The UK Code of Good Agricultural Practice to Reduce Fusarium Mycotoxins in Cereals

Please note that this document will be updated periodically.

Last updated: February 2007

Contents

1. Key Messages

- Mycotoxins are chemicals hazardous to human and animal health, produced by certain fungi.

- Fusarium mycotoxins can be produced on cereal crops in the field as a result of fusarium ear blight.

- The major sources of dietary intake of fusarium mycotoxins are products made from cereals, in particular wheat and maize.

- Legislative limits for fusarium mycotoxins in unprocessed cereals and cereal products exist to protect public health.

- The risk of exceeding legal limits for fusarium mycotoxins in UK cereals is low. This risk varies between years and regions depending on climate. The risk is lower in the north of England and Scotland.

- Good Agricultural Practice is the primary mechanism to reduce fusarium mycotoxins in cereals and cereal products.

- Risk assessments should be performed to determine the risk of fusarium mycotoxins.

- Good Agricultural Practice should be adopted to reduce the risk of fusarium mycotoxins.

- Good Agricultural Practice to reduce the risk of fusarium mycotoxins includes:

  Avoid maize as previous crop
  Minimise crop debris on soil surface
  Select resistant varieties
  Consider an ear spray application against ear blight
  Timely harvest

2. Introduction to Mycotoxins

Mycotoxins are natural toxic substances produced by fungi and exist in our diet as a result of the presence of specific fungi on food crops, either in the field or in store. Mycotoxins can be hazardous to the health of humans and animals even at low concentrations.

The most common mycotoxins of concern in UK cereals are the fusarium mycotoxins: deoxynivalenol (DON), HT-2, T-2 and zearalenone, which are produced on cereal crops whilst in the field; and ochratoxin A which is produced on cereal grains in store.

Legislation was introduced in 2006 which set maximum limits for fusarium mycotoxins in cereals and cereal products for human consumption. As fusarium mycotoxins are produced in the field, Good Agricultural Practice is the primary mechanism to reduce fusarium mycotoxins entering the food chain.

The European Commission has published a recommendation on the prevention and reduction of fusarium toxins in cereals and cereal products (Commission Recommendation 2006/583/EC[1]). As the regulatory body for food safety in the UK, the Food Standards Agency is responsible for the implementation and application of EU legislation, and as such, this Code of Practice takes into account the principles detailed in the recommendation and forms the official, UK-specific, Code of Practice for the reduction of fusarium mycotoxins in cereals.

Growers should assess the risk at critical points in the year (as described in the Risk Assessment section) to decide which measures should be taken to minimise fusarium mycotoxin concentrations in harvested cereals. This Code of Practice also advises growers how they can reduce the risk of fusarium mycotoxins by modifying their cereal agronomy.

This Code of Practice does not cover grain maize or oats grown for human consumption. For recommendations and regulations concerning grain maize and oats, growers should consult the European Commission documents (Commission Recommendation 2006/583/EC[1] and Commission Regulation (EC) 1881/2006[2]).

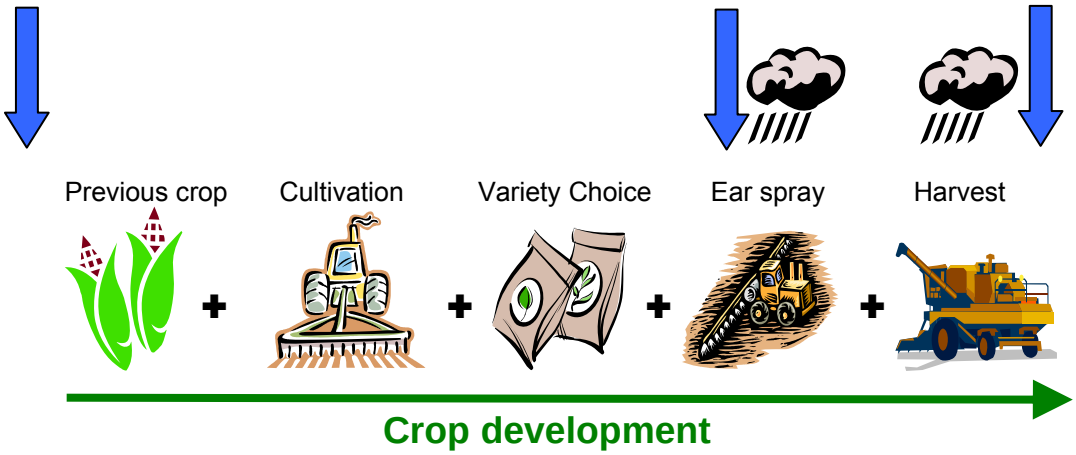
[1] http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_234/l_23420060829en00350040.pdf
[2] http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_364/l_36420061220en00050024.pdf
This Regulation applies from 1st March 2007, and replaces Commission Regulation (EC) 856/2005 (http://eur-lex.europa.eu/LexUriServ/site/en/oj/2005/l_143/l_14320050607en00030008.pdf)

2.1. Fusarium Mycotoxin: Important Factors

The fusarium mycotoxin content of cereals is determined by multiple factors of agronomy and weather. The diagram below indicates the important factors in determining fusarium mycotoxin contamination and provides examples of best practice and worst case scenarios. There is a cumulative effect of each component of the Good Agricultural Practice detailed in chronological order below. Wet weather either during flowering or at harvest is also a major risk factor.

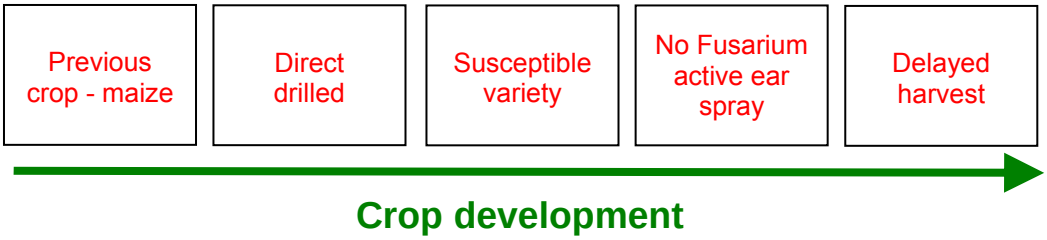
Risk assessments (blue arrows) can be performed at three points during the season.

At the start of the season to assess the agronomic risk
At ear emergence to assess the need for an ear spray
At harvest to assess the overall risk (weather + agronomy)



2.1.1. Best practices

2.1.2. Worst case scenario



2.2. Fusarium Ear Blight

Fusarium ear blight (also referred to as fusarium head blight) of UK cereals may be caused by several fungal pathogens. Some of these fungi produce fusarium mycotoxins whilst others do not. Fusarium ear blight can be seen in crops around the milky ripe stage (Growth Stage 75) as premature ripening (bleaching) of individual spikelets. Orange/pink spores of *Fusarium* may be seen on infected spikelets. Infection can result in bleaching of the head above the point of infection. As the whole crop ripens the symptoms become less visible. At harvest, fusarium ear blight can result in fusarium damaged grains that may be shrivelled with a chalky white or pink appearance, although this is not always the case. The presence of fusarium damaged grains is a strong indication that the fusarium mycotoxins, DON and zearalenone, maybe present. However, the relationship between the number of fusarium damaged grains and mycotoxin content is not consistent. Grains may appear undamaged but still contain mycotoxins.

Individual bleached spikelet of wheat infected with Fusarium at milky ripe (Growth Stage 75).

Fusarium infection of wheat with partial ripening of the head at milky ripe (Growth Stage 75).

Healthy (left) and fusarium damaged wheat grains (right)

Fusarium species can be readily isolated from seed, stem bases, soil, weeds and insects although the main source of inoculum is crop debris. The ideal conditions for *Fusarium* infection are heavy rainfall to splash spores from the base of the plant or crop debris up onto the cereal ears. Warm, humid weather then allows the fusarium spores to germinate and infect the cereal ears. Cereal crops are most susceptible to ear blight infection during flowering (Growth Stage 61-69). Once infection has occurred, further rainfall and humid conditions during the summer will allow secondary infection to occur. Once the crop is ripe (Growth Stage 92), wet weather allows further fungal growth and mycotoxin production to occur.

2.3. Fusarium Mycotoxins

The fungal plant pathogens known as *Fusarium* can produce several mycotoxins. The most common fusarium mycotoxin detected in small grain cereals is deoxynivalenol (DON). Another fusarium mycotoxin which is found less frequently is zearalenone. DON causes reduced feed intake, reduced weight gain and vomiting in farm animals, while high levels of this toxin have been shown to adversely affect growth and the immune system in animal studies. Nausea, vomiting, diarrhoea, abdominal pain, headache, dizziness and fever have been reported when high concentrations of DON were consumed by humans. Zearalenone has been found to be oestrogenic in experimental animals. The European Commission Scientific Committee on Food (SCF) has advised on tolerable daily intakes (TDIs) for DON and zearalenone of 1 and 0.2 µg/kg bodyweight/day, respectively.

The major sources of dietary intake of fusarium mycotoxins are products made from cereals, in particular wheat and maize. The European Commission has set legal limits for fusarium mycotoxins, DON and zearalenone, in order to protect human health.

2.4. European Legislation on Fusarium Mycotoxin

To ensure the safety of food, the European Commission has set maximum legal limits for the fusarium mycotoxins, DON and zearalenone in cereals and cereal products (Commission Regulation (EC) 1881/2006).[1] Maximum levels were set based on the current human exposure in relation to the tolerable intake of the toxin in question and which can be reasonably achieved following good practices at all stages of production.

Maximum limits for DON and zearalenone in unprocessed cereals and finished products intended for human consumption

Product	Mycotoxin (ppb)	
	DON	zearalenone
Unprocessed cereals other than durum wheat, oats and maize	1250	100
Unprocessed durum wheat and oats	1750	100
Unprocessed maize	1750	200
Cereal flour	750	75
Maize flour	750	200
Bread, pastries, biscuits, cereal snacks and breakfast cereals	500	50
Processed cereal-based food for infants and young children and baby food	200	20

The maximum levels set for unprocessed cereals apply to cereals placed on the market for processing. Cereal grains may have been cleaned, dried

[1] http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_364/l_36420061220en00050024.pdf This Regulation applies from 1st March 2007, and replaces Commission Regulation (EC) 856/2005 (http://eur-lex.europa.eu/LexUriServ/site/en/oj/2005/l_143/l_14320050607en00030008.pdf)

and/or sorted prior to being placed on the market; these grains are still classified as unprocessed cereals.

Maximum levels are set on unprocessed cereals to avoid highly contaminated cereals entering the food chain and to encourage all measures to minimise fusarium mycotoxin contamination to be taken in the field and storage stages of the production chain. Processing can reduce the mycotoxin content of some cereal products; limits for processed products are therefore lower.

The limits for fusarium mycotoxins in cereals, as mentioned above, apply throughout the food chain. All food business operators, from growers through to retailers, should therefore adhere to the set limits.

Food business operators have a responsibility under Regulation (EC) 178/2002 as read with the General Food Regulations 2004 (SI 2004/3279) to ensure that the food they supply is safe for consumption. Growers should therefore ensure that their quality assurance controls are carried out in such a manner that any 'due diligence' defence under relevant food law is available to them.

The European Commission also set guideline limits in 2006 for fusarium mycotoxins in animal feed.[1] The lowest guidance limits have been set for pigs due to their higher sensitivity to fusarium mycotoxins. The DON guidance value for complimentary and complete feedingstuffs for pigs is 900 ppb. The zearalenone guidance value for complimentary and complete feedingstuffs for sows and fattening pigs is 250 ppb and for piglets and gilts is 100 ppb.

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:229:0007:0009:EN:PDF

3. Risk Assessment

Firstly, it should be noted that fusarium mycotoxin levels in the UK are generally low. However, mycotoxin levels do vary from year to year, so the risk is greater in some years than others. The severity of ear blight also varies between regions depending on weather conditions and intensity of host crops present within a region. There is a consistent trend for lower levels of DON and zearalenone to occur in the north of England and Scotland; moderate levels to occur in west of England, Wales and Northern Ireland and highest levels to occur in south and east of England.

Weather is an important risk factor. Crops are particularly susceptible to severe ear blight infection if there is rain when cereal crops are in flower (Growth Stage 59-69). Once infection has occurred further rainfall during the summer, particularly once the crop has ripened, allows secondary infections to occur.

Although the significant risk factor of weather cannot be controlled, there are a number of other agronomic factors which can be used to minimise the risk of fusarium mycotoxin occurrence. These factors are described in more detail later; consideration of risk factors should be made in association with risk assessments.

3.1. Performing Risk Assessments

Risk assessments should be performed at three critical control points:

A. At the start of the season, when impact of weather later in the season is unknown, crop rotation and agronomy should be considered.
B. At early flowering (Growth Stage 59-65) when recent and forecasted rain should be considered before deciding on the need and content of an ear spray.
C. Finally, at harvest when all risk factors should be considered in determining grain end use.

Annual variations in *Fusarium* inoculum and ear blight disease levels in wheat are reported as part of the Crop Monitor project.[1] This information can be used to assess the overall risk on a yearly and regional basis. In a year with high ear blight nationally, the overall risk of fusarium mycotoxin occurrence in individual crops will be increased.

It is recommended for the purposes of traceability that you perform your risk assessment and document the actions to be taken. Please refer to your accreditation scheme for more information regarding this.

[1] http://cropmonitor.co.uk/wwheat/wheat-intro.cfm

3.2. Key Risk Factors

The table below summarises the key risk factors that contribute to the occurrence of fusarium mycotoxins in cereal crops, providing growers with an indication of the overall risk to their crops (please refer to the following full text for further details).

Assessment of Risk =	HIGH	MEDIUM	LOW
Region	South and East England	West England, Wales and Northern Ireland	North England and Scotland
Previous Crop	Maize	Wheat	Other Crop
Crop Residue Management	No Crop Debris Removal or Burial	Min-Till	Ploughing
Variety Choice		Low Ear Blight Resistance	High Ear Blight Resistance
Weather Conditions	Heavy Rain during Flowering	Slight Rain during Flowering	No Rain during Flowering
Fungicide Use		No Ear Blight Fungicide Used	Ear Blight Fungicide Used
Lodging		Crop Lodged	Crop Not Lodged
Harvest		Wet Harvest Conditions	Dry Harvest Conditions

For a quantified risk assessment please visit the Rural Payments Agency website.[1]

3.3. Agronomic Risk Factors

3.3.1 Cereal Host

Cereal species differ in their susceptibility to fusarium ear blight. Maize and wheat are the most susceptible cereal host crops. Ear blights and the fusarium mycotoxins, DON and zearalenone are present at much lower levels in barley and oats compared to wheat. The overall risk of DON exceeding legal limits in wheat is low and in barley and oats is very low.

3.3.2. Rotation

[1] http://www.rpa.gov.uk/rpa/index.nsf/0/F25F5C3DAA27D08680257000003EF2BA [see Mycotoxin Risk Assessment Model]

The growing of wheat after maize is the greatest agronomic risk factor for the occurrence of ear blight. The risk is highest after grain maize, probably due to the amount of crop residue produced. Intense rotations of maize (in particular) and wheat, which are host crops of *Fusarium* fungi, increase the risk of *Fusarium* inoculum build-up.

3.3.3. Crop Residue

Crop residue on the soil surface is the major source of ear blight inoculum. For the UK, this is particularly important when the preceding crop is (in descending order) grain maize, forage maize, wheat or potatoes. Straw removal and soil cultivation are important agronomic practices to reduce the amount of crop debris on the soil surface.

3.3.4. Variety Choice

Varieties vary in their resistance to ear blight. More resistant varieties have a lower risk of fusarium mycotoxin contamination. Current wheat varieties have a limited range of resistance.

3.3.5. Weeds and Insects

Fusarium can be found on a range of broad-leaf and grass weeds and on a range of insects, although neither is considered a major source of inoculum.

3.3.6. Fungicides

Recommended fungicides applied as an ear spray (Growth Stage 59-69) at a robust rate can reduce ear blight and subsequent mycotoxin production. Growers should consider the use of fungicides and PGRs for fusarium mycotoxin reduction in conjunction with the Food Standards Agency's Pesticide Residue Minimisation Crop Guide for Cereals.[1]

3.3.7. Lodging

Lodging can cause humid conditions conducive to mycotoxin production. Crops which have been lodged for a period of time will have a higher risk of fusarium mycotoxins than a standing crop.

3.3.8. Harvest

Fusarium can produce more mycotoxins once a crop has ripened if harvest is delayed due to wet weather.

[1] http://www.food.gov.uk/multimedia/pdfs/pestresidcropcereal.pdf

4. Good Agricultural Practice

The amounts of fusarium mycotoxins present within harvested grain are dependent on several factors. The most important of these are weather and regional factors which cannot be controlled. However other, agronomic factors can be modified to reduce the risk of exceeding legal limits for fusarium mycotoxins. The Good Agricultural Practice identified below is based on current knowledge and details what action can be taken to minimise fusarium mycotoxins in UK cereal production. The benefits of each component are cumulative so that by combining as many of the components as possible the risk of exceeding legal limits will be minimised. Modifying agronomy can reduce the risk of exceeding legal limits, but it can not remove this risk completely.

Good Agricultural Practice	Impact
Rotation and Previous Crop Avoid maize as previous crop	High
Crop Residue Management Minimise previous crop residue on soil surface	High
Variety Choice Choose more resistant varieties	Medium
Weed Control Control weed populations	Low
Insect Control Control insect pest population	Low
Fertiliser Use Use optimum nutrient inputs	Low
PGR Use Use where necessary to avoid lodging	Medium
Fungicide Use Consider an ear spray to control ear blight	Medium
Harvest and Storage Timely harvest and drying of grain	Medium

4.1. Rotation and Previous Crop **High**

Host crop debris is the major source of inoculum for ear blight. Growers should avoid growing wheat after maize. Intense rotations maize (in particular) and wheat should also be avoided.

4.2. Crop Residue Management **High**

Any agronomic practice which reduces crop debris on the soil surface will reduce *Fusarium* inoculum. This is particularly important when the preceding crop is maize, wheat or potatoes. Recent studies have shown that thorough mixing of crop debris into the upper soil layer during min-till operations can be as effective as ploughing at reducing fusarium mycotoxins in subsequent wheat crops.

Growers should use methods of removing crop debris from the soil surface. These include:

1) Straw removal
2) Ploughing
3) Min-till operations that mix the crop debris into the upper soil layer.

4.3. Variety Choice **Medium**

The HGCA recommended list details the ear blight resistance for winter wheat varieties.[1] Varieties with high ear blight resistance have lower fusarium mycotoxin content at harvest. Where possible, growers should select a variety with a high ear blight resistance score. Ear blight resistance ratings are not currently available for spring wheat, barley or oats.

4.4. Weed Control **Low**

Fusarium can be found on a range of broad-leaf and grass weeds. Growers should control weed populations to practically achievable levels.

4.5. Insect Control **Low**

Fusarium can be found on a range of insects. Insect damage is a potential route of infection for *Fusarium*. Growers should control insect pest populations to practically achievable levels.

4.6. Fertiliser Use **Low**

Too much or too little fertiliser is likely to be detrimental to the crop. It is particularly important to ensure that excessive nitrogen inputs do not result in lodging (see PGR use). Growers should match fertiliser inputs to crop requirements.

[1] http://www.hgca.com/content.template/23/0/Varieties/Varieties/Varieties%20Home%20Page.mspx

4.7. PGR Use Medium

The absence of a PGR treatment can result in increased lodging. Growers should consider a PGR application at the appropriate dose and timing to reduce the risk of lodging. The HGCA have published guidelines on how to avoid lodging in winter wheat.[1]

4.8. Fungicide Use Medium

Fungicides recommended to control ear blight can reduce the fusarium mycotoxin content of harvest grain. Growers should consider the use a fungicide ear spray (Growth Stage 59-69, traditional T3 timing) that is recommended to control ear blight. The fungicide should be applied at the recommended rate and timing. The need for an ear spray against ear blight should be based on the likelihood of rain during flowering. However, caution should be taken when using this strategy as:

a) Prediction of rainfall around June in the UK is inaccurate due to localised thunderstorms

b) The efficacy of fungicides against ear blight is dependant on timing application as close to the time of infection as possible.

4.9. Harvest and Storage Medium

The highest concentrations of fusarium mycotoxins are found on fusarium damaged grains and chaff, both of which are lighter than healthy grains. The correct combine settings, in particular fan speed, can reduce the amount of fusarium damaged grains and chaff present in harvested grain. Growers should ensure that combines are well maintained and correctly set to optimise threshing and grain separation.

Localised patches of weathered, lodged crops should be harvested and stored separately.

Cleaning of grain post-harvest may also result in a reduction in fusarium mycotoxins due to the removal of fusarium damaged grains and chaff.

It is important that preparations are made for harvest to ensure delays are minimised. Grain should be harvested as soon as possible once ripe. The concentration of fusarium mycotoxins can increase if harvest is delayed due to wet weather. Grain should be cooled and dried as soon as possible. For short-term storage grain should be cooled and dried to below 18% moisture content within days of harvest. For long-term storage grain should be dried and held below 15% moisture content.

[1] http://www.hgca.com/document.aspx?fn=load&media_id=1743&publicationId=2100

5. The Cumulative Benefit of Good Agricultural Practice

There is a cumulative effect of combining each component of the Good Agricultural Practice detailed above. Growers should incorporate as many components as possible to reduce the fusarium mycotoxin content of harvested cereals. It is important that criteria detailed above are balanced against the requirements of sustainable cereal production and the requirements of the end-user for other grain quality parameters.

6. Testing Grain for Fusarium Mycotoxins

A combination of high and moderate risk factors indicates that you should consider testing for fusarium mycotoxins. Diagnostic test kits are commercially available, which allow growers to perform an on-site assessment of their grain. Alternatively, grain samples can be sent for analysis by a laboratory. However, in either case, growers must ensure that a **representative sample** is taken. Mycotoxins tend to occur in hot spots rather than uniformly throughout a consignment of grain. Therefore it is recommended that a large number of small samples from a single lot of grain are collected and mixed to form a composite sample. Sampling methods and mycotoxin test kits have been evaluated by the HGCA[1,2]; for further information on sampling please refer to the HGCA Grain Sampling guide[3].

Using results from mycotoxin analysis, grain should be marketed accordingly, based on legislative and guideline limits detailed in the introduction of this Code. If grain is suspected of having a high mycotoxin content it should be stored separately from other cereals intended for human consumption and tested for fusarium mycotoxins. It is prohibited to mix products complying with the maximum levels with products known to exceed the maximum levels.

7. Organic Cereal Production

Organic producers can minimise fusarium mycotoxins in organic cereals using the cultivation practices detailed above, other than the use of pesticides or growth regulators. The use of long rotations and ploughing for weed, pest and disease control are of benefit in reducing fusarium mycotoxins in organic cereal production.

For further information please contact:

Dr Mat Barber
matthew.barber@foodstandards.gsi.gov.uk
020 7276 8780

This Code of Practice was produced by the Food Standards Agency Mycotoxins Branch, Chemical Safety Division and was informed by Food Standards Agency funded work investigating agronomic factors affecting fusarium toxin development in UK wheat, barley and oats undertaken by Harper Adams University College (C04022 and C04033).

[1] http://www.hgca.com/document.aspx?fn=load&media_id=697&publicationId=1259
[2] http://www.hgca.com/document.aspx?fn=load&media_id=2757&publicationId=3214
[3] http://www.hgca.com/cms_publications.output/2/2/Publications/Publication/Grain%20sampling%20-%20a%20farmers%20guide.mspx?fn=show&pubcon=1261