European network of information sources for an identification system of emerging mycotoxins in wheat based supply chains (MYCONET)

H.J. van der Fels-Klerx and C.J.H. Booij (Eds.)

Business Unit: Safety & Health
Group: Databases, Risk Assessment & Supply Chain Management

RIKILT – Institute of Food Safety
Wageningen University and Research Centre
Bornsesteeg 45, 6708 PD Wageningen, The Netherlands
P.O. Box 230, 6700 AE Wageningen, The Netherlands
Tel: +31 317 480256
Fax: +31 317 417717
Internet: www.rikilt.wur.nl
The research described in this report was funded by [project funders related to the SAFEFOODERA project, and the EU 6th Framework Programme (ERA_NET). programma en financier noemen]

Distribution list:

- Partners in project
- SAFEFOODERA leden
- Experts WP1
- NICE
- Marcel Mengelers, Dutch Food Safety and Product Authority
- Hub Noteborn, Dutch Food Safety and Product Authority
- Frank-Jan van der Valk, Ministry for Agriculture, Nature and Food Quality
- Rob Thelen, Ministry for Agriculture, Nature and Food Quality
- Richard Donker, Ministry for Agriculture, Nature and Food Quality (LNV), Directie Kennis
- Cor Wever, Ministry for Agriculture, Nature and Food Quality (LNV), Directie Kennis
- Rik Herbes, VWA
- VWS,

This report from RIKILT - Institute of Food Safety has been produced with the utmost care. However, RIKILT does not accept liability for any claims based on the contents of this report.
Summary

[De samenvatting is bedoeld om een globale indruk weer te geven van de hoofdzaken van het rapport, zodanig dat in hoofdlijnen de vraagstelling, het doel, werkwijze, resultaten, conclusie(s) en aanbevelingen worden weergegeven. De samenvatting is maximaal anderhalf A4 lang. De samenvatting begint op de rechter pagina]

Executive summary

Introduction
Nowadays early warning systems in the European Union are used to identify food safety hazards, however these systems need to be improved to identify potential (re-) emerging hazards in a early stage in the food and or feed supply chain. There is therefore a need to investigate the indicators (signals) and their information sources that indicate (directly or indirectly) the possibility of occurrence of an emerging hazard. Indicators may be directly related to different stages of a certain feed or food supply chain, or may also be connected to a particular chain via one or several links. In addition indicators may also be derived from outside the food chain. In the PERIAPT project the holistic approach was developed for a Emerging Risk (ER) identification system. This approach includes a host environmental analysis of the feed and food chain, meaning that indicators should be derived not only from inside, but also from outside the supply chain.

Main objective
The MYCONET project focused on emerging mycotoxins especially produced by Fusarium species in European wheat based supply chains for setting up a ER system.
The main objective of this project was in particular to initiate a conceptual sustainable platform/network of sources that could pro-actively provide specified key-information for a functional identification system for emerging mycotoxins. This objective was specified in several sub objectives: The holistic approach was applied in Work package 1 to identify the most important indicators as derived from various influential sectors, together with their relative importance.
Subsequently in Work package 2 the most relevant information sources on the specified indicators for the mycotoxin ER identification system were identified, together with their accessibility. Hereby, both information from expert knowledge and from a technical point of view (experimental data) were addressed. Furthermore an information model was proposed in work package 3 to link technical data on Fusarium epidemics and mycotoxins, expert knowledge and also information modules from the most important indicators from the various influential sectors. In work package 4, the form and type of information needed in order to utilize the information from the identification of emerging risk system, as perceived by different groups of stakeholders was investigated.

Methods used
The Delphi elicitation technique was used for retrieving expert opinion on the most important indicators for ER identification and to semi-quantify their relative importance. Information sources and technical data on the selected indicators was obtained via the expert network.

The need for an information system was investigated by having a workshop and a series of in-depth interviews with various the stakeholders in The Netherlands, Belgium, Germany and Scandinavia.

Results and conclusion

A protocol for a structured expert judgement study to select the most important indicators for emerging risk identification is described, based on the Delphi method. This protocol was applied to select the most important indicators for identification of emerging mycotoxins, starting from those produced by Fusarium spp., in wheat based supply chains. Starting with a gross-list of indicators from literature, the 12 most important indicators, together with their relative weights, for each of three stages of the wheat based supply chain were selected using the Delphi expert method. For cultivation, indicators selected include: relative humidity/rainfall, crop rotation, temperature, tillage practice, water activity of the kernels, and crop variety/cultivar for cultivation. For transport & storage these include water activity, relative humidity, ventilation, temperature, storage capacity and logistics, and for processing stage the selected indicators were quality data, the fraction of the cereal used, the water activity in the kernels, level of implemented traceability and quality systems, and carry over of contamination. Information sources on the selected indicators were identified in various European countries, including Portugal, Scandinavia, The Netherlands, Iceland and Germany via the project partners. Information sources showed to very scare, and if present not always publically assessable. Furthermore, in the stakeholders study it was shown that many stakeholders expressed a general interest in an ER identification system as conceptualized within this project. Such a system was considered to be helpful to improve risk management, control and monitoring strategies and ultimately could reduce the health risk for consumers.

Recommendation for various actors

Research Institutions
Evaluate predictive systems for (re) emerging mycotoxins in European countries
Link various technical data sources to create a sustainable platform of information sources
Make the various information sources compatible and useful at EU scale and link them to the sustainable platform
Use a central database for registration of the cultivation process including information on crop variety, pre-crop, tillage practices etc.

Authorities/EFSA
Communication with and incentives for supply chain partners
Long term funding for a dedicated scientific expert team to develop and run a ER system

Industry
Commitment and trust to share information with authorities in order to obtain a functional ER identification system which could provide industry and policy makers an early signal for the potential
occurrence of emerging mycotoxins. verband met het onderzoek en kan zaken bevatten als mededelingen welke van belang zijn voor de lezer zoals dankbetuigingen e.d. Het voorwoord begint op de rechter pagina]
## Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive summary</td>
<td>3</td>
</tr>
<tr>
<td>1 Introduction</td>
<td>8</td>
</tr>
<tr>
<td>2 Indicators for emerging mycotoxins</td>
<td></td>
</tr>
<tr>
<td>2.1 Design of expert judgement study</td>
<td></td>
</tr>
<tr>
<td>2.1.1 Selection of elicitation technique</td>
<td></td>
</tr>
<tr>
<td>2.1.2 Protocol expert judgement study</td>
<td></td>
</tr>
<tr>
<td>2.2 Expert judgement study</td>
<td></td>
</tr>
<tr>
<td>2.2.1 Design expert judgement study</td>
<td></td>
</tr>
<tr>
<td>2.2.2 Expert response</td>
<td></td>
</tr>
<tr>
<td>2.2.3 Indicator selection</td>
<td></td>
</tr>
<tr>
<td>2.3 Applicability protocol</td>
<td></td>
</tr>
<tr>
<td>2.4 Conclusions and outlook</td>
<td></td>
</tr>
<tr>
<td>3 Technical information sources</td>
<td>11</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>3.2 Characterization of information sources</td>
<td>2</td>
</tr>
<tr>
<td>3.3 General information sources</td>
<td>3</td>
</tr>
<tr>
<td>3.3.1 Management and ICT systems</td>
<td>3</td>
</tr>
<tr>
<td>3.3.2 Mycotoxin research networks/organizations</td>
<td>4</td>
</tr>
<tr>
<td>3.4 Cultivation stage</td>
<td>4</td>
</tr>
<tr>
<td>3.4.1 General information for farmers</td>
<td>4</td>
</tr>
<tr>
<td>3.4.2 Weather</td>
<td>5</td>
</tr>
<tr>
<td>3.4.3 Crop rotation</td>
<td>6</td>
</tr>
<tr>
<td>3.4.4 Tillage</td>
<td>6</td>
</tr>
<tr>
<td>3.4.5 Crop varieties</td>
<td>7</td>
</tr>
<tr>
<td>3.4.6 Harvest conditions</td>
<td>7</td>
</tr>
<tr>
<td>3.4.7 Plant health in general</td>
<td>8</td>
</tr>
<tr>
<td>3.4.8 Water activity in kernels</td>
<td>8</td>
</tr>
<tr>
<td>3.4.9 Use of pesticide and fungicide</td>
<td>8</td>
</tr>
<tr>
<td>3.4.10 Changes in Fusarium species composition</td>
<td>9</td>
</tr>
<tr>
<td>3.4.11 Regional infection pressure</td>
<td>9</td>
</tr>
<tr>
<td>3.5 Transport and Storage</td>
<td>9</td>
</tr>
<tr>
<td>3.5.1 Water activity in kernels</td>
<td>10</td>
</tr>
<tr>
<td>3.5.2 Silo conditions</td>
<td>10</td>
</tr>
<tr>
<td>3.5.3 Grain quality general</td>
<td>11</td>
</tr>
<tr>
<td>3.5.4 Blending/mixing practices</td>
<td>11</td>
</tr>
<tr>
<td>3.5.5 Carry-over of contaminants</td>
<td>11</td>
</tr>
<tr>
<td>3.5.6 Traceability and quality management systems</td>
<td>12</td>
</tr>
<tr>
<td>3.5.7 Awareness food safety</td>
<td>12</td>
</tr>
<tr>
<td>3.6 Processing</td>
<td>12</td>
</tr>
<tr>
<td>3.6.1 Grain Quality</td>
<td>12</td>
</tr>
<tr>
<td>3.6.2 Fractions of cereals used</td>
<td>13</td>
</tr>
<tr>
<td>3.7 Conclusions and recommendations</td>
<td>13</td>
</tr>
</tbody>
</table>
4 Information model
4.1 A theoretically based information model 16
4.1.1 Defining impact of indicators 17
4.1.2 A basic regression model 17
4.1.3 Adapting the model to chain characteristics 18
4.1.4 Handling the level of detail in the model. 19
4.1.5 How to handle uncertainty 20
4.2 Matching modeling with current practices 21
4.3 Known mycotoxins and emerging mycotoxins and other hazards 22
4.4 Recommendations 23
5 Stakeholders need 1
5.1 Introduction  Feil! Bokmerke er ikke definert.
5.2 Empirical Data Collection  Feil! Bokmerke er ikke definert.
5.4 Relevance and Aims Attached to an Early Identification System for Emerging Mycotoxin Risks  Feil! Bokmerke er ikke definert.
5.5 Requirements for Application in Practice  Feil! Bokmerke er ikke definert.
5.5.1 Information type, format and transmission  Feil! Bokmerke er ikke definert.
5.5.2 The Prominent Role of Information on Indicators Related to Cultivation  Feil! Bokmerke er ikke definert.
5.5.3 Major Challenges of Implementation in the View of Stakeholders  Feil! Bokmerke er ikke definert.
5.6 Conclusions  Feil! Bokmerke er ikke definert.
6 Conclusion  Feil! Bokmerke er ikke definert.
7 Acknowledgements  Feil! Bokmerke er ikke definert.
8 References  Feil! Bokmerke er ikke definert.
1 Introduction

With the establishment of Regulation (EC) No. 178/2002 (‘General Food Law’), basic principles and requirements of food law were laid down and the European Food Safety Authority (EFSA) was established. EFSA is an independent source of scientific advice, information and risk communication in the area of feed and food safety. One of the responsibilities of EFSA is to set up a pan-European system for the identification and evaluation of emerging risks: “the Authority shall establish monitoring procedures for systematically searching for, collecting, collating and analyzing information and data with a view to the identification of emerging risks in the fields within its mission (Regulation (EC) No. 178/2002, Article 34.1). An emerging risk (ER), hereby, is defined as a feed- or food borne or diet-related hazard that may in the future present a risk for human health. As risk is a function of hazard and exposure (CAC, 1999), the indication of a feed- or food borne ER may relate to 1) a significant exposure to a hazard not recognized earlier or 2) a new or increased exposure to a known hazard (it is then called re-emerging risk) (EFSA, 2006). ER thus may include 1) unidentified new form(s) of a (group of known) hazard(s); 2) not well characterized hazards; 3) characterized hazards not previously associated with feed or food (new exposure routes) or 4) re-emerging hazards (Noteborn & Ooms, 2005).

For ER identification, a system or procedure aimed at proactively identifying and preventing a potential hazard from becoming a risk is needed. Key-sources of ER identification form the indicators; signals that indicate (directly or indirectly) the possibility of occurrence of an ER. Indicators may be directly related to different stages of a certain feed or food supply chain, or may also be connected to the particular chain via one or several links. Information on indicators may or may not be supplied by or related to the feed or food production process (Noteborn & Ooms, 2005). In addition, sources of information on indicators may include technical (‘hard’) data derived from experiments and monitoring processes as well as data derived from expert judgment studies.

Following the holistic approach, developed in two previous European projects (Noteborn & Ooms, 2005; Noteborn, 2006), ER identification includes an host environmental analyses of the feed and food supply chain, implying investigation of fields of interest not only from inside, but also from outside the supply chain. In such an host environmental analyses influential sectors with their critical factors are identified. From these critical factors, indicators for the ER system can be drawn (Noteborn & Ooms, 2005). See Annex I for a summary on the holistic approach. The evaluation and validation of the indicators for each potential risk is very resource demanding and will be achievable by EFSA only in the long term perspective. Therefore, as a first step, EFSA was advised by the Scientific Committee to exercise its vigilance to a limited number of key areas and direct its work toward the identification and validation of relevant indicators for these areas (EFSA, 2006). One of these key areas of interest includes ER related to mycotoxins. As the risks of mycotoxins are widespread, indicators are partly available and monitored, and knowledge is sufficiently present and developing, this type of ER seems to be ideal for a case study. The risks from several mycotoxins are well-known and documented, but new mycotoxins are still detected with the improvement of detection and analytical tools in this area, e.g., within the group of mycotoxins produced by Fusarium species. Risks of these ‘new’ toxins and indicators for their occurrence are still poorly understood. Furthermore, known mycotoxin hazards may (re-)emerge or be (re-)introduced, or new ones may be formed, as a result of effects like climate change, global trade and changes in the processing industries. Outbreaks of toxin producing fungal diseases occur quite frequently, especially in the developing countries, but also in Europe. Mycotoxins have been/are the focus of various case studies in projects on ER, among others, including EMRISK.
(Noteborn, 2006), SAFEFOODS (see http://www.safefoods.nl) and PERIAPT (Noteborn & Ooms, 2005). In addition to these case studies, predictive models of mycotoxin development during crop growth have been made (e.g., Hooker et al., 2002; Hooker and Schaaasma, 2004) and are currently in development (e.g., Franz et al., 2008). These models are all focused on specific mycotoxins such as DON and ZON, and mainly used by farmers for disease control.

According to the opinion of the Scientific Committee (EFSA, 2006), there is a need for working out a functional ER identification system, starting with specification of a limited set of the most relevant indicators, for key areas of ER. The MYCONET project described in this report will contribute to these needs as it aims to select the most important indicators for identification of emerging mycotoxins as well as the most relevant information sources for the indicators selected. These indicators and information sources are the basic elements in developing a functional ER identification system. Furthermore, the project initiates upon bringing together the various information sources into a sustainable network. The MYCONET project in particular focuses on indicators for the occurrence of emerging mycotoxins, especially related to Fusarium spp., in wheat based feed and food supply chains. This specific type of ER has many aspects to be extended to other types of (mycotoxin related) ER in feed and food chains such as the uncertain scenarios in this field due to climate change, global trade, and land use patterns; the variety of stakeholders such as (international) authorities, trading companies, feed and food industry, and consumers; and the availability of the (necessary) base level of knowledge. This research project focuses on European wheat based feed and food supply chains, as wheat covers a large production area in Europe and is an important commodity for human food and animal feed sensitive to Fusarium related mycotoxins. As the spread and persistence of toxins during production, trade, and processing is complex, a knowledge based system focused on the needs of stakeholders will help to predict and avoid emerging risks in this case.

The main objective of the MYCONET project described in this report is to initiate to a sustainable platform/network of sources that will proactively provide specified key-information for a functional identification system for emerging mycotoxins. It focuses on the occurrence of emerging mycotoxins in European wheat based feed and food supply chains; starting from those toxins produced by Fusarium species. More specifically, the project focuses on:

- Selection of the most important indicators for the occurrence of emerging mycotoxins, together with their relative importance, as judged by a panel of experts. Hereby, indicators are evaluated from various influential sectors.
- Identification of the most relevant information sources for the selected indicators;
- Definition of an information model to link information sources on the selected indicators;
- Identification of the form and type of information needed to utilize the information from the identification system for emerging mycotoxins, as perceived by different groups of stakeholders;
- Recommendations to make the various types of information sources compatible and useful at the European level and to link them into a platform of information sources;
- Recommendations to create a sustainable network/platform aimed to supply a functional mycotoxin related ER identification system with the necessary data;
- Generic conclusions with regard to the initiation of sustainable networks of key-information sources for other types of mycotoxin related ER and/or production chains.

Chapter 2 of this report focuses on the selection of indicators for ER identification, together with their relative importance, by using expert judgement. The Chapter presents a protocol for executing a structured expert judgement study for this purpose. Also, it describes the design and results of the
actual expert study held to select indicators for emerging mycotoxins in wheat based supply chains. In the selection of indicators, the holistic approach was followed and, consequently, indicators were evaluated from various influential areas. Next, information sources on the selected key-indicators were identified from various European countries, see Chapter 3. The information sources were evaluated for their characteristics, taking into account criteria like level of detail and accessibility. Also, in this Chapter, the several recommendations (mentioned above) are presented, as based on the experiences gained in this research. Chapter 4 present an information model to integrate the various indicators, having different characteristics and level of detail. Chapter 5 focuses on investigation of the information needed by various groups of stakeholders for ER identification, specifically related to mycotoxins in wheat. Finally, the main conclusions of the MYCONET research project are presented.
2 Indicators for emerging mycotoxins

By HJ van der Fels-Klerx, C. Kandhai

This Chapter describes the selection of the most important indicators and their relative importance for an ER identification system. Indicators are selected and evaluated for their relative importance by using expert opinion. To this aim, a structured expert judgement study was held, following a pre-set protocol. More specifically, the expert judgment study aimed to select the most important indicators for the occurrence of emerging mycotoxins, particularly related to Fusarium spp., in wheat based feed and food supply chains, as well as to semi-quantify their relative importance. In the expert study, the holistic approach (see Annex 1) was applied and, consequently, indicators were evaluated and selected. Also, indicators were evaluated and selected for each of three relevant stages from various influential sectors of the wheat based supply chain, i.e., cultivation, transport & storage, and processing, separately. As a second aim, a protocol for the expert study was designed beforehand, i.e., prior to the expert judgement study, and evaluated by the experiences gained in the actual expert study.

Section 2.1 describes the approach for a study aimed at using expert judgement for the selection of the most important indicators for ER identification. It starts with an evaluation of various elicitation techniques and their characteristics for this purpose. Section 2.2 describes the actual expert judgement study as well as its results. These results include the most important indicators for identification of the occurrence of emerging mycotoxins, particularly related to Fusarium spp., together with an indication to their relative importance, for each of three stages of the wheat based supply chain.

2.1 Design of expert judgement study

The actual elicitation technique to be applied for retrieving expert judgement depends on various factors such as the (complexity of the) subject of interest, the specific questions to be answered, and practical matters. The elicitation technique should be carefully chosen taking into account the study pre-requisites. To achieve expert judgement in a scientifically way, amongst others, the expert study should carefully follow a pre-set protocol. Although there are some generic steps to be included in the protocol for an expert judgement study, the elicitation technique to be applied affects this protocol to a large extent. Therefore, as a first step, the elicitation technique should be chosen and, next, the protocol should be designed.

Various types of elicitation techniques could be used for retrieving expert opinion on the most important indicators for ER identification and for retrieving an indication to their relative importance. These elicitation techniques vary from group discussion with a panel of experts to individual in-depth interviews. As a first step, various elicitation techniques were evaluated for the purpose of the current expert study. Section 2.1.1 describes the results of this evaluation as well as the method chosen for the current subject of interest. Next, the design of the expert study, applying the elicitation technique selected, is described in section 2.1.2.
2.1.1 Evaluation and selection of elicitation technique

2.1.1.1 Evaluation elicitation techniques

Elicitation techniques vary in their features like anonymity, feedback, and interaction, and from bilateral in-depth interviews to interactive group processes (Cooke, 1991). Various elicitation methods were evaluated for their applicability - based on their characteristics - to the current subject of interest. These methods include: individual in-depth interviews (a), group discussion (b), Delphi method (c) and conjoint analysis (d). A summary of the characteristics of these methods is given below.

a) Individual interviews: individual in-depth interviews with (a series) of experts have the advantage that the rationale of experts behind the individual experts’ judgements could be obtained. Also, the potential effect of expert dominance is avoided. The main disadvantages are that there is not interaction between experts, which could make it difficult to obtain consensus. Also resources required for interviewing a large number of experts are high.

b) Group discussion: a group discussion, with a panel of experts has the advantage that information from various experts could be shared, and interaction could be used to obtain consensus. A drawback of this form of expert elicitation, however, could be that the most dominating persons influence the outcomes, and that the opinion of the less dominating ones is not heard. This effect could be avoided by using a Group Discussion Room technique. With this form of group interaction, experts are individually and anonymously interviewed in several rounds using an electronic support system to share their opinion and also to generate new ideas. The output is used each time for further discussion.

c) Delphi technique: Delphi is an interviewing technique with the characteristics of both group interview and written poll. Experts are interviewed individually and anonymously, e.g. e-mail or postal mail. With Delphi the disadvantages of group dynamics could be avoided, while still having high levels of interaction among experts (Van der Fels-Klerx et al., 2000). The experts could form a studied opinion in which various viewpoints are weighed against each other.

d) Conjoint analysis: Conjoint analysis typically is used to elicit the relative weights of a limited set of parameters, together with their levels. Adaptive conjoint analysis uses a computerized administered format which is customized to each respondent (Van der Fels-Klerx et al., 2000). Interactions between (levels of) indicators could be included, but to a very limited extent.

2.1.1.2 Selection of elicitation technique

By using expert opinion to select the most important indicators that should be used in an ER identification system, the experts need to agree (to some extent) upon the most important indicators. To obtain consensus among a panel of experts, some form of interaction – like with group discussion and the Delphi technique - is necessary. In order to select the most important indicators for ER identification, hereby taking the holistic approach, a series of individual interviews could be very useful, as a first start, but should be combined with some form of expert interaction afterwards. This procedure was applied in an expert study held in The Netherlands aimed at the selection of indicators for the occurrence of known mycotoxins (Van der Fels-Klerx et al., submitted). Conjoint analysis is appropriate for obtaining individual experts’ judgements on relative weights for pre-defined factors and their levels. Hence, this method seems to more relevant in case a selected set of most important
indicators, together with their levels and interactions, is available. With having group interaction, preferably, expert dominance should be avoided, which could be achieved by application of the group discussion room and the Delphi method.

The current subject of interest is characterized by an European wide approach and a wide list of potential indicators that should be evaluated. Given these characteristics and evaluation of the advantages and disadvantages of the expert elicitation techniques mentioned, the Delphi technique is most applicable. With the Delphi technique, group interaction can be facilitated such to achieve consensus (to a more or lesser extent) among the expert panel, while avoiding the effect of expert dominance. In contrary to the group discussion room, a wide range of experts from various countries can be approached. Additionally, the technique is easy to understand and to apply, and can be held in relative short a time frame. Hence, the Delphi method was applied as the elicitation technique in the current expert judgement study.

2.1.2 Protocol expert judgement study
Given the application of the Delphi method as the elicitation technique to retrieve expert opinion on the most important indicators for ER identification, a protocol for the entire expert judgement study was designed. Hereby, the protocol defined by Goossens et al. (1996) was used as the starting point. Their protocol was aimed at retrieving experts’ individual quantitative assessments on specific variables of interest. It includes 15 steps divided over three phases of the expert judgement study (preparation, elicitation, and analyses). Although the field of interest and elicitation method was different as compared to the current study, the protocol of Goossens et al. (1996) includes several generic steps for executing an expert judgement study, relevant to the current study as well. The protocol to retrieve expert judgement on the most important indicators for identification of emerging risks defined is as follows:

2.1.2.1 Preparation of the elicitation
1. Definition of the case structure, describing the field of interest as well as the specific items on which expert judgement is required;
2. Definition of a gross list of potential indicators for ER identification;
3. Definition of a background document on the holistic approach, the study aim, and a short description of the expert judgement study;
4. Definition of the expertise required and identification of the experts
5. Selection of the experts;
6. Definition of the elicitation format describing the exact questions and format for the expert elicitation;
7. Format for evaluation and combination of the individual experts’ answers;
8. Dry-run exercise describing the try-out of the elicitation format document to a few experts;

Elicitation
9. Expert elicitation session applying the Delphi method. Delphi is used for the elicitation of experts’ opinions with the aim of obtaining a group response, preferably consensus, among a panel of experts. Delphi replaces direct confrontation and debate by a carefully planned, orderly program of sequential individual interrogations usually conducted by questionnaires (Brown, 1968). Typically, the Delphi method comprises a couple of rounds held by mail (postal or e-mail). In each round, question(s) are
given to the panel of experts, and the individual experts are asked to respond to the questions in writing. The answers of the experts are evaluated such to achieve a common response with deviations. In each round experts are given the opportunity to review their answers of the previous round, taking into account the anonymous and summarized response of the other experts in the panel. Ultimately, this method aims to reach consensus among experts on the subject of interest. Delphi thus has both the characteristics of group interview and of the written poll, and combines the advantages of group interaction and individual response. Figure I illustrates the Delphi method. The Delphi method starts with the gross-list of indicators (step 2) and aims to reduce this list to a selected set of most important indicators for ER identification.
Figure 1: Main steps required for the Delphi implementation

1\textsuperscript{st} questionnaire round in Delphi survey

Analysis of the results

2\textsuperscript{nd} questionnaire round in Delphi survey

Analysis of the results

3\textsuperscript{rd} questionnaire round in Delphi survey

Analysis of the results

Evaluation of the results

FINAL OUTCOMES
**Post-elicitation**

10. After each Delphi round (see step 9), the individual experts’ answers on the questionnaires (related to the importance of the indicators) are examined closely, with the aim to obtain a common response, together with differences from this broad outline. After each round, the obtained information is returned to the individual participants with the request to consider their initial answers taking into account the (anonymous) considerations of the other experts. The ultimate aim is to obtain consensus on a selected set of most important indicators.

11. Robustness and discrepancy analysis; the answers from the panel of experts are evaluated for discrepancy between individual judgement and outliers. The robust of the results can be analysed by deleting an individual expert’s response, one by one, and evaluate its effects on the overall results.

12. Feed back communication with the experts; the final results of the study are reported to the panel of experts.

**Documentation of the results.**

13. The expert judgement study and its results are carefully described in a report.

---

**2.2 Expert judgement study**

The protocol for the expert judgement study, described in section 2.1.2 was applied to the current study. This resulted in a selection of the most important indicators for identification of the occurrence of emerging mycotoxins, starting from those produced by Fusarium species, in wheat based feed and food supply chains, together with an indication to their relative importance, as judged by experts. By experiences gained in the expert study, the pre-defined protocol was evaluated for its potentials in eliciting expert judgement on indicators for ER identification. Section 2.2.1 describes the steps followed in the protocol, and section 2.2.2, describes the experiences gained in the actual application of this protocol.

---

**2.2.1 Design expert judgement study**

In executing the expert judgement study for the current subject of interest, the pre-defined protocol, described in section 2.1.2, was carefully followed. Below, the various steps of the protocol, as applied in the current study, are described in detail.

1. Case structure: the specific field of interest and items to be retrieved from the experts were defined. In fact, this related to the current study focus, i.e., selection of indicators to identify the occurrence of emerging mycotoxins, especially related to Fusarium spp., in wheat based supply chains;

2. Gross list of potential indicators: a gross list of indicators was identified by a literature review, evaluating the results from related previous studies (Noteborn, 2006; Park and Bos, 2007; Van Wagenaar et al., 2003; Van der Fels-Klerx et al., 2008; Van der Fels-Klerx et al., submitted). All potential indicators mentioned in these studies were evaluated, and appointed to relevant stage(s) of the wheat based supply chain (cultivation, transport and storage, and processing). The resulting gross-list was used at the starting point for the Delphi elicitation procedure;

3. A back ground document was defined to be sent to the selected experts on beforehand (as back ground information). This document describes the holistic approach, the study aim and the design of the expert judgement study;
4. Definition and identification of the expertise: experts were defined on the basis of the criteria that they should be researchers and/or advisors with experience on mycotoxins such to ensure that they had the same field of expertise and the same cultural and legislative background.

5. Selection of the experts: Nine key persons form various European countries, including Portugal (2), Sweden (1), Iceland (1), Norway (2), Germany (1), and The Netherlands (3), were selected. They were asked to suggest candidates for the expert panel. Furthermore the SAFE FOODS expert database was consulted (http://www.safefoods.nl), and the contacted panel candidates were asked to suggest other relevant experts. The aim was to obtain response from at least 25-30 experts in each Delphi round. Given an average response rate of about 40-50% with interviews held by e-mail (Lee, 2007), the aim was therefore to include at least 50-60 experts in the panel. In total 78 experts were approached of whom 65 persons were interested to participate. All correspondence was performed via e-mail;

6. Definition of elicitation format: Questionnaires were prepared prior to each Delphi round, including a given set of indicators for each of the three stages of the wheat based supply chain. In each round, experts were asked to select and to semi-quantitatively score indicators. Experts were asked to respond to each questionnaire by writing their answers in the elicitation format document;

7. Format for evaluation and combination of the individual experts’ answers: An excel sheet (Microsoft Excel 2003) was established for analysing the scores given by the individual experts. This sheet was used for further analysing and combining the results. More specifically, the scores of the various experts were summed up, per indicator, and the average score per indicator was calculated. The average scores were used as criteria for bringing indicators to the next round. Hereby, the threshold score was based on a distinction between groups of more and lesser important indicators;

8. Dry run exercise: The elicitation format of the first Delphi round was discussed with four experts from The Netherlands. These experts did not participate in the expert study. The questionnaires of the second and third Delphi round were discussed with three (of these four) experts. Based on the experiences of the dry-run, the elicitation format was adapted, if necessary;

9. Expert elicitation: The aim of the Delphi study was to iteratively reduce the gross list of indicators such to obtain the most important ones, to obtain consensus on the selected set, as well as to obtain an indication to their relative importance. Here, in the first Delphi round (first questionnaire) the experts were provided the gross list of indicators, per stage of the chain. Experts were asked to evaluate each indicator for its relevance as indicator for the occurrence of emerging mycotoxins. Also experts were asked to add additional (missing) indicators to this pre-defined list, if relevant, together with a rationale. The next question was to select the 10 most important indicators from the list of indicators (including the ones added) and, subsequently, to relatively rank the indicators selected. The individual expert was asked to do so by scoring the 10 indicators he/she had selected (per stage of the chain), with scores ranging from 1 (less important) to 10 points (most important). The second Delphi round started with the indicators that received highest scores in the first round as well as the additional indicators mentioned to be relevant. Starting from these indicators, the experts again were asked to select the 10 most important indicators and to score these indicators for their relative importance.

Based on the scoring results from the second round, the third round started with a selected set of most important indicators, per stage of the chain. Experts were asked to relatively rank this selected set of indicators by dividing scores. The entire expert elicitation started in November, and ended in February 2008. Reminders were sent to experts not complying with the deadlines.

10. Analyses of the results: After each round (see 9), the individual experts’ answers are examined closely, and broad outlines and differences were identified. For the indicator selection procedure in successive rounds, average score thresholds were used to delimit the new set of indicators. Total scores
from the third round were used to categorise the list of indicators on importance. The results are given in more detail in section 2.2.

11. Analysis of discrepancy and robustness of the results. The scores of the individual experts were examined for outliers. Also, statistics like mean, median, standard deviation, minimum and maximum were evaluated. The robustness of the results was analysed by evaluating the difference in the ranking of the indicators between experts that responded to one round and the group of experts that responded to each round.

12. Feedback communication with the experts. The experts were sent a summary of the study and its results, as soon as available (after the analysis). This was done in April 2008;

13. Documentation of the results: The results were carefully described in a working document, (this) final report of the MYCONET project, and a manuscript to be submitted for publication in a scientific journal (Kandhai et al., to be submitted).

2.2 Results

2.2.2 Expert response
In total 78 experts were invited being from Austria (1), Belgium (3), Czech Republic (1), Denmark (2), Finland (1), France (2), Germany (8), Hungary (2), Iceland (1), Italy (11), The Netherlands (16), Norway (7), Poland (2), Portugal (3), Russia (1), Spain (1), Sweden (2), Switzerland (6), Turkey (1) and United Kingdom (7).
Among the 65 experts interested to participate, 29 (45 %) responded to the first Delphi round. During the first round, 22 experts indicated not to participate in the Delphi study. In the second round, the questionnaires were sent to 43 experts. Of these, 26 persons (60%) responded. In the third round, the questionnaire was sent to 40 experts, and 23 (58%) responded. In total 21 experts responded in all the three rounds, being from Switzerland (3), Norway (3), Germany (2), Sweden (2), France (2), The Netherlands (2), Italy (2), Belgium (1), Portugal (1), United Kingdom (1), Iceland (1), and Finland (1).

2.2.3 Indicator selection
This gross-list of indicators, as based on the literature review (section 2.1, step 2 of the protocol) is presented in Table 2.1. The gross list of indicators, together with their definitions (Annex I), was used as the starting point for the first Delphi round. It consisted of 41 indicators for the cultivation stage; 26 indicators for the transport and storage stage; and 34 indicators for the processing stage. In this first round, three experts added one new indicators for the cultivation step. The resulting additional indicator was “competence of Fusarium species to synthesize new mycotoxins”. For the transport and storage stage, no additional indicators were mentioned. The gross-list for the processing stage was expanded with two new indicators. These were: “water activity profiles recorded during the wet phase processing” and “fractions of the cereal grains used in the final feed and food product” (whole grain or outer layer of the grains compared to the inner starchy endosperm only). Indicators that received an average score of more than 10 points in the first Delphi question round were selected for the second question round (see Table 2.2). Hereby, the threshold (and consequent number of indicators selected) was based on a clear distinction between scores of indicators. Newly added indicators were also included to the second round.
<table>
<thead>
<tr>
<th>Indicator (Cultivation stage)</th>
<th>Indicator (Storage &amp; transport stage)</th>
<th>Indicator (Processing stage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative humidity/rainfall (air and soil)</td>
<td>Water activity in kernels</td>
<td>Water activity in kernels</td>
</tr>
<tr>
<td>Crop rotation</td>
<td>Relative humidity (product)</td>
<td>Grain Quality</td>
</tr>
<tr>
<td>Tillage practice</td>
<td>Temperature</td>
<td>Carry over of contamination</td>
</tr>
<tr>
<td>Temperature</td>
<td>Ventilation</td>
<td>Level of technology used</td>
</tr>
<tr>
<td>Water activity in kernels</td>
<td>Storage capacity and logistics</td>
<td>Level of implemented</td>
</tr>
<tr>
<td>Crop variety / Cultivars</td>
<td>Level of implemented</td>
<td>Traceability an Quality systems</td>
</tr>
<tr>
<td>Harvest conditions</td>
<td>Traceability an Quality systems</td>
<td>Grain Quality data which may be related to fungal infestations</td>
</tr>
<tr>
<td>Pesticide/fungicide use</td>
<td>Carry over of contamination</td>
<td>Blending/mixing practices</td>
</tr>
<tr>
<td>Changes in composition of fungal populations</td>
<td>Level of technology used</td>
<td>Ventilation</td>
</tr>
<tr>
<td>Fertilization levels</td>
<td>Grain Quality</td>
<td>Awareness of food safety</td>
</tr>
<tr>
<td>Regional infection pressure</td>
<td>National and EU legislation</td>
<td>Number of products passing through national borders without inspection</td>
</tr>
<tr>
<td>Plant health(stress factors)</td>
<td>Awareness of food safety</td>
<td>National and EU legislation</td>
</tr>
<tr>
<td>Awareness of food safety</td>
<td>Changes in composition of fungal populations</td>
<td>Outbreaks of defined species</td>
</tr>
<tr>
<td>Conditions for lodging (unbalanced nutrition and weather)</td>
<td>Transport duration and distance</td>
<td>New/improved detection methods for mycotoxins</td>
</tr>
<tr>
<td>Price premiums offered for higher quality</td>
<td>Blending/mixing practices</td>
<td>Influence of science on the production and legislation</td>
</tr>
<tr>
<td>Soil preparation</td>
<td>Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles</td>
<td>Logistics</td>
</tr>
<tr>
<td>New/improved detection methods for mycotoxins</td>
<td>Characteristics of local supply chain organization (scale, variability and transparency)</td>
<td>Knowledge Dissemination of Mycotoxins</td>
</tr>
<tr>
<td>Irrigation and drainage</td>
<td>Number of products passing through national borders without inspection</td>
<td>Increased number of identification requests for diseases on cereals</td>
</tr>
<tr>
<td>Changes in disease-resistance figures for cultivars</td>
<td>Knowledge Dissemination of Mycotoxins</td>
<td>Compliance with rules and regulation about food safety awareness by businesses per sector</td>
</tr>
</tbody>
</table>
Major shifts in the composition of plant diseases from year to year in particular when it concerns wheat diseases or Fusarium species/types
Decontamination of seeds

Foreign control of enterprises

Influence of science on the production and legislation

New cereal based products entering the consumer market at a large scale (in combination with other risk factors)

Increasing occurrence or unexpected local occurrence of animal diseases without clear diagnosis

Price premiums offered for higher quality

Knowledge Dissemination of Mycotoxins

Compliance with rules and regulation about food safety awareness by businesses per sector

Index of country of origin and trade volumes

Communication/trust between trade parties

Foreign control of enterprises

National and EU legislation

International trade agreements

Index of country of origin and trade volumes

Communication/trust between trade parties

Technology forcing

Food innovations

Outbreaks of defined species

Index of country of origin and trade volumes

Communication/trust between trade parties

Use of growth inhibitors

Index of WTO trade agreements

Level of implemented Exotification

Characteristics of local supply chain organization (scale, variability and transparency)

Communication/trust between trade parties

Foreign control of enterprises

Influence of science on the production and legislation

Use of growth inhibitors

Weed management

Carry over of contamination

Major changes in cultivar choice over wide areas

Spraying technology

Percentage of land covered by energy crops

Certified crop management

International trade agreements

Increased number of identification requests for diseases on cereals

Sowing density

Yield (per Ha)

Level of technology used

Price levels for energy and food cereals

Consumption patterns

Technology forcing

International trade balance
Table 2.2 presents the list of indicators that was used as the starting point for the second Delphi round. In the second round, the list of indicators was further reduced by selecting and ranking the 10 most indicators. The indicators with a total score of 30 points of more in the second round were used as input for the third question round. This resulted in 12 indicators for the cultivation - and processing stage and 13 indicators for the transport and storage stage.
Table 2.2 Reduced list of indicators for emerging mycotoxins, particularly related to Fusarium spp., cultivation, transport and storage, and processing of wheat, used as input for the 2nd Delphi round.

<table>
<thead>
<tr>
<th>Indicator (Cultivation stage)</th>
<th>Indicator (Storage and Transport stage)</th>
<th>Indicator (Processing stage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative humidity/rainfall (air and soil)</td>
<td>Ventilation</td>
<td>Water activity in kernels</td>
</tr>
<tr>
<td>Crop rotation</td>
<td>Temperature</td>
<td>National and EU legislation</td>
</tr>
<tr>
<td>Temperature</td>
<td>Water activity in kernels</td>
<td>New/improved detection methods for mycotoxins</td>
</tr>
<tr>
<td>Water activity in kernels</td>
<td>Relative humidity (product)</td>
<td>Grain Quality</td>
</tr>
<tr>
<td>Crop variety / Cultivars</td>
<td>Awareness of food safety</td>
<td>Grain Quality</td>
</tr>
<tr>
<td>Tillage practice</td>
<td>Carry over of contamination</td>
<td>Awareness of food safety</td>
</tr>
<tr>
<td>Pesticide/fungicide use</td>
<td>Storage capacity and logistics</td>
<td>Level of implemented</td>
</tr>
<tr>
<td>Harvest conditions</td>
<td>National and EU legislation</td>
<td>Traceability an Quality systems</td>
</tr>
<tr>
<td>Conditions for lodging (unbalanced nutrition and weather)</td>
<td>Changes in composition of fungal populations</td>
<td>Blending/mixing practices</td>
</tr>
<tr>
<td>Changes in composition of fungal populations</td>
<td>Level of technology used</td>
<td>Level of technology used</td>
</tr>
<tr>
<td>Regional infection pressure</td>
<td>Grain Quality</td>
<td>Carry over of contamination</td>
</tr>
<tr>
<td>Plant health(stress factors)</td>
<td>Level of implemented</td>
<td>Knowledge Dissemination of Mycotoxins</td>
</tr>
<tr>
<td>Fertilization levels</td>
<td>New/improved detection methods for mycotoxins</td>
<td>Logistics</td>
</tr>
<tr>
<td>Irrigation and drainage</td>
<td>Blending/mixing practices</td>
<td>Ventilation</td>
</tr>
<tr>
<td>Awareness of food safety</td>
<td>Transport duration and distance</td>
<td>Influence of science on the production and legislation</td>
</tr>
<tr>
<td>Soil preparation</td>
<td>Knowledge Dissemination of Mycotoxins</td>
<td>Outbreaks of defined species</td>
</tr>
<tr>
<td>Changes in disease-resistance figures for cultivars</td>
<td>Number of products passing through national borders without inspection</td>
<td>Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles</td>
</tr>
<tr>
<td>Price premiums offered for higher quality</td>
<td>Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles</td>
<td>Price premiums offered for higher quality</td>
</tr>
<tr>
<td>Compliance with rules and regulation about food safety awareness by businesses per</td>
<td>Characteristics of local supply chain organization (scale, variability and transparency)</td>
<td>Index of country of origin and trade volumes</td>
</tr>
<tr>
<td>sector</td>
<td>Influence of science on the production and legislation</td>
<td>Increasing occurrence or unexpected local occurrence of animal diseases without clear diagnosis</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Decontamination of seeds</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major shifts in the composition of plant diseases from year to year in particular when it concerns wheat diseases or Fusarium species/types</td>
<td>Compliance with rules and regulation about food safety awareness by businesses per sector</td>
<td>Increased number of identification requests for diseases on cereals</td>
</tr>
<tr>
<td>Outbreaks of defined species</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New/improved detection methods for mycotoxins</td>
<td></td>
<td>Compliance with rules and regulation about food safety awareness by businesses per sector</td>
</tr>
<tr>
<td>Specific competence of each Fusarium strain to synthesize mycotoxins on the field</td>
<td></td>
<td>Foreign control of enterprises</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grain Quality data which may be related to fungal infestations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water activity profiles recording during wet processing steps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fractions of the cereal grains used (whole grain or outer layer of the grains compared to the inner starchy endosperm only) for production of the final food or feed products</td>
</tr>
</tbody>
</table>
Based on the results i.e total scores, average and medians for each indicator from the third question round, the 12 most important indicators (with the highest average scores) were selected on relative importance. Tables 2.3 A-C present the results of the third round, i.e. the 12 most important indicators for each of the three stages of the wheat chain, together with their relative weights. For cultivation, indicators selected include: relative humidity/rainfall, crop rotation, temperature, tillage practice, water activity of the kernels, and crop variety/cultivar for cultivation. For transport & storage these include water activity, relative humidity, ventilation, temperature, storage capacity and logistics, and for processing the selected indicators were quality data, the fraction of the cereal used, the water activity in the kernels, level of implemented traceability and quality systems, and carry over of contamination. Analysis of the robustness and discrepancy of the results showed only slight differences in the mean, and not on the total scores. Ranking of the indicators on relative importance was therefore not influenced.

Table 2.3A: Overview of the most important indicators, together with their scores, for identification emerging mycotoxins, particularly related to Fusarium spp., in cultivation stage of wheat, resulted from the third Delphi round.

<table>
<thead>
<tr>
<th>Indicator (Cultivation stage)</th>
<th>Total score (N=24)</th>
<th>Median</th>
<th>Average</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative humidity/rainfall (air and soil)</td>
<td>216</td>
<td>10</td>
<td>9.4</td>
<td>1.0</td>
</tr>
<tr>
<td>Crop rotation</td>
<td>154</td>
<td>7</td>
<td>6.7</td>
<td>2.5</td>
</tr>
<tr>
<td>Temperature</td>
<td>145</td>
<td>8</td>
<td>6.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Tillage practice</td>
<td>125</td>
<td>6</td>
<td>6.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Water activity in kernels</td>
<td>118</td>
<td>8</td>
<td>6.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Crop variety / Cultivars</td>
<td>107</td>
<td>5</td>
<td>5.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Harvest conditions</td>
<td>88</td>
<td>4</td>
<td>4.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Changes in composition of fungal populations</td>
<td>85</td>
<td>3</td>
<td>4.3</td>
<td>2.8</td>
</tr>
<tr>
<td>Pesticide/fungicide use</td>
<td>79</td>
<td>4</td>
<td>4.2</td>
<td>1.9</td>
</tr>
<tr>
<td>Plant health (stress factors)</td>
<td>60</td>
<td>3.5</td>
<td>3.8</td>
<td>2.4</td>
</tr>
<tr>
<td>Regional infection pressure</td>
<td>60</td>
<td>2</td>
<td>2.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Awareness of food safety</td>
<td>28</td>
<td>2</td>
<td>2.5</td>
<td>1.6</td>
</tr>
</tbody>
</table>
Table 2.3B: Overview of the most important indicators, together with their scores, for identification emerging mycotoxins, particularly related to Fusarium spp., in the transport and storage stage of wheat, resulted from the third Delphi round.

<table>
<thead>
<tr>
<th>Indicator (Storage and Transport stage)</th>
<th>Total score (N=24)</th>
<th>Median</th>
<th>Average</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water activity in kernels</td>
<td>210</td>
<td>10</td>
<td>9.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Relative humidity (product)</td>
<td>193</td>
<td>9</td>
<td>8.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Ventilation</td>
<td>160</td>
<td>7.5</td>
<td>7.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Temperature</td>
<td>154</td>
<td>7.5</td>
<td>7.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Storage capacity and logistics</td>
<td>104</td>
<td>4.5</td>
<td>4.7</td>
<td>2.7</td>
</tr>
<tr>
<td>Grain Quality (kernel size, color)</td>
<td>79</td>
<td>4.5</td>
<td>4.4</td>
<td>1.7</td>
</tr>
<tr>
<td>Carry over of contamination</td>
<td>76</td>
<td>5</td>
<td>4.5</td>
<td>2.0</td>
</tr>
<tr>
<td>Level of implemented Traceability and Quality systems</td>
<td>69</td>
<td>3.5</td>
<td>3.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Blending/mixing practices (of various lots)</td>
<td>66</td>
<td>4</td>
<td>3.9</td>
<td>2.1</td>
</tr>
<tr>
<td>Awareness of food safety</td>
<td>62</td>
<td>3.5</td>
<td>3.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Level of technology used</td>
<td>52</td>
<td>3</td>
<td>3.5</td>
<td>2.4</td>
</tr>
<tr>
<td>National and EU legislation</td>
<td>46</td>
<td>3.5</td>
<td>2.9</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Table 2.3C: Overview of the most important indicators, together with their scores, for identification emerging mycotoxins, particularly related to Fusarium spp., in the processing stage of wheat, resulted from the third Delphi round.

<table>
<thead>
<tr>
<th>Indicator (Processing Stage)</th>
<th>Total score (N=24)</th>
<th>Median</th>
<th>Average</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Quality data (e.g. colour, kernel size, protein content), which may be related to fungal infestations</td>
<td>180</td>
<td>8</td>
<td>7.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Fractions of the cereal grains used (whole grain or outer layer of the grains compared to the inner starchy endosperm only) for production of the final food or feed products</td>
<td>167</td>
<td>7</td>
<td>7.3</td>
<td>2.1</td>
</tr>
<tr>
<td>Water activity in kernels</td>
<td>152</td>
<td>9</td>
<td>8.0</td>
<td>2.7</td>
</tr>
<tr>
<td>Level of implemented Traceability and Quality systems</td>
<td>106</td>
<td>5</td>
<td>5.0</td>
<td>2.1</td>
</tr>
<tr>
<td>Carry over of contamination</td>
<td>104</td>
<td>6.5</td>
<td>5.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Awareness of food safety</td>
<td>98</td>
<td>5.5</td>
<td>4.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Blending practices (of various lots)</td>
<td>97</td>
<td>4</td>
<td>4.6</td>
<td>2.1</td>
</tr>
<tr>
<td>New/improved detection methods for mycotoxins</td>
<td>88</td>
<td>4</td>
<td>4.6</td>
<td>2.7</td>
</tr>
<tr>
<td>National and EU legislation</td>
<td>84</td>
<td>3</td>
<td>4.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Number of products passing through national borders without inspection</td>
<td>75</td>
<td>3</td>
<td>4.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Level of technology used</td>
<td>61</td>
<td>3</td>
<td>3.6</td>
<td>3.0</td>
</tr>
<tr>
<td>Ventilation</td>
<td>51</td>
<td>6</td>
<td>4.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>
Table 2.4 presents a summary of the indicator selection during the three rounds of the Delphi expert study. As can be seen from this Table the number of indicators reduced from over 100 to 36 final most important indicators.

Table 2.4: Number of indicators used in each question round

<table>
<thead>
<tr>
<th>Stage of wheat based supply chain</th>
<th>Cultivation</th>
<th>Transport &amp; storage</th>
<th>Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>First round</td>
<td>41</td>
<td>26</td>
<td>34</td>
</tr>
<tr>
<td>Dropped</td>
<td>18</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Added</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Second round (new)</td>
<td>24 (1)</td>
<td>21</td>
<td>27 (2)</td>
</tr>
<tr>
<td>Dropped</td>
<td>13</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Added</td>
<td>1</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Third round</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Final selection</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

In addition, potential interrelationships between indicators, as perceived by several experts, were identified. Some experts indicated that it was difficult to ranks some indicators as two or more indicators may depend upon each other. In that case, the specific indicators were given identical ranks. After completion of the Delphi study, potential interrelations between the selected 12 most important indicators (Table 2.3A-C) were identified per stage of the chain. This was done by having individual in-depth interviews with several additional experts. In the cultivation stage, a potential interrelation between relative humidity and temperature may exist, as well as between relative humidity and water activity in the kernels. Furthermore, there may be a dependency between crop rotation and tillage practice with tillage especially being important when maize is grown before wheat. After intensive cultivation of wheat it is necessary to have crop rotation. Fungicide and/or pesticide use could affect the changes in fungal composition. In the storage and transport stage interrelationships between the four indicators water activity in the kernels, temperature, relative humidity and ventilation were identified. Also, dependency may exist between grain quality, blending practices and level of implemented traceability/quality systems. In the processing stage, interrelationships between water activity in the kernels and ventilation were mentioned. Likewise, the four indicators grain quality data, the fraction of the cereal used, blending practices and the level of used traceability systems may have interrelationships with each other.

2.3 Applicability protocol

The protocol defined for the Delphi study showed to be applicable and useful for retrieving expert judgement on selecting indicators for emerging risk identification as well as their relative importance. In particular, the protocol is applicable to reach a wide range of experts from various countries within a relatively short time frame and with low resources. Experts can provide their answers given the (average) response of the other experts in the panel, anonymously. Using this method, some discussion can be held, but an in-depth discussion, e.g. on definitions of the indicators, is not possible. As a next
step, expert judgement could be used to reach consensus upon the most important interrelationships between indicators. This could also be done by a Delphi elicitation session or by means of a workshop with experts from various European countries.

2.4 Conclusions and outlook

This Chapter describes a protocol for having a structured expert judgement study to select the most important indicators for emerging risk identification. The protocol is based on the Delphi method as the elicitation technique. Next, the protocol was applied to the current study aim, i.e., to select the most important indicators for identification of emerging mycotoxins, starting from those produced by Fusarium spp., in wheat based supply chains. Starting with a gross-list of indicators from literature, the Delphi expert study resulted in the 12 most important indicators, together with their relative weights, for each of three stages of the wheat based supply chain. In addition interrelationships between the different indicators were identified. These interrelationships should be discussed and defined in more detail in further research. The most important indicators, together with their interactions, could be used in an identification system for emerging mycotoxins. The protocol for the Delphi elicitation technique showed to be useful for identifying indicators for emerging risks. As a result of this study a network of experts with mycotoxin expertise was established. As a next step, information sources on the most important indicators need to be identified. This is further elaborated upon in Chapter 3.
Annex 1:

<table>
<thead>
<tr>
<th>Indicator for the Cultivation stage</th>
<th>Description/reason for indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>The mean of the temperatures recorded during the various stages of growth. Measures of extremes are important due to their maximum biological impact. E.g. Critical T 24-26°C</td>
</tr>
<tr>
<td>Relative humidity/rainfall (air and soil)</td>
<td>Periods with high rainfall patterns can be considered as an important cause for mycotoxin production due to high relative humidity which promotes fungal infection. E.g. Critical Relative humidity &gt;80%</td>
</tr>
<tr>
<td>Water activity in kernels</td>
<td>Water content &gt;0.15 [-] is necessary for mycotoxin production. E.g. Minimum aw 0.89, Critical aw&gt;0.99</td>
</tr>
<tr>
<td>Crop rotation</td>
<td>Growing a series of dissimilar types of crops in the same space in sequential seasons for various benefits such as to avoid the build up of pathogens and pests that often occurs when one species is continuously cropped. E.g. Cultivation of maize before wheat.</td>
</tr>
<tr>
<td>Crop variety / Cultivars</td>
<td>The resistance levels of the cereal crops grown against Fusarium and other diseases</td>
</tr>
<tr>
<td>Pesticide/fungicide use</td>
<td>The type and amount of used fungicide/pesticide could influence the formation of mycotoxins</td>
</tr>
<tr>
<td>Spraying technology</td>
<td>The type of spraying technology used could influence the lodging of the wheat head</td>
</tr>
<tr>
<td>Decontamination of seeds</td>
<td>Inactivation of harmful and pathogenic microorganisms on seeds</td>
</tr>
<tr>
<td>Weed management</td>
<td>It is necessary knowing the weed management of the farmer, the row distance between the wheat plants and the way the weed is removed between the plants</td>
</tr>
<tr>
<td>Sowing density</td>
<td>The number of plants per m2 influences crop growth, microclimate and spread of diseases</td>
</tr>
<tr>
<td>Use of growth inhibitors</td>
<td>Using growth inhibitors, will increase mycotoxins formation</td>
</tr>
<tr>
<td>Conditions for lodging (unbalanced nutrition and weather)</td>
<td>Lodging of the wheat ear due to unbalanced nutrition and weather could increase the formation of mycotoxins</td>
</tr>
<tr>
<td>Fertilization levels</td>
<td>Too much or to many Nitrogen could give a risk for mycotoxin production</td>
</tr>
<tr>
<td>Major changes in cultivar choice over wide areas</td>
<td>Changes in crop planting patterns, large scale production of certain crops over time</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Regional infection pressure</td>
<td>The occurrence of Fusarium may depend on regional differences in climate and agricultural practices.</td>
</tr>
<tr>
<td>Tillage practice</td>
<td>Fusarium spp could survive saprophytically, meaning it could grow on dead material and therefore persist in crop residues remaining in the field following harvest. Ploughing diminishes the presence of plant remains on the soil. E.g. No ploughing, intermediate tillage.</td>
</tr>
<tr>
<td>Yield (per Ha)</td>
<td>The requirements for the yield. E.g. Low yield could be an indication for infection.</td>
</tr>
<tr>
<td>Irrigation and drainage</td>
<td>The amount of water in the field could influence the water activity of the soil. High water activity will increase mycotoxin formation.</td>
</tr>
<tr>
<td>Plant health(stress factors)</td>
<td>Due to stress factors, the plant health could decrease and the plants are more susceptible for Fusarium infection.</td>
</tr>
<tr>
<td>Major shifts in the composition of plant diseases from year to year in particular when it concerns wheat diseases or Fusarium species/types</td>
<td>Assessing the conservation status of species, changes to assessing changes in genetic diversity, identification of potential trends in genetic diversity.</td>
</tr>
<tr>
<td>Harvest conditions</td>
<td>Delay, duration and weather conditions, labour shortage.</td>
</tr>
<tr>
<td>Soil preparation</td>
<td>Bare soil or lacks of adequate vegetation, erosion. E.g. minimum pH&lt;2.4, optimum 6.0-8.0, maximum 10.2.</td>
</tr>
<tr>
<td>Percentage of land covered by energy crops</td>
<td>Energy crops may change land use patterns, shifts in (quality) of crops, prices etc.</td>
</tr>
<tr>
<td>Level of technology used</td>
<td>Trends in technological developments per country.</td>
</tr>
<tr>
<td>Awareness of food safety</td>
<td>Understanding of food safety within all steps of the food supply chain could decrease the production of mycotoxins.</td>
</tr>
<tr>
<td>Knowledge Dissemination of Mycotoxins</td>
<td>Due to improved electronic media, scientists all over the world could share research results/knowledge.</td>
</tr>
<tr>
<td>Increased number of identification requests for diseases on cereals</td>
<td>When laboratories receive more requests for mycotoxins/fungi analysis it could be an indicator that there are changes in the production chain.</td>
</tr>
<tr>
<td>Level of implemented Traceability an Quality systems</td>
<td>Level of documented traceability systems and the implementation of e.g. HACCP.</td>
</tr>
<tr>
<td><strong>Certified crop management</strong></td>
<td>Certified production may increase quality / marketability of crops, but also cropping systems (nutrients, pesticides).</td>
</tr>
<tr>
<td><strong>Carry over of contamination</strong></td>
<td>Spores which are still in the batch or storage container could sporulate when the Temperature and relative humidity is favourable.</td>
</tr>
<tr>
<td><strong>International trade agreements</strong></td>
<td>Trade agreement could help companies to enter and compete more easily in the global marketplace. Trade agreements encourage foreign governments to adopt open and transparent rulemaking procedures, as well as non-discriminatory laws and regulations.</td>
</tr>
<tr>
<td><strong>Price premiums offered for higher quality</strong></td>
<td>Tendency to produce as cheap as possible, leading to lower quality products.</td>
</tr>
<tr>
<td><strong>Characteristics of local supply chain organization (scale, variability and transparency)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Compliance with rules and regulation about food safety awareness by businesses per sector</strong></td>
<td>Depends on the quality of Risk managers per country, includes competing demands among governmental departments and the ability by local authorities to enforce and monitor the complex QA systems.</td>
</tr>
<tr>
<td><strong>National and EU legislation</strong></td>
<td>Rules and laws about the amount/presence of Mycotoxins.</td>
</tr>
<tr>
<td><strong>Changes in composition of fungal populations</strong></td>
<td>Because of e.g. climate changes, a shift in the fungal composition could occur.</td>
</tr>
<tr>
<td><strong>Outbreaks of defined species</strong></td>
<td>Increase of infections by known fungal species.</td>
</tr>
<tr>
<td><strong>Technology forcing</strong></td>
<td>Technology forcing is a strategy where a regulator mandates a standard that cannot be met with existing technology to internalise external costs associated with the production and/or use of a product.</td>
</tr>
<tr>
<td><strong>New/improved detection methods for mycotoxins</strong></td>
<td>Due to new improve methods it could be possible to detect new mycotoxins, or lower levels of existing ones.</td>
</tr>
<tr>
<td><strong>Influence of science on the production and legislation</strong></td>
<td>Due to development of new technologies it is possible to detect new mycotoxins, or lower levels of existing ones. Legislation may therefore become stricter. It also reflects to trends in the industry and food supply chains: increase pressure on dome.</td>
</tr>
<tr>
<td><strong>Changes in disease-resistance figures for cultivars</strong></td>
<td>Some varieties could be less insect resistant, or more prone to fungi growth.</td>
</tr>
<tr>
<td>Indicator for Transport and storage step</td>
<td>Description/reason for indicator</td>
</tr>
<tr>
<td>-----------------------------------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>Temperature</td>
<td>The mean of the temperatures transport, differences in temperature e.g. during day/night</td>
</tr>
<tr>
<td>Relative humidity (product)</td>
<td>Due to high relative humidity Fungi could grow, and produce mycotoxin. E.g. Relative humidity &gt; 80%</td>
</tr>
<tr>
<td>Water activity in kernels</td>
<td>Water content in the kernels need to be below 15 %. E.g. Water content &gt; 15 %, increased risk for mycotoxin production</td>
</tr>
<tr>
<td>Level of technology used</td>
<td>Trends in technological developments per country. E.g. control atmosphere</td>
</tr>
<tr>
<td>Awareness of food safety</td>
<td>Understanding of food safety could decrease the production of mycotoxins</td>
</tr>
<tr>
<td>Communication/trust between trade parties</td>
<td>Knowledge Dissemination of Mycotoxins Due to improved electronic media, scientists all over the world could share research results/knowledge</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Ventilation is necessary to keep the moisture content constant</td>
</tr>
<tr>
<td>Grain Quality</td>
<td>Quality of the grain, such as kernel size, colour</td>
</tr>
<tr>
<td>Level of implemented Traceability an Quality systems</td>
<td>Level of documented traceability systems and the implementation of e.g. HACCP</td>
</tr>
<tr>
<td>Carry over of contamination</td>
<td>Spores which are still in the batch or storage container could sporulate when the Temperature and relative humidity is favourable</td>
</tr>
<tr>
<td>Blending/mixing practices</td>
<td>Mixing of contaminated parties to reduce the contamination</td>
</tr>
<tr>
<td>Transport duration and distance</td>
<td>Availability of transport, required quality, e.g. Temperature, relative humidity during transport</td>
</tr>
<tr>
<td>Storage capacity and logistics</td>
<td>The storage circumstances, controlled or not</td>
</tr>
<tr>
<td>Index of country of origin and trade volumes</td>
<td>Country of origin is the country where the wheat comes from. When shipping products from one country to another, the products may have to be marked with country of origin, and the country of origin will generally be required to be indicated in the export</td>
</tr>
<tr>
<td>Number of products passing through national borders without inspection</td>
<td>Sampling rate versus the total trade volumes in order to establish the country's ability to control illegal imports of foods</td>
</tr>
<tr>
<td>Foreign control of enterprises</td>
<td>Relocation of production to low-wage countries.</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles</td>
<td>E.g. when there is not enough wheat in Europe, companies may import wheat from countries out of Europe from which little information is available about their cultivation procedure or prevalence of mycotoxins.</td>
</tr>
<tr>
<td>International trade agreements</td>
<td>Trade agreement could help companies to enter and compete more easily in the global marketplace. Trade agreements encourage foreign governments to adopt open and transparent rulemaking procedures, as well as non-discriminatory laws and regulations.</td>
</tr>
<tr>
<td>Characteristics of local supply chain organization (scale, variability and transparency)</td>
<td>Areas / countries vary with regard to the level of organization in food supply chains.</td>
</tr>
<tr>
<td>Compliance with rules and regulation about food safety awareness by businesses per sector</td>
<td>Depends on the experience of Risk managers per country: includes competing demands among governmental departments and the ability by local authorities to enforce and monitor the complex QA systems.</td>
</tr>
<tr>
<td>National and EU legislation</td>
<td>Rules and laws about the limits/presence of Mycotoxins.</td>
</tr>
<tr>
<td>Changes in composition of fungal populations</td>
<td>Because of e.g. climate changes, a shift in the fungal composition could occur.</td>
</tr>
<tr>
<td>Technology forcing</td>
<td>Technology forcing is a strategy where a regulator mandates a standard that cannot be met with existing technology to internalise external costs associated with the production and/or use of a product.</td>
</tr>
<tr>
<td>New/improved detection methods for mycotoxins</td>
<td>Due to new improved methods is could be possible to detect new mycotoxins, or lower levels of existing ones.</td>
</tr>
<tr>
<td>Influence of science on the production and legislation</td>
<td>Due to development of new technologies it is possible to detect new mycotoxins, or lower levels of existing ones. Legislation may therefore become more stricter. It also reflects to trends in the industry and food supply chains.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Indicator for the processing stage</th>
<th>Description/reason for indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water activity in kernels</td>
<td>Water activity &gt;0.15[-] is necessary for mycotoxin formation. E.g. Minimum 0.89, optimum &gt;0.99.</td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Price levels for energy and food cereals</td>
<td>Due to increase of bio-energy less wheat is produced and the prize of food cereals will increase, which could effect the quality.</td>
</tr>
<tr>
<td>Level of technology used</td>
<td>Trends in technological developments per country.</td>
</tr>
<tr>
<td>Awareness of food safety</td>
<td>Understanding of food safety could decrease the presence of mycotoxins in end products.</td>
</tr>
<tr>
<td>Communication/trust between trade parties</td>
<td></td>
</tr>
<tr>
<td>Knowledge Dissemination of Mycotoxins</td>
<td>Due to improved electronic media, scientists all over the world could share research results/knowledge.</td>
</tr>
<tr>
<td>increased number of identification requests for diseases on cereals</td>
<td>When laboratories receive more requests for mycotoxins/fungi analysis of end products it could be an indicator that there are changes in fungi infections.</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Ventilation is necessary to keep the moisture content constant.</td>
</tr>
<tr>
<td>New cereal based products entering the consumer market at a large scale (in combination with other risk factors)</td>
<td>Due to travelling European consumers would like to have other (exotic) products.</td>
</tr>
<tr>
<td>Grain Quality</td>
<td>Quality of the grain, such as kernel size, colour.</td>
</tr>
<tr>
<td>Level of implemented Traceability an Quality systems</td>
<td>Level of documented traceability systems and the implementation of e.g. HACCP.</td>
</tr>
<tr>
<td>Carry over of contamination</td>
<td>Spores which are still in the batch or storage container could sporulate when the Temperature and relative humidity is favourable and enter the end product.</td>
</tr>
<tr>
<td>Blending/mixing practices</td>
<td>Mixing of contaminated parties to reduce the contamination before processing.</td>
</tr>
<tr>
<td>Logistics</td>
<td>Managing and controlling the flow of wheat during the process step.</td>
</tr>
<tr>
<td>Index of WTO trade agreements</td>
<td>increased opportunity to import foodstuffs from regions/countries with less stringent standards.</td>
</tr>
<tr>
<td>Index of country of origin and trade volumes</td>
<td>Country of origin is the country where the wheat comes from. When shipping products from one country to another, the products may have to be marked with country of origin, and the country of origin will generally be required to be indicated in the export.</td>
</tr>
<tr>
<td>Number of products passing through national borders without inspection</td>
<td>Sampling rate versus the total trade volumes in order to establish the country's ability to control illegal imports of foods.</td>
</tr>
<tr>
<td>Foreign control of enterprises</td>
<td>Relocation of production to low-wage countries.</td>
</tr>
<tr>
<td>Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles</td>
<td>E.g. when there is not enough wheat in Europe, companies may import wheat from countries out of Europe from which little information is available about their cultivation procedure or prevalence of mycotoxins</td>
</tr>
<tr>
<td>International trade agreements</td>
<td>Trade agreement could help companies to enter and compete more easily in the global marketplace. Trade agreements encourage foreign governments to adopt open and transparent rulemaking procedures, as well as non-discriminatory laws and regulations.</td>
</tr>
<tr>
<td>Price premiums offered for higher quality</td>
<td>Tendency to produce as cheap as possible, leading to lower quality products</td>
</tr>
<tr>
<td>Price levels for energy and food cereals</td>
<td>Due to increase of bio-energy less wheat is produced and the prize of food cereals will increase</td>
</tr>
<tr>
<td>International trade balance</td>
<td>Measure the trends in overall trade balance, thus the balance in export and import of goods</td>
</tr>
<tr>
<td>Compliance with rules and regulation about food safety awareness by businesses per sector</td>
<td>Depends on the knowledge/experience of Risk managers per country; includes competing demands among governmental departments and the ability by local authorities to enforce and monitor the complex QA systems</td>
</tr>
<tr>
<td>National and EU legislation</td>
<td>Rules and laws about the amount/presence of Mycotoxins.</td>
</tr>
<tr>
<td>Outbreaks of defined species</td>
<td>Increase of infections by known fungal species</td>
</tr>
<tr>
<td>Increasing occurrence or unexpected local occurrence of animal diseases without clear diagnosis</td>
<td>Outbreaks and biodiversity, which involve large population explosions</td>
</tr>
<tr>
<td>Consumption patterns</td>
<td>Consumers can change their consumption pattern e.g. from totally wheat products to more maize products. New trends in consumer choices and shifts in demands towards products</td>
</tr>
<tr>
<td>Food innovations</td>
<td>New Improved food production methods could contribute to new food products</td>
</tr>
<tr>
<td>Exotification</td>
<td>Due to globalisation eating patterns could change in international products flows</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Technology forcing</td>
<td>Technology forcing is a strategy where a regulator mandates a standard that cannot be met with existing technology to internalise external costs associated with the production and/or use of a product.</td>
</tr>
<tr>
<td>New/improved detection methods for mycotoxins</td>
<td>Due to new improved methods it is could be possible to detect new mycotoxins, or lower levels of existing ones in the end product.</td>
</tr>
<tr>
<td>Influence of science on the production and legislation</td>
<td>Due to new technologies legislation may become more stricter. It also reflects to trends in the industry and food supply chains: introduction of novel foods.</td>
</tr>
<tr>
<td>Grain Quality data which may be related to fungal infestations</td>
<td>Quality decrease of the grain kernels arises from fungal growth.</td>
</tr>
</tbody>
</table>
3 Technical information sources

By: C.J.H. Booij, T. Börjesson, M. Martins, J.M. Costa, F. M. Bernardo and H.J. van der Fels-Klerx

3.1 Introduction

In Chapter 2, the most important indicators for emerging mycotoxins have been identified for each of three stages of the wheat based supply chain (cultivation; transport and storage; and processing). These indicators form the basic elements of an identification system for emerging mycotoxins. As a next step to the development of a functional ER identification system, information sources should be attached to each of the indicators. Information sources should be identified and linked into a platform that will fed the ER identification system with the necessary information. To establish a European platform of information sources on the indicators it is essential to make regional/national systems compatible such to guarantee quality, to identify missing information and to consider ways on how to make information accessible.

The quality of current risk assessment and risk management is largely based on a combination of available information and expert knowledge. Information can be direct (based on facts or direct measurements) or indirect (based on indicators). Usually, risk assessors and risk managers combine this information with their own expert knowledge and knowledge of a network of colleagues and experts in the field. Apart from knowledge and information among stakeholders, trust, experience, and handling uncertainty are basic ingredients of the risk management process.

The main aim of the research described in this Chapter was to identify information sources on the selected indicators in three European countries, being Portugal, Scandinavia, The Netherlands, as well as on the European level. An overview will be given of technical data sources, together with an evaluation of their characteristics and usefulness in a linked European platform. The overview includes available expert networks, databases with technical data on the indicators, public and private information systems, as well as data sources used by trade companies and processing industry.

As a second aim, recommendations will be given for:
- making various types of information compatible and useful at the European scale
- linking various types of information into a sustainable platform of information sources
- creating a sustainable platform of information sources to supply a functional ER identification system.

The central assumption of this Chapter is that easy access to well structured information may help risk assessors and managers to identify potential hazards earlier and to enhance the quality of the risk evaluation process.

Section 3.2 provides aspects considered in the characterization of information sources identified. Next, information sources on the indicators for identification of emerging mycotoxins are presented, together with their evaluation. Hereby, the information sources are arranged according to the indicators per stage of the wheat based supply chains (as identified in Chapter 1). Accordingly, information sources are presented for:

- General / all stages (section 3.3)
• Cultivation (section 3.4)
• Transport and storage (section 3.5)
• Processing (section 3.6)

Finally, conclusions and recommendations are presented in section 3.7

3.2 Characterization of information sources

The basic challenge of an ER identification system is to find information, combine information and filter information in an optimal way. The selection of indicators (as done Chapter 2) is the first step in focusing on the most relevant issues. This Chapter focuses on information sources that are assumed to be useful according to at least one of the following criteria:
• it should be linked to any of the indicators selected in Chapter 2;
• it should generate data that feeds the model toolbox as addressed in Chapter 5;
• the information should preferably be electronically available and potentially accessible in the near future.

It was assumed that information sources for the two groups of emerging mycotoxins (i.e., known (re-emerging) mycotoxins and yet unknown mycotoxins) are basically the same. Consequently, the information sources were not distinguished to these two groups.

The types of data sources that were evaluated include administration systems, databases, websites, news media and early warning systems. Information sources were identified by consulting the expert network from research, farmer organizations, processing industries, and food safety authorities. In addition library and web-searches were applied to find more information sources. The information available could be from:
• farmers / farm management systems
• farmer associations
• wheat collectors / traders
• wheat processing industries
• governmental organizations
• research organizations
• scientific literature
• quality test laboratories
• mycotoxin expert groups

In practice, the quality of available information can be extremely variable, ranging from rumors going around among stakeholders up to precise quantitative predictions or monitoring data. For some indicators, advanced information systems exist (e.g. weather) but for other indicators only best guesses can be made due to lack of data (e.g. awareness of food safety). The quality of the information sources identified was evaluated. In addition, the information sources were evaluated for the usefulness by the following criteria:
• is there a direct link to the indicator selected
• is the information a qualitative or a quantitative signal for the indicator
• how trustworthy and precise is the information
• the validity for the situation (scale and level of detail in time and space)
• accessibility for stakeholders

In the following three sections, a summary on the information sources identified is given. Information sources are presented per indicator per stage of the chain. The majority of the indicators selected in Chapter 2 was considered.

3.3 General information sources

This section describes two general sources of information on emerging mycotoxins, not related to a specific indicator or specific stage of the chain. These include management and ICT systems (section 3.3.1) and mycotoxin research networks (section 3.3.2).

3.3.1 Management and ICT systems

Linked to the three stages of the wheat based supply chain considered (cultivation; transport and storage; processing), the specific actors in the chain (farmers, traders, and processors) are the primary stakeholders in managing quality. Not surprisingly, they also generate and handle data and information in the chain stages that is relevant for the ER identification system. In the context of supply chain management, quality control and tracking and tracing, more and more data is registered and transferred throughout the supply chain. This makes data better available for all partners in the chain. ICT infrastructures to handle the information are under development at both the national and international level (for The Netherlands, see http://www.kennisopdeakker.nl/NL/ and for EU, see Theuvsen et al. 2007).

3.3.1.1 Cultivation

For the cultivation stage, weather conditions, crop properties, crop management, disease infection pressure, and harvest conditions are the main indicators for the occurrence of (emerging) mycotoxins at harvest. Most of this information is available at the farm level. In many modern farm management systems, crop management data is stored per field. In some cases, it is also transferred to cereal traders and processors. This information may include crops grown, cultivars, soil management, use of fertilizers and crop protection agents. Some farmers have their own local weather station but, mostly, weather data is only available from regional weather stations. Grain quality data (protein, water content, disease symptoms) before harvest is often roughly known to the farmer but not registered. Information related to regional infection pressure and Fusarium species composition is usually not known to farmers, and only scattered data is available at research organizations. Awareness of food safety among farmers is hard to measure and no indirect indicator is available yet.

3.3.1.2 Storage and Transport

In the storage and transport stage, another set of indicators is relevant that relates to the extent of mycotoxin formation from harvest up to permanent storage. The most important indicator is water activity in the kernels (Chapter 2), related to the extent and the duration, that promotes fungal growth.
This is in turn influenced by weather conditions during harvest, drying facilities, and storage conditions. Moisture content usually is measured at harvest or at intake by traders. In many cases data is registered for each batch before storage. The information linked to the indicators such as storage technology, implementation of quality systems, blending practices is usually available in private trade and processing companies.

3.3.1.3 Processing stage

In the processing stage, indicators related to quality control become dominating. Most processors have their own storage systems, and properties of wheat batches are often measured and registered in detail to manage quality and to select batches for further processing steps. Blending to dilute mycotoxins is not allowed, but blending for other purposes is a common and procedure in many processing industries. Current quality systems used in industry require secure information management. Data is often stored in databases but generally not externally accessible.

3.3.2 Mycotoxin research networks/organizations

This section presents three research networks and organizations, including RASFF, Engormix and EMAN.

- RASFF: Under the RASFF system, EU Member States, 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 Regulation No. EC/178/2002 ("General Food Law"), RASFF is hosted by 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);

- ENGORMIX: World wide news on mycotoxins around cereal production and dairy feed industry (http://www.engormix.com);

- EMAN: The European Mycotoxin Awareness Network (EMAN) exists to provide high quality scientific information and news about mycotoxins to industry, consumers, legislators and the scientific community (http://www.mycotoxins.org/).

3.4 Cultivation stage

3.4.1 General information for farmers
### Sweden
- **Jordbruksaktuellt (News for the farming business).**
  - Information Source / Website: [www.ja.se](http://www.ja.se)
  - Comments: Agribusiness online news

### Netherlands
- **AgriHolland**
  - Information Source / Website: [www.agriholland.nl](http://www.agriholland.nl)
  - Comments: Agribusiness online news

### Portugal
- **United Kingdom**
  - **Crop Monitor CSL**
    - Information Source / Website: [cropmonitor.csl.gov.uk/wwheat/wheat-intro.cfm](http://cropmonitor.csl.gov.uk/wwheat/wheat-intro.cfm)
    - Comments: Farmers/traders online news

### Weather

All European countries have a meteorological network of weather stations that register the most essential parameters for the identified climatic indicators (relative humidity, rainfall and temperature) at an hourly interval. Data resolution depends on density of weather stations which differs per country. Local parameters at the field may deviate considerably from the nearest weather station, depending on distance, altitude and/or local microclimate in general. Data interpolation is usually applied to make best estimates and to generate climatic maps. For region-oriented emerging risk modeling European maps/data sources maybe useful when national databases are inaccessible or incomplete. In Europe, national meteorological databases are more and more linked and stored in a fixed format.

#### Europe
- **Mars project Joint Research Centre (JRC) in Italy**
  - Information Source / Website: agrifish.jrc.it/marsfood/ecmwf.htm
    - Comments: Climatic and weather maps interpolated from weather stations

- **European Centre for medium-range weather forecast**
  - Information Source / Website: www.ecmwf.int/

#### Sweden
- **Jordbruksaktuellt (news for the farming business).**
  - Information Source / Website: [www.ja.se/smhi/vader.asp](http://www.ja.se/smhi/vader.asp)
  - Comments: Online Weather forecast for Agriculture (no past weather data)

- **Lantmet**
  - Information Source / Website: [www.dacom.nl/lantmet_new/index](http://www.dacom.nl/lantmet_new/index), [www.ffe.slu.se](http://www.ffe.slu.se)
    - Comments: Agric. Weather station network

- **Jordbruksverket (Swedish Board of Agriculture)**
  - Information Source / Website: [www.smh.se](http://www.smh.se)
    - Comments: Official Swedish Weather Site

#### Netherlands
- **KNMI**
  - Information Source / Website: [www.knmi.nl](http://www.knmi.nl)
    - Comments: Hourly temperatures, rainfall and humidity per
**3.4.3 Crop rotation**

Most data per field is only available from farmers own registration systems. When farmers get permanent relations with traders and processors or with online registration systems, crop rotation could be derived from the central databases, if accessible (but data are usually protected). From country statistics on crop area/crop per region (such as in Sweden and the Netherlands), most common rotations in different regions may be roughly estimated.

<table>
<thead>
<tr>
<th>Information Source / Website</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sweden</strong></td>
<td></td>
</tr>
<tr>
<td>Jordbruksverket (Swedish Board of Agriculture)</td>
<td><a href="http://www.sjv.se">www.sjv.se</a></td>
</tr>
<tr>
<td><strong>Netherlands</strong></td>
<td></td>
</tr>
<tr>
<td>Kennis op de Akker</td>
<td><a href="http://www.kennisopdeakker.nl/NL/gewassen/graan/">www.kennisopdeakker.nl/NL/gewassen/graan/</a></td>
</tr>
<tr>
<td>Farm Registration System</td>
<td><a href="http://statline.cbs.nl/statweb/">http://statline.cbs.nl/statweb/</a></td>
</tr>
<tr>
<td>LEI / CBS</td>
<td></td>
</tr>
<tr>
<td><strong>Portugal</strong></td>
<td></td>
</tr>
<tr>
<td>Instituto Geográfico</td>
<td><a href="http://www.igeo.pt/">http://www.igeo.pt/</a></td>
</tr>
<tr>
<td>Português</td>
<td></td>
</tr>
</tbody>
</table>

**3.4.4 Tillage**

Most data per field on deep/minimum or non tillage are only available at farmers own registration system. When farmers get permanent relations with traders and processors or with online registration systems, rotation could be derived from the central databases, if accessible (but data are usually protected). No databases are available.

As regulations on tillage are currently discussed by the EU, future registration may be obligatory. At present accessibility of information is problematic.
### 3.4.5 Crop varieties
Resistance level of cultivars is an important indicator for the occurrence of Fusarium under spp. favorable conditions. In most European countries cultivars are tested for resistance against Fusarium fungi. They are classified for their resistance, often expressed in some kind of resistance-figure (e.g. low, medium, or highly resistant). Though farmers register the cultivars grown and seed supplying companies register the cultivars sold, public data for cultivar use/region was not found.

<table>
<thead>
<tr>
<th>Country</th>
<th>Information Source / Website</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>Lantmännen <a href="http://www.lantmannen.se">www.lantmannen.se</a></td>
<td>Not public</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Agrifirm <a href="http://www.agrifirm.nl">www.agrifirm.nl</a></td>
<td>Not public</td>
</tr>
<tr>
<td>Portugal</td>
<td>DGADR - Direcção Geral de Agricultura e do Desenvolvimento Rural</td>
<td>Not public</td>
</tr>
</tbody>
</table>

### 3.4.6 Harvest conditions
Harvest conditions can be estimated both by using weather statistics (see above) during the main harvest period or derived from water content data upon delivery of grains, for instance at Lantmännen. The grain must then have been delivered without drying at the farm level.

<table>
<thead>
<tr>
<th>Country</th>
<th>Information Source / Website</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweden</td>
<td>Lantmännen <a href="http://www.lantmannen.se">www.lantmannen.se</a></td>
<td>Not Public, data on water content</td>
</tr>
<tr>
<td></td>
<td>Svenska Foder <a href="http://www.svenskafoder.se">www.svenskafoder.se</a></td>
<td>Not public, data on water content</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Agrifirm <a href="http://www.agrifirm.nl">www.agrifirm.nl</a></td>
<td>Not Public</td>
</tr>
<tr>
<td>Portugal</td>
<td>DGADR - Direcção Geral de</td>
<td>Not public</td>
</tr>
</tbody>
</table>
3.4.7 Plant health in general

**Sweden**
- Kemikaliinspektionen: [www.kemi.se](http://www.kemi.se)
- Jordbruksverket: [www.sjv.se](http://www.sjv.se)

**Netherlands**
- Productschap Akkerbouw

**Portugal**
- ISA- Instituto Superior de Agronomia: [www.isa.utl.pt](http://www.isa.utl.pt)

3.4.8 Water activity in kernels

**Sweden**
- Lantmännen: [www.lantmannen.se](http://www.lantmannen.se)
- Svenska Foder: [www.svensakfoder.se](http://www.svensakfoder.se)

**Netherlands**
- Cereal Traders / processors: [www.agrifirm.nl](http://www.agrifirm.nl), [www2.cefetra.com](http://www2.cefetra.com)
- Agrifirm, Cefetra, Rijnvallei, and others.

**Portugal**
- Food and Feed business operators records, ACICO, ANPOC

3.4.9 Use of pesticide and fungicide

**Sweden**
- Kemikalieinspektionen: [www.kemi.se](http://www.kemi.se)

**Netherlands**
3.4.10 Changes in Fusarium species composition

Changes in the occurrence of the different Fusarium species can have effect on the toxin spectrum. Continuous monitoring is not applied in Europe. Ad hoc projects have and will be carried out in different countries both focused on disease symptoms as well as by molecular detection tools. Reports and publications of research organizations can be a relevant for trends (which are likely to be slow: over years).

3.4.11 Regional infection pressure

Fusarium problems tend to be affected by regional factors. It is hard to unravel the factors behind these differences, but infection pressure is suggested as one of the relevant factors. Cropping systems, crop use, soil, regional weather, and agricultural intensity may all be involved in causing additional problems in some areas (related to spore density in the air during infection periods). No structured data is available at present.

3.5 Transport and Storage

Though storage conditions may be variable, there is a general awareness about the risk and much pressure is given to farmers, traders and processors to manage their storage conditions well. We could not find any actual data on variability of storage technology in different regions thus far. One of the issues mentioned by experts is carry-over of contamination. However, due to dilution and blending of batches during further processing, this is an indicator that is not easy to track. A serious problem that
makes information flows less transparent is caused by combining batches during transport and storage. Hereby, the accuracy of data at the field level is often lost. Though trade organizations avoid mixing batches of largely different quality, uncertainty and bias in measurements may increase problems in worst case mixing scenarios.

Traders often ask for certified products or only buy from certified companies. The increasing levels of traceability and possible claims often is supported with administration of data concerning quality measures such as precise origin, cultivar, water content, and even mycotoxin measurements. These data are stored at trader organizations. Intensive contacts between buyers and suppliers and rumors and news are common sources of information among traders. Trust among stakeholders is something which is hard to quantify, but important to judge basic quality. Certifying cereal suppliers is one step in formalizing trust. The level of certification may be a good indicator of known risks.

Most information is available at the collectors and traders of wheat. Most firms that buy batches from farmers measure cereal quality characteristics and take samples for kernel moisture and protein content, and often also for mycotoxins. They take care of the way batches are stored in silo’s, distribution to processors and guarantee certificates. They are generally organized locally or regionally. Data is generally not accessible for the public or food safety authorities.

3.5.1 Water activity in kernels

Water activity in the kernels / moisture when entering transport and storage is a factor that is considered to be under control by industry. However, even when under control it can be an important indicators for identification of (emerging) mycotoxins.

<table>
<thead>
<tr>
<th>Information Source / Website</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sweden</strong></td>
<td></td>
</tr>
<tr>
<td>Lantmännen</td>
<td><a href="http://www.lantmannen.se">www.lantmannen.se</a></td>
</tr>
<tr>
<td><strong>Netherlands</strong></td>
<td></td>
</tr>
<tr>
<td>Agrifirm (trade, processing)</td>
<td><a href="http://www.agrifirm.nl">www.agrifirm.nl</a></td>
</tr>
<tr>
<td>Cefetra (trade)</td>
<td><a href="http://www2.cefetra.com/">www2.cefetra.com/</a></td>
</tr>
<tr>
<td>TRUSQ</td>
<td></td>
</tr>
</tbody>
</table>

3.5.2 Silo conditions

Silo conditions and technology refers to drying processes, ventilation, temperature etc.

<table>
<thead>
<tr>
<th>Information Source / Website</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sweden</strong></td>
<td></td>
</tr>
<tr>
<td>Lantmannen</td>
<td><a href="http://www.lantmannen.se">www.lantmannen.se</a></td>
</tr>
</tbody>
</table>
3.5.3 Grain quality general

At most collectors and trader companies, grain quality is measured and registered per batch. This include mycotoxin samples and indirect indicators such as kernel size and ergosterol content (Sweden). Data are often stored in databases but not freely accessible.

Information Source / Website Comments

Sweden
Lantmannen www.lantmannen.se Ergosterol, registered as a mold risk indicator in each batch

Netherlands
Agrifirm (trade, processing) www.agrifirm.nl Registered per batch/ silo
Cefetra (trade) www2.cefetra.com/ Registered per batch/ silo
TRUSQ Registered per batch/ silo
Nutreco http://www.nutreco.nl/ Registered per batch/ silo

3.5.4 Blending/mixing practices

Harvested batches from more fields are often stored into one silo, both in trade and processing stages. Depending on silo size and average field size, the number of batches can vary considerably. Trade companies such as Lantmännen, Agrifirm, Rijnvallei tend to store batches based on their quality and other properties (e.g. protein content). Mycotoxin levels may be one of the criteria on the decision where to store such to lead batches into different processing directions (food or feed). The number of batches per silo could be an indicator for uncertainty, but this kind of data is usually not available.

3.5.5 Carry-over of contaminants
At Lantmännen Mills, random samples are taken, but samples with high ergosterol are further analyzed. Today, mostly silos are sampled, but the ambition is to sample grain batches, so that the effect of transfer of contamination is avoided. Regularly, ELISA analyses of DON, T2, HT-2 and ochratoxin are performed. DON is more frequently analysed than the other mycotoxins. In the Malmö-mill, per season, about 50 analyses are performed for DON, and 30 for the other mycotoxins. More intensive samples are taken at two occasions: 1) in the beginning of a new harvest, and 2) when storage moulds could have caused a problem. In these 2 cases, about 15 samples from different silos in the mill are taken. This is synchronized for the four mills in Sweden. The ambition is to reach batch-level, i.e. to analyze each truck-load coming in.

3.5.6  Traceability and quality management systems

**Portugal**: ASAE, DGADR, DGV, GPP, Food and Feed business operators

ASAE - Autoridade para a Segurança Alimentar e Económica (National Food Inspection Authority)

ACICO - Associação nacional de armazenistas, comerciantes e importadores de cereais e oleaginosas (Traders association)

ANPOC - Associação Nacional de Produtores de Cereais, Oleaginosas e Proteaginosas (Grain Producers Assotiation)

DGADR - Direcção Geral de Agricultura e do Desenvolvimento Rural (National Directorate General of Agriculture)

DGV - Direcção Geral de Veterinária (National Veterinary Authority)

GPP - Gabinete de Planeamento e Políticas

3.5.7  Awareness food safety

For this indicator no information sources could be found. Probably other indirect indicators should be sought for, e.g. training followed on feed and food safety management.

3.6  Processing

The cereal based feed and food processing industry generally buys batches from cereal collectors and traders, having some kind of quality certificate that may or may not include data about mycotoxin analysis. Processing industries may re-check the grain quality with respect to mycotoxins such to avoid risks, in particular when they have less trust in the supplier or when the origin of the batch indicates higher risk levels (based on information in the earlier phases of the supply chain). Re-growth of Fusarium fungi during storage at the processor's plant or during processing itself is not likely to occur. Other mycotoxins can be formed when other fungi such as Penicillium spp. or Aspergillus spp. occur due to bad storage or processing circumstances. However, these fungi and toxins are outside the scope of the current research. Risk of Fusarium-based mycotoxins in the processing step can only occur due to relatively high concentrations of these toxins in the incoming batches which are unknown, not accurately detected, or concentrated during the processing steps.

3.6.1  Grain Quality

General grain quality may be an indicator for the presence of DON and other less or unknown mycotoxins as Fusarium spp. tends to effect grain quality in general.
3.6.2 Fractions of cereals used

Different parts of the kernel may contain different mycotoxin levels. In particular, when chaff is used as an important ingredient for end products, mycotoxin levels / kg may increase. This may be the case in some bread types or in animal feed.

3.7 Conclusions and recommendations

Many (potential) information sources on indicators, from three European countries, were identified in this research project. Accessibility of data and lack of particular data seem to be the major bottlenecks for use of all these information sources for identification of emerging mycotoxins. For using the full potential of information, data from farmers, trade organizations and processors should be related to the major indicators and be as transparent as possible. Much more information could be made available if grain from particular fields could be kept separate until quality analyses have been performed. Data on other indicators such as weather, crop variety, spraying, crop rotation and tillage practice could become easily retrievable from farmers when the necessary information structure is developed. Tracking and tracing systems (current systems or systems under development) are the most promising systems upon which this information could be elaborated. In order to make such a system working at a larger scale
(for each country or for the whole of Europe), close collaboration between authorities, research companies, industry and farmers is needed. Thus, both public and commercial actors need to cooperate. Clearly, there should be incentives to involve all stakeholders in the wheat based feed and food supply chain. As long as specific data sources are (partly) not accessible, systems should be based on general and less precise information.

Independent quality laboratories often have data on mycotoxin measurements which are not used for scientific analysis. We see potential here to retrospectively analyse patterns of occurrence and co-occurrence of mycotoxins.

- Recommendations to make the various types of information sources compatible and useful at the European level and to link them into a platform of information sources;

Recommendations:
1) to make the various types of information sources compatible and useful at the European scale, and to link them into a platform of information sources:
- discuss similarities and differences of national information sources on the indicators between the different European countries;
- start with collecting and storing the necessary information at the national level. An ER identification system at the European level could, in first instance, be provided with this data from the national level. This results in a signal on the expected occurrence of (emerging) mycotoxins on the national/region level;
- in a later stage, evaluate possibilities for scaling up the information on the indicators to the European level;
- develop a central European database for data storage and link this database to supply the ER identification system at the European level. The central database preferably is a web-based application that is directly linked to the national databases.

2) to the creation of sustainable platform of information sources to supply a functional ER identification system with the necessary data:
- In various European countries, data and systems on mycotoxins are currently used for research and/or risk management. From the current research, it is known that, in at least several European countries, a system for prediction of known mycotoxins is running or under development. The current available systems, including these predictive systems, but possibly also other systems for early warning or trend analysis, should be evaluated for use as a basis for designing a system at the larger (European) scale. As a next step, the selected predictive system could be 'extended' with expert knowledge and/or technical information on additional indicators from the "host environment" (as selected in Chapter 2) to also include information on emerging mycotoxins;
- Start with simple implementation of an ER identification system, e.g. with several indicators, and early involvement of the various stakeholders in the chain;
- Communication with all actors in the wheat based supply chain is very important, as well as incentives for all actors to supply the system with the necessary information;
- Long term funding for a dedicated expert team to develop and run the system is essential. This team should involve experts on mycotoxins, computer experts and a central person (responsible) for communication with all stakeholders.
These two recommendations also apply to initiating a sustainable network of key-information sources for other types of mycotoxin related ER and/or production chains.
4 Information model

By CJH Booij and HJ van der Fels-Klerx

In Chapter 2 indicators for identification of emerging mycotoxins have been selected. In Chapter 3, potential information sources on these indicators as well as on the occurrence of fungi and mycotoxins have been identified. Both the indicators and information sources identified showed to be very diverse with regard to origin, completeness, certainty and maybe relevance to the goal of emerging risk identification. This aim of the research described in this Chapter, therefore, is to develop a framework or conceptual model that can handle the various kinds of information at different levels of detail. Also, recommendations are formulated to make information compatible and useful for emerging risk identification at the European scale.

The specific objectives addressed in this Chapter are:

- Definition of an information model to link technical mycotoxin and epidemiological (monitoring) data, expert knowledge and information modules from indicators from the influential sectors. This model will be elaborated from earlier models, including Van Wagenberg et al. (2003) and Dekkers et al. (2008).
- Identification of knowledge to handle different levels of detail with regard to availability of information on indicators as well as for unknown mycotoxins to be leading for future project Information analysis with regard to consistency but also with regard to region specific conditions. Conflicting and missing information from WP1 and WP2 will be addressed and procedures should be suggested how to handle information mismatch and knowledge gaps;
- Defining criteria to value available / incoming information with regard to usefulness and accuracy;
- Defining criteria to value information streams for accessibility and timeliness (speed of delivery);
- To perform some kind of hierarchy analysis to suggest pre-filtering tools of information;
- Defining ways to handle new ER information sources to make the system adaptive;
- Recommendations to link the various information sources with an eye on the creation of a sustainable platform of information sources for early identification of emerging Fusarium related mycotoxins;
- Ensure compatibility with Early Warning systems currently used by Food Safety Authorities or Industries/Trade;
- Generic recommendations for setting up a sustainable platform of information sources for early identification of other types of (mycotoxin related) ER and/or production systems.

4.1 A theoretically based information model

Options to develop a (semi)-quantitative model to predict the occurrence of emerging mycotoxins in an (particular) unit of wheat was evaluated. This model aims at gaining quantitative insight by applying a supply chain approach. The applicability of the model depends on:

- the availability of information on selected indicators at the appropriate scale in time and space and
• knowing the impact of each indicator on the model outcome
• knowing the interaction among different indicators (additive, multiplicative etc)

Given the variety in the nature of the selected indicators and in the level of detail of information available, the model especially focused on taking into account these characteristics of indicators in an ER identification system.

4.1.1 Defining impact of indicators
The selected indicators vary in their type and range of values they can take (see Table I). In this regard, they may be classified into quantitative or qualitative indicators. A quantitative indicator can be expressed as a numerical quantity defined by e.g., its mean and range. Examples of such indicators related to ‘biobased economy’ might be the ‘percent of land covered by energy crop’ and ‘prices’. Qualitative indicators can not be expressed into a number, but can be put into classes with levels. An example of a qualitative indicator, related to ‘agronomical practices’, is ‘tillage practice’, which might include the three levels of ‘deep-ploughing’, ‘intermediate ploughing’ and ‘no-tillage’. The (estimated) impact of the various indicators on the occurrence of emerging mycotoxins, expressed in their predictive value, will vary according to their relative contribution in a particular setting. The predictive value of a particular indicator represents the increase in the (estimated) occurrence of emerging mycotoxins by an increase in the specific indicator. In fact, this increase is affected by two factors, being the (statistical) relationship between the particular indicator and the occurrence of emerging mycotoxins, and the relative importance of the particular indicator in comparison to other relevant indicators. Besides the individual indicators, relevant interactions between indicators also need to be taken into account. This is because, due to synergistic effects, an increase in the level of two low-impact indicators may have more effect then a high level of one high-impact indicator.

4.1.2 A basic regression model
The relationships between indicators and the predicted occurrence of emerging mycotoxins in a particular stage of the wheat based supply chain can be approximated statistically, in case of two indicators, by the following additive model:

\[ Y_{l,m,s} = (\alpha_{l,m,s} * x_{s,1}) + (\beta_{l,m,s} * x_{s,2}) + (c_{l,m,s} * x_{s,1}x_{s,2}) + E_{l,m,s} \]  

(1)

Where,

- \( Y_{l,m,s} \): the occurrence (possibly after suitable data transformation) of emerging mycotoxins in a unit of wheat in stage s of the supply chain, with information on location and time of the unit being available at the level l and m, respectively
- l: level of detail of information available on location of the unit (with l = 1, 2, …, L; and with L being the most detailed level applicable)
- m: level of detail of information available on time of the unit (with m = 1, 2, …, M; and with M being the most detailed level applicable)
- s: stage of the wheat based supply chain (with s = 1, 2, …, S; and with S being the total number of stages in the supply chain; e.g. 1= cultivation; 2= transport, 3=storage, 4=processing)
- xs,n: level of indicator n (with n – in this case - being 1 or 2) in stage s
\(a_{l,m,s}, b_{l,m,s}, c_{l,m,s}\): regression coefficients (predicted impact values) for the main effect of indicators \(x_{s,n}\) (with \(n\) – in this case - being 1 or 2) or an interaction term, given information on location and time of the unit is available at level 1 and \(m\), respectively

\(e_{l,m,s}\): error variable for the estimated occurrence of emerging mycotoxins

Equation 1 illustrates the relationship for two indicators. When more indicators are used in an ER identification system all relevant indicators and interaction terms should be taken into account. As the selected indicators could vary between the different stages of the chain they are - either directly or indirectly - linked to (see Table 1), Equation (1) needs to be further defined, per stage \(s\) of the supply chain, by identification of the relevant indicators and interaction terms, and an estimation of their predictive values. In principle, the occurrence of emerging mycotoxins in any consecutive stage of the wheat based supply chain after harvest, depends – to some extent - on the (estimated) occurrence in one or more of the previous stages. This can be written as:

\[
Y_s = f(Y_{s-1}, Y_{s-2}, \ldots, Y_1)
\]  

(2)

With,

\(Y_s\): occurrence of emerging mycotoxins in a unit of wheat in stage \(s\) of the supply chain

\(s\): stage of the wheat based supply chain (with \(s = 1, 2, \ldots, S\); and with \(S\) being the total number of stages of the supply chain)

4.1.3 Adapting the model to chain characteristics

The basic model (in particular Equation 2) should be adapted to the fact that the prediction unit, in this case the unit of wheat, varies in relation to the stages of the supply chain. This is due to mixing and splitting of units throughout stages of the supply chain and related production processes. For example, the unit may vary from a batch at the farming field level, via trading lots, up to shipping volumes. This may complicate the calculations as figures have to be combined and different information sources are needed according to the purpose. An additional complicating factor is that location (l) and time (m) may vary along the supply chain (batches of grain are usually produced, stored and processed at different locations and at different times). So the model should handle all information available along the chain.

Application of Equation 1 to predict the occurrence of emerging mycotoxins in a particular unit of wheat, in a certain stage of the supply chain, starts with further definition of the unit, e.g. a batch, and identification of the stage of the chain the unit is in. Suppose, the unit is a batch of wheat derived from one field of a farmer. The position of the batch with regard to location and time, and possibly also its history, must be known to estimate the levels of the particular indicators, together with their predictive values, in the model. The next step is to identify the extent to which this information on origin (location and time) is available for each of the indicators (and related information sources). E.g. in the trade stage, the grower of the batch of wheat, the field the batch is derived from, and date of harvest may be exactly known; on the other hand, the only information available might be the particular batch comes from Northern America and is harvested in a particular year. In the first case, information on amount of rainfall and temperature around flowering, two potential indicators, can be derived from weather institutes - in particular in case the geographical coordinates of the field are exactly known, whereas, this is not possible in the second case. Note that indicators that can be estimated visually or measured on
the batch quickly (e.g. kernel size) are independent of the level of detail of information on origin available and, in principle, can always be estimated.

4.1.4 **Handling the level of detail in the model.**

Overall, for a given indicator, for a particular unit of wheat in a particular stage of the supply chain, a certain level of detail of information on position and history with regard to location and time of the unit will be available, varying from not known at all to exactly known at the most detailed level possible. Theoretically, each combination of levels of detail of location and time is possible, depending on the used definition for the unit. The level of detail of information available will affect the precision of the regression coefficients (predictive values) of the indicators in the model and, herewith, also of the estimated occurrence of emerging mycotoxins. The relationship between the available information on origin (location and time) of units of wheat and the precision of the predictive value of the particular indicator is illustrated in Figure III, with examples of levels for location (l) and time (m) for a batch of wheat in the cultivation stage (s=1).

<table>
<thead>
<tr>
<th>Stage of chain (s)</th>
<th>1) Not known</th>
<th>2) Year</th>
<th>3) Month</th>
<th>4) Week</th>
<th>5) Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Not known</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>2) Continent</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>3) Country</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>4) Region</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>5) Town</td>
<td>...</td>
<td>A5,2,1</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>6) Farm</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
<td>(\alpha_l,m,s)</td>
</tr>
</tbody>
</table>

Derived from Van Wageneberg et al. (2003)

**Figure x.** Relationship between the available information on origin (location and time) of units of wheat and precision of the predictive value of the particular indicator, illustrated with levels for location and time for a batch of wheat (derived from a field from one farm) in the cultivation stage (s=1). With \(\alpha_l,m,s\): regression coefficient for a given indicator with information available on origin of a batch of wheat being at level \(l\) for its location and level \(m\) for time.

From Figure III it can be seen that an indicator for the occurrence of emerging mycotoxins in a unit of wheat, in a particular stage of the supply chain, can be appointed to a cell \((l,m)\) in the matrix depending on the level of detail of information on origin of the unit available. The level of detail of the available information increases from the left upper corner to the right bottom corner in the matrix. In the left upper cell of the matrix, there is no information available on location and time of the unit, whereas in the right bottom cell, this information is exactly known at the most detailed level. The principle presented in Figure III, and illustrated for the cultivation stage, is not restricted to (this) one stage of the supply chain; it applies to all consecutive stages of the chain as well. For each stage, the particular
indicators will vary in the level of detail of available information on location of the unit of wheat (where is the unit stored, where is it processed) and time (when was it stored, when is it processed etc). The level of available information detail is a major constraint for the predictive power of a model as described above as well as the quality (preciseness of the information). However, the relevance of having detailed information is most crucial for the indicators that have most impact on the occurrence of emerging mycotoxins. Therefore, missing or less precise information is not always that essential. The optimal level of information detail for a particular indicator depends on the defined unit of wheat and the indicator itself. For example, for the infection pressure indicator ‘percent of land covered by energy crops’ a sufficient level of detail might be “region” and “year” when from a batch only region is known, which is much less detailed than the information needed for the weather indicator ‘amount of rainfall during cultivation’, preferably being available on the farm field level if we know the exact origin of the wheat batch.

For some relationships it may be justified to assume that they can be generalize i.e. that regression coefficients (or simply the impacts) also hold for other situations in time and space. For instance that rainy days around flowering have the same impact on mycotoxin risks irrespective of the country or year.

4.1.5 How to handle uncertainty

Predictive values on indicators from other influential sectors are less likely to be available or to be obtained in the short term, and will – in the most ideal situation – be best guesses. For an ER identification system for really new or little known emerging hazards, the entire model will have a qualitative character and expert estimates on the predictive values need to be used, as historical information (per definition) is not available for all the indicators.

The conceptual model developed can take into account various levels of accuracy of the estimated predictive values (from datasets, experts) of the indicators, as well as the variety in the nature of indicators and level of detail of information available on these indicators.

To handle known uncertainty this conceptual model could be applied using Bayesian methods, as this statistical technique can handle various levels of hierarchy. In addition, using Bayesian methods will also provide the possibility of using a-priori knowledge. Bayesian methods are based on a principle, known as Bayes’ theorem, for combining data (observable quantities) with prior information on the parameters of a model (unobservable quantities) (Gosh et al., 2006). Specifically, the fundamental steps of a Bayesian method are: 1) formulating a probability model for the data given the model parameters (termed the likelihood); 2) formulating a prior distribution for the model parameters; and 3) combining the prior distribution and the likelihood to calculate the posterior distribution of the parameters.

Bayesian methods are especially suited for hierarchical models where the basic observations are thought to come from distributions with parameters that themselves again are modeled as coming from a higher-level distribution. So, for example, data on a national level could be used to formulate a priori distribution to be used together with observed data on the farm scale.

To be realistic it will be impossible (at present) to obtain datasets from which all regression coefficients for all indicators at different time/location detail levels can be estimated including their uncertainty levels. So for the moment the theoretical model can only serve as a basic concept from which simplified systems can be derived and tested using lots of simplifications. (see 4.2)
Initiatives projects that register and store detailed data from each individual field attached to each batch up to the processor stage, may generate a lot of data for analysis and model building. When most risk indicators are monitored in such a system this would allow predictive modeling of emerging mycotoxins much more feasible and precise.

4.2 Matching modeling with current practices

The question how an information model can contribute to emerging risk management and how this should be set up is not an easy one. From the foregoing modeling perspectives and the conclusions from Chapters 2 and 3 the following issues should be taken into consideration:

1. Experts generally agree about the most important indicators that have a link with the occurrence of known mycotoxins and assume that these indicators too a large extent are also valid for emerging (unknown) mycotoxins.
2. Experts and early warning models rank or use weather, wheat variety, crop rotation and tillage parameters as the main indicators/predictors for the occurrence of known mycotoxins explaining 90% or more of the incidents.
3. Apart from weather data, very little information is available on line and up-to-date.
4. Depending on the chain organization, most detailed information is available in the trade and cereal collectors industry as part of their purchasing strategy, quality control and channeling of commodities.
5. DON and other mycotoxins are more and more often measured at critical control points in the chain to avoid losses.
6. Regarding the heavy data dependency of the model described above it is unlikely that such a model can be fully parameterized and implemented and fed with sufficient information/data in the short turn.
7. For new emerging mycotoxins quantification is problematic per definition as any direct quantitative information is lacking.

To our opinion a more flexible and qualitative modeling approach could be useful on the sort term. Such an approach should be based to a lesser extent on detailed and quantitative prediction but more on qualitative prediction, use of current (expert) knowledge, and ways to handle lack of information and uncertainty. It is in the area of most uncertainty where risk managers have to make the most difficult decisions. Of course any information that is available at such a moment can be helpful.

The level of detail approach as described in paragraph 4.1.4. is useful in many cases. An example may illustrate a typical case of uncertainty and information need.

1. Due to scarcity of high quality cereals among their usual certified suppliers a purchasing agent has to decide about a batch of grain from a new supplier (grain collector) in region A. The agent has no network of contacts who might give additional information and the supplier says the quality is OK. However, only one mycotoxin measurement has been taken from one part of the batch which originated from one out of 20 different fields. No further detailed information is available for the specific batch. But of course the geographical region and country is known. An information model could generate a risk profile for the batch based on static and dynamic information that is available digitally.

It can be imagined that the purchaser needs the following information to base his risk perception upon:
- Was the growing reason relatively wet compared to other years?
- Did rainy periods of more 2-3 days occur and if so when?
- Where there any rainy periods in the main harvesting period that could have caused delay?
- What are the most common varieties in the region and did they flower in critical periods?
- Are the most common varieties susceptible for Fusarium?
- How dominant are cereals in the area and is maize a frequently grown crop?
- Did local agricultural news letters say anything about cereal yields and quality this year?
- What is the level of storage technology in the area (drying facilities and quality control)?

Some of the answers to this information request (indicators) may indicate to a high risk of emerging mycotoxin but as there is much hierarchy and interdependence among the various indicators it is not easy to integrate the information.
Given that half of the information is available at least qualitatively at some level of spatial scale (town, region or country), the basic model described above still can be applied albeit there is much uncertainty and lack of information.

The first prediction of mycotoxin occurrence will be based on available weather data and any knowledge about the estimated flowering period of the main wheat cultivars in the area. Here, immediately uncertainty comes in as the synchrony of bad weather with flowering of susceptible varieties will generate a high risk. When the flowering period is not known rather precisely and varieties are unknown the model may only generate a chance that mycotoxin formation is at high level. If this chance is negligible there seems no problem but if this chance is say 40% the model may have added value to estimate the risk. It is exactly in that case where additional risk indicators may enhance or lower the risk and become relevant for evaluation. For example, common growing of maize in the area or signals of delayed harvest may trigger the purchaser to refrain from buying the batch or to ask for additional mycotoxin testing.

If the model is functioning in a proper way this would mean that basic prediction can be done on validated accurate forecasts of DON based on weather which should be as local as possible and further modeled by additional indicators for which the information can be on all levels of detail. For the time being the challenge may be to quantify the impact of different indicators starting form the one that are ranked highest taking into account how the information for those indicators could be available and at which scale. Origin (location) of batches gives the best opportunity to get information about risk factors as most registration systems are location bound. On the long term GIS based databases may generate maps for different indicators that can be used to feed the ER models.

### 4.3 Known mycotoxins and emerging mycotoxins and other hazards

The modeling concept and approaches presented here forms the basic concept of linking indicators, for various stages of the chain, to predict the occurrence of emerging mycotoxins in the wheat based supply chain. Although the concept model is developed for the case of emerging mycotoxins, it should be realized that the selection of indicators arose from different expert meetings, interviews and literature starting from a wide holistic approach. Yet - as discussed in chapter 2- the indicators are not essentially
different from those selected for known indicators. Our idea is that the way of modeling is not principally different for known or emerging hazards. Indicator selection and impact estimation are the basis a generic concept of an ER identification system for the occurrence of any other type of emerging hazard. Out of the box thinking by experts and analyzing real life uncertainties and unexpected events may help to find and define new indicators and/or relationships between indicators. Technical and human errors have not been seriously taken into account in our approach but they are known to be the trigger of serious incidents. For the case of emerging mycotoxins technical failures in mycotoxins measurements or inspections may lead to hazards that are hard to predict. But … not everything can be under control.

4.4 Recommendations

The major constraints with predicting emerging mycotoxin risks is that models can can probably only be derived from models of mycotoxins, that relevant information is only partly available and that there is much uncertainty. Tools to handle uncertainty at best give a guess about how uncertain you are. As known mycotoxin models are the principle starting point, they should be as good as possible and should be able to include risk factors that are recognized as potentially relevant by experts. So the risk influencing impact of critical factors should be estimated for a number of scenarios (even though are considered to be of minor importance for known mycotoxins).

Therefore any improvement of existing DON models can help to develop models for other toxins. Setting up a model for a toxin such as T2 may help to identify similarities and differences with respect to the indicator set and unforeseen factors. In both cases scenarios should be studied where the availability and detail of information varies to see how models can handle knowledge gaps by using alternative, qualitative and general information.

Synchronous measurements of different mycotoxins in batches, anywhere in the supply chain may generate data that are useful to analyze co-occurrence of different toxins. This will put some light on the assumption that risk indicators for one toxin can be extrapolated to other toxins. Bayesian methods could be used to evaluate the levels of uncertainty that is acceptable for decision support.

User involvement from industry or food safety authorities is crucial to test practical relevance and to translate user experience into modeling tools for a functional ER identification system. As it is foreseen that these aims and conditions vary among specific groups of users, such as industry or authorities, they must be defined for each of these groups, separately.

E.g., national control authorities might want to focus their border inspection activities depending on the expected occurrence of mycotoxins in particular units of wheat at arrival. On the other hand, industry might want to use an ER identification system to underpin decision-making on buying and processing of units. Also, the format of the model outcome – in this case being the estimated occurrence of emerging mycotoxins - that will be provided to the particular user must be clearly defined.

Risk managers might want to obtain the overall model outcome of the predicted occurrence, taking into account all indicators at the same time, or a signal in case this model outcome exceeds a certain pre-set level to base their decisions upon. On the other hand, they also may want to know the severity level of each indicator in the model, together with its relative contribution to the overall predicted occurrence of the emerging mycotoxins. In the last case, they may want to use this insight into how the mycotoxin occurrence was estimated and on which indicators it is based. In combination with their own knowledge and expertise, they may arrive at a final decision how to act in a particular situation.
To make optimal use of modeling, the organization of data in the supply chain and aggregation of information at a higher (regional) scale is needed. The combination of weather and (average) farmers field data on crops, varieties, crop rotation and tillage are the base of any predictive model for mycotoxin occurrence. Overlays of GIS maps with risk indicator values in combination with model may be most promising as most risk managers start with the questions where risks are coming from or where they came from. Origin of batches and risk profiles for that origin are considered by us as leading issues for future modeling approaches.
5 Stakeholders need

By Marion Dreyer, Sigrid Brynestad and Ellen Morrison

5.1 Introduction
In the development of a functional identification system for emerging mycotoxins it is necessary to clearly define its aims and conditions for application in practice. These aims and conditions may vary among different groups of end-users such as public authorities, political decision-makers, and food and feed industries.

The objective of the research described in this Chapter is to investigate the aims and needs of various key-stakeholder groups in relation to the envisioned early identification system for emerging mycotoxins in European wheat based feed and food supply chains. Two key-stakeholder groups were distinguished including a) public authorities involved in risk assessment and/or risk management, and b) economic actors of the feed and food supply chain.

The overall research objective was broken down into two sub-objectives. First, the research aimed at helping to understand the specific aims that public authorities and economic actors might attach to the early identification system. It also aimed at contributing to understand the conditions under which these groups of end-users would make use of such a system. The latter includes the type and format of information that would be provided by the system. In order for the envisioned system to be workable, the information supplied needs to be targeted at the end-users, i.e. should be in a format that is useful for the needs of these recipients. The research described has dealt, amongst others, with the question of what are desired contents and design of information. Second, the research aimed at identifying possible input that the user groups could contribute to the envisaged early identification system. The present chapter sets out the main results of this research and, in doing so, highlights some of the key challenges of integrating the envisioned early identification system into current practices.

The chapter is organised into six sections. The second section, following this introduction, describes the methodology used. The third section sketches current practices with regard to handling (emerging) mycotoxins produced by Fusarium spp. in wheat based supply chains. The fourth section sets out varying degrees of relevance and the different aims that public authorities and economic actors attach to the early identification system. The fifth section describes the basic requirements, perceived by the two user groups, for introducing the system into current practices. The last section presents the main conclusions and highlights major challenges of putting the system into practice.

5.2 Empirical Data Collection

The stakeholder needs have been investigated by two major elicitation sessions: a stakeholder workshop and a series of in-depth interviews.
The one-day workshop “Identification of Emerging Mycotoxins in International Wheat-Based Supply Chains” was organised on 20 September 2007 in Rotterdam. At this workshop, the development of a system for early identification of emerging mycotoxins was discussed by an audience with broad practical experience and profound specialist expertise. The specific aim of the workshop was to identify what type of information different groups of end-users (risk managers and risk assessors, feed and food industry) would need to practically address situations concerning Fusarium-toxins in wheat based feed and food supply chains, and also to identify possible input that these actors could contribute to the supply of the envisaged identification system.

The event brought together 23 participants, including 14 invitees and 9 members of two teams of EU-funded projects ranging from practitioners in food and feed safety governance from the public and private sectors to experts in research on mycotoxins, from the Netherlands and Belgium (see Annex X for the list of participants). During this workshop, scenario-based group discussions were held to bring forth perspectives on the usefulness and viability of the envisioned early identification system. Two subgroups were formed. One included representatives of the feed and food industry. The other subgroup comprised representatives of public authorities with responsibilities for food/feed risk assessment and/or risk management. In each subgroup, two (identical) pre-defined scenarios on emerging mycotoxins in wheat were discussed. The discussion in each subgroup was led by one member of the project team, two other members took notes. The scenarios referred to situations in which conditions potentially affecting the presence of Fusarium-toxins in wheat had been changed. During the discussion, experts were asked - for each of the two envisioned situations - to bring forward: - their specific information needs; - the relevance they would attach to information provided by an emerging risk identification system; - own resources that could be fed into an emerging risk system.

After the workshop, a series of individual in-depth interviews was held with public authorities and economic actors in five European countries, including Sweden, Norway, Finland, Denmark and Germany. In total thirteen structured interviews were conducted. Four interviews were conducted with public authorities: one with a responsibility for food/feed risk assessment, one responsible for food/feed risk management, and two with responsibilities for both assessment and management. Eight interviews were conducted with economic actors, including six representatives of companies from the feed/food

---

1 In order to use the time and personnel resources of the invited institutions in an efficient manner, the workshop was carried out in cooperation with the SAFE FOODS project; this project aims at developing a predictive model for (re-)emerging mycotoxins in wheat, maize and nuts.
2 Scenario 1 described a situation in which rainfall and temperature patterns in an area of Germany signal potentially high levels of mycotoxins on wheat. At the same time research results indicate unregulated mycotoxins on the crop that have been described as potentially hazardous for human health in publications by consumer organisations.
Scenario 2 described a situation in which more and more wheat is grown for biofuel production which results in a potential shortage of bread quality wheat in Europe. Alternatives are wheat imports from the USA and Canada, which however, could be insufficiently tested, and the wheat was grown for biofuel production (for a more detailed description of the two scenarios and the questions posed to the workshop participants see Annex 2).
production sector, and two representatives of interest associations (one of feed producers, the other of milling companies). One interview was with a laboratory of a research institute in the agriculture and food sector that coordinated an emerging risk prediction system. Six of the interviews were conducted face-to-face, seven over the telephone (see Annex 3 for a list of the institutions and persons that were interviewed). Prior to the series of interviews, a structured questionnaire was developed (see Annex 4). The questionnaire was aimed at gathering information related to four major aspects referring to the viability and application requirements of the envisioned emerging mycotoxin identification system. These are the four aspects:

1) current provisions and key information sources for handling risks related to mycotoxins in wheat, and the role that early-stage-identification of possible risks plays in terms of provisions, plans and/or considerations in current practice;
2) interest of the interviewed organisation in the envisioned early identification system and basic requirements for use of the system and the information that it would provide by the organisation;
3) information that the organisation itself could make available to the system;
4) perspectives of the organisation on what could be appropriate information sources for the key indicators for emerging mycotoxins in the wheat-based supply chain (see Chapter 2).

The results of the two elicitation sessions (workshop and series of interviews) were integrated. A general overview of each of the four items addressed is presented in the following sections.

5.3 Current Practices of Managing Fusarium Related (emerging) Mycotoxin Risks in Wheat Based Supply Chains

Fusarium was an area of interest for all participating stakeholders. Currently, analysis is the main source of information on mycotoxins in wheat based supply chains for both authorities and industry. Provisions for early identification of emerging mycotoxins are not part of current practices in most countries, neither of quality management activities of the industry nor of the monitoring activities carried out by the public authorities. The exception was in Finland; an early warning system has been developed where all stakeholders contribute to the database and utilize the results in their risk management practices. Some of the economic actors and authorities were involved in projects cooperating with research institutes for testing of various types of mycotoxins. The German and Dutch authorities were also involved in research developing concepts of how to deal with (re)-emerging mycotoxins.

---

In the industry in all countries, the mycotoxin testing regime is related to total quality testing to meet the specified demands from customers and authorities. Testing in the food industry is, in general, performed to ensure legal compliance with EU and national legislation. Testing in the feed industry is often performed to ensure compliance with guidance values and maximum limits for Fusarium toxins in products intended for animal feeding as set out in the 2006 Recommendation of the European Commission. Factors influencing the extensiveness of testing include size of the company as well as the extent to which companies and regions were affected by mycotoxin infestation in the past. In the Scandinavian countries, there was a difference between the control of grain grown by contract farmers within the country and purchases on the open market. Grain bought on the open market is, generally, of a specified quality including mycotoxin testing results. Some random sampling of this grain was often part of the quality control plan. Grain grown by contract farmers was, in general, subjected to testing, with regimes ranging from detailed risk-based total management systems to systems designed primarily to ensure legal compliance (testing for tricothecenes and zearalenone).

The information sources used by the feed and food industries reflect those information sources used for other quality parameters. The types of information sources used include:

- The EU’s Rapid Alert System for Food and Feed (RASFF) or other rapid alert systems
- European Grain Monitoring (EGM)
- Internet, journals and newsletters
- Agents/buyers information
- Information from suppliers
- Agricultural research institutes
- Meteorological institute
- Experts from quality manager networks
- Information from the grower
- Historical data on farms, weather and Fusarium spp.
- Internal company experts
- National/international experts on mycotoxins

The level of information use varied from extensive use of the indicators for an early identification system (see Chapter 1) to visual inspection and testing of delivered harvest for questionable quality.

4 The relevant European Community Law is Regulation (EC) No 1881/2006 setting maximum levels for certain contaminants in foodstuffs. This Regulation includes maximum limits for Fusarium toxins in cereals and cereal-based products.


6 The European Grain Monitoring (Europäisches Getreidemonitoring, EGM) was initiated by the Verband Deutscher Mühlen e.V. and is carried out in cooperation with the Laboratory Services Hamburg (SGS). The monitoring is aimed at a control and documentation of the concentration of unwanted substances in the grain. A European-wide cooperation is intended. Currently, the following associations take part in the EGM: Verband Deutscher Mühlen (VDM), Deutscher Raiffeisenverband (DRV), Bundesverband der Agrarwrblichen Wirtschaft (BVA), Fachverband der Nahrungs- und Genussmittelindustrie Österreichs, Verband der Mühlenindustrie (ÖVM), Bundesinnung der Müller Österreichs (BMÖ); cp. Europäisches Getreidemonitoring, Auswertung des Getreidewirtschaftjahres 2006/2007, Hamburg, SGS Germany GmbH.
Compared with the situation in Germany, the major emerging risk indicators identified by MYCONET seem to be more extensively used in Scandinavia. One company in Scandinavia, which purchases most of the grain from contract farmers, had a system where farmers provided information about farming practices (area use, crop rotation, type of crop, pesticide use, tillage, etc). This database was coupled to local meteorological information, and the risk for mycotoxin development was determined for decisions such as pre-harvest/pre-delivery testing. This system is a co-operation between the company, the Agri-food Research institute and the authorities with communication channels between all stakeholders. This company also actively used the grain quality data as an input to the testing regime. Storage and transport was, in general, not seen as an emerging risk issue by the economic actors. One company in Scandinavia evaluated the grain that had been stored during the winter and took tests based on quality parameters; another had standardised systems that were under control; the rest did not consider these parameters.

5.4 Relevance and Aims Attached to an Early Identification System for Emerging Mycotoxin Risks

Many of the stakeholders expressed a general interest in an early identification system for (emerging) mycotoxins as conceptualised by MYCONET and exemplified for the specific case of Fusarium mycotoxins in wheat based supply chains. It was stressed by several that high concentrations of mycotoxins in grain usually lead to severe restrictions in use and marketing of the grain. If not properly handled in food production, these high concentrations could present a risk to consumer safety. An early identification system was seen as a positive step towards addressing the challenges faced by authorities and industry around mycotoxin management. It was considered a tool in reduction of efforts in risk management, control and monitoring and, ultimately, reduction of consumer health risks. In evaluating such a system, the stakeholders did not distinguish systematically between early identification of well-known mycotoxins produced by Fusarium fungi (such as DON and ZEA), re-emerging Fusarium related mycotoxin hazards, and new Fusarium related mycotoxin hazards (the latter two being the focus of the MYCONET research). Explicitly or implicitly, their statements indicated that a system exclusively related to newly emerging mycotoxin risks - i.e. the occurrence of unknown hazards - was considered overly specific. The stakeholders from Scandinavia in particular, did not distinguish between Fusarium in wheat and in other grains in their systems, given the high focus on mycotoxins in the Northern countries. Hence, most of the economic actors and public authorities interviewed took a broader view in their assessments and viewed/evaluated the relevance and possible aims of an early identification system for Fusarium related mycotoxin hazards and risks in that light.

Representatives of public authorities suggested that national and regional authorities could use the (emerging) mycotoxin identification system to tailor their monitoring and inspection activities (e.g. extent of testing, focus of testing) and focus border inspection activities depending on the expected occurrence of mycotoxins in particular units of wheat upon arrival. Hence, the system could be a means to increase the efficiency of ‘pre-arrival’ controls.

From the point of view of several of the economic actors, the envisioned system was deemed useful in decisions concerning processing units, the purchase of new lots, and testing regime. In their opinion, the
system could be of particular use in the short-term if it provided information on where to buy products, and in the long-term if it provided information on probable developments in certain growing areas related to the existence and emergence of mycotoxins.

Some of the economic actors expected limited additional value of the envisioned early identification system to their current systems of mycotoxin management. From their point of view, the information basis of the current public and private mycotoxin management systems was able to ensure a sufficiently effective management. Information needs, these actors underlined, exists in other aspects, including toxicity data based on in-depth studies, timely information about upcoming legislation and regulation, and incidence levels of previous mycotoxin related events.

Economic actors who have a close relationship with the growers and can directly influence the quality of the grain that they receive showed more interest in an early identification system than those who primarily buy grain on the open market. The latter are more interested in what types of testing should be required from the seller and the quality control testing regime needed to comply with national and EU regulations and guidelines.

5.5 Requirements for Application in Practice

The value of an early identification system for mycotoxins was widely appreciated. However, all stakeholders highlighted several basic requirements and some major challenges around the practical application of the system.

5.5.1 Information type, format and transmission

Both stakeholder groups underlined that the envisioned system should provide information from all of Europe (at the level of countries or regions). The output should be easily accessible and in a user friendly, easy to read format. Across both stakeholder groups an online searchable database was considered an appropriate tool for information transmission and sharing. Some of the economic actors stressed that the database should provide information readily available in interpreted formats in addition to facilitating personalised searches. Regarding information content, specified data on incidents, correlations between different indicators, specific regions, specific requirements for food (such as baby food) and feed types as well as product details were highlighted. Such information should be useful for determining potential Fusarium mycotoxin risks, what to test for, the frequency of testing, where to buy from, and the quality of grain that could be expected from specific areas. Several of both the economic actors and the authority representatives considered a field mapping of Europe by use of a so-called "traffic light model" (Dekkers et al., 2008) an appropriate format that could be provided by the searchable database as well. Such field mapping, in particular, could be readily used in purchase decisions and to facilitate more targeted sampling. In addition to that, a few of the economic actors were interested in receiving warnings about specific areas, products, and conditions by electronic mail. Several of the economic actors stressed they consider such a database as an additional information source to their own resource-intensive systems of information, and emphasised that this additional information should be low cost.
All stakeholders stressed the reliability of the information provided by the mycotoxin identification system and the trustworthiness of the information sources were vital for an effective implementation of the system. Another major requirement, noted by several of them, was that relevant information would be available from all countries and to all stakeholders. This was considered a basic prerequisite for avoiding discrimination of agricultural areas with good early identification systems compared to areas with poor systems.

The economic actors agreed that potentially damaging testing results concerning a company would not be made available. Certain information could be provided through interest organisations in an anonymous form. There was some concern that the system could negatively affect certain growers, firms and regions and could have detrimental commercial and trade implications. It was considered pivotal that the system be made available to all contributors with anonymised and aggregated data.

One of the economic actors (of the processing industry) stressed that it was essential to make clear to the recipients that the system output presented an estimation – more or less accurate depending on the level of accessibility and detail of the required information – of the occurrence of (emerging) mycotoxins, and not evidence of mycotoxin occurrence. This was essential to reduce the risk of severe adverse market and trade repercussions.

Some of the economic actors emphasised that the process of providing information on estimated occurrences of (emerging) mycotoxins in a given year should be continuous. They felt that it would be useful to have both ‘early information’ as well as retrospective information. This retrospective information could also serve as a means to validate the early identification information (on this point see also 5.2).

It was clear to all stakeholders that the MYCONET research used emerging mycotoxins, especially related to Fusarium spp. on wheat, as a case study. None the less, some industry actors (in particular feed producers) stressed that a system providing information on this case alone was of limited benefit. These stakeholders were mostly interested in mycotoxins in grain (oats, rye, wheat) in general. They emphasised that the database would have to contain all the grain products to really be of interest and useful to the food and feed industry.

One representative of a public authority stated that the information gathering required for using an identification system for emerging risks could be facilitated with establishing a forum of experts. Such a forum would allow experts to exchange information on early, non-published findings in scientific research, and provide interested experts access to these findings. The acrylamide case would have demonstrated the need for such a ‘first-findings forum’.

5.5.2 The Prominent Role of Information on Indicators Related to Cultivation
The majority of both stakeholder groups underlined that the most vital indicators for an emerging mycotoxin identification system relate to the stage of cultivation and, consequently, depend on information from the farmers. Some stressed that the information elicited would need to be at the level of farms, agricultural areas, and regional agricultural practices. They cautioned that this information was possible to get from contract farmers, but could be more difficult to collect for other farmers.
Most industry actors stressed in this context that the main responsibility for the safety of the grain would lie with the farmers. It was clearly the cultivation stage, they noted, that was the most appropriate stage to deal with mycotoxin occurrence in a pro-active manner. As a more general note, many of the interviewees from the milling industry and the food and feed industry stated that it was essential to motivate farmers to follow recommended best agricultural practices regarding fusarium and mycotoxins. In comparison, they underlined, the actors operating at the subsequent stages of the supply chain had minimal influence on this risk.

Some of the industry actors stressed at the same time, that their own quality management could profit from the information provided by an early identification system. In this line of argument, one stakeholder from the processing industry emphasised that it was essential to report information on indicators for each of the following stages of the feed and food supply chain separately; cultivation, transport/storage, processing. This would allow the actors of the supply chain to respond to the information gathered at preceding stage(s) and adapt their own quality management activities accordingly. Testing results produced by the processing industry may be used for verification (or falsification) of indicator validity/suitability for eliciting information on emerging mycotoxin risks at cultivation and transport/storage stages.

If, for instance, information on the cultivation indicators pointed to a higher probability of (re-)emerging mycotoxins those operating at the stages of transport, storage and processing could respond to this information with painstaking testing with increased frequency. The results of extensive testing at downstream supply chain stages could then be used to help reviewing the validity of the emerging risk in use.

5.5.3 **Major Challenges of Implementation in the View of Stakeholders**

All stakeholders who were interviewed felt that in order to put the envisioned system into practice, input from all actors participating in the food and feed supply chain was required. Input was needed from farmers as well as from the feed and food industry. However, several stakeholders stressed that it was not always easy to acquire this information. Public authority representatives emphasised that industry would gain a great deal of valuable information which, however, was not publicly available. For instance, besides the mycotoxins for which legal limits exist, industry would also analyse mycotoxins for which there are no legal limits, data that is of great interest to the public authorities. From this perspective, it was stressed that there is a need for improved interaction between the public authorities and the feed and food industries in terms of information exchange. More generally, it was noted, that the exchange of information between all actors involved in the feed and food supply chain would need to be improved in terms of quality, frequency and speed.

Industry actors pointed out that their reserve in transmitting information on testing results to public authorities was partly based on the concern that the information could be used to lower maximum limits or – with regard to the feed – change guidance values into maximum levels. In this context, it was stressed that industry would pass on testing results and other data only in an anonymised and aggregated format. This was to avoid scrutiny of particular regions or individual companies by the authorities or even the wider public. Public exposure could have detrimental commercial and trade implications. The representative of one public authority expressed concern that complete anonymity and aggregation of
data could be an incentive to report only data which was favorable to the respective actor, thereby distorting data passed on to the authorities.

Furthermore, several of the interviewed public authorities pointed out that a European system for identifying emerging risks would face the great challenge of wide differences in quantity and quality of information across Europe making it very difficult to integrate information across countries. Hence, there was a need for improved interaction and information exchange between countries requiring an initial effort in raising awareness of the valuable contributions that the envisioned emerging risk identification system could make to the overall European food safety governance system.

There was one question on traceability systems that was asked during the interviews. It was clear that the traceability systems utilised in the grain industry was such that precise information on the mycotoxin status of the products was not possible after the silage. There is a considerable amount of mixing of the products, and the batches that are defined for traceability purposes are often very large. In order to effectively utilise the data from the farm level at later stages in the production chain, traceability systems that operate with a smaller granularity, or batch size will need to be taken into use. Better traceability systems are needed before an emerging risk identification system can be utilised optimally. The development of traceability systems in grain production may even be enhanced by implementing such as system because more information that is relevant for many of the stakeholders will be generated and traceability systems are needed to ensure that this information is passed on through the supply chain.

Another major challenge that was pointed to by representatives of both stakeholder groups was that grain markets are global. It was deemed difficult to check local situations abroad (outside EU) with regard to each of the indicators. It was considered feasible to ‘monitor’ growing areas abroad for good or bad experiences with regard to the extent to which farmers live up to safety and quality expectations. This, however, required a traceability system. Several stakeholders agreed that it is often technically feasible to trace backwards or upstream and that it is likely that in some cases empirical information is available. Politically, however, the public authorities stressed that there was currently no real incentive to gather such information.

In this context, it was argued that any traceability system must be cost effective and useful for more targeted sampling and testing. An official database that could provide information for traceability systems was of interest "but it should not be established at any cost".

Some stakeholders stressed that the emerging risk identification system and output represented should be tailored to specific needs of various stakeholder groups (industry, public authorities, policy makers, NGOs, consumers) making the design and operation of the system much more demanding.

5.6 Conclusions

Many of the stakeholders whose views were elicited in the MYCONET empirical research expressed a general interest in an identification system for (emerging) mycotoxins, as conceptualised by the project and exemplified for the specific case of Fusarium spp mycotoxins in wheat based supply chains. Several of those interviewed considered the envisioned information system a positive step towards addressing
the challenges faced by authorities and industry around mycotoxin management. They felt this system could be a means to help to improve risk management, control and monitoring and, ultimately, reduce health risks for the consumers.

The national public authorities that were interviewed consider emerging risk identification systems an interesting and promising field of research. They see the relevance and benefit of such systems for the future. In their view, the emerging risk identification system as envisioned by MYCONET could help to tailor their monitoring and inspection activities. Accordingly, they also generally appreciate that the European Food Safety Authority (EFSA) is involved in the setting up of a pan-European system for the identification and evaluation of emerging risks. At the same time they acknowledge that this is an undertaking which is still in its very early stages. What they consider as a basic requirement for the future implementation of emerging risk identification systems is an enhancement in the exchange of information and overall interaction between the different actors in the feed and food supply chain and between the European countries and regions supposed to participate in these systems.

The responses of the economic actors were heterogeneous. Some of them appreciated the envisioned information system as a possible additional component of their quality management systems, which currently focus only on well-known mycotoxin risks. They expressed openness towards retrieving and accounting for information on (re-)emerging mycotoxin risks. In their view, this information could be used for underpinning decision-making on buying and processing units, on the purchase of new lots, and on what to test for. Others were sceptical. Some of those economic actors who expressed reservations regarded the output that the proposed information system could provide as too uncertain to be useful for being integrated into the current quality management systems. Others were concerned that the use of this type of system would imply additional testing based on indicators. Most of the company representatives stated that they want to provide safe food and feed but would like to keep the testing regime as simple and cheap as possible. Another concern shared by most of those who expressed skepticism was that information on particular growers, regions and/or suppliers, though uncertain, could have severe economic and trade implications. Where a national mycotoxin prediction and risk management scheme was set up with involvement of all stakeholders, the industrial actors had integrated this information into their quality control systems. It did take some time after the mycotoxin prediction scheme was initiated until the information could be fully utilized by the industry.

The major conclusions that can be drawn from the empirical research in relation to the conditions for implementing the envisioned information system can be summarized as follows:

1) A central database established at the EU-level which would be easy to use and contain data from at least all European countries and all major actors operating in the feed and food supply chain is an information provision mode which promises to meet with broad support among authorities and industry.


A field mapping of Europe by use of a traffic light model is an information format that promises to meet with support from both stakeholders groups. Such a field mapping could be readily used to underpin purchase decisions and to facilitate more targeted sampling.

2) A major challenge of implementation will be to include all those actors into the envisioned pan-European network of information sources who could act as relevant sources of information for the key indicators that the MYCONET project has identified. It can by no means be taken for granted that all of the major actors operating in the feed and food supply chain – farmers, trade companies, processing industry - will consider the envisioned system as something from which they could benefit as well. The one integrated national system that was in place showed that considerable effort, time and development of effective communication channels and meeting places will be needed to prove to the various stakeholders that this type of system benefits all participants. The empirical insights that were gained through WP4 research indicate that there is a lack of incentive for at least a part of the economic actors to contribute to the system. These actors doubt that the system could provide an added value to their current quality management systems and are worried about even more demanding testing requirements. Moreover, they are concerned that the traceability of information that signals an occurrence of (re-)emerging mycotoxins could entail economic disadvantages for the respective region(s) and supply chain actors. One way to get the relevant information sources into a network, which was put forward for consideration by one public authority representative, would be a certification system. Under such a system all actors in the chain would be liable if they did not document and report accurate data on the key indicators for early identification of emerging Fusarium-based risks related to the stages of cultivation, storage/transport and processing.

3) Another major challenge of implementation following from the above mentioned will be the assurance of the reliability of information and information sources. If the established policy of companies to pass on information to interest organisations and public authorities in an anonymised and aggregated manner only was adopted, this might increase the probability that a lot of information interpretable as signals for emerging risks would not find their way into the system. Due to a lack of traceability of data there would be no possibility to control the correctness of the data. A certain extent of traceability would be required, however, at least on the regional level, to render possible that early reports of the probable occurrence of a hazard (that has not yet become a risk) could specify the respective region(s).

4) Early identification of potential risks always implies the challenge of incomplete and equivocal information. This should be acknowledged and made transparent by those maintaining and operating the envisioned information system, if possible, by specification of the degree of (un-)certainty. This is essential information for the targeted end-users who are expected to respond to the available information with adequate control and management measures.

From these insights we shall draw the following overall conclusion: The key challenge in implementing the envisioned emerging risk identification system will be to assure that there are incentives for farmers

in particular and trade and transport companies and the processing industry as well to supply the system with information on what MYCONET has identified as key indicators for emerging mycotoxin risks. Active support of the system by these supply chain actors requires that they perceive the system's output to be of added value to their current mycotoxin risk management provisions. The empirical research indicates that further basic requirements for support are:
- that the supply chain actors agree that the information provided by the system, however charged itself with uncertainty, can be used to mitigate the challenges implied with the uncertainty involved in the current systems of mycotoxin risk management; these are based for the most part on sampling large bulks of grain with the samples being usually not representative;
- that the operators of the envisioned system communicate to all information sources, potential users and possible observers information about the uncertainty involved;
- that the information provided includes both prospective and retrospective information for the purpose of validation.

In the light of the scepticism of some of the economic actors (from the processing industry) whose views we elicited, we would suggest to devote some future research to investigating the role that the institutional set-up of the envisioned information system might play as a condition for integrating all relevant information sources into a sustainable information network. This should include an analysis of the possible relation between the institutional-organisational design of the system's operating body - e.g. in terms of its scientific/political/financial independence - and its potential for integration. An in-depth analysis of the Finnish outstanding example of a successfully established early warning system for mycotoxins involving all major stakeholders could provide important insights in this respect. The Finnish system is operated by a laboratory of an expert body operating under the Finnish Ministry of Agricultural and Forestry. As another focus of future research we would suggest the possibilities of using a monitoring or certification system for establishing a sustainable information network. A monitoring or certification system could take the form of a private initiative, a public-private project, or a regulatory measure. These different options should be analysed and discussed as possible procedural arrangements for making the emerging risk identification system work.
Annex I. Holistic approach

This annex presents a summary of a structured and proactive approach, named the ‘holistic approach’, for early identification of emerging risks, as developed in Noteborn & Ooms (2005). An emerging risk (ER) is defined as a feed or food borne hazard that may in the future present a risk for human health. As risk is a function of hazard and exposure (Codex Alimentarius Commission, 1999), the indication of an ER may relate to 1) a significant exposure to a hazard not recognized earlier or 2) a new or increased exposure to a known hazard (it is then called re-emerging risk) (European Food Safety Authority, 2006). ER thus may include 1) unidentified new form(s) of a (group of known) hazard(s); 2) not-well characterized hazards; 3) characterized hazards not previously associated with feed or food, or 4) re-emerging hazards and/or new exposure routes. For ER identification, a system or procedure is needed that pro-actively identifies a potential hazard and prevents it from becoming a risk. Such a pro-active system needs more knowledge and information than is available from the feed and food supply chain only. Therefore, the ‘holistic approach’ (illustrated in Figure I) must be taken, implying a large area of disciplines and a variety of different fields of expertise, besides those directly related to the supply chain, to be explored.

Figure I.1: Holistic approach for identification of emerging risks in the feed or food supply chain (derived from Noteborn, 2006).

First, the fields of interest or ‘influential sectors’ must be identified, both from inside and outside the supply chain. Thereafter, for each relevant influential sector, one or more critical factors are selected, from which potential indicators for the ER identification system can be drawn. The derivation of indicators from influential sectors and critical factors is illustrated in Figure II.
An indicator is defined as a signal that indicates the possibility of occurrence of an ER. Indicators may directly be related to one or more stages of a particular feed or food supply chain, or may be connected to the particular (stage of the) chain via one or several links (Noteborn et al., 2005). Information sources must be attached to each indicator to provide an estimation of the level of the particular indicator. The information on indicators may or may not be supplied by or directly related to the feed or food production process itself.

As an example from the field of mycotoxins, fungal growth and their formation of mycotoxins on cereals can occur during crop cultivation, in particular around flowering. The unforeseen and undesirable contamination of cereal products by emerging mycotoxins is affected by factors from various influential sectors. For example, critical factors from the ‘environment and energy’ and the ‘agricultural’ sector might be related to meteorological conditions and on-farm agronomical practices, respectively. Rainfall during flowering might be an indicator related to the weather conditions. Weather stations could be the primary information source to supply data on this indicator. For this and other influential sectors, many more critical factors can be identified, however, information on most of the related indicators from historical or technical data will be difficult, or impossible, to obtain. For more information on this holistic approach the reader is referred to Noteborn et al. (2005) and/or Noteborn (2006).
Annex II. List of workshop participants

[bijlagen worden genummerd met Arabische nummers, en hele titel is vetgedrukt, de pagina’s van de bijlagen worden doorgenummerd vanaf de hoofdtekst en staan ook in de inhoudsopgave]

Workshop “Identification of Emerging Mycotoxins in International Wheat-Based Supply Chains” held at Office of Det Norske Veritas (DNV) in Rotterdam on 20 September 2007

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daan Barug</td>
<td>Ranks Meel</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Hans De Keijzer</td>
<td>Dutch Organisation of Millers</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Frank Driehuis</td>
<td>NIZO the Food Researchers</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Bert Evenhuis</td>
<td>WUR*-Plant Research International (PRI)</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>David Kloet</td>
<td>private consultant</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Jurgen Kohl</td>
<td>WUR-PRI</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Gerrit Koornneef</td>
<td>Hoofdproductschap Akkerbouw</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Marcel Mengelers</td>
<td>VWA***, Office for Risk Assessment</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Sofie Monbaliu</td>
<td>University of Gent</td>
<td>Belgium</td>
</tr>
<tr>
<td>Hub Noteborn</td>
<td>VWA***, Office for Risk Assessment</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Stephan Peters</td>
<td>The Netherlands Nutrition Centre</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Martien Spanjer</td>
<td>VWA, Amsterdam</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Cees Waalwijk</td>
<td>WUR-PRI</td>
<td>The Netherlands</td>
</tr>
</tbody>
</table>

Organising Committee

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kees Booij</td>
<td>WUR-PRI</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Sigrid Brynestad</td>
<td>Det Norske Veritas (DNV)</td>
<td>Norway</td>
</tr>
<tr>
<td>Marion Dreyer</td>
<td>DIALOGIK</td>
<td>Germany</td>
</tr>
<tr>
<td>Chantal Kandhai</td>
<td>WUR-RIKILT</td>
<td>The Netherlands</td>
</tr>
<tr>
<td>Ellen Morrison</td>
<td>DNV</td>
<td>Norway</td>
</tr>
<tr>
<td>Ine van der Fels-Klerx</td>
<td>WUR-RIKILT</td>
<td>The Netherlands</td>
</tr>
</tbody>
</table>

* Wageningen University and Research Centre (WUR)
** RIKILT - Institute of Food Safety
*** Food and Consumer Product Safety Authority (VWA)
Annex III. Two (workshop) scenarios on emerging mycotoxins

Scenario 1:
The rainfall and temperature patterns in a large area of Germany indicate that there could be high levels of mycotoxins on the wheat crop from that area. There are local differences, and the level of Fusarium-toxins in most of the wheat is acceptable, but there is a possibility of very high levels in some of the harvests. At the same time an EU funded research project has shown that the wheat contains various other mycotoxins that do not currently have maximum limits in EU regulation, but potential negative effects of these toxins in food on human health have widely been published by consumer organisations.

Which criteria are most important?
What type of information is needed to determine the testing regime?
What are the current information sources, and how reliable are they?
Is there information that you would like to have available but that is difficult to obtain at the moment?
How could a risk model (such as addressed this morning) be useful in this situation?

Scenario 2:
The area of wheat grown for biofuel production has increased in many areas of the EU on fields adjacent to fields of wheat intended for feed and food production. Wheat for biofuel is generally of lower quality than that for animal and human consumption, and the presence of mycotoxins is generally not of concern in biofuel usage.

What type of information is needed in relation to the quality of wheat for feed and food production?
What type of information is needed to determine the testing regime? [in wheat for feed and food production]
Which criteria are most important?
What are the current information sources, and how reliable are they?
Is there information that you would like to have available that is currently difficult to obtain?
How could a risk model (such as addressed this morning) be useful in this situation?
The focus on growing wheat for biofuels has resulted in a shortage of bread quality wheat in Europe.
The USA and Canada have a large harvest of wheat, but there are indications that some of the wheat being sent to Europe may have invalid or insufficient test certificates. There is a good market with favourable prices for wheat biofuel. There are several large shipments of wheat on the way to Rotterdam that is intended for human consumption.

What type of information is needed to evaluate if the wheat is suitable for consumption?
What type of information is needed to determine the testing regime?
Which criteria are the most important?
What are the current information sources, and how reliable are they?
Is there information that you would like to have available that is now difficult to obtain?
How could a risk model (such as addressed this morning) be useful in this situation?
The participants in the scenario discussions were asked to consider the following:
Which information do you already have and use
Which information would you use if it was available
What format should the information be in to best meet your needs, for example:
Detailed information based on geography and indicators
Estimation on the level of each indicator
Estimated predicted occurrence/ indicator
The participants in the scenario discussions were asked to consider the following:

- Which information do you already have and use
- Which information would you use if it was available
- What format should the information be in to best meet your needs, for example:
  - Detailed information based on geography and indicators
  - Estimation on the level of each indicator
  - Estimated predicted occurrence/indicator
  - Integrated information into 1 estimated occurrence
## Annex IV. List of interviewed authorities and economic actors in series of interviews

### Authorities:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Interviewee</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Institute for Risk Assessment, BfR, Germany</td>
<td>Horst Klaffke</td>
<td>(Head of the National Reference Laboratory for Mycotoxins)</td>
</tr>
<tr>
<td>Federal Office of Consumer Protection and Food Safety, BVL, Germany</td>
<td>Andreas Kliemant</td>
<td>(Unit for Matters of Principle with Foods, Foods of Non-Animal Origin/ Referat für Grundsatzangelegenheiten bei Lebensmitteln, Lebensmittel nichttierischer Herkunft)</td>
</tr>
<tr>
<td>National Food Administration Sweden</td>
<td>Anders Jansson</td>
<td>(Inspection department, Livsmedelsverket)</td>
</tr>
<tr>
<td>Norwegian Food Safety Authority</td>
<td>Laila Jensvoll</td>
<td>(Department for Inspection, Plants and Vegetables.)</td>
</tr>
</tbody>
</table>

### Economic Actors:

<table>
<thead>
<tr>
<th>Companies</th>
<th>Features</th>
<th>Interviewee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rasio PCL, Finland</td>
<td><strong>Raisio’s main products are foods and functional food ingredients, as well as feeds and malts</strong></td>
<td>Lauri Laukkanen (Quality Leader)</td>
</tr>
<tr>
<td>Felleskjøpet, Norway</td>
<td><strong>Agricultural purchasing and marketing Co-op</strong></td>
<td>Sveiniung Skretting, (Quality Assurance, purchasing)</td>
</tr>
<tr>
<td>Lantmännens Mills, Denmark</td>
<td>Scandinavia's largest producer of grain-based products with 12 production facilities in Sweden, Norway, Denmark and Latvia (self-portrayal)</td>
<td>Camilla Krook, (Quality Leader)</td>
</tr>
<tr>
<td>Valsemøllen A/S, Denmark</td>
<td><strong>Milling company, one of two big actors in the Scandinavian market; the other being Lantmännens Mills (self-definition)</strong></td>
<td>Susanne Danielsen, (Quality Director)</td>
</tr>
<tr>
<td>Kampffmeyer Mühlen GmbH, Germany</td>
<td>Leading commodity partner of the whole food and pasta industry (self-portrayal)</td>
<td>Christoph Persin (Head of Research and Development)</td>
</tr>
</tbody>
</table>
Raiffeisen, Kraftfutterwerke Süd GmbH; Germany

www.rkw.sued.de

Interest organisations

Deutscher Verband Tiernahrung e.V. (DVT), Germany

http://www.dvtiernahrung.de

Verband Deutscher Mühlen (VDM), Germany

http://www.muehlen.org

Research Institute:

Institution
Agrifood Research Finland MTT, MTT Laboratories (MTT is an expert body operating under the Finnish Ministry of Agriculture and Forestry)

Interviewee
Veli Hietaniemi (Laboratory Manager)

Svetlana Peganova
(Marketing, Head of Product Development)

Peter Radewahn
(Managing Director)

Alexander Meyer-Kretschmer (Lawyer), Nico Turian MSc. oec. Troph
Annex V. Questionnaires for interviews with authorities and economic actors

Questionnaire for interviews with economic actors
Name of person interviewed:
Company/Association:
Contact information:
Date of interview:
Location (on site address or phone):
Name of interviewer:

On current practice:
Is there any system/procedure in place for the identification of mycotoxins in wheat produced by Fusarium fungi?

On information resources
What kind of information sources are utilised regarding mycotoxins in wheat produced by Fusarium fungi?
Do you (do the members of your association) carry out your own tests? If yes, what do these look like, and what determines the extent to which tests are carried out?
Do you use data of suppliers?
Do you use data/reports of the growers?
Do you use data of other companies or of industry associations?
Is the traceability system here of any relevance?

On current practice in relation to early-stage-identification:
Are there also any provisions/plans/considerations for/on identifying at a very early stage known and/or new hazards resulting from Fusarium fungi?

On reform needs
What would you consider the strengths and weaknesses of the current practices?

On interest in using the early-identification system
How would you judge the interest of your company (association/ the members of your association) in using such an “early identification system”?
What format of information would be desirable/ optimal?
What would be other basic requirements for using the system and the information that it would provide?

On possible input into the system
What information could your company (your association/ the members of your association) make available to an early identification system?
What type of testing is performed by the company (the members of your association) that could be made available to the system?
On access to information
Does your company (association/ the members of your association) have access to information regarding the indicators given (see below: “key indicators”)?

On appropriate information sources
What could be appropriate information sources for the key indicators?

Questionnaire for interviews with authorities
Name of person interviewed:
Authority:
Contact information:
Date of interview:
Location (on site address or phone):
Name of interviewer:

On current practice:
Is there any system/procedure in place for the identification of mycotoxins in wheat produced by Fusarium fungi?
Are controls carried out? What do they look like?
Do you inspect imports?

On current practice in relation to early-stage-identification:
Are there also any provisions/plans/considerations for/ on identifying at a very early stage known and/or new hazards resulting from Fusarium fungi?

On information resources
What kind of information sources are utilised regarding mycotoxins in wheat produced by Fusarium fungi?
Own tests, weather reports, farm reports, information from growers, suppliers, industry, interest organisations, traceability systems

On reform needs
What would you consider the strengths and weaknesses of the current practices?

On interest in using the early-identification system
How would you judge the interest of your institution in using such an “early identification system”?
What format of information would be desirable/ optimal?
What would be other basic requirements for using the system and the information that it would provide?

On possible input into the system
What information could the authorities make available to an early identification system?
What type of testing is performed by the authority(ies) that could be made available to the system?

On access to information
Does your institution have access to information regarding the indicators given (see below: “key indicators”)?

On appropriate information sources
What could be appropriate information sources for the key indicators?

Key Indicators (results of the literature study and an expert Delphi)

Indicators with score >60% should be information that is sought after or circulated in an early warning system.

Cultivation
Categorization of the indicators:
Score >60%:
Relative humidity/rainfall (air and soil)
Crop rotation
Temperature

Score between 30-60%
Tillage practice
Water activity in kernels
Crop variety / Cultivars
Harvest conditions
Changes in composition of fungal populations
Pesticide/fungicide use
Transport and storage
Categorization of the indicators:
Score >60%:
Water activity in kernels
Relative humidity (product)
Ventilation
Temperature

Score between 30-60%
Storage capacity and logistics
Grain Quality (kernel size, color)
Carry over of contamination
Processing
Categorization of the indicators:
Score >60%:
Grain Quality data (e.g. colour, kernel size, protein content), which may be related to fungal infestations
Fractions of the cereal grains used (whole grain or outer layer of the grains compared to the inner starchy endosperm only) for production of the final food or feed products
Water activity in kernels

Score between 30-60%
Level of implemented Traceability and Quality systems
Carry over of contamination
Awareness of food safety
Blending practices (of various lots)
New/improved detection methods for mycotoxins
National and EU legislation
Number of products passing through national borders without inspection
Annex VI. Mycotoxin work in Iceland 2007-2008

By: Olafur

Matis has used the participation in the MYCONET project to build a national network on mycotoxins. Different agencies and companies have been contacted to study the availability of mycotoxin data. Valuable contacts were established with the people involved. In November 2007 a national seminar on mycotoxins was hold with participation from industry, the Icelandic Food and Veterinary Authority and the Agricultural University. The seminar served well to inform people, especially in industry, and enhance our ability to respond to mycotoxin risk.

Mycotoxin data

Wheat is not grown in Iceland, it is imported from Europe and North-America for the feed and food industries in the country. Importers receive information on mycotoxin testing from suppliers and samples are taken for mycotoxin analysis in the import harbour. The Food and Veterinary Authority is responsible for this inspection and also carries out surveillance studies on mycotoxins and other contaminants. Mycotoxins are included in the Icelandic part of the EU regulatory programme for control of residues in food, although wheat is not included. Mycotoxins are not among the research topics in universities in Iceland but the Agricultural University has provided valuable information on related topics. Mycotoxins are no longer analysed in Iceland since it turned out to be more economical to send samples abroad for analysis. Screening of mycotoxins is however carried out at Matis. It is now being considered if mycotoxin analysis should start in Iceland again.

Icelandic data on Fusarium toxins has turned out to be very limited. The Food and Veterinary Agency concentrates more on other toxins and little attention has been paid to wheat. Data from importers has been very limited.

The Icelandic network on mycotoxins

The following institutes, importers and university have participated in the network.

(a) Institutes
Matis - Icelandic Food Research
Skulagata 4, IS-101 Reykjavik, Iceland
Matis is a R&D company, among the roles of Matis are to enhance public health through research and dissemination of knowledge and to provide risk assessment regarding safety of food and feed.

Contact: Olafur Reykdal (olafur.reykdal@matis.is)

The Icelandic Food and Veterinary Authority – MAST
Austurvegi 64, IS-800 Selfoss, Iceland
MAST is an inspection and administrative body dealing e.g. with food safety and supervision of domestic food control.
Contacts: Thuridur Petursdottir (feed) (thuridur.petursdottir@mast.is) and Rognvaldur Ingolfsson (food) (rognvaldur.ingolfsson@mast.is).

(b) Importers
Fodurblandan
Korn gordum 12, IS-104 Reykjavik, Iceland
The company imports considerable part of the wheat used for feed in the country.

Contact: Pall Hoskulds son, quality manager (pallh@fodur.is).

Lifland - Kornax
Korn gordum 5, IS-104 Reykjavik, Iceland
The company imports considerable part of the wheat used in the baking industry.

Contact: Berghthora Thorkeldsson (berghthora@lifland.is).

(c) Food industry
Myllan bakeries
Skeifan 19, IS-108 Reykjavik, Iceland
The Myllan bakeries are the biggest user of wheat for human consumption in Iceland.

Contact: Valgard Thoroddsen (valgard@myllan.is)

(d) University
The Agricultural University of Iceland
Hvanneyri, IS-311 Borgarnes, Iceland
Research at the university include feed quality and fungi.

Contact: Halldor Sverrisson (halldors@lhhi.is)

Aspects regarding information that will be addressed in the project include, among others, types of information sources (e.g. expert panels, databases), identification of existing and missing data sources, availability of and accessibility to information sources (including barriers), methods to obtain information from the sources (particularly related to expert judgement), and recommendations to link the various sources such to contribute to a sustainable pan-European network. The results of this study, i.e., the most important indicators for the occurrence of emerging mycotoxins in wheat based supply chains could be used as basic elements in an identification system for emerging mycotoxin risks. In such a system, data-sources need to be attached to each indicator, and information on the indicator retrieved on a regular basis. Ultimately, such an identification system will pro-actively identify emerging
mycotoxin hazards. Risk managers may use this information in order to control and prevent these hazards from actually becoming a risk to animal or human health.
Toelichting bij deze file:

Dit bestand bevat alle opmaak-elementen die nodig zijn om een rapport te kunnen schrijven in RIKILT rapport format.
Deze opmaakelementen zijn niet via de standaard knoppen bovenaan, maar alleen via opmaakprofielen te benaderen. Zet hiervoor in de rechterkantlijn het lijstje met alle profielen waaruit je kunt kiezen (selecteer onder “opmaak” de optie “opmaakprofielen en opmaak” om snel overzicht te hebben).

Als je begint aan je rapport, save dit bestand dan onder een nieuwe naam op je eigen M gebied. Deze twee blz met toelichting kun je verwijderen uit het uiteindelijke rapport.

Figuren en tabellen kun je het beste in een apart bestand maken (lettertype times new roman, korpsgrootte 9 of 10 in de tabel), dan zet de management assistente ze er op de juiste plaats in. Als je tabellen er direct in wilt zetten, besef dan dat het format slechts een beperkt aantal tabelmogelijkheden bevat.

Door met dit bestand te werken kun je zelf direct het juiste format gebruiken, en wijzigingen zelf doorvoeren. De management assistente hoeft dan alleen nog maar te controleren of het format aan de gestelde eisen voldoet, het rapportnummer toe te kennen en de inhoudsopgave te maken.

Het is de bedoeling dat deze template en de aangepaste RSV0042 bijdragen aan een versnelling van het productieproces en een kwaliteitsverbetering (zowel qua inhoud als qua opmaak) in de RIKILT rapporten.

Voor een uitgebreide uitleg in het aparte instructie-document “handleiding RIKILT rapport templates”: op intranet onder “standaardformulieren” “communicatie” “RIKILT rapport”.

Wat tussen haakjes staat in het format: […] is bedoeld als toelichting, en moet er in het definitieve rapport uitgehaald worden.