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MYCONET

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

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Fact-sheet

Title

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

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Key-words

emerging risks/hazards, mycotoxins, wheat based supply chain, holistic approach, information sources, model, stakeholders

Abstract

This report describes the results of the MYCONET project, an international research project aimed at initiating a sustainable platform (network) of information sources that proactively provides specified information for an emerging risk identification system. As a case study, the project focused on emerging mycotoxins, in particular related to *Fusarium* spp., in European wheat based feed and food supply chains.
Basic elements for setting up an identification system for emerging mycotoxins were addressed. First, the most important indicators for the occurrence of emerging mycotoxins were selected by using

expert judgement. The expert study was based on the Delphi method and used a European panel of experts. The holistic approach was applied and, consequently, the experts evaluated factors from various influential sectors. The expert study resulted in the 12 most important indicators for each of three relevant stages of the wheat based supply chain, including cultivation, transport and storage, and processing. The experts judged the cultivation stage to be the most relevant one. Indicators selected for this stage showed to coincide largely with factors affecting known mycotoxins (e.g., deoxynivalenol) during wheat cultivation. As a next step, information sources were identified on the key-indicators in each of three countries - Scandinavia, The Netherlands, and Portugal - as well as on the European level. However, accessibility of data and lack of particular data seem to be the major bottlenecks for the use of most of these information sources for the identification of emerging mycotoxins. For using the full potential of information, data from economic actors should be related to the key-indicators and be as transparent as possible. Also, there should be incentives for these economic actors to supply the system with their data. A basic information model was developed to link the key-indicators and their information sources with the aim of identifying emerging mycotoxins. As the indicators showed to have different characteristics, the model is able to deal with, amongst others, different types of information sources and levels of information available. More specifically, the basic model is able to handle qualitative and quantitative information, technical data and expert knowledge, and different levels of detail of information, e.g., with regard to spatial scale. 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, was investigated by means of an empirical study. This study included a one-day workshop, followed by a series of in-depth interviews, with groups of experts from Europe. From this study, it was concluded that a major challenge in establishing an identification system for emerging mycotoxins is to get everyone involved in sharing data and information. Communication to all economic actors and stakeholders is very important. Also, long term funding for a dedicated project team to develop and run the system is essential.

Executive summary

Introduction

Nowadays, early warning and predictive systems are used in the European Union for the early notification of food safety hazards. Besides these systems for known hazards, a more pro-active approach is needed for the identification of emerging hazards. Only the early identification of an emerging hazard will provide risk managers the ability to take measures to prevent the specific hazard from actually becoming a risk. Key-sources of an emerging risk identification system form the indicators; signals that indicate (directly or indirectly) the possibility of occurrence of the emerging hazard. Indicators may be directly related to different stages of a certain feed or food supply chain, or may be connected to a particular chain via one or several links. Therefore, indicators should be derived not only from inside the feed and food supply chain but also from outside the chain. In previous projects, the so-called holistic approach for developing an Emerging Risk (ER) identification system has been developed. It includes a host environmental analysis of the feed and food supply chain, in which potential indicators are selected. This approach forms the basis of the current MYCONET research project.

Main objective

The main objective of MYCONET is to initiate upon a sustainable platform/network of sources that will proactively provide specified key-information for an ER identification system. As a case study, the project focused on the occurrence of emerging mycotoxins, starting from the mycotoxins produced by *Fusarium* species, in European wheat based feed and food supply chains. The main objective was broken down into the following four objectives:

- selection of the most important indicators for the occurrence of emerging mycotoxins, together with their relative importance, as judged by experts;
- identification of information sources for the selected indicators;
- definition of a generic information model, based on the selected indicators, to identify emerging mycotoxins;
- identification of the form and type of information needed to utilize the output from an identification system for emerging mycotoxins, as perceived by different groups of stakeholders.

Furthermore, based on the experiences gained in the project, several recommendations were given.

Methods used

The selection of the most important indicators, together with their relative importance, was based on expert judgement. For this purpose, an expert study, based on the Delphi method, was held. This study used a panel of 65 European experts and comprised three indicator selection rounds held by mail. Once, the key-indicators were selected, information sources on these indicators were searched for in three European countries, including Portugal, Sweden, and The Netherlands, as well as at the European level. This was done by means of consulting literature, networks of experts, internet, etc. A basic information model was developed that links the key-indicators and their information sources with the aim to predict the occurrence of emerging mycotoxins. Model development aimed at extending existing predictive statistical models for known mycotoxins to include more qualitative indicators and uncertainty. It was explored how such a system could be linked to location-specific information sources. The stakeholders' needs were investigated by means of a workshop followed by a series of individual in-depth interviews with various groups of European experts.

Results and conclusion

The Delphi based expert study resulted in consensus on the 12 most important indicators for each of three stages of the supply chain (cultivation, transport and storage, processing), separately. For cultivation, indicators selected include: relative humidity/rainfall, crop rotation, temperature, tillage practice, water activity of the kernels, and crop variety/cultivar. For transport and storage, these include water activity, relative humidity, ventilation, temperature, storage capacity and logistics. For processing, the selected indicators were quality data, the fraction of the cereal used, water activity in the kernels, implemented traceability and quality systems, and carry-over of contamination. The relative importance of these indicators was evaluated as well. Cultivation was judged to be the most relevant stage, in which most mycotoxins are formed. Key-indicators for this stage were found not to differ much from factors influencing known mycotoxins during wheat cultivation. Some additional indicators, however, were identified.

In the three countries, information sources on most of the key-indicators were identified. Accessibility of data and lack of particular data seem to be the major bottlenecks for the use of all these information sources for the identification of emerging mycotoxins. For using the full potential of information, data from farmers, trade organisations and processors should be available for the key-indicators and be as transparent as possible to predict the occurrence of emerging mycotoxins. Information from these economic actors could be become more easily achievable when the necessary information structure is developed. Tracking and tracing systems (current systems or systems under development) are the most promising systems in which this information could be elaborated. In order to make such a system work at a larger scale (on the national level or the European level), close collaboration between authorities, research companies, industry and farmers is needed. To achieve this, 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.

As the most important indicators showed to have different characteristics, the basic information model should be able to deal with, amongst others, different types of information sources and levels of information available. More specifically, the basic model developed is able to handle qualitative and quantitative information; technical data and expert knowledge, and; different levels of detail of information, e.g., with regard to spatial aspect (fields, regions).

From the stakeholders study, it was found that the majority of the stakeholders expressed a general interest in an ER identification system for mycotoxins. Such a system was considered to be helpful to improve risk management, control and monitoring strategies and, ultimately, to reduce the consumers' health risk. However, it was concluded that a major challenge in establishing an identification system for emerging mycotoxins is to get all economic actors provide their data on the key-indicators into the network of information sources. As the economic actors, particularly farmers but also trade, transport and processing companies, potentially have the information that is needed most, it must be assured that there are incentives for all actors such to ensure the emerging risk identification system will be supplied with the necessary data. Communication to all economic actors and stakeholders is very important to get every party on board. Also, long term funding for a dedicated project team to develop and run the system is essential.

Recommendations per target group

1) Authorities/EFSA

- Communication to all economic actors and stakeholders of the wheat based supply chain about the functionality and benefits of an ER identification system and their role in it is very important to get every one on board.
- Carefully define incentives for the economic actors to provide their data on the key-indicators.
- Long-term funding as well as a dedicated project team is essential to further develop and run the identification system for emerging mycotoxins.

2) Research institutions

- Further evaluate the currently available predictive and early warning systems and information networks in Europe on mycotoxins in wheat for their suitability to serve as a basis for the envisioned identification system for emerging mycotoxins.
- Start simple with one or two systems with several indicators at the national level. Elaborate upon this system by scaling up to more indicators, also from other influential sectors (a more holistic approach), qualitative information, uncertainty, expert judgement, more countries etc.
- Includes modes for degree of uncertainty into the ER identification system for communication to the economic actors as well as interaction between indicators.
- Investigate current systems (e.g., tracking and tracing, quality management, monitoring) for suitability as a basis for establishing a sustainable information network.
- Describe a step-wise process for organisation of collection of data, database-building as well as construction and testing of models.

3) Feed and food industry

- Create commitment and trust to share information with authorities and others in order to obtain a functional ER identification system.
- Provide information that is both prospective and retrospective.

4) All

- Close collaboration between all stakeholders, including authorities, research companies, feed and food industry and farmers, is essential. To achieve this, both public and commercial actors need to cooperate.
- All actors in the chain and other stakeholders should be involved at a very early stage in developing a functional ER identification system.
- Considerable time, effort and development of effective communication channels and meeting places is needed to prove the system benefits to all stakeholders.
- Create trust between each other.

Contents

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 main 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 (EC/178/2002). 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 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) (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 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 judgement studies.
Following the holistic approach, developed in two European projects (Noteborn & Ooms, 2005; Noteborn, 2006), ER identification starts with a host environmental analysis 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 a host environmental analyses influential sectors with their critical factors are identified. From these critical factors, indicators for the ER identification 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. This is because the risks of mycotoxins are widespread, indicators are partly available and monitored, and knowledge is sufficiently present and developing. 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 technological changes in the processing industries (Beyer *et al*., 2007; Magan & Aldred, 2007). Outbreaks of toxin producing fungal diseases occur quite frequently, especially in the developing countries, but also in Europe (Morgavi & Riley, 2007). Mycotoxins have been/are the

focus of various case studies in projects on ER, among others, including EMRISK (Noteborn, 2006), PERIAPT (Noteborn & Ooms, 2005) and SAFEFOODS (see http://www.safefoods.nl). In addition to these case studies, predictive models of mycotoxin contamination during crop growth have been developed (e.g., Hooker *et al.,* 2002) and are currently in development (e.g., Franz *et al.,* submitted; Schaafsma & Hooker, 2007). These models are focusing on specific mycotoxins such as deoxynivalenol (DON) 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 research 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. MYCONET 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 (inter)national authorities, trading companies, feed and food industry, and consumers; and the availability of the (necessary) base level of knowledge. This 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* spp. related mycotoxins. As the spread and persistence of toxins during production, trade, and processing is complex, a knowledge based system addressing the needs of various stakeholders can help to identify emerging mycotoxins such to prevent them from actually becoming risks.

The main objective of the MYCONET project 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. The main objective is broken down into the following four objectives:

- 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 key-indicators;
- definition of an information model to link information sources on the selected key-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;

Furthermore, based on the experiences gained, recommendations will be given for:

- making various types of information sources compatible and useful at the European level and to link them into a platform of information sources;
- creating a sustainable network/platform aimed to supply a functional mycotoxin related ER identification system with the necessary data.

Also, generic conclusions will be drawn 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 expert study held to select indicators for identification of 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. Chapter 3 also presents the recommendations as mentioned above. Chapter 4 presents an information model to integrate the various indicators, having different characteristics and levels of detail. Chapter 5 focuses on investigation of the information needed by various groups of stakeholders for ER identification, especifically related to mycotoxins in wheat. Finally, the main conclusions of the MYCONET research project are presented in Chapter 6.

2 Indicators for emerging mycotoxins

By H.J. van der Fels-Klerx, C.J.H. Booij and M.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 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 I) was applied and, consequently, indicators were evaluated and selected from various influential sectors. This was done for each of three relevant stages of the wheat based supply chain, i.e., cultivation, transport and 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 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 Expert study design

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 (Van der Fels-Klerx *et al*., 2002). 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 (Cooke, 1991). Although there are some generic steps to be included in the protocol for an expert judgement study, the elicitation technique to be applied affects the steps to be followed to a large extent. Therefore, first, 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 an indication to their relative importance (Verschuren & Doorewaard, 1999). These 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 Elicitation techniques

2.1.1.1 Evaluation of elicitation techniques

Elicitation techniques vary in their features like anonymity, feed-back, 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 the above mentioned methods is given below.

a) Individual interviews:
An in-depth interview with an individual expert (or a series of interviews with a panel of experts) has the advantage that the rationale behind the expert’s judgements could be obtained. Also, the potential effect of expert dominance is avoided. The main disadvantage is that it is very resource demanding to obtain information from a panel of experts. Also, interaction between experts is not possible, which makes it difficult to obtain consensus.

b) Group discussion:
A group discussion with a panel of experts has the advantage that information from various experts could be shared, and interaction between experts could be used to obtain consensus. A draw-back of this form of expert elicitation, however, could be that the opinion of the most dominating persons highly affects the outcomes, and that the less dominating ones are not heard. This effect could be avoided by using a Group Discussion Room technique (GDR) (Verschuren & Doorewaard, 1999). With GDR, the experts come together in a room with an electronic meeting support system. Each participant has a workstation which enables computer mediated collaboration with the other group members. In this way, the experts are able to share their opinions anonymously. GDR is typically used for a participative approach to complex tasks. It supports collaborative processes, the generation of new ideas (brainstorming), the convergence of a list of ideas, focus the discussion, the organizing of ideas in categories or structures, the evaluation of ideas on different criteria, and consensus building. Various electronic support tools are available. Besides anonymity of the expert's response, they all have the following features: participants contribute their ideas in parallel and enabling of structured discussions. The latter is focused on structured organisation of the contributions of the group members in order to create insight in relations and shared understanding on concepts shared by the group.

c) Delphi technique:
Delphi is used for the elicitation of experts' opinions with the aim of obtaining a group response, preferably consensus, among a panel of experts. Typically, the Delphi method comprises several questionnaire rounds held by mail (e.g., by postal mail 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 individual experts are evaluated to achieve a common response with deviations. After each round, the experts are given the opportunity to revise their answers, taking into account the anonymous and summarized response of the other experts in the panel (Brown, 1968; Verschuren & Doorewaard, 1999). Thus, Delphi has the characteristics of both group interview and the written poll. The disadvantages of group dynamics could be avoided, while still having high level of interaction among experts (Van der Fels-Klerx *et al.*, 2000).

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 (preferably) need to agree upon the most important indicators. Therefore, to obtain consensus among a panel of experts, some form of interaction – like with GDR and Delphi - is necessary. Applying the holistic approach in selecting indicators, 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 (Dekkers *et al*., 2008). 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 when 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 GDR 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 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 GDR, 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 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, which are relevant to the current study as well. The protocol to retrieve expert judgement on the most important indicators for ER identification includes the following steps:

2.1.2.1 Preparation
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 back ground document on the holistic approach, the study aim, and a short description of the expert judgement study;

4) Definition of the expertise required;
5) Identification of the experts;
6) Selection of the experts;
7) Definition of the elicitation format describing the exact questions and format for the expert elicitation;
8) Format for evaluation and combination of the individual experts' answers;
9) Dry-run exercise describing the try-out of the elicitation format document to a few experts;

2.1.2.2 Elicitation

10) Expert elicitation session applying the Delphi elicitation method. The first Delphi round starts with the gross-list of indicators (defined in step 2). The aim is to reduce this list to a selected set of most important indicators for ER identification. This will be achieved in several rounds; in each round the expert panel is asked to select and rank the indicators. Each following round starts with a reduced set of indicators. See Figure 1 for an illustration of the Delphi method;

2.1.2.3 Post-elicitation

11) Analyses of results: after each Delphi round (see step 10), the individual experts' answers on the questionnaires, related to the selection and evaluation of the importance of the indicators, are examined. The aim is to obtain a common response, together with differences from this broad outline. After each round, the obtained information is returned to the individual participants (in the next round) with the request to consider their initial answers taking into account the (anonymous) considerations of the other experts;
12) Robustness and discrepancy analysis; the answers from the panel of experts are evaluated for discrepancy between individual judgement and outliers. The robustness of the results can be analysed by deleting an individual expert's response, one by one, and evaluate the effects on the overall results (Goossens *et al*., 1999);
13) Feed-back communication with the experts: the final results of the study are reported to the expert panel;
14) The expert judgement study and its results are carefully described in a report.

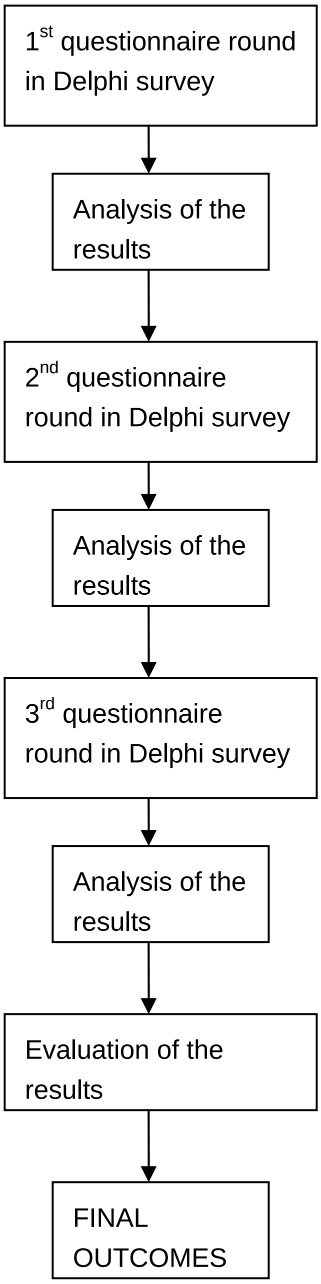

Figure 1 Main steps required for the Delphi implementation

2.2 Expert judgement study

The protocol for the expert judgement study, as 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 emerging mycotoxins, starting from those produced by *Fusarium* species, in wheat based feed and food supply chains, together with 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 results gained in its actual application.

2.2.1 Application protocol

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 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 established by a literature review, evaluating the results from related previous studies (Van Wagenberg *et al*., 2003; Noteborn, 2006; Park and Bos, 2007; Dekkers *et al.*, 2008). All potential indicators mentioned in these studies were evaluated, and appointed to relevant stage(s) of the wheat based supply chain, being cultivation, transport and storage, and processing. The resulting gross-list of indicators was used at the starting point for the Delphi elicitation procedure (Annex II).

3) Back ground document

A document with back ground information was established. This back ground document describes the holistic approach, the study aim and the design of the expert judgement study. It was sent to the selected experts on beforehand (before the elicitation).

4) Definition 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 (Verschuren & Doorewaard, 1999).

5) Identification of experts

Nine key-persons from 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 SAFEFOODS expert database was consulted (http://www.safefoods.nl) and the contacted panel candidates were asked to suggest other relevant experts. The goal 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 to include at least 50-60 experts in the expert panel.

6) Selection of experts

All experts identified in step 5 were approached for participation in the expert study.

7) Elicitation format
Questionnaires were prepared prior to each Delphi round, including a table with a given set of indicators for each stage of the supply chain. Each table included a column with the indicators and a column for inserting the expert's scores. In each Delphi round, experts were asked to select and, next, to semi-quantify the selected indicators. Experts were asked to respond to each questionnaire by writing their answers in the elicitation format document (table).

8) Evaluation format
An excel spreadsheet (Microsoft Excel 2003) was established for analysing the scores given by the individual experts. This spreadsheet was used for further analysing and combining the results.

9) 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.

10) Expert elicitation
The aim of the Delphi study was to iteratively reduce the gross list of indicators such to obtain a) the most important indicators, b) consensus on the selected set of indicators, and c) an indication to the relative importance of each indicator. Hereto, in the first Delphi round (first questionnaire) the experts were provided the gross list of indicators, per stage of the chain. They were asked to evaluate each indicator for its relevance as indicator for the identification 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 gross list of indicators - including the ones added - and, subsequently, to relatively rank the selected indicators. 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 most points in the first round as well as the additional indicators mentioned. 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 assigning scores. The entire expert elicitation started in November 2007 and ended in February 2008. Reminders were sent to experts not complying with the deadlines. All correspondence was performed via e-mail.

11) Analyses of the results
After each of the three Delphi rounds (see step 10), the individual experts' answers were examined closely, and broad outlines and differences were identified. For the indicator selection procedure in successive rounds, the scores of the experts were summed up, per indicator, and both the total score and average score per indicator were calculated. The average score was used as criteria for bringing the indicator to the next round. Hereby, the threshold score was based on a distinction between groups of more and lesser important indicators. After the third round, the total and median scores of the indicators were used as well to categorise the list of indicators based on their relative importance. The results are given in more detail in section 2.2.2.

12) Discrepancy and robustness analyses
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.

13) Feed-back communication
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.

14) Documentation
The results were carefully described in a working document, (this) final report of the MYCONET project, and a manuscript submitted for publication in a scientific journal.

2.2.2 Results

2.2.2.1 Expert response

In total 78 persons were identified as being experts. All of them were approached to participate in the expert panel, 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). Of these 78 experts, 65 persons were interested to participate.

Of the 65 experts, 29 (45 %) responded to the first Delphi round. During the first round, 22 experts indicated to have no time 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).

2.2.2.2 Indicators

In the first round, one expert added a new indicator (not on the gross list) for the cultivation step. This 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 extended with two additional indicators, being “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 to be included in the second question round (see Table 1). Hereby, the threshold (and consequent number of indicators selected) was based on a clear distinction between scores of indicators. The newly added indicators were also included into the list of indicators in the second round. Table 1 presents the list of indicators that was used as the starting point for the second Delphi round.

Table 1 Reduced list of indicators for identification of emerging mycotoxins, particularly related to Fusarium spp., during cultivation, transport and storage, and processing of wheat, used as input for the 2nd Delphi round.

Cultivation stage	Transport and Storage stage	Processing stage
Relative humidity/rainfall (air and soil)	Ventilation	Water activity in kernels
Crop rotation	Temperature	National and EU legislation
Temperature	Water activity in kernels	New/improved detection methods for mycotoxins
Water activity in kernels	Relative humidity (product)	Grain quality
Crop variety / Cultivars	Awareness of food safety	Awareness of food safety
Tillage practice	Carry over of contamination	Level of implemented traceability and quality systems
Pesticide/fungicide use	Storage capacity and logistics	Grain quality data
Harvest conditions	National and EU legislation	Number of products passing through national borders without inspection
Conditions for lodging (unbalanced nutrition and weather)	Changes in composition of fungal populations	Blending/mixing practices
Changes in composition of fungal populations	Level of technology used	Level of technology used
Regional infection pressure	Grain quality	Carry over of contamination
Plant health (stress factors)	Level of implemented traceability and quality systems	Knowledge dissemination of mycotoxins
Fertilization levels	New/improved detection methods for mycotoxins	Logistics
Irrigation and drainage	Blending/mixing practices	Ventilation
Awareness of food safety	Transport duration and distance	Influence of science on the production and legislation
Soil preparation	Knowledge dissemination of mycotoxins	Outbreaks of defined species
Changes in disease-resistance figures for cultivars	Number of products passing through national borders without inspection	Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles

Cultivation stage	Transport and Storage stage	Processing stage
Price premiums offered for higher quality	Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles	Price premiums offered for higher quality
Compliance with rules and regulation about food safety awareness by businesses per sector	Characteristics of local supply chain organisation	Index of country of origin and trade volumes
Decontamination of seeds	Influence of science on the production and legislation	Increasing occurrence or unexpected local occurrence of animal diseases without clear diagnosis
Major shifts in the composition of plant diseases from year to year in particular when it concerns wheat diseases or *Fusarium* species/types	Compliance with rules and regulation about food safety awareness by businesses per sector	Increased number of identification requests for diseases on cereals
Outbreaks of defined species		Compliance with rules and regulation about food safety awareness by businesses per sector
New/improved detection methods for mycotoxins		Communication/trust between trade parties
Specific competence of each *Fusarium* strain to synthesize mycotoxins on the field		Foreign control of enterprises
		Grain quality data which may be related to fungal infestations
		Water activity profiles recording during wet processing steps
		Fractions of the cereal grains used for production of the final food or feed products

In the second Delphi round, the list of indicators (Table 1) was further reduced by selecting and ranking the 10 most indicators. The indicators that received a total score of about 30 points of more in the second round were included in the third questionnaire round. This resulted in 12 indicators for each stage of the wheat supply chain (see Tables 2-4).

Table 2   The 12 most important indicators, together with their scores, for identification of emerging mycotoxins, particularly related to Fusarium spp., during wheat cultivation, resulting from the third Delphi round.

Indicator	Total score (N=23)	Median	Average	SD
Relative humidity/rainfall (air and soil)	216	10	9.4	1.0
Crop rotation	154	7	6.7	2.5
Temperature	145	8	6.9	2.5
Tillage practice	125	6	6.0	2.4
Water activity in kernels	118	8	6.9	2.9
Crop variety / cultivars	107	5	5.4	1.8
Harvest conditions	88	4	4.9	2.2
Changes in composition of fungal populations	85	3	4.3	2.8
Pesticide/fungicide use	79	4	4.2	1.9
Plant health (stress factors)	60	3.5	3.8	2.4
Regional infection pressure	60	2	2.9	1.7
Awareness of food safety	28	2	2.5	1.6

Table 3 The 12 most important indicators, together with their scores, for identification of emerging mycotoxins, particularly related to Fusarium spp., during wheat transport and storage, resulting from the third Delphi round.

Indicator	Total score (N=23)	Median	Average	SD
Water activity in kernels	210	10	9.1	1.5
Relative humidity (product)	193	9	8.8	1.0
Ventilation	160	7.5	7.3	2.1
Temperature	154	7.5	7.0	2.0
Storage capacity and logistics	104	4.5	4.7	2.7
Grain quality data	79	4.5	4.4	1.7
Carry over of contamination	76	5	4.5	2.0
Level of implemented traceability and quality systems	69	3.5	3.5	1.8
Blending/mixing practices	66	4	3.9	2.1
Awareness of food safety	62	3.5	3.9	2.3
Level of technology used	52	3	3.5	2.4
National and EU legislation	46	3.5	2.9	1.7

Table 4 The 12 most important indicators, together with their scores, for identification of emerging mycotoxins, particularly related to Fusarium spp., during wheat processing, resulting from the third Delphi round.

Indicator	Total score (N=23)	Median	Average	SD
Grain quality data	180	8	7.8	2.2
Fractions of the cereal grain used for production of the final food or feed products	167	7	7.3	2.1
Water activity in kernels	152	9	8.0	2.7
Level of implemented traceability and quality systems	106	5	5.0	2.1
Carry over of contamination	104	6.5	5.8	2.8
Awareness of food safety	98	5.5	4.9	2.4
Blending practices (of various lots)	97	4	4.6	2.1
New/improved detection methods for mycotoxins	88	4	4.6	2.7
National and EU legislation	84	3	4.4	3.0
Number of products passing through national borders without inspection	75	3	4.2	2.4
Level of technology used	61	3	3.6	3.0
Ventilation	51	6	4.6	3.2

Tables 2-4 also present the results of the third round, being the scoring results for each of the 12 most important indicators (per stage of the wheat chain). Based on the scoring results, including total scores, average and medians for each of the 12 indicators, the indicators were ranked based on their relative importance.
For cultivation, indicators selected include: relative humidity/rainfall, crop rotation, temperature, tillage practice, water activity in the kernels, and crop variety/cultivar. For transport and storage, these include water activity, relative humidity, ventilation, temperature and storage capacity and logistics. For processing, the selected indicators were grain quality data, the fraction of the grain used, water activity in the kernels, level of implemented traceability and quality systems, and carry-over of contamination.
Analysis of the robustness of the results showed only slight differences in the mean, and no differences in the total scores. The ranking of the indicators on relative importance was not influenced.

Table 5 presents a summary of the indicator selection during the three rounds of the Delphi expert study. As can be seen the number of indicators was reduced from over 100 indicators to 36 most important indicators for identification of emerging mycotoxins in the wheat based supply chain.

Table 5 Number of indicators in the Delphi elicitation

	Stage of wheat based supply chain		
	Cultivation	Transport & storage	Processing
First round	41	26	34
Dropped	18	5	9
Added	1	0	2
Second round (new)	24	21	27
Dropped	13	9	17
Added	1	0	2
Third round	12	12	12
Final selection	12	12	12

During the Delphi rounds, some experts indicated that it was difficult to rank 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 (Tables 2-4) were identified per stage of the chain. This was done by means of individual in-depth interviews with several additional experts (not participating in the Delphi study). 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 were identified between the following four indicators: water activity in the kernels, temperature, relative humidity, and ventilation. Also, dependency may exist between grain quality, blending practices, and levels of implemented traceability and 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 traceability and quality systems may have interrelationships with each other.

2.3 Applicability of the protocol

The protocol defined - as based on the Delphi method - showed to be useful for retrieving expert judgement to select indicators for ER identification and to evaluate 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 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 ER 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 chain. These indicators for emerging mycotoxins showed to be comparable too a large extent to factors related to the occurrence of known mycotoxins (e.g., see 2006/583/EC), especially with regard to the cultivation stage. Potential interrelationships between the indicators were also identified. These interrelationships should be discussed and defined in more detail in future research. The most important indicators, together with their interrelationships, could be used in an identification system for emerging mycotoxins.

The protocol for the Delphi elicitation technique showed to be useful for the selection of the most important indicators for ER identification. In addition, as a result of this Delphi study, a European wide network of mycotoxin experts was established. As such, the current method to select indicators could also be applied to other ER cases. As a next step, information sources on the most important indicators need to be identified. This is further elaborated upon in Chapter 3.

3 Technical information sources

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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. The selected 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 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 such a European platform of information sources, it is essential to make regional and national systems compatible in such a way that quality is guaranteed, information is accessible, and can be shared.
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 plus the knowledge from 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:

1) making various types of information compatible and useful at the European scale, and link them into a sustainable platform of information sources;
2) 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 in the early identification of emerging hazards and, as such, enhances the quality of the risk management process.

Section 3.2 provides aspects considered in the characterisation of information sources. Next, information sources on the indicators for identification of emerging mycotoxins are presented, together

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with their evaluation. The information sources are arranged according to the indicators per stage of the wheat based supply chain (as identified in Chapter 2).
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. It should be stressed that the lists of information sources is as extensive as possibly, but not fully all-embracing. Also, as part of identifying information sources, a national network on (emerging) mycotoxins has been built in Iceland (see Annex VII).

3.2 Characterisation of information sources

The basic challenge of an ER identification system is to find, combine and filter information in an optimal way. The selection of indicators (see 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 provides the model toolbox as addressed in Chapter 4;
- 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 for 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 organisations, processing industries, and food safety authorities. In addition, library and web-searches were applied. The information available could be from:

- farmers / farm management systems
- farmer associations
- wheat collectors / traders
- wheat processing industries
- governmental organisations
- research organisations
- scientific literature
- quality test laboratories
- mycotoxin expert groups

In practice, the quality of available information can be extremely variable, ranging from rumours 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 of the information sources identified is given. Information sources are presented per indicator and per stage of the chain. The majority of the indicators selected in Chapter 2 were 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 that are 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/; 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 organisations. Awareness of food safety among farmers is hard to measure and no indirect information source is available yet.

3.3.1.2 Transport and storage

In the transport and storage 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, which 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

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 mycotoxin contamination is not allowed, but blending for other purposes is a common procedure in many processing industries. Quality systems currently used in industry require secure information management. Data is often stored in databases but generally not externally accessible.

3.3.2 Mycotoxin networks

This section presents three research networks and organisations, 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 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 EC/178/2002 ("General Food Law"), RASFF is hosted by EFSA. The European Commission publishes weekly RASFF overviews of 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 *et al*., 2008). 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

3.4.1 General information for farmers

Table 6

Information Source	Website	Comments
	Sweden	
Jordbruksaktuellt (News for the farming business).	www.ja.se	Agribusiness online news
	The Netherlands	
AgriHolland	www.agriholland.nl	Agribusiness online news
Agrarisch Dagblad	http://www.agd.nl/	
	Portugal	
	Not found	
	United Kingdom	
Crop Monitor CSL	cropmonitor.csl.gov.uk/wwheat/wheat-intro.cfm	Farmers/traders online news

3.4.2 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 climate maps. For region-oriented ER modeling European maps/data sources may be useful when national databases are inaccessible or incomplete. In Europe, national meteorological databases are more and more linked and stored in a fixed format.

Table 7

Information Source	Website	Comments
Europe		
Mars project Joint Research Centre (JRC) in Italy	agrifish.jrc.it/marsfood/ecmwf.htm	Climatic and weather maps interpolated from weather stations
European Centre for medium-range weather forecast	www.ecmwf.int/	
Sweden		
Jordbruksaktuellt (news for the farming business).	www.ja.se/smhi/vader.asp	Online weather forecast for agriculture (no past weather data)
Lantmet	www.dacom.nl/lantmet_new/index www.ffe.slu.se	Agric. weather station network
Jordbruksverket (Swedish Board of Agriculture)	www.sjv.se	
Swedish Meteorological and Hydrological Institute	www.smhi.se	Official Swedish weather site
The Netherlands		
KNMI	www.knmi.nl	Hourly temperatures, rainfall and humidity per region
Meteo consult	www.weer.nl	Hourly temperatures, rainfall and humidity per region
Portugal		
SNIRH- Sistema Nacional de Recursos Hídricos	http://snirh.inag.pt/	Current and historical precipiation and temperatures
Instituto Nacional de Meteorologia	http://www.meteo.pt	Hourly temperatures
CGE- Centro de Geofísica de Évora	http://www.cge.uevora.pt	Daily temperatures and relative humidity EVORA area southern Portugal

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 rotation schemes in different regions may be roughly estimated.

Table 8

Information Source	Website	Comments
Sweden		
Jordbruksverket (Swedish Board of Agriculture)	www.sjv.se	Crop areas/region, statistics
The Netherlands		
Kennis op de Akker	www.kennisopdeakker.nl/NL/gewassen/graan/	Farm based ICT infrastructure
Farm Registration System LEI / CBS	http://statline.cbs.nl/statweb/	Retrospective figures on crop area / region
Portugal		
Instituto Geográfico Português	http://www.igeo.pt/	Statistics

3.4.4 *Tillage*

Most data per field on deep/minimum or non tillage are only available from farmers' own registration systems. When farmers get permanent relations with traders and processors or with online registration systems, tillage practices could be derived from the central databases, if accessible (but data are usually protected). 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* spp. under favourable conditions. In most European countries cultivars are tested for resistance against *Fusarium* fungi. Cultivars are classified for their resistance, often expressed in some kind of resistance-figure (e.g., low, medium, or highly resistant). Although farmers register the cultivars grown and seed supplying companies register the cultivars sold, public data for cultivar use per region was not found.

Table 9

Information Source	Website	Comments
	Sweden	
Lantmännen	www.lantmannen.se	Not public
	The Netherlands	
Agrifirm	www.agrifirm.nl	Not public
	Portugal	
DGADR - Direcção Geral de Agricultura e do Desenvolvimento Rural		Not public

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 10

Information Source	Website	Comments
	Sweden	
Lantmännen	www.lantmannen.se	Not public, data on water content
Svenska Foder	www.svenskafoder.se	Not public, data on water content
	The Netherlands	
Agrifirm	www.agrifirm.nl	Not public
Cefetra	www2.cefetra.com	Not public
	Portugal	
DGADR - Direcção Geral de Agricultura e do Desenvolvimento Rural		Not public

3.4.7 *3.4.7 Plant health in general*

Table 11

Information Source	Website	Comments
Sweden		
Kemikaliinspektionen jordbruksverket	www.kemi.se www.sjv.se	Pesticides surveys
The Netherlands		
Productschap akkerbouw	http://www.productschapakkerbouw.nl/	Surveys, not public, but accessible within research projects
Portugal		
ISA- Instituto Superior de Agronomia	www.isa.utl.pt	Surveys, not public, but accessible within research projects

3.4.8 *Water activity in kernels*

Table 12

Information Source	Website	Comments
Sweden		
Lantmännen Svenska Foder	www.lantmannen.se www.svensakfoder.se	Not public
The Netherlands		
Cereal Traders / processors Agrifirm, Cefetra, Rijnvallei, and others.	www.agrifirm.nl www2.cefetra.com	Data often stored in databases per incoming batch (from the harvested product) and silo. Not public
Portugal		
Food and Feed business operators records, ACICO, ANPOC		

3.4.9 *Pesticide and fungicide use*

Table 13

Information Source	Website	Comments
Sweden		
Kemikalieinspektionen	www.kemi.se	
The Netherlands		
Kennis op de Akker	www.kennisopdeakker.nl/NL/gewassen/graan/	Farm based ICT infrastructure
Farm Registration System LEI / CBS	http://statline.cbs.nl/statweb/	Retrospective figures on pesticide use / crop
Portugal		
Estação Agronómica Nacional	http://www.iniap.min-agricultura.pt/	Yearly data for use / crop

3.4.10 Fusarium species composition

Changes in the occurrence of the different *Fusarium* species can affect the mycotoxin spectrum. Continuous monitoring of the *Fusarium* species is - to our knowlegde - 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 organisations can be relevant for trends (which are likely to be slow over years).

Table 14

Information Source	Website	Comments
Sweden		
Swedish University of Agricultural Sciences Swedish Farmers' Foundation for Agricultural Research	www.slu.se www.lantbruksforskning.se	
Netherlands		
Wageningen University and Research Centre	www.wur.nl	Experts are C. Waalwijk and J. Köhl (PRI)
Portugal		
ISA- Instituto Superior de Agronomia	www.isa.utl.pt	Surveys, not public, but accessible within research projects

3.4.11 Regional infection pressure

Fusarium spp. related 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 organisations 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 organisations. Intensive contacts between buyers and suppliers, and rumours 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. Certification of the 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 the cereal quality characteristics and take samples to analyse the kernel moisture and protein content, and often also for mycotoxins. They take care of the way batches are stored in silos, 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 the industry. However, even when under control it can be an important indicator for identification of (emerging) mycotoxins.

Table 15

Information Source	Website	Comments
Sweden		
Lantmännen	www.lantmannen.se	Measured when stored and when silos are opened for further processing.
The Netherlands		
Agrifirm (trade, processing)	www.agrifirm.nl	
Cefetra (trade)	www2.cefetra.com/	
TRUSQ	http://www.trusq.nl/	

3.5.2 *Silo conditions*

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

Table 16

Information Source	Website	Comments
Sweden		
Lantmännen	www.lantmannen.se	Drying should be sufficient before storage. Over 70% of the silos have temperature control.
The Netherlands		
Food and feed cereal commodity traders*		Not public
Portugal		
Food and Feed business operators records, ACICO**, ANPOC***		Not accessible

** Agrifirm, Cefetra, Rijnvallei, Nutreco and others.*

***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 Association)*

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.

Table 17

Information Source	Website	Comments
Sweden		
Lantmannen	www.lantmannen.se	Ergosterol, registered as a mould risk indicator in each batch
Netherlands		
Various parameters are registered including data on toxins.		
Agrifirm (trade, processing)	www.agrifirm.nl	Registered per batch/ silo

Information Source	Website	Comments
Cefetra (trade)	www2.cefetra.com/	Registered per batch/ silo
TRUSQ	http://www.trusq.nl/	Registered per batch/ silo
Nutreco	http://www.nutreco.nl/	Registered per batch/ silo

3.5.4 Blending

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 public 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 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). Out-growth of *Fusarium* fungi during storage at the processor's plant or during processing itself is not likely to occur. However, 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 project. Risk of *Fusarium* spp. related 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 influence the grain quality in general.

Table 18

Information Source	Website	Comments
Sweden		
Lantmännen	www.lantmannen.se	Ergosterol is measured as a general indicator
The Netherlands		
Portugal		

3.6.2 Fractions of cereals used

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

Table 19

Information Source	Website	Comments
Sweden		
Lantmännen	www.lantmannen.se	Recipes
The Netherlands		

Information Source	Website	Comments
Meneba	http://www.meneba.nl/	Melanges/ blends/ recipes / waste
Nutreco	http://www.nutreco.nl/	Feed industry, not accessible
Portugal		
IACA - Associação Nacional dos Fabricantes de Alimentos Compostos para Animais	http://www.iaca.pt/	Feed industry, accessible data on year basis
FIPA - Federação Indústrias Portuguesas AgroAlimentares		

3.7 Conclusions and recommendations

Many (potential) information sources on indicators, from three European countries and at the European level, were identified in this research project. However, accessibility of data and lack of particular data seem to be the major bottlenecks for the use of all these information sources for the identification of emerging mycotoxins. For using the full potential of information, data from farmers, trade organisations and processors should be related to the key-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. Besides weather related data, information on indicators related to agronomical practices (such as crop variety, spraying, crop rotation and tillage practice) could become more easily retrievable from the 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 work at a larger scale (on the national level or the European level), close collaboration between authorities, research companies, industry and farmers is needed. To achieve this, 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.

From the experiences gained in the identification of information sources on the key-indicators, some specific recommendations can be made. These are given below.

Recommendations to make the various types of information sources compatible and useful at the European scale, with the aim to link them into a platform of information sources:

1) Discuss similarities and differences of national information sources on the indicators between the different European countries.
2) 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 national data from various European countries. This then will result in a signal on the expected occurrence of

(emerging) mycotoxins for the specific regions/countries. In a later stage, possibilities need to be evaluated for scaling up the information on the indicators to the European level.

3) 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 could be in the form of a web-based application that is directly linked to the national databases. The set of key-indicators could be used as a starting point for setting up databases on which regional systems can be developed.

Recommendations to create a sustainable platform of information sources to supply a functional ER identification system with the necessary data:

1) Communication with all actors in the wheat based supply chain is very important, as well as incentives for all actors of the wheat chain to supply the system with the necessary information. Especially, incentives for the industry should be clearly defined and taken utmost care of. So, put effort in getting information from economic actors in the chain as they (potentially) can supply essential information.
2) An information system to collect and store data from all stages and actors in the chain could start from tracking and tracing systems (running or under development). Aspects that should certainly be addressed in organizing data exchange are competition, legislation and liability.
3) Start at the national level in several European countries with developing the necessary information structure, organisation, actor involvement, communication etc. In a later stage, a central European database can be built by linkage to the national information systems.

These two recommendations are generic in the sense they will - too a large extent - also apply for initiating a sustainable network of key-information sources for other types of mycotoxin related ER and/or production chains.

4 Information model

By C.J.H. Booij and H.J. van der Fels-Klerx

4.1 Introduction

In Chapter 2 the most important indicators for identification of emerging mycotoxins have been selected. In Chapter 3, potential information sources on these indicators have been identified for various European countries as well as on the European level. The information sources showed to be very diverse with regard to availability, level of detail, completeness, certainty and maybe also relevance for ER identification. The aim of the research described in this Chapter, therefore, is to develop a framework or conceptual model that uses the various indicators and can handle the various kinds of information at different levels of detail.

The specific objectives addressed in this Chapter are:

1) to propose a generic information model that is based upon the key-indicators for identification of emerging mycotoxins. As the indicators have different characteristics, the model should be able to deal with, amongst others, different types of information sources and levels of information available. The model will be based upon experiences from previous studies, including Van Wagenberg *et al.* (2003), Dekkers *et al*. (2008) and Franz *et al.* (submitted). More specifically, the model should be able to handle:
    a) qualitative and quantitative information;
    b) technical data and expert knowledge;
    c) different levels of detail of information, e.g., with regard to space and time;
    d) uncertainty and missing information;
2) to match emerging mycotoxin modelling (as part of ER identification) with current practices, starting with the generic model developed.
3) to propose recommendations related to modelling emerging mycotoxins.

4.2 A generic information model

In this section, a theoretically-based, generic model for identification of emerging mycotoxins in wheat based supply chains is proposed. The model aims at gaining quantitative insight into the occurrence of emerging mycotoxins in a (particular) unit of wheat. Given the variety in the nature of the selected indicators (Chapter 2) and in the level of detail of information available (Chapter 3), the model especially focused on taking into account these characteristics of indicators. The applicability of the generic model depends on:

1) knowing the impact of each indicator on the model outcome;
2) knowing interactions among different indicators (additive, multiplicative etc) and their impacts;
3) the availability of information on selected indicators at the appropriate scale in time and space.

Part of this section has been described previously in Van der Fels-Klerx *et al.* (2008).

4.2.1 Impact of indicators

The selected indicators vary in their type and range of values they can take (Chapter 2). 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.

4.2.2 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 (Equation 1):

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

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 $l = 1, 2, \ldots, l$; and with *l* being the most detailed level applicable)
- *m*: level of detail of information available on time of the unit (with $m = 1, 2, \ldots, m$; and with *m* being the most detailed level applicable)
- *s*: stage of the wheat based supply chain (with $s = 1, 2, \ldots, s$; and with *s* being the total number of stages in the supply chain; e.g., 1= cultivation; 2= transport, 3=storage, 4=processing)
- $x_{s,n}$: level of indicator *n* (with *n* – in this case - being 1 or 2) in stage *s*
- $\alpha_{l,m,s}$, $\beta_{l,m,s}$, $c_{l,m,s}$: 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 *l* and *m*, respectively
- $E_{l,m,s}$: error variable for the estimated occurrence of emerging mycotoxins

Equation 1 illustrates the relationship for two indicators (*n*=2). When more indicators are used in an ER identification system all relevant indicators and interaction terms should be taken into account.

4.2.3 *Supply chain characteristics*

As the selected indicators could vary between the different stages of the chain they are - either directly or indirectly - linked to, 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 (Equation 2):

$$Y_s = f(Y_s, Y_{s-1}, ..., Y_{\text{s-S+1}}) \tag{2}$$

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,…, S; and with S being the total number of stages of the supply chain)

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 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.

4.2.4 *Handling the level of detail*

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.
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 Table 20, with examples of levels for location (l) and time (m) for a batch of wheat in the cultivation stage (s=1).

Table 20 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).

		Level of detail time (m) →				
	Stage of chain (s)	1) Not known	2) Year	3) Month	4)Week	5) Day
↓ Level of detail location (l)	1) Not known	…	…	…	…	…
	2) Continent	…	…	…	…	…
	3) Country	…	…	…	…	…
	4) Region	…	…	…	…	…
	5) Town	…	$\alpha_{5,2,1}$	…	…	…
	6) Farm	…	…	…	...	$\alpha_{l,m,s}$

Where:

$\alpha_{l,m,s}$: *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.*

as an example, $\alpha_{5,2,1}$: *predicted value for a given indicator in the model for the cultivation stage with information on the unit of wheat being available at the town level (location being at level 5) at the yearly basis (time being at level 2).*

Derived from Van Wagenberg et al. (2003)

From Table 20 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 Table 20, 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 detail of the available information as well as its quality (preciseness of the information) are major constraints for the predictive power of the model described above. 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 on the indicator it selves. 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 only region is known for a batch, 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 generalized, i.e., that regression coefficients (or simply the impacts) also hold for other situations in time and space. For instance, rainy days around flowering have the same impact on mycotoxin risks, irrespective of the country or year.

4.2.5 Handling uncertainty

As compared to weather and agronomical practices, 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) (Ghosh *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 modelled 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. So for the moment the theoretical model can only serve as a basic concept from which simplified systems can be derived and tested applying simplifications (see 4.3).

Initiatives to 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 such a system monitors the majority of the indicators this would allow predictive modeling of emerging mycotoxins much more feasible and precise.

4.3 Matching modelling with current practices

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

1) Experts generally agree on the most important indicators for the occurrence of known mycotoxins and assume that these indicators to a large extent are also valid for emerging (unknown) mycotoxins.
2) Experts and early warning models rank or use parameters related to weather and agronomical practices (wheat variety, crop rotation and tillage) in the cultivation stage as the main indicators for the occurrence of known mycotoxins, explaining up to 90% of the occurrence.
3) Apart from weather data, very little information is available on line and up-to-date.
4) Depending on the chain organisation, most detailed information is available in the trade and cereal collectors industry as part of their purchasing strategy, quality control and channelling of commodities.
5) Nowadays, DON and other mycotoxins are more and more often measured at critical control points in the supply chain such to avoid losses.
6) Regarding the heavy data dependency of the generic information model described (in section 4.2) it is unlikely that, in the short turn, such a model can be fully parameterized and implemented and fed with sufficient information/data.
7) For new emerging mycotoxins quantification is per definition problematic as any direct quantitative information is lacking.

To our opinion a more flexible and qualitative modelling approach could be useful in the sort term. Such an approach should be based to a lesser extent on detailed and quantitative predictions but on more qualitative estimations, use of (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 approach proposed - as described in paragraph 4.2 - is useful in many cases. The following example may illustrate a typical case of uncertainty and information need.
Due to scarcity of high quality cereals among the 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 does not have a network of contacts that might give additional information. The supplier says the quality of the batch is good. However, only one mycotoxin measurement has been taken from one part of the batch, originating from one out of 20 different fields. No further detailed information is available for the specific batch. But, 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/her risk perception upon:

- Was the growing season 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 a delay of harvest?
- What are the most common varieties in the region and did they flower in critical periods?
- Are the most common varieties susceptible for *Fusarium* spp.?
- 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 probability of the occurrence of (emerging) mycotoxins, 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 still can be applied albeit there is much uncertainty and lack of information.

The first estimation 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 probability. When the flowering period is not known precisely and varieties are unknown the model may only generate a chance that mycotoxin formation is at a high level. If this chance is negligible there seems to be 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 estimated occurrence and thus 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, basic estimations could be done on validated accurate forecasts for DON, based on weather data, which should be as local as possible. Next, further modelling should include 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 from the ones that are ranked highest taking into account how the information for those indicators could become 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 ER identification models.

4.4 Model application

The modelling concept and approaches presented form the basic concept of linking indicators, for various stages of the chain, to estimate the occurrence of emerging mycotoxins in the wheat based supply chain. Although the conceptual model is developed for the case of emerging mycotoxins, it should be realized that the indicators - selected from different expert meetings, interviews and literature and starting from a wide holistic approach - as discussed in Chapter 2- are not essentially different from those selected for known mycotoxins. Our idea is that the way of modelling is not principally different between known and emerging hazards. Indicator selection and impact estimation are the basis for a generic concept of an ER identification system for the occurrence of any other type of emerging hazard as well. 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 mycotoxin measurements or inspections may lead to hazards that are hard to predict. But … not everything can be under control.

4.5 Recommendations on modelling emerging mycotoxins

The major constraints with estimating emerging mycotoxins is that ER identification models can probably only be derived from models for known 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 predictive models for known mycotoxins are the principle starting point, they should be as good as possible and should be able to include factors that are recognized as potentially relevant by experts. So, the impact of critical factors should be estimated for a number of scenarios (even though considered to be of minor importance for known mycotoxins). Hence, improving existing models for known mycotoxins in wheat, such as for DON (e.g., Hooker *et al*., 2002; Franz *et al.*, submitted), can help to develop models for other (emerging) toxins. Setting up a model for a toxin such as T2 may help to identify similarities and differences with respect to the set of indicators and unforeseen factors. In both cases, scenarios should be evaluated with varying availability and detail of information 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 is useful to analyze co-occurrence of different toxins. This will put some light on the assumption that indicators for one toxin can be extrapolated to other toxins. Bayesian methods could be used to evaluate the levels of uncertainty that are acceptable for decision support.

User involvement from industry and food safety authorities is crucial to test practical relevance and to translate user experiences into modelling 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 (see Chapter 5). 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 modelling, the organisation of data in the supply chain and aggregation of information at a higher (regional) scale is needed. The combination of weather data and (average) farmers' agronomical field data (e.g., on crops, varieties, crop rotation and tillage) forms the basis for any predictive model for mycotoxin occurrence. Overlays of GIS maps with indicator values in combination with the 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 leading issues for future modelling approaches.

5 Stakeholders' needs

By M. Dreyer, S. Brynestad, E. Morrison and H.J. van der Fels-Klerx

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 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 ER 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 ER 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 ER 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 ER 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 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 (emerging) *Fusarium* spp. 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 ER 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 III 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 ER 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. See Annex IV for a description of the two scenarios. The discussion in each subgroup was led by one member of the MYCONET project team, two other members took notes. The scenarios referred to situations in which conditions potentially affecting the presence of (emerging) *Fusarium*-toxins in wheat had been changed. During the discussion, experts were asked - for each of the two envisioned situations (see Annex IV) - to bring forward:

- their specific information needs;
- the relevance they would attach to information provided by an ER identification system;
- own resources that could be fed into an ER identification 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 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 early warning system for mycotoxins. Six of the interviews were conducted face-to-face, seven over the telephone (see Annex V for a list of the institutions and persons that were interviewed). Prior to the series of interviews, a structured questionnaire was developed (see Annex VI). The questionnaire was aimed at gathering information related to four major aspects referring to the viability and application requirements of the envisioned identification system for emerging mycotoxins. 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 identification of possible hazards plays in terms of provisions, plans and/or considerations in current practice;
2) interest of the interviewed organisation in the envisioned ER 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 for managing emerging mycotoxins

The area of *Fusarium* spp. mycotoxins 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 (EC/1881/2006). Testing in the feed industry is often performed to ensure compliance with guidance values and maximum limits for *Fusarium* spp. toxins in products intended for animal feeding as set out in the Recommendation of the European Commission (EC/576/2006). 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)[3]
- 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 ER identification system (see Chapter 2) to visual inspection and testing of delivered harvest for questionable quality. Compared with the situation in Germany, the major indicators - as identified in Chapter 2 - 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 Interest in an identification system for emerging mycotoxins

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* spp. 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.

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[3] 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 Agrarwerblichen 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.

An ER identification system was seen as a positive step towards addressing the challenges faced by authorities and industry around (emerging) 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), re-emerging *Fusarium* spp. related mycotoxins, and new *Fusarium* spp. related mycotoxins (the latter two being the focus of the MYCONET research). Explicitly or implicitly, their statements indicated that a system exclusively related to newly emerging mycotoxins was considered overly specific. The stakeholders from Scandinavia in particular, did not distinguish between *Fusarium* spp. 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* spp. related mycotoxins.

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 practical application

The value of an early identification system for (emerging) 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 and format

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* spp. mycotoxin related 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 of low costs.
All stakeholders stressed the reliability of the information provided by the (emerging) 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 anonymous 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 5.5.2).

It was clear to all stakeholders that the current project used emerging mycotoxins, especially related to *Fusarium* spp., in wheat, as a case study. Nonetheless, 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 etc.) 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 ER identification system 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 Information on indicators

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* spp. and related 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 ER 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 mycotoxins 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 ER in use.

5.5.3 Major challenges of implementation

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 gather 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 anonymous 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 favourable 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 ER identification 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 ER 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 silo. 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 ER identification system can be utilised optimally. The development of traceability systems in grain production may even be enhanced by implementing such a 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 ER identification system and output represented should be tailored to specific needs of various stakeholder groups (e.g., 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 empirical research described 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 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 improve risk management, control and monitoring and, ultimately, reduce health risks for the consumers.

The national public authorities that were interviewed consider ER 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 ER identification system - as envisioned by MYCONET - could help to tailor their monitoring and inspection activities. Accordingly, they also generally appreciate that EFSA is involved in the setting up of a pan-European system for the identification and evaluation of emerging risks (EC/178/2002). At the same time they acknowledge that this is an undertaking which is still in its very early stages (EFSA, 2006). What they consider as a basic requirement for the future implementation of ER 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. Most of them appreciated the envisioned ER identification system as a additional component of their quality management systems, which currently focus on well-known mycotoxins only. They expressed openness towards retrieving and accounting for information on (re-)emerging mycotoxins. 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. Some other persons were sceptical. Some of those economic actors who expressed reservations regarded the output of the proposed information system as too uncertain to be useful for being integrated into current quality management. 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 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 ER identification 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 from authorities and industry. A field mapping of Europe by use of a traffic light model is an information format that promises to meet the 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 for the key-indicators. 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 from as well. The one integrated national system that is in place showed that considerable effort, time and development of effective communication channels and meeting places is needed to prove to the various stakeholders that this type of system benefits all participants. The empirical insights gained indicate that there is a lack of incentives for at least part of the economic actors to contribute to the system. These actors doubt whether 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 the 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 identification of emerging mycotoxins.

3) Another major challenge of implementation 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 anonymous and aggregated manner only was adopted, this might increase the probability that a lot of information interpretable as signals for ER identification 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 (Wiedemann *et al*., 2002). This should be acknowledged and made transparent by those maintaining and operating the envisioned ER identification 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 ER identification system will be to assure that there are incentives for economic actors in the chain - particularly for farmers but also for trade and transport companies and the processing industry - to supply the system with information on the key-indicators for identification of emerging mycotoxins. 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;
- the operators of the envisioned system communicate to all information sources, potential users and possible observers about the uncertainty involved;
- 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 ER identification 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 outstanding example of a successfully established national early warning system for mycotoxins involving all major stakeholders could provide important insights in this respect. 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 ER identification system work.

6 Conclusions

The research described in this report addresses the basic elements in the development of a system to identify emerging mycotoxin hazards, particularly produced by *Fusarium* spp., in European wheat based feed and food supply chains.
In order to match such a system with the needs of stakeholders and other end users (risk managers), their needs were thoroughly investigated. Furthermore, as part in developing an ER identification system for emerging mycotoxins, the most important indicators were identified, together with a semi-quantitative evaluation of their relative importance. Next, information sources on these key-indicators were evaluated in several European countries and at the European level. Also, a conceptual information model to link the various indicators and information sources has been developed. With its results, the MYCONET project, presented in this report, builds on the foundations on ER identification, as laid down before (Mengelers, 2005; Noteborn & Ooms, 2005; Noteborn, 2006). It provides a step forwards to the development of a functional system for identification of emerging mycotoxins in the wheat based supply chain (a.o., by Park and Bos, 2007; Dekkers *et al*., 2008; Van der Fels-Klerx *et al*., 2008). Although this project has generated the basic steps in the development of such a system, it also identified the problems and challenges for its actual realization. Recommendations for the next steps have been given.
The research described in this report focused on emerging mycotoxins, but its principles holds for other emerging hazards as well. In the development of an ER identification system for any other hazard, the main indicators and key-information sources should also be identified, according to the specific needs of various groups of stakeholders. Hence, the approaches and the conceptual model developed could be applied to any other hazard. As such, this research project also provides generic concepts for ER identification systems for the other types of emerging hazards.

The main conclusions and general recommendations from the project are:
1) The most important indicators for identification of emerging mycotoxins in the wheat based supply chain mainly refer to the cultivation stage, and are judged to be quite similar to indicators for known mycotoxins. However, apart from weather and agronomical practices, particularly indicators more indirectly related to the feed and food chain should be investigated more in-depth for their additional value in identifying emerging mycotoxins. Also, interactions between indicators should be studied in more detail.
2) In various European countries, data and systems on mycotoxins are currently used for research and/or risk management. From the current project, it is known that, in at least several European countries, a system for the prediction of specified known mycotoxins is running or under development. The current available systems for known mycotoxins, including these predictive systems but also systems for early warning and/or trend analysis, should be evaluated for their potential to be used as a basis for designing a system at the larger (European) scale. Also, they should be evaluated for the ability to also handle indicators from other influential sectors, such to address emerging toxins, as well as expert knowledge and different levels of uncertainty.
3) Put effort in getting information from economic actors in the chain as they (potentially) can supply essential information to make such a ER identification system for mycotoxins working.
4) Incentives for all actors, in particular those from industry, should be defined and taken utmost care of such to ensure the ER identification system will be supplied with the necessary data.

5) All actors in the chain and other stakeholders should be involved at a very early stage in developing a functional ER identification system.
6) Long term funding for a dedicated project team to develop and run an ER identification system is essential. This team should involve experts on mycotoxins, computer experts and a central person (responsible) for communication with all stakeholders.
7) An information system to collect and store data from all stages and actors in the chain could start from current systems (e.g., tracking and tracing, quality management). Aspects that should certainly be addressed in organizing data exchange are competition, legislation and liability. It is important to look for win-win situations for the economic actors involved (see 4).
8) Start at the national level in several European countries with developing the necessary information structure, ER identification system, organisation, actor involvement, communication, etc. At the national level, one project team should be responsible for organisation and communication. Project teams from the various countries should establish a network to collaborate and regularly exchange their experiences. Starting from the national levels, the system can be extended to the European level, and more and more countries can be hooked on;
9) Whether or not an European identification system for emerging mycotoxins can be based on one underlying predictive model, possibly with different parameter values per country or regions, or on one model per country can not be foreseen at this moment. This should be evaluated by the experiences gained by the national project teams. However, still the system can be built on the European level with different underlying models on the country basis;
10) Clearly, long-term commitment from all stakeholders and actors in the chain as well as financial contribution is essential for the set up of ER identification system. This accounts to both the national and European level

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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 2) 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.

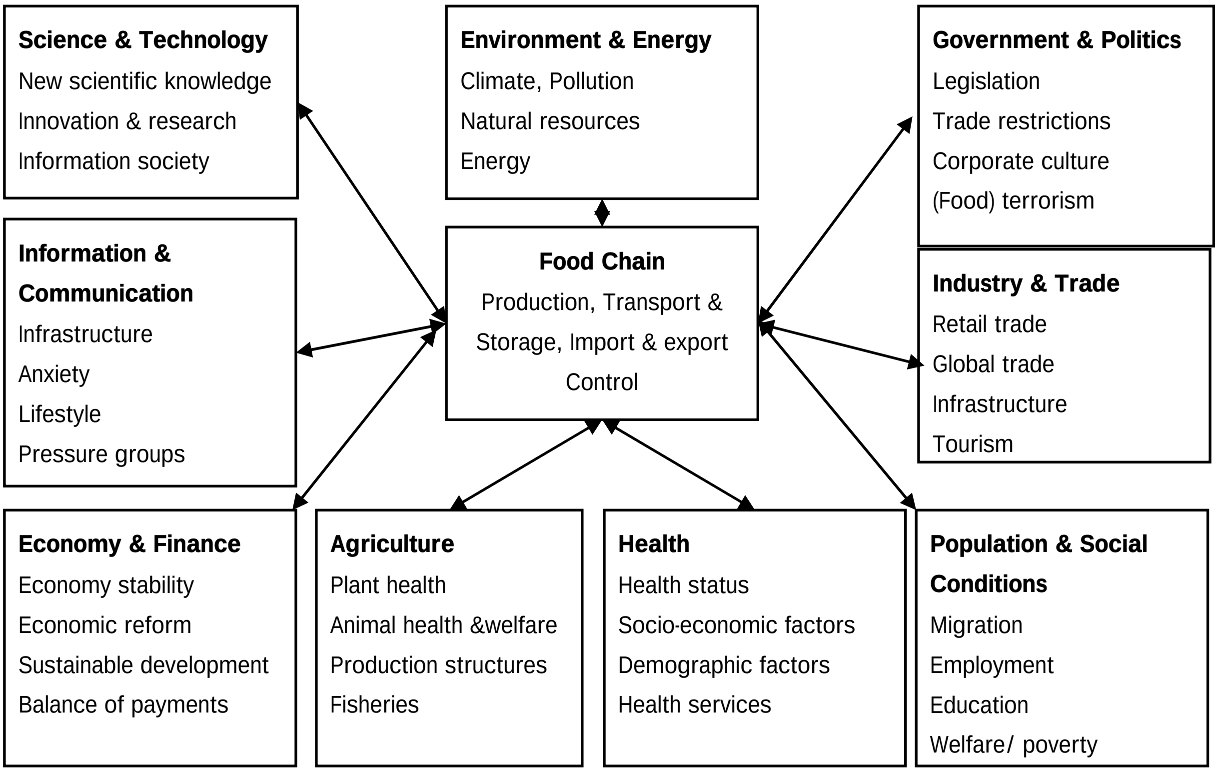

Figure 2 Holistic approach for identification of emerging risks in the feed or food supply chain (derived from Noteborn & Ooms, 2005).

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 3.

Influential sector → Critical factor → Indicator

Figure 3 Derivation of indicators in the holistic approach (derived from Noteborn & Ooms, 2005)

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 & Ooms, 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 it selves.

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 & Ooms (2005) and/or Noteborn (2006).

Annex II Gross-list of indicators

This annex presents the gross-list of indicators for identification of emerging mycotoxins in wheat based supply chains. The indicators are presented, together with their definition and/or reason, for each relevant stage of the chain, i.e., cultivation (Table 21), transport and storage (Table 22), and processing (Table 23). This gross-list of indicators was used as the starting point for the Delphi elicitation procedure, as described in Chapter 2.

Table 21 Indicators for identification of emerging mycotoxins during wheat cultivation

Indicator	Description/reason for indicator
Temperature	The mean of the temperatures recorded during the various stages of growth. Measures of extremes are important due to their maximum biological impact.
Relative humidity/rainfall (air and soil)	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 >80%
Water activity in kernels	Water content >0.15 is necessary for mycotoxin production.
Crop rotation	The crop that is grown on the field previously and/or previous year(s). Growing maize before wheat or wheat before wheat increases the possibility of the occurrence of mycotoxins.
Crop variety / Cultivars	The resistance levels of the cereal crops grown against *Fusarium* spp.
Pesticide/fungicide use	The type and amount of used fungicide/pesticide could influence the formation of mycotoxins
Spraying technology	The type of spraying technology used could influence the lodging of wheat
Decontamination of seeds	Inactivation of harmful and pathogenic micro organisms on seeds

Indicator	Description/reason for indicator
Weed management	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
Sowing density	The number of plants per m2 influences crop growth, microclimate and spread of diseases
Use of growth inhibitors	Using growth inhibitors will increase mycotoxins formation
Conditions for lodging	Lodging of the wheat ear due to unbalanced nutrition and weather could increase the formation of mycotoxins
Fertilization levels	Too much nitrogen could increase the risk for mycotoxin production
Major changes in cultivar choice over wide areas	Changes in crop planting patterns, large scale production of certain crops over time
Regional infection pressure	The occurrence of *Fusarium* spp. may depend on regional differences in climate and agricultural practices.
Tillage practice	*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.
Yield (per ha)	The requirements for the yield. E.g., Low yield could be an indication for infection.
Irrigation and drainage	The amount of water in the field could influence the water activity of the soil. High water activity will increase mycotoxin formation.
Plant health (stress factors)	Due to stress factors plant health could decrease and the plants are more susceptible for *Fusarium* infection.
Major shifts in the composition of plant diseases from year to year in particular when it concerns wheat diseases or *Fusarium* species/types	Assessing the conservation status of species, changes to assessing changes in genetic diversity, identification of potential trends in genetic diversity.
Harvest conditions	delay, duration and weather conditions, labour shortage.

Indicator	Description/reason for indicator
Soil preparation	Bare soil or lacks of adequate vegetation could affect the pH and the nutrient availability of the plant and therefore influence the fungal growth
Percentage of land covered by energy crops	Energy crops may change land use patterns, shifts in (quality) of crops, prices etc.
Level of technology used	Trends in technological developments per country.
Awareness of food safety	Understanding of food safety could decrease the production of mycotoxins.
Knowledge dissemination of mycotoxins	Due to improved electronic media scientists all over the world could share research results/knowledge.
Increased number of identification requests for diseases on cereals	When laboratories receive more requests for mycotoxins/fungi analysis it could be an indicator that there are changes in the production chain.
Level of implemented traceability and quality systems	Level of documented traceability systems and the implementation of e.g., HACCP.
Certified crop management	Certified production may increase quality / marketability of crops, but also cropping systems (nutrients, pesticides).
Carry over of contamination	Spores which are still in the batch or storage container could sporulate when the temperature and relative humidity are favourable. Also existing fungi could produce toxins and mycotoxins could be left..
International trade agreements	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.
Price premiums offered for higher quality	Tendency to produce as cheap as possible, leading to lower quality products.
Characteristics of local supply chain organisation	e.g. scale, variability and transparency

Indicator	Description/reason for indicator
Compliance with rules and regulation about food safety awareness by businesses per sector	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.
National and EU legislation	Rules and laws about the amount/presence of mycotoxins.
Changes in composition of fungal populations	Because of e.g., climate changes, a shift in the fungal composition could occur.
Outbreaks of defined species	Increase of infections by known fungal species.
Technology forcing	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.
New/improved detection methods for mycotoxins	Due to new improve methods it could be possible to detect new mycotoxins, or lower levels of existing ones.
Influence of science on the production and legislation	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.
Changes in disease-resistance figures for cultivars	Some varieties could be less insect resistant, or more prone to fungal growth.

Table 22 Indicators for identification of emerging mycotoxins during wheat transport and storage

Indicator	Description/reason for indicator
Temperature	The mean of the temperatures, differences in temperature e.g., during day/night
Relative humidity (product)	Due to high relative humidity fungi could grow and produce mycotoxin. E.g., Relative humidity > 80%.
Water activity in kernels	Water content in the kernels need to be below 15 %. E.g., Water content >15 % , increased risk for mycotoxin production.

Indicator	Description/reason for indicator
Level of technology used	Trends in technological developments per country. E.g., control atmosphere.
Awareness of food safety	Understanding of food safety could decrease the production of mycotoxins.
Communication/trust between trade parties	
Knowledge dissemination of mycotoxins	Due to improved electronic media, scientists all over the world could share research results/knowledge.
Ventilation	Ventilation could be necessary to keep the moisture content constant when the kernels are not dry enough (< 15 %).
Grain quality	Quality of the grain, such as kernel size, colour, protein concentration
Level of implemented traceability and quality systems	Level of documented traceability systems and the implementation of e.g., HACCP
Carry over of contamination	Spores which are still in the batch or storage container could sporulate when the temperature and relative humidity is favourable.
Blending/mixing practices	Mixing of contaminated parties to reduce the contamination.
Transport duration and distance	Availability of transport, required quality, e.g., Temperature, relative humidity during transport.
Storage capacity and logistics	The storage circumstances, controlled or not.
Index of country of origin and trade volumes	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.
Number of products passing through national borders without inspection	Sampling rate versus the total trade volumes in order to establish the country's ability to control illegal imports of foods.
Foreign control of enterprises	Relocation of production to low-wage countries.

Indicator	Description/reason for indicator
Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles	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.
International trade agreements	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.
Characteristics of local supply chain organisation (scale, variability and transparency)	Areas / countries vary with regard to the level of organisation in food supply chains.
Compliance with rules and regulation about food safety awareness by businesses per sector	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.
National and EU legislation	Rules and laws about the limits/presence of mycotoxins.
Changes in composition of fungal populations	Because of e.g., climate changes, a shift in the fungal composition could occur.
Technology forcing	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.
New/improved detection methods for mycotoxins	Due to new improved methods is could be possible to detect new mycotoxins, or lower levels of existing ones.
Influence of science on the production and legislation	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.

Table 23   Indicators for identification of emerging mycotoxins during the wheat processing

Indicator	Description/reason for indicator
Water activity in kernels	Water activity >0.15 is necessary for mycotoxin formation.
Price levels for energy and food cereals	Due to increase of bio-energy less wheat is produced and the prize of food cereals will increase, which could effect the quality.
Level of technology used	Trends in technological developments per country.
Awareness of food safety	Understanding of food safety could decrease the presence of mycotoxins in end products.
Communication/trust between trade parties	
Knowledge dissemination of mycotoxins	Due to improved electronic media scientists all over the world could share research results/knowledge.
Increased number of identification requests for diseases on cereals	When laboratories receive more requests for mycotoxins/fungi analysis of end products it could be an indicator that there are changes in fungi infections.
Ventilation	Ventilation is only necessary to keep the moisture content (<15 %) if the kernels are not dry enough.
New cereal based products entering the consumer market at a large scale (in combination with other risk factors)	Due to travelling European consumers would like to have other (exotic) products.
Grain quality data	Quality of the grain, such as kernel size, colour.
Level of implemented traceability and quality systems	Level of documented traceability systems and the implementation of e.g., HACCP.
Carry over of contamination	Spores which are still in the batch or storage container could sporulate when at favourable temperature and relative humidity conditions and produce mycotoxins. Also "clean" wheat can be (re) contaminated with mycotoxins.
Blending/mixing practices	Mixing of contaminated parties to reduce the contamination before processing.
Logistics	Managing and controlling the flow of wheat during the process step.

Indicator	Description/reason for indicator
Index of WTO trade agreements	increased opportunity to import foodstuffs from regions/countries with less stringent standards.
Index of country of origin and trade volumes	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.
Number of products passing through national borders without inspection	Sampling rate versus the total trade volumes in order to establish the country's ability to control illegal imports of foods.
Foreign control of enterprises	Relocation of production to low-wage countries.
Major changes in international trade in particular when the origin is changing to areas with unknown risk profiles	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
International trade agreements	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.
Price premiums offered for higher quality	Tendency to produce as cheap as possible, leading to lower quality products
International trade balance	Measure the trends in overall trade balance, thus the balance in export and import of goods
Compliance with rules and regulation about food safety awareness by businesses per sector	Depends on the knowlegde/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
National and EU legislation	Rules and laws about the amount/presence of mycotoxins.
Outbreaks of defined species	Increase of infections by known fungal species
Increasing occurrence or unexpected local occurrence of animal diseases without clear diagnosis	Outbreaks and biodiversity, which involve large population explosions

Indicator	Description/reason for indicator
Consumption patterns	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
Food innovations	New improved food production methods could contribute to new food products
Exotification	Due to globalisation eating patterns could change in international products flows
Technology forcing	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.
New/improved detection methods for mycotoxins	Due to new improved methods is could be possible to detect new mycotoxins, or lower levels of existing ones in the end product
Influence of science on the production and legislation	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
Grain quality data which may be related to fungal infestations	Quality decrease of the grain kernels arises from fungal growth

Annex III List of workshop participants

This Annex presents the list of participants of the workshop held in the course of the MYCONET stakeholder study (see Chapter 5).
Workshop title: Identification of Emerging Mycotoxins in International Wheat-Based Supply Chains
Held: Office of Det Norske Veritas (DNV) in Rotterdam, The Netherlands
Date: 20 September 2007

Table 24

Name	Institution	Country
Invitees		
Daan Barug	Ranks Meel	The Netherlands
Hans De Keijzer	Dutch Organisation of Millers	The Netherlands
Frank Driehuis	NIZO the Food Researchers	The Netherlands
Bert Evenhuis	WUR*-Plant Research International (PRI)	The Netherlands
David Kloet	private consultant	The Netherlands
Jurgen Köhl	WUR*-Plant Research International (PRI)	The Netherlands
Gerrit Koornneef	Hoofdproductschap Akkerbouw	The Netherlands
Marcel Mengelers	VWA**, Office for Risk Assessment	The Netherlands
Sofie Monbaliu	University of Ghent	Belgium
Hub Noteborn	VWA**, Office for Risk Assessment	The Netherlands
Stephan Peters	The Netherlands Nutrition Centre	The Netherlands
Martien Spanjer	VWA**, Amsterdam	The Netherlands
Cees Waalwijk	WUR*-Plant Research International (PRI)	The Netherlands
Organising Committee		
Kees Booij	WUR*-Plant Research International (PRI)	The Netherlands
Sigrid Brynestad	Det Norske Veritas (DNV)	Norway
Marion Dreyer	DIALOGIK	Germany

Name	Institution	Country
Chantal Kandhai	WUR-RIKILT***	The Netherlands
Ellen Morrison	DNV	Norway
Ine van der Fels-Klerx	WUR-RIKILT***	The Netherlands

* *Wageningen University and Research Centre (WUR)*

** *Food and Consumer Product Safety Authority (VWA)*

*** *RIKILT - Institute of Food Safety*

Annex IV Workshop scenarios on emerging mycotoxins

This annex presents a description of two scenarios addressed during the stakeholder study (see Chapter 5).

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.

1) Which criteria are most important?
2) What type of information is needed to determine the testing regime?
3) What are the current information sources, and how reliable are they?
4) Is there information that you would like to have available but that is difficult to obtain at the moment?
5) How could a risk model (such as addressed during the workshop) 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.

1) What type of information is needed in relation to the quality of wheat for feed and food production?
2) What type of information is needed to determine the testing regime? (in wheat for feed and food production)
3) Which criteria are the most important?
4) What are the current information sources, and how reliable are they?
5) Is there information that you would like to have available that is currently difficult to obtain?
6) How could a risk model (such as addressed this morning) be useful in this situation?
7) 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.
8) What type of information is needed to evaluate if the wheat is suitable for consumption?
9) What type of information is needed to determine the testing regime?
10) Which criteria are the most important?
11) What are the current information sources, and how reliable are they?
12) Is there information that you would like to have available that is now difficult to obtain?
13) 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:

1) Which information do you already have and use?
2) Which information would you use if it was available?
3) What format should the information be in to best meet your needs, for example:
   a) detailed information based on geography and indicators;
   b) estimation on the level of each indicator;
   c) estimated predicted occurrence/ indicator;
   d) integrated information into 1 estimated occurrence?

Annex V List of interviewed authorities and economic actors in series of interviews

This annex present a list of organisations (authorities, economic actors etc.) interviewed, as part of the MYCONET stakeholder study (see Chapter 5).

Table 25 Authorities

Institution	Interviewee
Federal Institute for Risk Assessment, BfR, Germany http://www.bfr.bund.de	Horst Klaffke (Head of the National Reference Laboratory for Mycotoxins)
Federal Office of Consumer Protection and Food Safety, BVL, Germany http://www.bvl.bund.de	Andreas Kliemant (Unit for Matters of Principle with Foods, Foods of Non-Animal Origin/ Referat für Grundsatzangelegenheiten bei Lebensmitteln, Lebensmittel nichttierischer Herkunft)
National Food Administration Sweden http://www.slv.se	Anders Jansson (Inspection department, Livsmedelsverket)
Norwegian Food Safety Authority http://www.mattilsynet.no/	Laila Jensvoll (Department for Inspection, Plants and Vegetables.)

Table 26 Economic Actors

Companies	Features	Interviewee
Rasio PCL, Finland www.raisio.com	Raisio's main products are foods and functional food ingredients, as well as feeds and malts	Lauri Laukkanen (Quality Leader)
Felleskjøpet, Norway http://www.fk.no	Agricultural purchasing and marketing Co-op	Sveiniung Skretting (Quality Assurance, purchaising)
Lantmännen Mills, Denmark http://www.lantmannen.com/en/Lantmannen-COM/Business/Lantmannen-Mills	Scandinavia's largest producer of grain-based products with 12 production facilities in Sweden, Norway, Denmark and Latvia (self-portrayal)	Camilla Krook (Quality Leader)

Companies	Features	Interviewee
Valsemøllen A/S, Denmark http://www.valsemollen.dk	Milling company, one of two big actors in the Scandinavian market; the other being Lantmännen Mills (self-definition)	Susanne Danielsen (Quality Director)
Kampffmeyer Mühlen GmbH, Germany http://www.hartweizengriess.de	Leading commodity partner of the whole food and pasta industry (self-portrayal)	Christoph Persin (Head of Research and Development)
Raiffeisen, Kraftfutterwerke Süd GmbH; Germany www.rkw.sued.de	Largest compound feed manufacturer in southern Germany (self-portrayal)	Svetlana Peganova (Marketing, Head of Product Development)
Interest groups		
Deutscher Verband Tiernahrung e.V. (DVT), Germany http://www.dvtiernahrung.de	The association represents the interests of medium-sized enterprises which produce, store and trade mixed feed and pre-mixtures for farm animals and pets	Peter Radewahn (Managing Director)
Verband Deutscher Mühlen (VDM), Germany http://www.muehlen.org	The association represents about 750 mills with more than 90% of the bread cereal comminution (wheat and rye) in Germany (self-portrayal)	Alexander Meyer-Kretschmer (Lawyer), Nico Turian MSc. oec. Troph

Table 27 Research Institute

Institution	Interviewee
Agrifood Research Finland MTT, MTT Laboratories (MTT is an expert body operating under the Finnish Ministry of Agriculture and Forestry) https://portal.mtt.fi/portal/page/portal/www_en	Veli Hietaniemi (Laboratory Manager)

Annex VI Questionnaires for interviews with authorities and economic actors

This annex presents the questionnaires for the in-depth interviews held in the course of the MYCONET stakeholder study (see Chapter 5).

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 Table VI).

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 Table VI)?

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

Table VI. Pre-selection of indicators for identification of emerging mycotoxins, per stage of the wheat based supply chain

Cultivation	
• Relative humidity/rainfall (air and soil) • Crop rotation • Temperature	• Tillage practice • Water activity in kernels • Crop variety / cultivars • Harvest conditions • Changes in composition of fungal populations • Pesticide/fungicide use
Transport and storage	
• Water activity in kernels • Relative humidity (product) • Ventilation • Temperature	• Storage capacity and logistics • Grain quality (kernel size, colour) • Carry over of contamination
Processing	
• 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	• 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 VII Mycotoxin work in Iceland 2007-2008

By Olafur Reykdal

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
Korngordum 12, IS-104 Reykjavik, Iceland
The company imports considerable part of the wheat used for feed in the country.
Contact: Pall Hoskuldsson, quality manager (pallh@fodur.is).

Lifland - Kornax
Korngordum 5, IS-104 Reykjavik, Iceland
The company imports considerable part of the wheat used in the baking industry.
Contact: Bergthora Thorkelsdottir (bergthora@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@lbhi.is)