**What are mycotoxins?**

Mycotoxins are toxic chemicals produced by certain fungi that can grow on a variety of different crops and foodstuffs. Different fungal species produce mycotoxins of widely varying toxicity to humans and animals.

In cereals, mycotoxins can result from fungi that either develop in stored crops or from field-borne infections.

### Fusarium mycotoxins

There are five *Fusarium* species and two *Microdochium* species that infect cereals and may cause ear or head blight:
- *Fusarium avenaceum*
- *Fusarium culmorum*
- *Fusarium graminearum*
- *Fusarium poae*
- *Fusarium langsethiae*
- *Microdochium nivale*
- *Microdochium majus*

In the UK, the main mycotoxin-producing species are *F. culmorum*, *F. graminearum* and *F. avenaceum*. *Microdochium* species do not produce mycotoxins.

### Fusarium life cycle

In established crops, spores are splashed up the plant stem and leaves by rainfall during flowering and grain formation. This may lead to head blight and seed-borne infection.

Crop debris, stubble and volunteers are more important sources of *Fusarium* than seed. Early infections in wet weather can cause seedling diseases, eg damping off, which may threaten establishment of untreated seed.

The key factors affecting likely mycotoxin risk in wheat are:
- Preceding crop
- Crop residues
- Variety
- Agronomy
- Weather at flowering
- Weather at harvest

This publication aims to help the industry identify the risk factors and the appropriate agronomy which can minimise risk of fusarium mycotoxins. It should be read in conjunction with the UK Codes of Practice produced by the Food Standards Agency [www.food.gov.uk/business-industry/farmingfood/crops/mycotoxinsguidance](http://www.food.gov.uk/business-industry/farmingfood/crops/mycotoxinsguidance).

The presence of ear blight is not a good indicator of likely mycotoxin risk in UK crops and there is little correlation between fusarium-damaged (pink or chalky-white and shrivelled) grains and mycotoxin occurrence.

### Fusarium life cycle diagram

- **Head blight symptoms**
  - Dark brown lesions on stem base and vertical streaks up stem
- **Splash dispersal of conidia up plant**
- **Overwinters in crop debris, grass weeds and volunteers, and as chlamydospores in soil**
- **Seed infection**
  - Seed infection causes damping off and early infection of plant
Legal limits

Regulations exist that set legal limits for certain mycotoxins in cereals and cereal products intended for human consumption.

Deoxynivalenol (DON) and zearalenone (ZON)

There are legal limits for DON and ZON in wheat intended for human consumption and guidance limits for grain for feed (Tables 1 and 2). Depending on end use, processors may require a lower limit at intake than the legal limit for unprocessed cereals to ensure finished products conform to legal limits.

It is the responsibility of all food business operators (including farmers, merchants and processors) not to place on the market any cereal or cereal products that exceed the legal limits. This means that all sellers must be able to demonstrate due diligence in determining the levels of mycotoxins that are present.

<table>
<thead>
<tr>
<th>Table 1. Legal limits for mycotoxins (ppb) in grain intended for human consumption</th>
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<tbody>
<tr>
<td>Deoxynivalenol (DON)</td>
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<tr>
<td>Unprocessed wheat and barley</td>
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<tr>
<td>Unprocessed oats</td>
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<tr>
<td>Flour</td>
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<td>Finished products</td>
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<td>Infant food</td>
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<tr>
<th>Table 2. EU guidance limits for mycotoxins (ppb) in grain intended for animal feedstuffs</th>
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<tr>
<td>Deoxynivalenol (DON)</td>
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<tr>
<td>Feed grains</td>
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<tr>
<td>Complete feedstuffs for pigs</td>
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<tr>
<td>Complete feedstuffs for calves, lambs and kids</td>
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<th>Table 3. EU indicative levels for the combined concentration of HT-2 and T-2 (ppb) in unprocessed cereals</th>
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<tbody>
<tr>
<td>HT-2 and T-2</td>
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<tr>
<td>Unprocessed wheat</td>
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<tr>
<td>Unprocessed barley</td>
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<td>Unprocessed oats</td>
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</tbody>
</table>

Definitions

**Legal limits** – maximum levels for specific mycotoxins in cereals and cereal products as defined by European Commission regulations and applied at the point of sale.

**Guideline limits** – to provide guidance as to the acceptability of feed and feedstuffs.

**Indicative levels** – to provide guidance on when investigations should be conducted into why high levels have occurred and what mitigation can be used to reduce future high levels.

T-2 and HT-2

Currently (2016), there are no legal limits for T-2 and HT-2. In 2013, the European Commission published a Recommendation that included indicative levels for the combined concentration of T-2 and HT-2 (Table 3). The Recommendation states that Member States, in conjunction with industry, should continue to monitor these mycotoxins and, where they exceed the indicative level, investigations should be conducted to determine why the exceedances occurred and what mitigation can be used to avoid exceedances occurring in the future.

Occurrence in UK cereals

Data on the occurrence of fusarium mycotoxins in UK cereals was generated from several extensive surveys conducted by AHDB and the Food Standards Agency from 2001 to 2013. Continued monitoring of fusarium mycotoxins is conducted as part of the series of AHDB Cereals & Oilseeds-funded contaminants projects (RD-2012-3779).

Wheat

DON and ZON are frequently detected in wheat but average concentrations are usually below the legal limits. During the period 2001 to 2013, it was only in wet harvest years that a significant percentage exceeded the legal limits for DON and ZON.

Barley

DON, ZON, HT-2 and T-2 levels in barley have been routinely low and legal limits were rarely exceeded between 2002 and 2009. ZON was the most commonly detected mycotoxin above legal limits, with exceedances in about 2% of samples in 2013 and highest occurrences in the wet harvest of 2008.

Oats

The predominant *Fusarium* species that infect oats produce the mycotoxins HT-2 and T-2. From 2002–2008, these mycotoxins exceeded the indicative level of 1,000 ppb in 17% of samples, with higher exceedances in seasons with drier summers, such as 2003 and 2005. There is good evidence that at least 90% of mycotoxins are removed during dehulling. Previous FSA surveys of fusarium mycotoxins in retail oat products have identified that exposure to these toxins from oat products in the UK diet is very low.
Before drilling

Region
In wheat, levels of DON and ZON tend to be lower in northern England and Scotland; moderate in western England, Wales and Northern Ireland and highest in southern and eastern England. Evidence suggests that higher humidity in coastal areas may increase risk.

Preliminary evidence suggests that levels of HT-2 and T-2 are similar across all UK regions.

The risk of DON and ZON occurrence in individual crops will be increased in a year with high levels of head blight nationally, and *Fusarium graminearum* incidence in particular.

Rotation and cultivation
Crop residue on the soil surface is the major source of head blight inoculum, especially after (in descending order) grain maize, forage maize, sugar beet or grass.

Rotation helps to reduce overwintering inoculum by lowering levels of infected crop debris on the soil surface.

Cultivation should effectively bury infected crop debris.

Variety
More resistant varieties have a lower risk of fusarium mycotoxin contamination.

Current UK wheat varieties have a limited range of resistance to head blight.

Actions:
- Plan rotation to minimise wheat after maize
- Remove straw to help reduce crop debris
- Ensure crop debris is buried by ploughing, or cultivate to mix crop debris into the upper soil layer

Actions:
- Consider head blight resistance in choice of winter wheat varieties from AHDB Recommended List
- Seed treatment is the main method of controlling seedling blight

Risk assessment – pre and during season
Assess risk at:
1. Start of season – consider likely effects of rotation and agronomy
2. Early flowering – take account of recent and forecast rain in deciding need to spray against *Fusarium*
3. Harvest – review all factors to determine mycotoxin risk and potential end use for grain

For traceability purposes, it is always best to document the actions to be taken when performing a risk assessment.

For more information
[cereals.ahdb.org.uk/mycotoxins](cereals.ahdb.org.uk/mycotoxins)
Pre-flowering

**Early season weather**
Conditions from sowing to around GS31 influence the build-up of inoculum. Warm, dry weather poses the highest risk.

**Weather during flowering**
During flowering (GS59–69), crops are particularly susceptible to severe head blight infection. Further rainfall after infection, particularly after ripening, allows secondary infection.

**T1 fungicides**
T1 fungicides control stem-base disease but are not appropriate if only fusarium is present.

**Lodging**
Lodging causes humid conditions conducive to mycotoxin production.

**Fungicides**
Effective T3 fungicides (eg metconazole, tebuconazole or prothioconazole) specifically control fusarium head blight and other diseases

AHDB Cereals & Oilseeds-funded research has indicated that:
- Using azoles at half to full rate significantly reduces DON concentration in harvested grain
- More reliable fusarium head blight control may be achieved by angling nozzles backwards
- Medium spray quality or air-included sprays may provide better control than fine sprays

**Harvest**

**Weather**
At harvest, fusarium mycotoxins may increase if wet weather causes delays.

**Other agronomic factors**
A range of broad-leaved and grass weeds, as well as some insects, can carry *Fusarium*, leading to infected weed and crop debris as well as a carry-over of spores.

**Actions:**
- Consider a PGR application at the appropriate dose and timing
- Consider the need for ear spray, especially if weather is forecast to be, or is, wet during flowering
- Apply fungicide at the recommended rate as near to infection time as possible
- Measure rainfall as accurately as possible during flowering

**Actions:**
- Prepare before harvest to minimise delays
- Harvest grain as soon as possible, once ripe
- Set combine, especially fan speed, to minimise retention of light fusarium-damaged grains and chaff
- Harvest and store grain from localised patches of weathered or lodged crops separately
- Measure rainfall as accurately as possible during this period

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**Moderate**

**Low**

**High**

Rain-delayed harvest (more than two weeks)

Rain-delayed harvest (less than two weeks)

Standing crops

Damaged grain

Lodged crops

Cold and wet

Cold or dry

Warm and dry

Warm and wet
Storage and sampling

Grain that could be contaminated must be stored separately from other cereals intended for human consumption.

Test suspect samples for fusarium mycotoxins

Effective sampling for mycotoxins is essential, as the distribution is not likely to be uniform within a stored bulk.

The sampling protocols in the Grain sampling guide (AHDB Cereals & Oilseeds, 2013) have been designed to meet the more demanding requirements of sampling for mycotoxins, as well as other aspects of grain assessment and monitoring.

Meeting end-user needs

Using as many components of ‘Good Agricultural Practice’ (ie factors presenting a low risk) as possible helps minimise fusarium mycotoxins at harvest. However, requirements of sustainable cereal production and of the end user also need to be considered.

Consult end user on grain requirements

Consider testing if you are aware of high fusarium incidence in your crop or evidence of chalky-white, shrivelled or pink grains in harvested grain.

In addition, surveys conducted by AHDB Cereals & Oilseeds and local merchants provide further information on the levels of mycotoxins in particular areas each year.

Testing

Testing methods range from simple on-farm tests indicating the presence or absence of a specific mycotoxin to officially recognised and validated methods quantifying any levels present. For all methods, prior extraction from a ground sample of grain is needed.

Qualitative lateral flow dipstick methods indicate the presence or absence of a specific mycotoxin above a set threshold. Presence, or absence, of a test band is interpreted by reference to the manufacturer’s instructions.

Quantitative assay methods measure the concentration of a specific mycotoxin. Test kits are available in two formats. Quantitative lateral flow is suitable when a single determination is required, eg grain storage/intake. Microtiter plate ELISA is suitable for analysing multiple samples.

Confirmatory analysis uses sophisticated, costly instruments operated by highly skilled staff. Methods are validated according to (EC) No 401/2006 and conducted by laboratories with current UK Accreditation Service (UKAS) status.

Testing records should be kept for at least two years
Further information

AHDB Cereals & Oilseeds information

Publications and details of projects funded by AHDB Cereals & Oilseeds are all available at cereals.ahdb.org.uk

Guides

AHDB Recommended Lists for cereals and oilseeds (annual)

G64 Barley disease management guide (updated online annually)
G63 Wheat disease management guide (updated online annually)
G60 Grain sampling guide (2013)
G52 Grain storage guide for cereals and oilseeds, 3rd edition (2011)
G41 The encyclopaedia of cereal diseases, AHDB/BASF (2008)

Information Sheets

IS49 Fungicide activity and performance in barley (2016)
IS48 Fungicide activity and performance in wheat (2016)
IS40 Risk assessment for fusarium mycotoxins in wheat (2015)
IS33 Ergot in cereals (2014)

Project Reports

PR555 Investigation of HT2 and T2 mycotoxins in oats from the 2014 harvest (2016)
PR550 Fungicide performance on winter wheat (2016)
PR549 Integrated strategy to prevent mycotoxin risk (Inspyr) (2015)
PR510 Ensuring that UK cereals used in malting, milling and animal feed achieve food and feed safety standards (2013)
SR23 Study of Fusarium langsethiae infection in UK cereals (2013)
PR500 Improving risk assessment to minimise fusarium mycotoxins in harvested oats and malting barley (2012)

Current AHDB Cereals & Oilseeds-funded projects

3779 Monitoring of mycotoxins and other contaminants in UK cereals used in malting, milling and animal feed
2130001105 Fusarium risk reporting – based on real time data collection

Other information

Food Standards Agency www.food.gov.uk
Agricultural Industries Confederation www.agindustries.org.uk
National Association of British and Irish Millers www.nabim.org.uk
Maltsters’ Association of Great Britain www.ukmalt.com
United Kingdom Accreditation Service www.ukas.org

For European Commission regulations
http://europa.eu/eu-law/decision-making/legal-acts

Commission Regulation (EC) No 401/2006 of 23 February 2006 laying down the methods of sampling and analysis for the official control of the levels of mycotoxins in foodstuffs

Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs
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