Updated Spring 2014

Guidelines to minimise risk of *Fusarium* mycotoxins in cereals

HGCA

AHDB Agriculture & Horticulture Development Board

Fusarium mycotoxins

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

These guidelines aim to help the industry identify the risk factors and the appropriate agronomy which can minimise risk of mycotoxins from field infections. They also aim to identify when testing is appropriate without incurring needless costs.

These guidelines 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

Occurrence and significance

Mycotoxins are toxic chemicals produced by specific fungi which infect crops. Different fungal species produce mycotoxins of widely varying toxicity to humans and animals; hence there are different permitted levels in foodstuffs and feed.

In cereals, mycotoxins can result from fungi that either develop in stored crops or from field-borne infections. This publication focuses on the *Fusarium* mycotoxins, which can arise from field-borne infection. While *Fusarium* mycotoxins do not decrease during storage in the UK, levels are most unlikely to increase under good storage conditions.

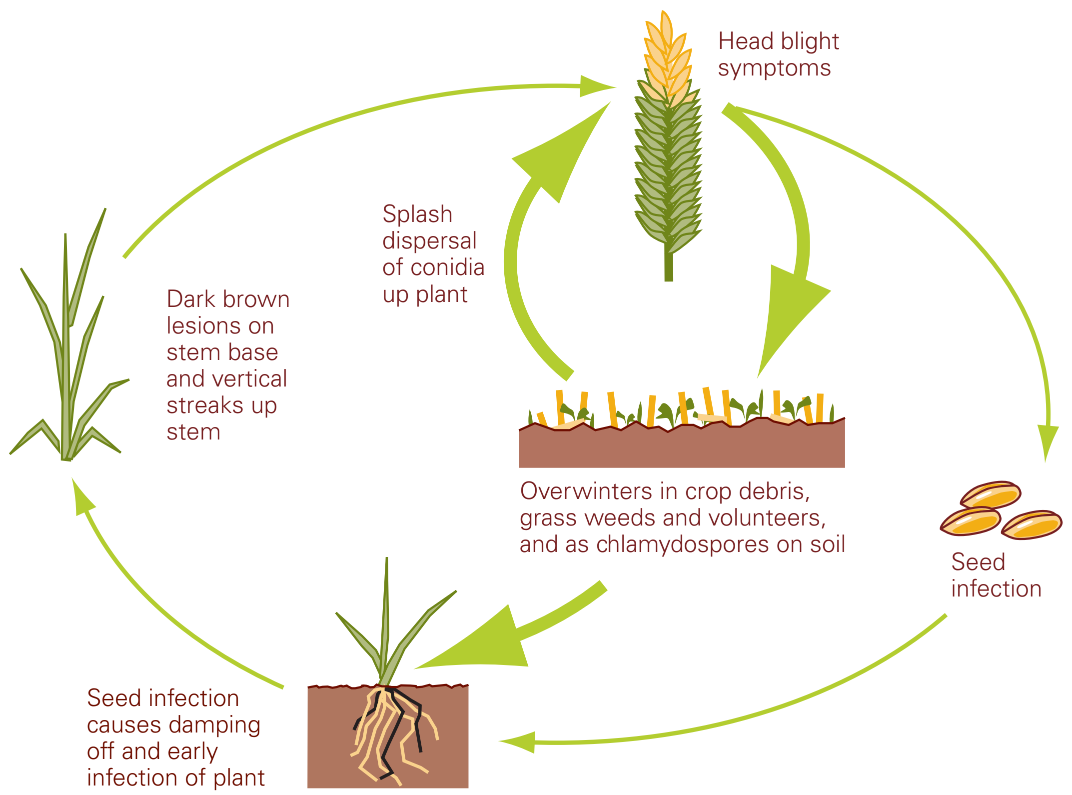
Mycotoxins from field fungi

There are five *Fusarium* species (*F. avenaceum, F. culmorum, F. graminearum, F. poae* and *F. langsethiae*) and two *Michrodochium* species (*M. nivale* and *M. majus*) that infect cereals and may cause 'head' (ear) blight. However, *Microdochium* species do not produce mycotoxins.

Some *Fusarium* and *Microdochium* species also cause seedling blight and brown foot rot (see **The encyclopaedia of cereal diseases**).

Infection of ears by *Fusarium* species can result in mycotoxin development when the weather is warm and wet at flowering. Mycotoxin occurrence may be greater when wet weather delays harvest.

Crops infected at flowering may have individual bleached spikelets, or partially bleached ears, resulting at harvest in pink or chalky-white shrivelled grains. However, there is little correlation between *Fusarium*-damaged grains and mycotoxin occurrence.



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.

Figure 1. Life cycle of *Fusarium* species

Occurrence of mycotoxins in UK cereals

Levels of mycotoxins in cereals were assessed in HGCA- and FSA-funded work across the UK.

The most common *Fusarium* mycotoxins of concern are deoxynivalenol (DON) and zearalenone (ZON). There are legal limits for these mycotoxins in grain intended for human consumption. HT-2 and T-2 are also found in cereals and legal limits are under consideration.

Average results for DON and zearalenone in wheat are shown in Figures 2 and 3 (data from HGCA project 3573). DON and ZON levels in barley and oats have been routinely low.

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.

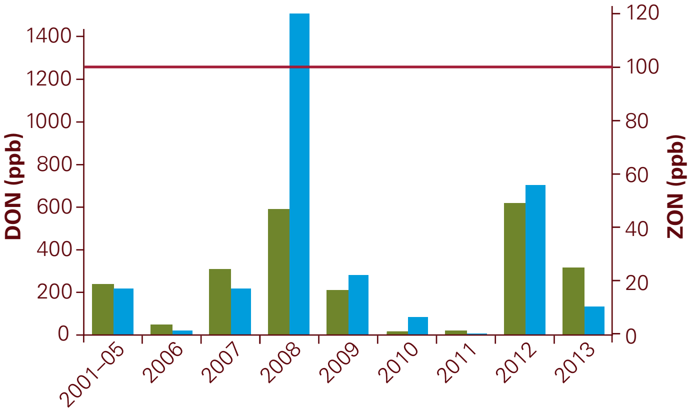


Figure 2. Average DON and ZON concentration in ex-combine wheat samples.

Red bar indicates maximum permitted levels of DON (1,250 ppb) and ZON (100 ppb) for unprocessed wheat intended for human consumption.

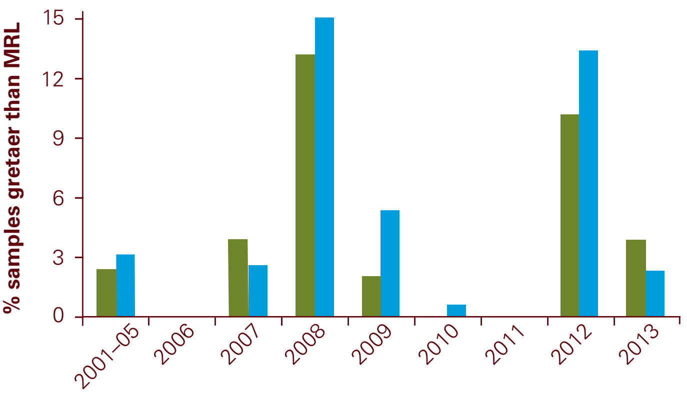


Figure 3. Percentage of ex-combine wheat samples exceeding 1,250 ppb DON and 100 ppb ZON maximum regulatory limits (MRL).

Barley

In general, barley had very low levels of DON and ZON compared to wheat and legal limits were not exceeded (2001 to 2009 data).

Oats

The predominant *Fusarium* species that infect oats produce the mycotoxins HT-2 and T-2. Ongoing research is investigating the risk factors associated with mycotoxins in oats.

There is good evidence that at least 90% of mycotoxins are removed during de-hulling. In 2003, a FSA survey of *Fusarium* mycotoxins in retail oat products concluded "exposure to these toxins from this group in the UK diet is very low".

Maize

In the UK, crop debris from maize grown for silage or grain can be a significant source of *Fusarium* inoculum for following small grain cereal crops.

Control of *Fusarium* in wheat

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

Fungicides can provide control at various stages of the disease's life cycle:

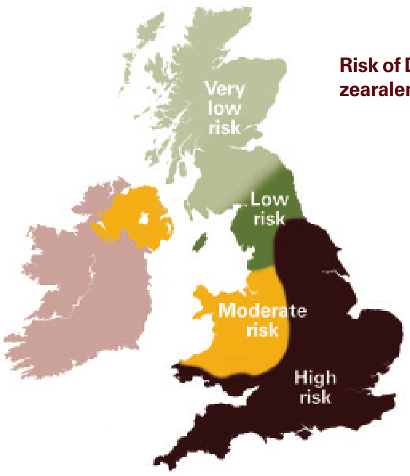
1. Seed treatment: the main method of controlling seedling blight.
2. T1 fungicides: control stem-base disease, but not appropriate if only *Fusarium* is present.
3. Effective T3 fungicides (eg dimoxystrobin, metconazole, tebuconazole or prothioconazole): specifically control *Fusarium* head blight and other diseases (see **Wheat disease management guide**).

HGCA-funded research has indicated that:

– using azoles at half to full rate significantly reduced 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.

Assessing mycotoxin risk in wheat

The risk factors	Importance
Previous cropping and crop residues	
Crop residue on the soil surface is the major source of head blight inoculum, especially after (in descending order) grain maize, forage maize, wheat or potatoes. Rotation helps to reduce overwintering inoculum by lowering levels of infected crop debris on the soil surface. Cultivation should effectively bury infected crop debris. **– Plan rotation to minimise wheat after maize.** **– Remove straw to help reduce crop debris.**	**High risk** Grain or forage maize **Moderate risk** Wheat, potatoes **Low risk** Others
Cultivations	
The aim of cultivations is to effectively bury crop debris. **– Ensure crop debris is buried by ploughing.** **OR** **– Cultivate to mix crop debris into the upper soil layer.**	**High risk** 'Min-till' or 'no till' **Low risk** Plough
Region	
In wheat, levels of DON and zearalenone tend to be lower in northern England and Scotland; moderate in western England, Wales and Northern Ireland and highest in southern and south-eastern England. Evidence suggests that higher humidity in coastal areas may increase risk. The risk of *Fusarium* mycotoxin occurrence in individual crops will be increased in a year with high head blight nationally. Annual variations in *Fusarium* inoculum and head blight disease levels in wheat, reported as part of the **CropMonitor** (www.cropmonitor.co.uk) project, can be used to assess overall risk on a yearly and regional basis. Preliminary evidence suggests that HT-2 and T-2 levels are similar across all UK regions. 	**See map**
Weather	
Early season (sowing to around GS31) conditions influence the build-up of inoculum. Warm, dry weather poses the highest risk.	**High risk** Warm and dry **Low risk** Cold and wet
During flowering (GS59-69) crops are particularly susceptible to severe head blight infection. Further rainfall after infection, particularly after ripening, allows secondary infection. **– Consider 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 this period.**	**High risk** Warm and wet **Low risk** Cold and dry
At harvest, *Fusarium* mycotoxins may increase if wet weather causes delays. **– Prepare before harvest to minimise delays.** **– Harvest grain as soon as possible once ripe.** **– Harvest and store separately grain from localised patches of weathered or lodged crops.** **– Measure rainfall as accurately as possible during this period.**	**Moderate risk** Rain-delayed harvest

Mycotoxin levels in grain vary from year to year and between regions. The key factors affecting likely risk in wheat are: preceding crop, crop residues, variety, agronomy, and weather at flowering and harvest.

The risk factors	Importance
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. – **Consider head blight resistance in choice of winter wheat varieties from the HGCA Recommended List.**	**Moderate risk** Wheat varieties with rating 5 and below **Low risk** Wheat varieties with rating 6 and above
Lodging	
Lodging causes humid conditions conducive to mycotoxin production. – **Consider a PGR application at the appropriate dose and timing.**	**Moderate risk** Lodged crops **Low risk** Standing crops
Harvest	
The highest concentrations of mycotoxins are found in *Fusarium*-damaged grains and chaff. – **Set combine, especially fan speed, to minimise retention of light *Fusarium*-damaged grains and chaff.** – **Combine and store weathered or lodged crop areas separately where possible.**	**Moderate risk** Damaged grain Delayed harvest
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.	

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.

Grain that could be contaminated

must be stored separately from other cereals intended for human consumption.

– **Test suspect samples for *Fusarium* mycotoxins.**

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.**

Sampling and legal limits

Assessing your level of risk

Table 1. The risk to your winter wheat crop

Factor	Details	Risk	Score
Region (see map)	High	4	
	Moderate	2	
	Low	-2	
	Very low	-4	
Previous crop	Maize	6	
	Other	0	
Cultivation	Direct-drilled	4	
	Standard non-inversion tillage	3	
	Intensive non-inversion tillage	2	
	Plough (soil inversion)	0	
Wheat variety	RL resistance rating 1–5	1	
	RL resistance rating 6–9	0	
	RL resistance rating unknown	1	
	Pre-flowering score		
T3 fungicide	<50% dose rate of approved fungicide	0	
	50–74% dose rate of approved fungicide	-2	
	75% or above dose rate of approved fungicide	-3	
Rainfall at flowering (GS 59–69)	More than 80 mm	9	
	40–80 mm	6	
	10–40 mm	3	
	Less than 10 mm	0	
Rainfall pre-harvest (GS 87 to harvest)	More than 120 mm	12	
	80–120 mm	9	
	40–80 mm	6	
	20–40 mm	3	
	Less than 20 mm	0	
		Total score	

Risk	Total score
High	**Over 15**
Medium	**10–15**
Low	**Under 10**

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 HGCA and local merchants provide further information on the levels of mycotoxins in particular areas each year. See **www.hgca.com/mycotoxins** for more information.

Implications for sampling

It is good practice to sample every trailer load coming into a store, taking samples of at least 1kg. Composite samples, representing a given bulk, can be obtained by thoroughly mixing individual samples. Such samples are used for a range of purposes including moisture and quality assessments.

Effective sampling for mycotoxins is essential as the distribution is not likely to be uniform within a stored bulk. If composite samples were not obtained as the store was loaded, it is important to take as many sub-samples of the bulk as possible to obtain a representative aggregate sample.

For official control purposes, one hundred incremental 100g sub-samples are taken from any lot exceeding 20 tonnes (Commission Regulation 401/2006).

Table 2 shows legal limits for *Fusarium* mycotoxins in cereals intended for human consumption. 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.

Legal limits for *Fusarium* mycotoxins do not currently apply for grain fed to animals. However, EU guidance values were introduced in 2006 (Table 3).

Table 2. Legal limits for mycotoxins (ppb) in grain intended for human consumption

	DON	Zearalenone
Unprocessed wheat and barley	1,250	100
Unprocessed oats	1,750	100
Flour	750	75
Finished products	500	50
Infant food	200	20

Table 3. EU guidance values for mycotoxins (ppb) in grain intended for animal feedstuffs

	DON	Zearalenone
Feed grains	8,000	2,000
Complete feedstuffs for:		
– pigs	900	250 (100*)
– calves, lambs and kids	2,000	500

* Applies to piglets and gilts

Testing

Testing methods

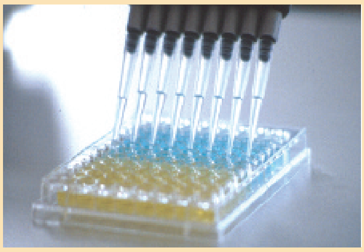
Methods range from simple on-farm tests indicating the presence/absence of a specific mycotoxin, to officially-recognised and validated methods quantifying any levels present. For all methods prior extraction from a ground sample of grain is needed.

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, similar to the qualitative method, is suitable when a single determination is required, eg grain storage/intake (typically £15–£24 per test).

Micro-titer plate ELISA measures the intensity of colour produced by chemical reactions and is suitable for analysing multiple samples (typically £30 per test).



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 (over £100/test).

Testing records should be kept for at least two years.

Examples of DON test kits

Test supplier	Charm Sciences	Neogen Corporation	R-Biopharm Rhone	Romer Labs
Qualitative test	*Rosa® DON P/N	*RevealQ+® for DON	RIDA®QUICK DON	N/A
Quantitative test	Rosa® DON Quantitative	Veratox®5/5	RIDASCREEN® Fast DON	AgraQuant® DON
Contact details	www.charm.com UK agent: Calibre Control International Ltd www.calibrecontrol.com Asher Court Lyncastle Way Appleton Warrington WA4 4ST Tel: 01925 860401 info@calibrecontrol.com	www.neogeneurope.com Cunningham Building Auchincruive Ayr KA6 5HW Tel: 01292 525 275 info@neogeneurope.com	www.r-biopharmrhone.com West of Scotland Science Park Unit 3.06 Kelvin Campus Glasgow G20 0SP Tel: 0141 945 2924 info@r-biopharmrhone.com	www.romerlabs.com Tel: 0845 519 50 10 enquiry@romerlabs.com

* Semi-quantitative

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Disclaimer

HGCA information

HGCA publications and details of HGCA-funded projects are all available on the HGCA website – **www.hgca.com**

For all HGCA's relevant publications, tools, videos and further information, please see **www.hgca.com/mycotoxins**

HGCA Publications

IS29 HGCA risk assessment for *Fusarium* mycotoxins in wheat (2014)

IS27 Fungicide activity and performance in barley (2014)

IS26 Fungicide activity and performance in wheat (2014)

G60 HGCA Grain sampling guide (2013)

G59 HGCA Barley disease management guide (2013)

G58 HGCA Wheat disease management guide (2013)

G52 HGCA Grain storage guide for cereals and oilseeds, 3rd edition (2011)

G41 The encyclopaedia of cereals diseases, HGCA/BASF (2008)

HGCA Project Reports

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)

PR477 Improving risk assessment to minimise *Fusarium* mycotoxins in harvested wheat grain (2011)

PR459 Monitoring risks of mycotoxin contamination caused by *Fusarium* head blight pathogens in winter wheat (2009)

PR432 Understanding the basis of resistance to *Fusarium* head blight in UK winter wheat (2008)

SR08 *Fusarium langsethiae* infection and mycotoxin production in oats (2008)

Current HGCA-funded projects

3453 Integrated strategy to prevent mycotoxin risks (Inspyr)

3573 Improved modelling of *Fusarium* to aid mycotoxin prediction in UK wheat

3574 *Fusarium* mycotoxins in UK oat varieties – monitoring in preparation for legislation

3779 Monitoring of mycotoxins and other contaminants in UK cereals used in malting, milling and animal feed

Other information

CropMonitor www.cropmonitor.co.uk

Food Standards Agency
www.food.gov.uk

Code of Good Agricultural Practice for the reduction of mycotoxins in UK cereals
http://multimedia.food.gov.uk/multimedia/pdfs/mycotoxincop2007.pdf

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/index_en.htm

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
http://eur-lex.europa.eu/legal-content/AUTO/?uri=CELEX:02006R0401-20100313&qid=1396518749773&rid=1