be done for crop rotation practices, based for example recommendations by Code of Practices, Good Agricultural Practices, and regional or even local agricultural institutes.

6.1.2.3 Crop variety

For the user of the model, the crop variety that arrives at the border (for Food Safety Authorities) or that is imported (for industrial users) should be known together with the country or region of origin. For several commodities, resistance data are available via product boards or governmental institutes. Since these resistance data are site specific, a database could be established with resistance data for the countries or regions of interest.

6.1.3 Data sources for drying and storage and transport conditions

Data on drying of the crop and storage and transport conditions will only be available from the farmer and/or the storage and/or transport facilities. For industrial users of the model, it may be possible to request such data as a prerequisite for the purchase of certain commodities. For governmental users, these data may not be readily available. However, general knowledge and experience on drying, storage and transport quality in several (parts of) countries may exist that can be used as an alternative.

6.1.4 Data sources for insect damage

Park and Bos (2007) concluded that according to their knowledge, no indicators are currently available to monitor the prevalence of pests in agricultural crops. They refer to the North Carolina State University / Animal and Plant Health Inspection Service Plant Pathogen Forecasting System (NAPPFAST). The NAPPFAST system is a novel Internet based research tool used to predict the potential establishment of exotic pathogens and pests. The primary purpose for the design of the system is to support the predictive pest mapping needs of the U.S. Cooperative Agricultural Pest Survey (CAPS) program. Also in other regions, systems may be available that monitor local or national problems relating to pests. Such systems may be useful to assess the risk of occurrence of mycotoxins in specific regions. However, these systems are expected to be quite cost and labour intensive, as it requires crop and pest specific information input at the crop source (the farmer). However, without such monitoring systems, data on insect damage will only be available from the farmer and/or the storage facilities. For industrial users of the model, it may be possible to request such data as a prerequisite for the purchase of certain commodities. For governmental users, these data may not always be available. In addition to possible monitoring systems mentioned above, also from news paper and other information sources, the occurrence of serious pests may be noticed and this information may be used in the model.

6.1.5 Data sources for blanching of nuts

For the user of the model, the quality of blanching of the nuts that arrive at the border (for Food Safety Authorities) or that are imported (for industrial users) will be visible by inspection and these observations can be used as input for the model. Especially for industrial users, it would be better to know beforehand which quality of blanching can be expected for a certain lot. Again, for industrial users, it may be possible to request such data as a prerequisite for the purchase of certain commodities.

6.2 Data available for governmental and industrial users.

Table 6.1 shows on which indicators information is available for a governmental stakeholder (VWA) and two industrial stakeholders. At this moment, the VWA does not structurally monitor or register information on any of the indicators of the proposed model to assess the risk on mycotoxin contamination. Knowledge on certain areas and circumstances associated with mycotoxin contamination of certain commodities is available, but not registered in a system. The VWA registers which of the tested lots are contaminated with mycotoxins but does not register the origin of these lots on the level of detail that is necessary to obtain information on the indicators. However, although it is currently not monitored, it is possible for the VWA to backtrack a certain lot from the Netherlands to a storage facility or even to a farmer or a parcel. For imported commodities it is difficult to obtain more information or to trace the farmer, mostly it is only possible up to the region.

The first industrial stakeholder does not structurally monitor or register information on any of the indicators of the proposed model with the aim to assess the risk of occurrence of mycotoxins. However, they are working on a database in which information on, amongst others, crop variety, crop rotation and tillage is stored, and in which the results of mycotoxin analyses are incorporated.

The second industrial stakeholder has data on most of the indicators of the proposed model. They have a (regional) registration system for their own supplying farmers in which information about tillage practices, crop variety, crop rotation is registered. Mostly it is also known for the imported wheat and maize via the purchaser.

6.3 Conclusions on data sources

Table 6.1 provides an overview of the information that is available on the indicators included in the blueprint of the model. For the indicators that are included in the conceptual model, not many ready-to-use (open access) data sources are available, except for the indicators related to meteorological conditions. The two industrial stakeholders that were interviewed indicated that they are developing or having an information system in which information on various indicators is included. These data are not publicly available.

Table 6.1 Data available in (open access) data sources or for governmental and/or industrial stakeholders.

Indicator	**Other (open access) data sources**	**Governmental stakeholder**	**Industrial stakeholder 1**	**Industrial stakeholder 2**
Temperature and (relative) humidity	Meteogroup, KNMI, World Climate Service, Website MARS, Website GIEWS	Not monitored	Not monitored	Yes
Crop rotation	Website MARS? Website GIEWS?	Not monitored	Yes	Yes
Tillage	-	Not monitored	Yes	Yes
Drying	-	Not monitored	Not monitored	Yes
Storage and transport conditions	-	Not monitored	Not monitored	Not monitored
Crop variety	Website MARS?	Not monitored	Yes	Yes
Insect damage	Website GIEWS?	Not monitored	Yes	Yes
Blanching of nuts	Not monitored, but can be determined for each lot by visual inspection	Not relevant	Not relevant	Not relevant

Depending on the availability of monitoring data on each indicator, it may be useful to make databases with data on several indicators from those regions in which the user is interested. A prerequisite for the use of such databases is the availability of accurate information on the origin of the lots that need to be evaluated. When lots originate from different farms or even from different countries, it may be difficult to obtain all information of its origin. Furthermore, the frequency of the information update of such databases is important. Several indicators are rather static and will not change much over the course of, for example, a year or a few years. This is the case for, amongst others, tillage policy, crop rotation and crop susceptibility. Therefore, for these parameters, databases could be established that are updated or reviewed periodically. For other indicators, like ‘insect damage’, sudden changes are to be expected over the course of time, and therefore this information should be updated more frequently.

In summary, for industrial users of the model, it may be possible to ask certain data (e.g. humidity of the kernel, crop rotation) from the farmers/exporters as prerequisite for the sale agreement. However, for food safety authorities, an infrastructure should be established to obtain sufficiently detailed information on all indicators included in the (conceptual) model.

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7 Conclusions and recommendations

This report describes the development of a blueprint of a model to assess the risk of occurrence of re-emerging mycotoxins in wheat, maize, peanuts and tree nuts according to a holistic approach. Based on literature studies and an expert study consisting of in-depth interviews and a workshop, the relevant indicators for such a model were selected. These indicators were temperature and (relative) humidity, crop variety, crop rotation (not for tree nuts), tillage (not for tree nuts), drying of the kernel, storage and transport conditions, insect damage and blanching (for peanuts and tree nuts only). These indicators were further defined and measurable (sub-)indicators (model parameters) were determined.

Twenty-five persons, covering a wide variety in expertise and fields of interests, participated in the interviews and/or the workshop. During the workshop, which focused on re-emerging mycotoxins in wheat, consensus was reached on the seven most important indicators for the risk of occurrence of re-emerging mycotoxins in wheat and the interactions between these indicators. Therefore, consulting additional experts is not believed to lead to changes in the main important indicators for wheat.

A holistic approach was followed in this study, but eventually the seven main indicators for wheat all belong to the influential sectors food chain, agriculture and environment and energy, and not to influential sectors that are less related to the food chain. Indicators from other influential sectors such as industry and trade and health will probably be judged more important if the study focus is broadened from occurrence to health risks of mycotoxins.

Using all relevant (sub-)indicators for the different commodities, a blueprint of a 'traffic light' model was developed to assess the risk of occurrence of mycotoxins on wheat, maize, peanuts and tree nuts. This model was specified for each commodity, by defining the relevant risk categories (and corresponding cut-off values) and importance score for the various (sub-)indicators. In this model, the user input on the various sub-indicators leads to a classification of the risk of occurrence of mycotoxins into a low (green), intermediate (yellow) or high (red) risk.

This model may be used by risk assessors, risk managers and industrial stakeholders to anticipate on the potential presence of mycotoxins by proactive risk management strategies or by adjusting purchasing strategies. One of the advantages of this new model is that it is a generic model aimed to assess the risk of occurrence of the most relevant mycotoxins in a certain commodity from any region in the world, provided enough information on the indicators can be obtained. Although the model is designed to assess the risk of occurrence of re-emerging (known) mycotoxins, the indicators that were defined for re-emerging mycotoxins will probably also have predictive value for emerging mycotoxins.

The next task that has to be done is a performance assessment of the conceptual model. Analyses of a sufficient number of historical or 'real-time' cases of mycotoxin contamination should be undertaken, to assess whether the proposed (sub-)indicators, risk categories (and corresponding cut-off values) and importance scores lead to an accurate prediction of the mycotoxin contamination. For the indicators that are included in the conceptual model, not many ready-to-use (open access) data sources are available, except for the indicators related to meteorological conditions. Therefore, the performance assessment should be performed in cooperation with the industry, since industry may have data on the indicators and the corresponding mycotoxin levels of various batches. During the performance assessment, it should also be determined whether the model can estimate the mycotoxin contamination accurately even when several indicators can not be filled in due to lack of data.

To enable implementation of the model for governmental stakeholders, an infrastructure should be established to obtain sufficiently detailed information on all indicators included in the (conceptual) model. Some industrial stakeholders may already have data available on most of these indicators for various purposes. In addition, it may be possible for industrial stakeholders to ask certain data from the farmers/exporters as prerequisite for the sale agreement.

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Acknowledgements

The contribution of all experts who participated in the interviews and/or the workshop is highly appreciated. In addition, the authors would like to thank Sigrid Brynestad and Ellen Morison from Det Norske Veritas (Norway) and Marion Dreyer from Dialogik (Germany) for the cooperation in the workshop. Also, the contributions of Hub Noteborn and Marcel Mengelers from the Office for Risk Assessment of the Food and Consumer Product Safety Authority, Cees de Heer from the RIVM, Hans Marvin from RIKILT and WP2 members of the SAFE FOODS project are highly appreciated. The project team greatly acknowledges the financial support from the 6th Framework Program of the EU (the SAFE FOODS project), the Dutch Food and Consumer Product Safety Authority (VWA) (Research Program 9.4.1) and the Dutch Ministry for Agriculture, Nature and Food Quality (LNV) (Strategic Research Theme 6).

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List of abbreviations

A.	*Aspergillus* (e.g. *A. flavus* = *Aspergillus flavus*)
AF	Aflatoxin (e.g. AFB1 = aflatoxin B1)
BEA	Beauvericin
DON	Deoxynivalenol
EFSA	European Food Safety Authority
EU	European Union
F.	*Fusarium* (e.g. *F. graminearum = Fusarium graminearum)*
FAO	Food and Agricultural Organization of the United Nations
FU	Fumonisin (e.g. FUB1 = Fumonisin B1)
HACCP	Hazard Analysis and Critical Control Point
HT-2	HT-2 toxin
IF	Importance factor
MON	Moniliformin
NIV	Nivalenol
OTA	Ochratoxin
PRI	Plant Research International
RASFF	Rapid Alert System for Food and Feed
RIKILT	Institute of Food Safety
RIVM	National Institute for Public Health and the Environment
SANCO	Health and Consumer Protection Directorate-General of the European Commission
SCOOP	Scientific Co-operation on Questions relating to Food
T-2	T-2 toxin
TDI	Tolerable Daily Intake
VWA	Food and Consumer Product Safety Authority
WHO	World Health Organization
WUR	Wageningen University and Research Centre
ZEA	Zearalenone

List of definitions

Cut-off values	Threshold values which separate the risk categories from each other.
Emerging risk	A potential food or feed borne or diet-related unidentified new hazard that may become a risk for human health in the (near) future.
Indicator	A factor that indicates (or is directly or indirectly related to) the possibility of the occurrence of a (re)-emerging hazard or risk (e.g. ‘storage and transport conditions’).
Importance factor	A weight factor that reflects the importance of an (sub-) indicator.
Influential sector	Areas of disciplines, in this report these are more or less related to the food production chain.
Re-emerging risk	A potential food or feed borne or diet-related known hazard that may become a risk for human health in the (near) future.
Risk category	Categories within an indicator referring to: a) a high risk (red), b) intermediate risk (yellow), or low risk (green) of, for example, mycotoxin contamination.
Sub-indicators	Measurable variables that are defined for an indicator (e.g. ‘water content of the kernel’ and ‘temperature differences in the storage facility’ as sub-indicators for the indicator ‘storage and transport conditions’).

Annex 1: List of indicators based on literature review

Possible indicators to predict the presence of re-emerging mycotoxins in wheat, maize, peanuts and tree nuts.

Food Supply Chain
Coordination • Exporter/importer producer information sharing • Market orientation • Production flexibility • Customer orientation • Vertical integration • Vertical coordination • Segregation **Processing and packaging** • Drying drying in the field moisture content unsuitable driers drying on the ground drying temperature water activity of product time and velocity of drying inappropriate pest control oxygen concentration no ventilation refrigeration • Sorting mixing healthy and damaged plants mixing irrigated with non-irrigated plants Etiella (*Etiella behrii*) grub infestation • Cleaning no kernel cleaning blanching • Grain heating and grain humidification • Wholemeal bread production • Delayed hulling of the nuts • No removal of crop debris • Shell staining **Storage and transport** • Storage quality moisture content ventilation contact with ground or storage on floor, stock piling inappropriate storage facilities inappropriate protection from moisture/insect/bird/rodent infestation no use of insecticide

storage in inappropriate bags exposure to airborne fungal spores free water in plant tissue • Transport quality duration distance cleaned containers protection from moisture, insect, bird and rodent infestation **Quality, safety and hygiene** • HACCP systems (including personal hygiene) • Traceability systems • Social responsibility • Controlled units/total unites by type of sector • Number of violations/controlled units by sector • Number of administrative sanctions • Penal sanctions • Samples taken for each products/national production • Non-regular samples/total samples • Quantity of sequestered products/total production • Controlled units/total units by type of product/country
Agriculture
Production and harvest • Personal hygiene • Lack of application of good practices • Quality of equipment • Timing of harvest • Timing of seeding • Weed growth and weed control • Mixing healthy and damaged plants • Mixing irrigated with non-irrigated plants • Mechanical damaging during harvest • Contamination through contact with animal waste, plant debris or ground • No removal of crop debris • Exposure to airborne fungal spores **Pest related issues** • Rate of outbreaks by sector/product (prevalence of pests including fungi and insects, inoculum dispersal, latent and infectious periods etc.) • Use of pesticides or fungicides by sector • Evidence of pest/mechanical damage by country/sector • Insect activity • Crop growing region and practices by country • Phytophage control/phytophagous damage • Contaminated neighbouring fields • Sporulation • Spore dispersal • Infection • Fungal species • Season • Spore catches

Choice of crop variety

- Use of Bt transgenic maize
- Number of commercial crop varieties
- Changing in crop planting patterns

Land use and soil related issues

- Land use patterns
- Crop rotation and multiple hosts
- Land preparation (e.g. preparing orchard for next year)
- Organic/chemical intensive use
- Soil type
- Soil condition (pH, erosion)
- Insufficient cultivation and crop protection
- Agricultural population per hectare of arable and permanent crop land
- Number of free outdoor ranging livestock

Other issues related to crop growth

- Irrigation
    - Intensity
    - Water quality
- Plant spacing
- Drainage of ground water

Environment and Energy

Weather conditions

- Relative humidity
- Temperature
- Soil temperature
- Air temperature
- Rainfall
- Wind
- Incoming short-wave radiation
- Incoming long-wave radiation

Energy and water

- Sector energy consumption by type of use
- Intensity of water use by sector
- Water consumption by sector

Industry and Trade

Retail trade

- Crop demand
    - price
    - production
- Trends market research report data
    - market share
    - price premiums offered for higher quality products
- Import and export data

Services

- Number of food services, products and technologies exported
- Paved roads as % of total road mileage
- Volumes of food shipped
- Public expenditure on private transportation
- Destinations with direct flights in/out of airports

Business and information infrastructure • Electronic communication tools used by sector • Freight traffic by mode of transport by sector • Good-facilities by sector • Rate of missing volume (loss)/total volume by sector • Containers transported through seaport by sector
Economy and Finance
Economic stability • New business starts by sector • Employment growth by sector • Unemployment growth by sector • Inflation rate • Strikes **Economic reform** • Government subsidies by sector • Control intensity by sector **Sustainable development** • Growth in gross domestic product • Personal income per capita • Distribution of source of income for the population **Balance of payments** • Value of goods exported internationally by sector
Government and Politics
Corporate Culture • Index of compliance with rules and regulations by businesses per sector **Global trade restrictions** • Index of WTO trade agreements by sector (trade barriers) • Index of trade partners and trade volumes per sector • Number of products passing through national borders without inspection • Foreign control of enterprises **Legislation** • Percent of food safety development compatible legislation per sector • Pesticide registration • Transport company registration
Information and Communication
Communication infrastructure • Newsletter coverage • Scientific journal coverage **Pressure groups** • Number of new activists groups • Demands by consumer/civil NGO organizations • Changes in expert opinions **Public Information and anxiety** • Number of environmental/food safety education programs for community • Number of customer complaints • Level of consumer confidence • Fear factors

Science and Technology
Innovation and Research • Percent of gross domestic product spent on research and development • Levels of domestic horizon scanning committees • Changes in food/feed process technology **Information Society** • Estimates of preliminary research findings • Survey on innovation in enterprises **Knowledge based services** • Output (results) of risk assessments • Number of conferences by sector
Population and Social conditions
Poverty and social exclusion • Population below poverty line • Food insecurity conditions **Eating habits** • Food consumption intensities and patterns • Supply/demand for free-range/organic food **Demand for processed food** • Demand for ethical food • Demand for local food **Living conditions** • Average earnings per job • Effective buying income per capita • Cost of living index by country

Annex 2: Questionnaire interviews

The interview was conducted in Dutch. An English translation of the questionnaire is listed below.

Interview emerging risks mycotoxins

The aim of this interview is to establish a list of indicators that are relevant for the presence of mycotoxins on different crops on the basis of the questions listed below.

1. What is your area of expertise?

2. Which influential sectors do you think are most important for the occurrence of mycotoxins on different crops?

3. Are any influential sectors lacking according to you?

4. Which influential sectors are covered by your areas of expertise?

5. Which indicators do you think are relevant for the occurrence of mycotoxins on different crops?

6. Do you have any suggestions for other experts that can contribute to this project?

7. Do you agree with the inclusion of your name(s) in the reports of this project (the answers will remain anonymous).

We will send you a short report on this interview. In this report, a table will be included in which all indicators mentioned during the interview will be listed. Then we will ask you to answer the questions listed below.

8. Do you have any additions to the list of indicators? If so, could you please insert them in table 1?

9. Which indicators are specific or different for emerging *Fusarium* mycotoxins in wheat?

10. Can you scale the importance of each indicator mentioned in table 1 according to the ranking listed below (if possible for each crop separately)?
    1. very important
    2. reasonably important
    3. slightly important
    4. not important

11. Which five indicators from table 1 do you consider to be the most important ones (please list in table 2)?

12. How can these 5 indicators (see question 11) be monitored? Which data sources can be used for monitoring? (Please insert in table 2)

13. Can you indicate for these 5 indicators (see question 11) when an increased risk can be expected? (Is it possible to divide the values of the indicator in two risk categories, no risk versus increased risk of occurrence of mycotoxins?) (Please insert in table 2)

Table 1: Indicators for the presence of mycotoxins*.

Indicator	Wheat	Maize	Nuts

*** 1= very important, 2= reasonably important, 3= slightly important, 4= not important**

Table 2: Five most important indicators for the presence of mycotoxins.

Indicator	Data sources?	When increased risk?

Annex 3: List of conducted interviews

	Name	Institute/Company	Area of expertise								
			Food chain	Agriculture	Environment and Energy	Industry and Trade	Economy and Finance	Government and Politics	Information and Communication	Science and Technology	Population and Social circumstances
1	Mr. H.P. van Egmond, MSc Mr. R.C. Schothorst, PhD	National Institute for Public Health and the Environment (RIVM) – Laboratory for Food and Residue Analysis	x	x	x			x			
2	Mr. M.C. Spanjer, PhD	Food and Consumer Product Safety Authority (VWA), Region Northwest	x	x		x					
3	Mr. J. de Keijzer	Dutch Association of Flour Producers (NVM)	x	x		x	x	x			
4	Mr. J. Blaak	Food and Consumer Product Safety Authority (VWA), Region Southwest				x	x				
5	Mrs. Prof. J. Fink-Gremmels, PhD	Utrecht University, Faculty of Veterinary Medicine – Department of Veterinary Pharmacology, Pharmacy and Toxicology	x	x				x		x	
6	Mrs. Prof. L.J. Frewer, PhD	Wageningen University and Research Centre, Marketing and Consumer Behaviour Group						x	x		x
7	Mrs. P.W. van Kleef, MSc	Wageningen University and Research Centre, Marketing and Consumer Behaviour Group							x		x
8	Mr. R.A. Samson, PhD	Fungal Biodiversity Centre	x		x	x				x	
9	Mrs. M. de Rijke Mr. E. Baas	Rabobank International	x	x	x	x	x	x			
10	Mr. M.J.B. Mengelers, PhD	Food and Consumer Product Safety Authority	x	x				x	x	x	

	Name	Institute/Company	Area of expertise								
			Food chain	Agriculture	Environment and Energy	Industry and Trade	Economy and Finance	Government and Politics	Information and Communication	Science and Technology	Population and Social circumstances
	Mr. H.P.J.M. Noteborn, PhD	(VWA), Office for Risk Assessment (BuR)									
11	Mr. H.-J.Weekhout	C. Steinweg Handelsveem	x			x					
12	Mr. D. van Dijk Mrs. I. Schönherr, MSc	Meneba	x	x		x					
13	Mr. D. Barug, PhD	Ranks Meel B.V.	x	x		x					

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Annex 4: Complete list of indicators (interviews)

Influential sector: Food Supply Chain
Deviations from normal practices
Number of players in food production chain (fragmentation versus centralization)
State of the art (and technology)
Traceability
Hygiene
Mixing Adding brans to flour in mills
Sorting of nuts
Blanching of nuts
Drying
Post-harvest treatment (fungicides)
Transport conditions Infrastructure production country
Storage conditions and quality Processing of rejected products (e.g. in animal food)
Number of positive milk samples for mycotoxins
Processing in animal feed
Influential sector: agriculture
Agriculture small/large scale production
Deviations from normal practices
Tillage policy
Nutritional status field
Crop variety Short crops Genetically modified crops
Crop rotation/pre-crop
Production of low protein wheat for different market (biofuel)
Production of low protein wheat next to a field with high protein wheat
Cultivation practices
Plant growth
Plant health
Animal health
Season
Biological/Organic farming
Fertilization
Irrigation and drainage
Use of pesticides
Damage by insects and other animals

Presence of other or new fungi per country (e.g. due to climate change)
Pre harvest conditions
Harvest quality
Harvest conditions
Separate harvest and storage of suspected lots
Timing harvest
Mechanical damage
Influential sector: Climate and Energy
Humidity/drought Temperature Microclimate
Moderate climate
Climate change
Influential sector: Industry and Trade
Global trade
Trade within (expanding) EU
Land of origin
Size of sector per country (many producing countries)
Changes in trade flows
Use of new trade flows
Trade restrictions
Organization of trade (retail, supermarket)
Retail trade by farmers
Retail trade by specialized stores (e.g. 'toko's')
Infrastructure knowledge
Infrastructure goods
Infrastructure control facilities
Sales (of certain products)
Market price (of certain products) Other market (bio-fuel)
Possible alternative ingredients/nuts for products
International establishments importers
External audits by importers/processors in production country
Balance between commercial interests and safety product
Openness companies
Responsibility companies
Results mycotoxin monitoring begin new season
Decrease in total stores wheat
International pressure on limits
Influential sector: Economy and Finance
Economical circumstances and stability producing country
Financial dependence on export

Financial possibilities to adjust the production process
Financial position farmers and processors
Agriculture grants and investments
Economical interests in trade restrictions because of production in own country
Investment capacity
Sustainable agriculture
Influential sector: Government and Politics
Communication between different governments
Legislation relating to mycotoxins per country
Limits for presence of mycotoxins
Legislation relating to use of pesticides
Regulatory measures
Policy food authorities per country
Quality control system
Pre-arrival check
Influence of EU on import check capacity
Processing of condemned goods
Compliance to rules per country
Fraud per country
Chain responsibility and certification
Presence of fungi/mycotoxins according to obligatory certificates
Results previous checks on certain products by country/exporter
Political awareness mycotoxin issue
Topic on the political agenda
Political willingness and strategy
Allocation of resources
Influential sector: Communication and Information
Information flows (e.g. RASFF, but also to consumers)
Knowledge sharing
Volume of text (in newspapers, internet pages, e-mails)
Education within food production chain
Publications consumer organizations
Publications NGOs
NGO pressure (statements)
Awareness of mycotoxin risks by farmers
Less awareness due to few recent problems with mycotoxins
‘Hearsay’ on contaminated products
Transparency government on food safety
Openness communication exporter – importer
Suspicion exporter and/or importer
Influential sector: Science and Technology
Research and development standard per country
Number and size research groups on mycotoxins per country

Network of experts
Number of JECFA/EFSA opinions
Setting limits based on 'ALARA'
Knowledge of new mycotoxins
Knowledge in changes in presence of fungi per country
Knowledge on interactions between different fungi
Technology forcing
Technical resources in production chain (for prevention and control of mycotoxin contamination)
Improvement in production/harvest/blanching (for nuts)
Development of new strains on the basis of improvement in resistance against for example *Fusarium spp.*
Development of new strains on the basis of GM
Influential sector: Population and Social conditions
Home farming
Developing aid given as education
Influence of recalls on imago company
Damage to imago after mycotoxin affair food industry
Changes in consumption pattern
People getting ill

Annex 5: List of participants workshop

	Name	Institute/Company
1	Mr. D. Barug, PhD	Ranks Meel B.V.
2	Mr. F. Driehuis, PhD	NIZO Food Research
3	Mr. A. Evenhuis, PhD	Wageningen University and Research Centre – Applied Plant Research
4	Mrs. Prof. J. Fink-Gremmels, PhD	Utrecht University, Faculty of Veterinary Medicine – Department of Veterinary Pharmacology, Pharmacy and Toxicology
5	Mr. J. de Keijzer	Dutch Association of Flour Producers (NVM)
6	Mr. D.G. Kloet, MSc	Private consultant
7	Mr. J. Köhl, PhD	Wageningen University and Research Centre – Plant Research International
8	Mr. G.M. Koornneef, MSc	Central Product Board for Arable Products (HPA)
9	Mr. M.J.B. Mengelers, PhD	Food and Consumer Product Safety Authority (VWA), Office for Risk Assessment (BuR)
10	Mrs. S. Monbaliu, MSc	Ghent University, Faculty of Pharmaceutical Sciences – Department of Bioanalysis (Belgium)
11	Mr. H.P.J.M. Noteborn, PhD	Food and Consumer Product Safety Authority (VWA), Office for Risk Assessment (BuR)
12	Mr. S. Peters, MSc	The Netherlands Nutrition Centre
13	Mr. M.C. Spanjer, PhD	Food and Consumer Product Safety Authority (VWA), Region Northwest
14	Mr. C. Waalwijk, PhD	Wageningen University and Research Centre, Plant Research International

	Organizing Committee	
1	Mr. C.J.H. Booij, PhD	Wageningen University and Research Centre – Plant Research International
2	Mrs. S. Brynestad, PhD	Det Norske Veritas (Norway)
3	Mrs. S. Dekkers, MSc	National Institute for Public Health and the Environment (RIVM) – Centre for Substances and Integrated Risk Assessment
4	Mrs. M. Dreyer, PhD	Dialogik (Germany)
5	Mrs. H.J. van der Fels-Klerx, PhD	Wageningen University and Research Centre – RIKILT Institute of Food Safety
6	Mr. C. de Heer, PhD	National Institute for Public Health and the Environment (RIVM) – Centre for Substances and Integrated Risk Assessment
7	Mrs. S.M.F. Jeurissen, PhD	National Institute for Public Health and the Environment (RIVM) – Centre for Substances and Integrated Risk Assessment
8	Mrs. M.C. Kandhai, MSc	Wageningen University and Research Centre – RIKILT Institute of Food Safety
9	Mrs. E. Morrison, PhD	Det Norske Veritas (Norway)
10	Mr. C. Waalwijk, PhD	Wageningen University and Research Centre – Plant Research International

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