GMP+ Feed Safety Assurance scheme

D

Cultivation measures for the prevention of mycotoxin

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GMP+ D4.9

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Stadhoudersplantsoen 12
2517 JL The Hague
The Netherlands

Tel: +31 (0)70 370 86 70
Fax: +31 (0)70 370 86 71

info@gmpplus.org
www.gmpplus.org

Feed
for
Food

TABLE OF CONTENTS

1	**INTRODUCTION**	**4**
1.1	GENERAL	4
1.2	STRUCTURE OF THE GMP+ FEED SAFETY ASSURANCE SCHEME	4
2	**SUMMARY**	**6**
3	**INTRODUCTION**	**7**
3.1	GENERAL INTRODUCTION	7
3.2	AIM	7
3.3	CLIENT	7
4	**PRECONDITIONS FOR THE STUDY**	**8**
5	**RISK ANALYSIS**	**9**
6	**RISK DETERMINATION**	**10**
6.1	MYCOTOXINS CONTAMINATION ROUTES HAZARDS IDENTIFICATION	10
6.2	EXPOSURE	11
6.3	HAZARDS CHARACTERISATION	12
6.4	RISK CHARACTERISATION	13
7	**CONTROL MEASURES**	**14**
7.1	CULTIVATION	14
7.2	SOIL PREPARATION	14
7.2.1	Crop rotation	14
7.2.2	Seed	14
7.2.3	Choice of variety and sowing	15
7.2.4	Fertilising	15
7.2.5	Crop protection	15
7.2.6	Environmental stress	16
7.3	HARVESTING AND POST-HARVESTING	16
7.3.1	Harvesting	16
7.3.2	Harvesting technique	16
7.3.3	Storage and transport	17
7.3.4	Processing	17
7.4	OTHER CONTROL MEASURES	18
7.4.1	Determine the risk profile for the specified contaminants	18
7.4.2	Make information available through growers / traders to customers	18
7.4.3	Customer decision on the basis of reporting	19
7.4.4	Compound feed supplier and customer (farmer) measures	19

8 DISCUSSION 20

9 CONCLUSIONS 21

10 COMPOSITION OF THE PROJECT GROUP 22

11 REFERENCES 23

TABLE 1: MOST-USED RAW MATERIALS IN THE FEED INDUSTRY 25

TABLE 2: SOME LEVELS OF MYCOTOXINS IN FEED RAW MATERIALS 26

TABLE 3: CONTROL MEASURES WITH RESPECT TO MYCOTOXINS DURING THE CULTIVATION OF THE FEED RAW MATERIALS CHAIN 27

TABLE 4: CONTROL MEASURES IN THE RAW FEED MATERIALS CHAIN WITH RESPECT TO MYCOTOXINS, HARVEST AND POST-HARVEST 29

1 Introduction

1.1 General

The GMP+ Feed Safety Assurance scheme (GMP+ FSA) has been developing since 1992. This scheme was been administered from 1992 up until 2009 by the Product Board Animal Feed and, with effect from 2010, this will be administered by GMP+ International.

The GMP+ Feed Safety Assurance scheme (GMP+ FSA) is a complete scheme for assuring feed safety in all the links in the feed chain. It is also a scheme which can be used internationally.

The establishment and development of the scheme was primarily the result of demand from the subsequent links in the feed production chain for better control of feed safety. Another contributory factor was the damage caused by contamination incidents which were more serious and less serious.

In the initial phase the demand arose for better differentiation in an increasingly saturated European sales market for animal products. Since 1999, food safety has been a top issue internationally both politically and commercially because of serious incidents in the feed sector. Because of this, demonstrable assurance of feed safety has become a sales prerequisite.

The basic principle of the GMP+ Feed Safety Assurance scheme (GMP+ FSA) is that the feed chain is part of the animal production column. Proper quality assurance of feed safety worldwide has a high priority. Companies must live up to their responsibilities and respond properly and convincingly to the needs of food production. The GMP+ Feed Safety Assurance scheme (GMP+ FSA) is an aid to the realisation of this.

1.2 Structure of the GMP+ Feed Safety Assurance scheme

The documents within the GMP+ Feed Safety Assurance scheme (GMP+ FSA) are subdivided into a number of series. A diagram follows of these:

A General (framework) documents	These documents contain the requirements for participation in the certification scheme for companies and certification bodies (framework regulation, the use of logo’s, etc.). This series also includes a general list of definitions and abbreviations.

B Normative documents	These documents contain the international standards and additional country notes for use by companies with respect to the various feed products and production phases including cultivation and industrial production, treatment and processing, collection, trade, means of transport, storage and transhipment.

C Certification requirements	These documents contain the Rules of Certification including those for the approval of certification bodies and auditors, the frequency of audits, minimum audit time, assessment criteria, checklists, etc. There is also an explanation of how the supervision by certification bodies is implemented and of how GMP+ International supervises the certification process.

D Interpretations and accompanying texts	In addition to the above-mentioned normative documents, there are also supporting documents in the D series including a list of frequently-asked questions, manuals and guidance with additional information.

Document	Code	Name
	GMP+ Dx.x	e.g. GMP+ D4.9 Cultivation measures for the prevention of mycotoxin

All these documents are available through the website of GMP+ International (www.gmpplus.org) .

This document is designated as the standard GMP+ D4.9 *Cultivation measures for the prevention of mycotoxin* and is part of the GMP+ FSA scheme. It is not a norm document but research carried out in collaboration with the Product Board Animal Feed. Use is made in this document of the original text of the report. The information in this research can be used to give a better implementation of the GMP+ FSA norms.

2 Summary

The creation of mycotoxins during the cultivation, harvesting and/or storage was identified as a problem area with the highest priority in the study ‘Inventory of the risks of feed raw materials and possible control measures’ which was carried out in 1999 on behalf of the Product Board Animal Feed. The control measures for this problem area are proposed in this study.

The basic principle for the study being presented here is the prevention of contamination and/or the growth of moulds in crops in the field or in the product after harvesting. Contamination with mycotoxins will also be low as a result. This study does not so much address possible contamination with the individual currently known mycotoxins but more generically the mycotoxins already studied as an example for possible contamination routes. The measures also cover all the raw materials for the feed industry and all the areas from which the raw materials are obtained. The control measures are primarily focused on cultivation, harvesting and/or storage or transport. It was concluded that many of the proposed control measures in this area must be further examined. The lack of monitoring data for mycotoxins in raw materials for the feed industry plays an important role in the effective estimation of the control measures. There is also very limited data available in the field of mycotoxins which occur in crude feeds which are cultivated, preserved, stored and given as feed on farms. The data which is available indicates the possible presence of outliers with extremely high contamination with mycotoxins. The control measures for the post-harvest products have in common that the products must be well preserved, stored and/or given as feed.

At this moment it is assumed that by choosing less sensitive varieties, extensive crop rotation (at least one year) and turned soil treatment, the harm to the crops through moulds can be limited. Other control measures during cultivation must still be examined. Mould contamination and growth can then be limited by the prevention of damage and by dry storage (with the exception of silage) and transportation of products.

Monitoring programs would have to be carried out to gain insight into the contamination of feed raw materials and crude feeds by the indicator mycotoxins. This should be accompanied by the setting up of a chain management system and an Early Warning System for the tracing of batches.

3 Introduction

3.1 General introduction

The creation of mycotoxins during the cultivation, harvesting and/or storage was identified as a problem area with the highest priority in the study ‘Inventory of the risks of feed raw materials and possible control measures’ which was carried out in 1999 on behalf of the Product Board Animal Feed. The control measures for this problem area are proposed in this study.
Mycotoxins are formed by moulds in raw materials during the cultivation of crops and during the storage and processing of the products. The long-term or excess taking up of the mycotoxins via food or via feeds can have a negative influence on the health of humans and animals. *Fusarium* mycotoxins, for example, are associated with cancer of the trachea in humans, damage to the kidneys and to the immune system and with deviations in the hormone housekeeping system. These last two effects are also observed in productive livestock. A consequence of this may be an increase in zoonotic infections because the resistance of the animal does not function as it should and the chance is great that vaccinations are no longer effective. Aflatoxin B_1 and Ochratoxin A are known as, respectively, hepatotoxic and nephrotoxic in both animals and humans.
Control measures for mycotoxins in feed raw materials will have to be focused in all stages of the cultivation, harvesting and storage of the raw materials on making the conditions for mould growth as unfavourable as possible. These measures must primarily be taken in the areas of origin of the raw materials.

3.2 Aim

The aim of this study is to establish the actual control measure(s) to be taken in order to eliminate or to reduce to an acceptable level the risks in an identified problem area and in the creation of mycotoxins during cultivation, harvesting and/or storage.

3.3 Client

This study was carried out on behalf of the Product Board Animal Feed.

4 Preconditions for the study

The basic principle for the study was the risks to the consumer, both animal and human in this case. Humans were taken into consideration because of the possible transfer of the mycotoxins or metabolites of mycotoxins via the animal to humans. Little is known about this. The establishment of the norm will not be discussed.
The problem will be approached by way of the risk analysis method in which the measures per link in the feed raw materials chain will be examined. The problem will be approached generically which means here that the prevention of the production of mycotoxins is the focal point.
The basic assumption will be six (groups of) indicator mycotoxins:

- Aflatoxin, Ochratoxin A, Fumonisin B_1, Zearalenon, Deoxynivalenol and ergot alcaloids. Although there is already legislation for the aflatoxins these mycotoxins will still be handled here as indicator mycotoxins as stated earlier. It is very probable that a multiplicity of mycotoxins are produced by the moulds and that they could all be present in the raw materials.
- The reasons for choosing these indicator mycotoxins are that the contamination routes for these indicator mycotoxins are known and that there are methods for determining these indicator mycotoxins.
- The proposed control measures will relate to all feed raw materials from all areas.
- These study will repeatedly address the grain chain. The reason for this is that the most is known about this chain with respect to mould and mycotoxin contamination and about the contamination routes. This chain will therefore fulfil a kind of indicator chain function.
- The control measures which will be proposed will also relate to the crude feeds which are fed to the animals. If necessary the measures specifically for crude feeds will also be addressed.

5 Risk analysis

The risk analysis consists of a number of steps. The first part, the risk determination, inventories and describes the problem. In the second part, risk management, the possible solutions are examined further and possible recommendations are given.
There are four steps in the risk determination. The mycotoxins are generally specified in the hazards identification for which details are known of the toxicity or contamination routes. These are considered to be the most relevant. A determination must then be made per mycotoxin of the exposure and the hazards must be characterised. Finally, a statement is made about the possible hazards for the consumer due to the exposure and about the combination of the hazards characterisation into the risk characterisation.
After the risks determination, measures are taken in risks management to control the risks. The risk evaluation plays an important role in this. The risks are then quantified per link in the chain. Although the risk evaluation for mycotoxins still has to be developed, it can already be applied here. For each link a quantification is then done based on the risk determination.
Once the risks have been mapped out and quantified then there can be an examination of at which points the effects of intervention would be most effective. The mycotoxins can be monitored at these points and corrective actions can be taken.

6 Risk determination

6.1 Mycotoxins contamination routes hazards identification

Moulds occur worldwide and can infect more or less all agricultural crops or occur as a secondary infection. The production of the various mycotoxins by the mould is, however, dependent on the circumstances such as the species of mould present, the cultivation methods used and the climatological conditions. The consequence is that if live mould is found in a raw material then the mycotoxins do not actually have to be present and vice versa. Interest is currently focused on the mycotoxins of the mould genera *Aspergillus, Penicillium, Fusarium* and *Claviceps*. The best known mycotoxins produced by moulds of this genera are the hepatotoxic Aflatoxin B_1 (*Aspergillus*), the nephrotoxic Ochratoxin A (*Aspergillus/Penicillium*), the *Fusarium* mycotoxins Deoxynivalenol (growth retardant and immunotoxic), Zearalenon (oestrogen) and Fumonisin B_1 (cancer of the trachea, heart defects in pigs and brain damage in horses) and the neurotoxic ergot alcaloids (*Claviceps*) (de Nijs *et al*., 1996; Dalcero et al., 1996). Control measures can be provided by studying the contamination routes in order to keep the contamination of foodstuffs and feeds by mycotoxins as low as possible.

In a temperate climate the species of the genus *Fusarium* occurs as a plant pathogen and also as a non-plant pathogen (Langseth *et al.*, 1993; Snijders, 1990). The crop is contaminated in the field and the mycotoxins are produced there. In this climate area it is *Aspergillus* and *Penicillium* moulds which grow during the storage of the crops if the moisture content of the product rises. In the tropical areas, *Aspergillus* and *Penicillium* are also plant pathogens in addition to *Fusarium*. This means that in products from these areas aflatoxins and Ochratoxin may be expected during harvesting in addition to the *Fusarium* mycotoxins.

Infection from moulds can vary from year to year and the species on the plant can even vary during the growing season (Lees and Parry, 1993; Logrieco *et al.*, 1990; Usha *et al.*, 1993). The weather during the growing season has a very great influence on the prevalence of mould contamination and the species found. In particular, precipitation during bloom means an increased chance of infection. In addition, rain can cause more conidia to be spattered from the ground and contaminate the ear (Jenkinson and Parry, 1994). A lack of soil preparation could lead to more *Fusarium* contamination (Bailey and Duczek, 1996; Dodman and Wildermuth, 1989). Turned soil preparation could greatly reduce the Fusarium contamination. Burning the stubble can result in a reduction of infection in the next crop (Dodman and Wildermuth, 1989). Correct crop rotation can ensure that the chance of infection is less great (Clear and Abramson, 1986; Duthie *et al.*, 1986; Hall and Sutton, 1998). The influence of seed density, row density and seed depth are recognised but have not yet been determined quantitatively (Bailey and Duczek, 1996).

The incorrect use of fertiliser can also lead to an increase in moulds in the plant (Daamen *et al.*, 1991). A higher nitrogen level in the plant would ensure that more mould contamination occurs (Smiley *et al.*, 1996).

In addition, rapid growth of the plant could result in weakened resistance. The timing of the fertilising plays an important role in this.

Fusarium is considered to be the plant pathogen most resistant to fungicides. It seems that the use of fungicides assists the production of certain mycotoxins (Lees and Parry, 1993). This is quite possible because fungicides retard or stop a certain part of the energy cycle of the mould so that the mould forms a different metabolite to complete the energy cycle. Other crop protection agents such as insecticides may ensure, in the same way as a fungicide may ensure, that a certain mycotoxin is no longer produced (Dalcero *et al*. 1996). It is not known what the effects on mycotoxin production are of the elimination or minimising of part of the naturally-occuring moulds through the use of fungicides. The timing of the use of the crop protection agents is also of great importance here for the consequences in the area of mould contamination and mycotoxin production.

It is possible to breed plant varieties which are less sensitive to mould infection (Assabgui *et al.*, 1993). This is not, however, a solution for the non-pathogenic species of the genera. These mould species infect the plant after, for example, an insect or drought has provided an entry route (Jenkinson and Parry, 1994). It is therefore important that the cultivation measures are focused on limiting the stress to the plant. The development of plants which can degrade mycotoxins is a possible approach to the problem.

Most mycotoxins are stable during processing processes and the concentrations in the end products are hardly influenced by the processes which are used during the processing of raw materials into foodstuffs (Pittet *et al.*, 1992; Scott *et al.*, 1993). It is quite possible that the concentration of mycotoxins occurs in a particular phase. The water-soluble mycotoxins are, for example, concentrated in the water phase in processes in which water is used. The grains which are formed in the ear during the ergot contamination of rye with *Claviceps purpurea* have a lower specific gravity than healthy grains. The affected grains can be removed to a great extent from product so that the ergot alcaloid level is lowered to an acceptable level. The *Claviceps purpurea* mycotoxins are only found in the affected grains which are dark in colour and have a low specific gravity so that this method is very effective in removing the ergot alcaloids.

Carry-over of Ochratoxin A is known via pig meat. Ochratoxin A which is fat-soluble is taken up by the animals via the feed. The toxin is then stored in the fatty tissue of the animals. Aflatoxin B_1 is converted by the cow into Aflatoxin M_1 which is also carcinogenic and which is excreted in the milk. There is currently a suspicion that a number of *Fusarium* mycotoxins from contaminated feed are transferred to humans via animals.

The contamination routes referred to above for moulds are often quite clear. However, whether mould contamination also always leads to mycotoxin production is still not always clear. In this study it is assumed that contamination of raw materials by moulds and therefore by mycotoxins must be kept as low as possible so that the hazards of carry-over are more or less excluded. The list given here is undoubtedly not complete.

6.2 Exposure

Table 1 gives a brief summary of the raw materials most used in feeds. Table 2 gives a brief summary of a number of levels of mycotoxins which are found in a number of raw materials. Table 2 serves only as an illustration, there is in this project no extensive (literature) study into the presence of mycotoxins in feed raw materials. A number of general comments can be made about the published levels of mycotoxins.

- Many publications report on the levels found in feeds or raw materials in the event of an emergency. It may be expected that these levels are exceptional although the emergency may have occurred in an exceptionally sensitive animal group.
- Monitoring research is not always published because the data is often confidential. In addition, studies in which hardly measurable levels are found are seldom published.
- It occurs that only the range in which the samples were contaminated with the mycotoxin is published. This is often the case where many analyses have been carried out. The specification of the median, the average or the frequency distribution often provides more insight.
- In many reports the detection and determination limits are not specified. It is important to do this in order to get a good impression of the range of levels in which there is a determination.
- The determination method is not always properly shown.
- The range of the calibration graph is not always shown. There is not always an explanation of how the levels which are far above the maximum detection level are calculated. This can have a major influence on the accuracy of the test result.
- In most cases the high levels of contamination are not confirmed using another analysis method.
- Sometimes only the levels are specified of the samples in which the mycotoxins are found above the determination level.
- Details are often missing in the published data about the real country of origin of the samples.

The literature shows that there is data available for contamination by aflatoxins of peanuts and grains, especially wheat. Little is known about contamination of other feed raw materials by other mycotoxins. It is important also to examine these raw materials because a very high level of contamination of a product which has a low concentration in the recipe can still make a significant contribution to the damage caused by a feed.

Table 2 shows, among other things, that the concentrations of Deoxynivalenol in crude feeds can be enormously high. The table shows the results of a limited number of samples and for just two crude feeds. Mycotoxins can also occur in grass, silaged grass and bales.

Younger, older or pregnant animals or humans with a weakened immune system are considered to be more sensitive to the effects of mycotoxins.

Part of the exposure is the intake of quantities of raw materials by animals or humans. This point is not addressed in this setting due to the generic approach to the problem.

6.3 Hazards characterisation

Toxicity studies are carried out to characterise the hazards of mycotoxins. The tolerable daily intake is calculated on the basis of this toxicity data. The evaluation of toxicity studies is not part of the scope of this study.

6.4 Risk characterisation

The above is an indication of the contamination routes which are currently known and of the possible conditions for the production of mycotoxin for six indicator mycotoxins. These routes may also apply to the so far unknown mycotoxins which occur in raw materials in addition to those specified above. The result of this risk determination is therefore that the occurrence of mould contamination and growth must be minimised.

7 Control measures

Risk management is the next phase in the risk analysis. The possibilities for controlling the risk are examined in this phase. It is clear that the whole production chain must be involved in resolving mycotoxin problems and making them controllable.

Tables 3 and 4 show the structure for the control measures. The control measures are grouped together. An estimate is made for each group and section of what the effects on mould contamination or the mycotoxin level could be. It should be noted that many of the specified measures are based on assumptions or on a very limited amount of knowledge about the measure.

7.1 Cultivation

7.2 Soil preparation

It is known that certain soil preparation stages, especially turning the ground, decrease the chance of survival of moulds in the soil. More research is required however to determine the effect on mould contamination of the time in the season when this preparation is carried out. Soil turning is not possible however in all areas due to, among other things, erosion problems.

It is known that the burning of stubble decreases the chance of infection. The burning of stubble is however prohibited in the Netherlands.

During the growing season one must ensure that the plants are not damaged. A number of soil preparation steps such as mechanical harrowing or ridging can damage the plants so that the plant is more sensitive to mould infections and an entry is provided for non-pathogenic moulds.

7.2.1 Crop rotation

A good crop rotation, longer than one year, ensures a lower chance of infection in the next crop. The optimum crop rotation for the prevention of mycotoxins still has to be examined, however. Maize must be excluded as a preceding crop for other grains. The current practice in the cultivation of silage maize meaning that maize on the same piece of ground every year results in a high mould density in the crops.

7.2.2 Seed

The seed used must as far as possible be free of plant pathogenic germs. The use of contaminated seed means that not only the crop is infected but it may assist the introduction of pathogenic species. The crop measures proposed here will also have an influence on the mould contamination of the cultivated seed itself. There are also methods available, or they will have to be developed, for seed decontamination both chemically and biologically (acids).

7.2.3 Choice of variety and sowing

The variety used for a crop must also be less sensitive to the plant pathogens which occur in the area. No processing can be done against non-plant pathogenic moulds. It is however possible to control the conditions in which these moulds infect such as the control of insects. In the future varieties should be chosen which can degrade the mycotoxins formed. The feasibility of this control measure is by no means certain.

In the case of grains it is known that the ears of a short straw variety are contaminated quicker with moulds than the ears of a long straw variety. This is because of, among other things, the infection being spattered from the ground during rain. The long straw crop also dries more quickly after precipitation. Short straw varieties, however, are currently preferable because lodging occurs less often. The use, however, of growth retardants and correct fertilising can prevent this. The two-rowed ears which occur in barley dry more quickly so that the chance of infection by moulds is lower. Less dense sowing could lead to stronger plants which dry more quickly.

7.2.4 Fertilising

The dosage of an excess of minerals (N) would lead to an increased level of nitrogen in the plant. This would result in an increase in mould infections. The reasoning is that the plant grows so quickly that it is weak. In addition, an excess of minerals encourages more leaf on the plant so that the crop dries less quickly. A higher level of protein makes the plant more attractive to bugs and results in slower ripening so that the risk of mould contamination is increased. The timing of fertilising also plays a role.

7.2.5 Crop protection

The use of fungicides can lower the chance of mould if applied correctly. The mould *Fusarium* is however not very sensitive to fungicides. Because of this, this mould can form a large part of the contamination. The use of fungicides could then decrease the total chance of mould but a number of resistant species, including the *Fusarium* species, will remain dominant.

Fungicides, and also insecticides, can influence the metabolism of the mould. Because of this the mould can switch over to the production of a completely different mycotoxin. This mycotoxin could be more toxic than that which was previously produced. The production of a particular type of mycotoxin can be repressed in this way.

Weeds. especially grasses, between the plants can be a source of contamination from which the plants are continually infected with moulds. They can also be a survival location for insects. The insects can then damage the crop so that there are entry points for mould contamination by non-pathogenic moulds. It is therefore necessary to counteract weeds properly.

It is known that representatives of some species are not able to make a certain mycotoxin.

If these strains replace the producing strains then the production of certain mycotoxins could decrease. This is risky, however, because a new species could be forced very quickly or a new species might make other, perhaps more toxic, substances.

7.2.6 Environmental stress

The mould contamination can be dependent on environmental factors. The total mould contamination will therefore be high if the growing season has been wet. This also has an influence on the prevalent pathogenic mould species. It is known that the production of certain mycotoxins is limited to a number of mould species so that mycotoxin production can be dependent on the climate during the growing season. In periods of extreme drought in combination with the absence of sprinkling, the crops can be damaged by stress. An entry point is created for mould infections. Because of this, the non-plant pathogenic mould species which requires little moisture for growth can infect the crops and form mycotoxins. In many cases these are the *Aspergillus* and *Penicillium* species which can form aflatoxins and Ochratoxin A.

The ambient temperature has an influence on the mycotoxin production of some species. A higher average temperature would therefore be needed for the forming of Fumonisin B_1 in maize by *Fusarium proliferatum*.

7.3 Harvesting and post-harvesting

7.3.1 Harvesting

The crops must be harvested at the right time. This is usually the point at which the crops are properly ripened. The correct moisture content is important for grains at the moment of harvesting. It may be necessary to dry the harvested crops afterwards. If because of the conditions such as rain the crop can only be harvested much later then one needs to be very careful about the forming of mycotoxins during the period when the ripe crop was still in the field.

7.3.2 Harvesting technique

The method of harvesting must be correct to ensure in particular that damage to the product is prevented. Damage, for example, to grains ensures that starch becomes available for infection by and growth of moulds and the associated possible production of mycotoxins. This does not apply to silage maize because the crop is processed immediately after harvesting.

A separation technique for the removal of non-standard products such as damaged seeds or grains could be carried out during the harvesting or prior to storage. This could lower the mycotoxin level (ergot alcaloids) or decrease mould contamination (broken seeds).

7.3.3 Storage and transport

The products must be treated so that mould contamination and mould growth in particular is prevented. The grains can be dried afterwards. All harvested products must be stored in controlled conditions as far as possible. Damage caused by rodents or insects, major temperature fluctuations and the forming of condensation must be avoided. This also applies to the transportation of the products. The products must be transported in clean wagons under a canvas and must be protected as far as possible from temperature fluctuations. This includes transport by train wagons and vessels. The treatment of the harvested products with an anti-mould agent is one of the possibilities for post-harvest preservation.. This can be chemical or also biological.

A great number of products are fermented. This applies to a large part of the crude feeds which are cultivated, stored and transported on farms. Agents can be added to improve quality. These may include the addition of preservatives such as starter cultures, salts or acids.

The crops which are cultivated, stored and transported at the farm itself or sold directly to others as feed (they do not reach the market) and include grass, silage or grains and they form a risk. The quality of the harvested crop, especially the moisture content, and the storage conditions must meet strict requirements. The conditions must be such that no mould contamination or growth can occur. In the event of faulty storage such as excess moisture, aflatoxins and/or Ochratoxin A can be formed in grains which are cultivated in a temperate climate zone.

7.3.4 Processing

The products can be cleaned before, during and after storage. Attention must be given to the removal of damaged products. In the case of contamination with *Claviceps purpurea*, the ergot grains can be mechanically removed on the basis of the weight of the grains. The level of ergot alcaloids in the cleaned grain then drops greatly. The broken and damaged grains can also be sieved out of the product when it arrives. The starch, in broken grains for example, can easily be infected by the moulds *Aspergillus* and *Penicillium* which can produce the aflatoxins and Ochratoxin A. The sieved fraction can therefore be highly contaminated with mycotoxins. During wet processes, the water-soluble mycotoxins can be concentrated in the water fraction.

During the processing of the products care must be taken to ensure that no conditions occur in which moulds can grow and mycotoxins can produce. This also applies to the occasional products which may be processed in the feeds. The risks will have to be examined per product flow. The wet products are in any event almost always risky and are therefore often preserved by lowering the pH.

7.4 Other control measures

In addition to control measures which directly affect cultivation, harvesting or the post-harvesting phase, a number of control measures can be formulated for the subsequent links in the chain. These control measures may also have the desired effect ultimately by preventing the forming of mycotoxins during the previous links. After all, the raw materials from growers or suppliers which can not comply with the wishes and requirements of their customers will have to be rejected in the feed chain.
The following additional measures can be formulated between the various parties in the chain.

7.4.1 Determine the risk profile for the specified contaminants

A customer for feed raw materials could record for each raw material the sensitivity to contamination with mycotoxins for a certain raw material. This activity could be described as recording the risk profile for each raw material.

Example

Determination of the risk profile for raw materials could, for example, be carried out by dividing the raw materials into categories. On the basis of an arbitrary sequence, raw materials could be classified from *not mycotoxin sensitive* to *very mycotoxin sensitive*. The possible presence of the indicator mycotoxins mentioned earlier in this report would have to be estimated (qualitatively).
In this way there could, for example, be subdivision created into four classes in which:

1. the danger of contamination with mycotoxins is not relevant
2. the danger of contamination with mycotoxins is improbable
3. the danger of contamination with mycotoxins is present
4. the danger of contamination with mycotoxins is great

7.4.2 Make information available through growers / traders to customers

The customer can decide on the basis of the risk profile which measures will be asked of the supplier.
A customer has a possibility to question his supplier with respect to a number of matters. In anticipation of an expansion of the quality systems in the chain (whereby the tendency is for quality systems to creep further into the chain), the customer can even now set a number of requirements for his supplier with respect to mycotoxins. The higher the risk profile, the more extensive the measures to be agreed must be. The suppliers who fall into class 3 or 4 will in any event be asked to supply details.

The grower / supplier must provide insight (for each cultivation period) into the following details:

- the production process (map out using a description or flowchart) (one-time)
- relevant cultivation details (seed used, how was the seed contaminated, which crop protection agents were used during contamination, how did fertilising take place, what were the climate conditions during the cultivation)
- the details of the origin (within the framework of traceability)
- other relevant details or measures measures to prevent the forming of mycotoxin
- the number of samples which, on the basis of the above details, were analysed for mycotoxins stating the analysis method (match the analysis frequency on the basis of the analysis results, risk profile, literature, etc.).

N.B.: If the supplier does not have a monitoring program then the customer must (provisionally) analyse a number of samples before the batch is taken. (for 6 indicator-mycotoxins per batch (commodity)).

N.B.: If individual batches comply with the (internal) norms then it is assumed that mixed batches also comply.

A report is drawn up from this data including the analysis results for the samples tested (the report may if desired be drawn up by an independent inspection agency).
The report is intended for, among others, the customer who can obtain insight in this way into the quality of the batches delivered.

7.4.3 Customer decision on the basis of reporting

The quality service of the customer must decide on the basis of the report provided whether a batch can be accepted or whether batches can be delivered during a certain period of time.
In addition to deciding about whether to accept the batch or not, a customer can also of course take a number of measures in the longer term. The measures agreed can thus be included in contracts. The customer can then put more effort into entering into partnerships with approved suppliers. If a supplier has high values too often then there is a possibility to transfer to another supplier. The reduction of the number of suppliers to a manageable number is also part of this.

7.4.4 Compound feed supplier and customer (farmer) measures

(Compound) feed companies maintain their relationships with their customers, the farmers. Feed company information providers guide the farmer. These information providers who guide the farmer can keep an eye on non-standard situations at the farms. Suspect animal wastage or feed refusal must be reported back immediately. The measure therefore consists of setting up a feedback system for the information providers. In the future this feedback system could be linked to the Early Warning System.

8 Discussion

It is generally assumed that by choosing less sensitive varieties, extensive crop rotation (at least one year) and turned soil treatment, the harm to the crops through moulds can be limited. The exact effects of the other control measures still has to be examined. The proposed control measures can be properly implemented in the Dutch situation. Agriculture in other countries, especially outside the European Union, will be probably be more difficult to adjust. Attention will have to be given to which other measures there are which could be taken. Research into the best control measures for this is necessary

As far as the treatment during and after the harvesting is concerned, the control measures can be implemented in all areas. In particular, the prevention of damage, dry storage (with the exception of silage) and the transportation of crops can be implemented. The setting up of a chain monitoring system is necessary to be able to trace the batches in the event of an emergency.

It appears that data is known for only a very limited number of feed raw materials with respect to contamination with mycotoxins. The data which is available does not always present the true picture because, for example, the feed in question caused intoxication. It is therefore necessary to establish a monitoring program in which the feed raw materials are analysed for the indicator mycotoxins. By carrying out this monitoring program for a number of years, an impression will be gained of the fluctuations per area, year and crop. The data which is collected in this monitoring program can be used for an Early Warning System. This system should also contain regional and weather information. If problems are signalled with raw materials from a particular area or year then action can be taken. A good chain monitoring system is essential in this.

Crude feeds are a separate problem. Little or nothing is known about contamination with mycotoxins. A monitoring program will first have to be started. This means that the mycotoxin level of the feed silage will have to be followed over time. The control measures for the cultivation of crude feeds will generally be the same as those for other crops. The rule, however, for extensive crop rotation does not apply to grassland. Special attention will have to be given to grains which are not put on the market but which are stored and provided as feed on the farm. In the Netherlands these constitute a risk for the formation of Aflatoxin and Ochratoxin A.

Finally, the working group is of the opinion that having (feasible) norms for mycotoxins is very important to accompany the control measures specified in this report and then to strengthen them. In addition, when formulating the proposed control measures, it is important that the measures are taken internationally.

9 Conclusions

The following control measures are proposed by the subgroup on the basis of the various considerations shown in this report:

Cultivation

- Choose less sensitive varieties
- The use of extensive crop rotation in which maize is not the predecessor of the other grains
- The use of turned soil preparation

Other control measures during cultivation must still be examined.

Storage

- The prevention of damage, dry storage and the transportation of raw materials.

Quality system measures (to be agreed between the relevant links in the chain)

- Draw up a risk profile for raw materials (by the compound feed factory or customer)

- Entering into (contractual) agreements between the supplier and customer (hand over analysis results, hand over reports or audit results)

Sampling

- Carry out an entry check by way of (periodic) sampling of incoming raw materials (fit into the quality system), or
- Insight into the analysis results of the supplier

As a supplement to these measures, more information must in the future be gained in the field of mycotoxins. Monitoring programs would have to be carried out to gain insight into the contamination of feed raw materials and crude feeds by the indicator mycotoxins. This should be monitored per year and per area. Data on climatic conditions should be collected. This should be accompanied by the setting up of a chain management system (including a traceability system) and an Early Warning System.

10 Composition of the project group

Mr. A. Blonk	Blonk C.V.	
Mr. P. Enthoven	Cehave CCL	
Dr. M. de Nijs	TNO Voeding	Secretary
Mr K. Otte	ACM	
Mr E. Roberts	Meneba N.V.	
Dr. R. Sijtsma	Hendrix UTD	Chairman

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Table 1: Most-used raw materials in the feed industry

Raw material	Mycotoxins found
Potato peelings, steamed	Unknown
Brewers' grains (fresh or silaged)	Unknown
Brewer's yeast	Unknown
Beet (pressed) pulp	Unknown
Peas	Unknown
Barley	Aflatoxin B_1, Ochratoxin A, Deoxynivalenol, Zeara-lenon, T-2 toxin, ergot alcaloids
Millet	Aflatoxin B_1, ergot alcaloids
Gluten	Zearalenon
Ground nuts	Aflatoxin B_1, Zearalenon, Ochratoxin A
Oats	Aflatoxin B_1, Ochratoxin A, Deoxynivalenol, Zeara-lenon, T-2 toxin
Hay	Deoxynivalenol, T-2 toxin
Cotton seed	Aflatoxin B_1
Rape seed and by-products	Unknown
Lucerne	Aflatoxin B_1
Maize and by-products	Aflatoxin B_1, Ochratoxin A, Deoxynivalenol, Zeara-lenon, Fumonisin B_1, T-2 toxin
Mycelium	Unknown
Oils	Unknown
Rice and by-products	Aflatoxin B_1, Zearalenon, Ochratoxin A
Rye	Aflatoxin B_1, Ochratoxin A, Deoxynivalenol, Zeara-lenon, ergot alcaloids
Soya	Aflatoxin B_1
Sorghum	Aflatoxin B_1, Zearalenon, Ochratoxin A, T-2 toxin
Straw	Deoxynivalenol, T-2 toxin
Tapioca	Aflatoxin B_1, Zearalenon
Wheat and by-products	Aflatoxin B_1, Ochratoxin A, Deoxynivalenol, Zeara-lenon, ergot alcaloids
Wheat by-products	See wheat
Triticale	Ergot alcaloids
Fats	Unknown
Sunflower seed	Alternariol
Dairy by-products whey	Aflatoxin M_1

Table 2: Some levels of mycotoxins in feed raw materials

Raw material	DON* (ppb)	NIV* (ppb)	ZEA* (ppb)	FB1* (ppb)
Wheat	4-20500 2000-40000 0-1800 450-4300 20-230 2-43800 0-3310 0-4500 0-5000 0-2390	3-320 10 7-203	1-840 10-2000 0-120 2-174	
Maize	3960-20000			10-1500 700 8-3350
Barley	2200-13330 4-152	30-145	4-9	
Oats	1300-2600 7200-62050 56-147	17-39	16-29	
Rye	8-384	10-34	11 133	
Tapioca			5-106	
Maize silage	10000- 20000			
Maize cores	4000- 320000			
Corn cobs+spil (CCM)	9000- 927000			
Maize waste feed			3710	
Maize gluten feed (meal)			94-681	500-2560 2050-2500
Rice extract			117	

* DON = Deoxynivalenol; NIV = nivalenol; ZEA = Zearalenon; FB1 = Fumonisin B_1

Table 3: Control measures with respect to mycotoxins during the cultivation of the feed raw materials chain

Control measure	Process parameter	Effect on mould contamination or mycotoxin level	Increase or decrease in mycotoxins
Soil preparation	- None - Ploughing - Remove straw - Burn stubble - Crop damage	- Increased chance of infection with moulds - Decreased chance of infection with moulds - Decreased chance of infection with moulds - Decreased chance of infection with moulds - Increased chance of infection with moulds	> < < < >
Crop rotation	- Tight crop rotation - Extensive crop rotation	- Increased chance of infection with moulds - Lower chance of infection with moulds	> <
Seed	- Mould-free seed - Low-mould seed - Fungicide-treated[*] - Biologically treated	- Decreased chance of infection with moulds - Decreased chance of infection with moulds - Decreased chance of infection with moulds - Decreased chance of infection with moulds	< < <[*] <
Variety choice and sowing	- Short straw varieties - Long straw varieties - 6-row ears - 2-row ears - Less sensitive crops - GMO variety which is resistant[#] - Variety which degrades mycotoxin - GMO variety which degrades mycotoxin[#] - Dense sowing	- More sensitive to moulds - Less sensitive to moulds - More sensitive to moulds - Less sensitive to moulds - Greatly decreased chance of infection by pathogenic moulds - Greatly decreased chance of infection by pathogenic moulds - Greatly decreased mycotoxin contamination - Greatly decreased mycotoxin contamination - More sensitive to moulds	> < > < < <[#] < <[#] >
Fertilising	- Excess fertiliser	- More sensitive to moulds	>
Crop protection	- Fungicides[*]	- Decreased mould damage, increase in mycotoxins	>[*]

	- Insecticides, chemical weed killing* - Insecticides, biological weed killing - Substitution with non-pathogenic strain	- Decreased mould damage, decrease in mycotoxins - Decreased mould damage - Decreased mycotoxin production	< * < <
Environmental stress	- Wet growing season - Hot growing season - Wet growing season (wet periods)	- Increased chance of infection with moulds - Lower chance of infection with moulds - Increased chance of infection with moulds	> < >

* There must be compliance with the residue norms.
\# no regulations yet in this area

Table 4: Control measures in the raw feed materials chain with respect to mycotoxins, harvest and post-harvest

Control measure	Process parameter	Effect on mould contamination or mycotoxin level	Increase or decrease in mycotoxins
Harvest	- Wet - Dry - Hot - Fungicides* - Biological	- Increased chance of infection with moulds - Low moulds chance of infection - Low moulds chance of infection - Increased chance of infection with moulds - Decreased mould damage	> < < >* <
Harvesting technique	- Prevent product damage	- Prevent mould growth	<
Storage and transport	- Drying of crop - Anti-mould treatment, chemical* - Anti-mould treatment, biological - Conditioned storage - Non-conditioned storage - Transport means, conditioned - Transport means, non-conditioned - Silage	- Prevent mould growth - Prevent mould growth - Prevent mould growth - Prevention of rodent damage and mould growth - Rodent damage and mould growth - Prevention of rodent damage and mould growth - Rodent damage and mould growth - Prevent mould growth	< <* < < > < > <
Processing	- Cleaning of crop - By-products of cleaning - Concentration in, for example, starch washing water Other production by-products	- Less moulds and mycotoxins - More mycotoxins - More mycotoxins, possibly more moulds in the event of wet fractions. - ?	< > > ?

* There must be compliance with the residue norms.