



The UK Code of Good Storage Practice to Reduce Ochratoxin A in Cereals

Please note that this document will be updated periodically.

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Contents

1. Key Messages	3
2. Introduction to Mycotoxins	4
3. Ochratoxin A	5
3.1. Important Factors for the Reduction of Ochratoxin A	5
3.2. European Legislation on Ochratoxin A	6
4. Risk Assessment	7
5. Good Storage Practice	8
5.1. Good Store Design and Condition	9
5.2. Good Harvest and Store Hygiene	9
5.3. Timely Harvest	9
5.4. Adequate Drying Capacity	9
5.5. Rapidly Dry Grain	9
5.6. Rapidly Cool Grain	10
5.7. Continued Drying	11
5.8. Continued Cooling	11
5.9. Monitor Temperature and Moisture Content	11
5.10. Monitor Insect and Mite Activity	11
6. Testing Grain for Ochratoxin A	12
7. Organic Cereal Production	12
8. Other Quality Parameters	12

1. Key Messages

- Mycotoxins are chemicals hazardous to human and animal health, produced by certain fungi.
- Ochratoxin A can be produced in cereal grain during storage.
- The major source of dietary intake of ochratoxin A are products made from cereals.
- Legislative limits for ochratoxin A in unprocessed cereals and cereal products exist to protect public health.
- Grain temperature and moisture content are critical storage factors that affect ochratoxin A production.
- Effective management of grain temperature and moisture content can reduce the risk of ochratoxin A contamination.
- Good Storage Practice is the primary mechanism to reduce ochratoxin A in cereals and cereal products.
- Good storage practice to reduce the risk of ochratoxin A includes:
 - Good store hygiene and maintenance
 - Rapid drying of grain to below 18% moisture content
 - Rapid cooling of grain
 - Maintaining grain at low moisture content
 - Continued monitoring of grain

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 health of humans and animals even at low concentrations.

The most common mycotoxins of concern in UK cereals are 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 crops in store.

Legislation was introduced in 2002 that set maximum limits for ochratoxin A in cereals and cereal products for human consumption. As ochratoxin A is produced in storage, Good Storage Practice is the primary mechanism to reduce ochratoxin A entering the food chain.

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 is intended to provide information to help growers to perform a risk assessment for ochratoxin A. Growers should perform a risk assessment at harvest to identify which crops are at risk from ochratoxin A contamination. This Code of Practice also advises growers how they can reduce the risk of ochratoxin A by using Good Storage Practice.

It is important to note that this Code of Practice specifically deals with Good Storage Practice to reduce ochratoxin A. Good Storage Practice for other quality parameters are not detailed in this code and for advice on these issues growers should consult general grain storage literature such as the HGCA Grain Storage Guide.¹

¹http://www.hgca.com/cms_publications.output/2/2/Publications/Publication/Grain%20Storage%20Guide%20-%202nd%20Edition.msp?fn=show&pubcon=820

3. Ochratoxin A

Ochratoxin A has been shown to damage, and cause cancer of, the kidneys in laboratory animals. The European Food Safety Authority (EFSA) recently assessed ochratoxin A, and established a Tolerable Weekly Intake (TWI) of 120 ng/kg bodyweight.

Ochratoxin A can be produced by a number of fungi such as *Aspergillus* species and *Penicillium verrucosum* in a range of crop commodities worldwide. In UK cereal production, *Penicillium verrucosum* is believed to be the sole species responsible for ochratoxin A production. *Penicillium verrucosum* is only rarely found on cereals in the field and ochratoxin A is not found on crops of cereals in the field. However, this fungus is readily found in cereal grain stores and can accumulate on old grains and dust remaining in stores and machinery from the previous harvest. During harvesting, transportation and entry into store, freshly harvested grain can become contaminated with this fungus.

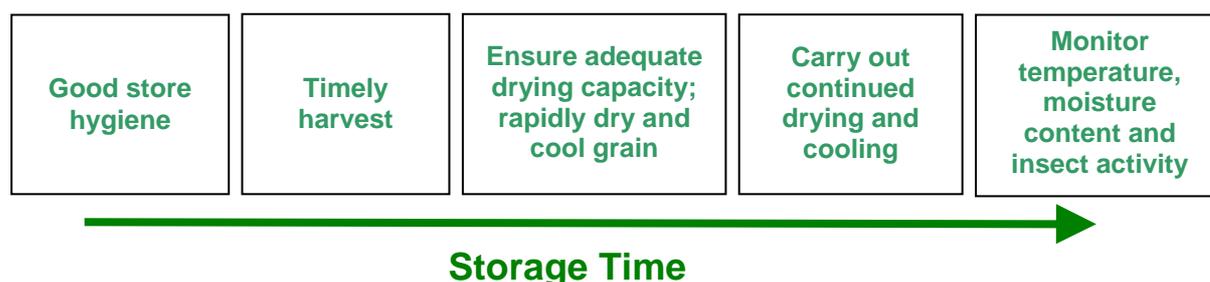
As for all micro-organisms, *Penicillium verrucosum* has a specific range of conditions required for growth. The temperature and moisture requirements for this fungus to grow and produce ochratoxin A are particularly relevant to grain storage. The availability of water to micro-organisms is measured by water activity (A_w). The water activity of pure water is 1.0; at a constant moisture content the availability of water drops as the temperature drops. Consequently, cooling grain not only reduces fungal activity due to lower temperatures but it also reduces fungal activity by reducing the availability of water.

The optimum conditions for *Penicillium verrucosum* production of ochratoxin A is 0.95 water activity (about 24% moisture content) and 20°C. The cooler and drier the conditions then the slower the rate of ochratoxin A production. The minimum temperature for ochratoxin A production is about 3°C and the minimum water activity is 0.80 (about 18% moisture content at 20°C). Further details can be found in Section 4.

The main contributors to the dietary intake of ochratoxin A are cereals and cereal products. European legislative limits were introduced for cereals and cereal products in 2002 to protect human health.

3.1. Important Factors for the Reduction of Ochratoxin A

The ochratoxin A content of cereals can be reduced by addressing the following important issues:



3.2. European Legislation on Ochratoxin A

To ensure the safety of food consumed the European Commission introduced maximum legal limits for ochratoxin A in dried vine fruit, cereals and cereal-based products in 2002. Coffee, grape juice and wine have since been included (Commission Regulation (EC) 1881/2006¹). Maximum levels were set based on the current human exposure in relation to the safety guidelines for ochratoxin A, taking into account what can be reasonably achieved following good practices at all stages of production.

Maximum limits for ochratoxin A in raw cereal grain and finished products intended for human consumption

Product	Ochratoxin A (ppb)
Unprocessed cereals	5.0
All products derived from unprocessed cereals (including processed cereal products and cereals intended for direct human consumption)	3.0
Processed cereal-based foods and baby foods for infants and young children	0.5

The maximum levels set for raw cereals apply to cereals placed on the market for processing. Processing can reduce the mycotoxin content of some cereal products; limits for processed products are therefore lower. Cereal grains may have been cleaned, dried and/or sorted prior to being placed on the market; these grains are still classified as raw cereals.

Maximum levels are set on raw cereals to avoid highly contaminated cereals entering the food chain and to encourage all measures to minimise ochratoxin A contamination to be taken in the early stages of the production chain.

The limits for ochratoxin A 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 has also set guideline limits for ochratoxin A in animal feed.² The guideline limit for ochratoxin A in cereal and cereal product feed materials is 250 ppb, in addition lower limits for complementary and complete feedingstuffs for pigs and poultry have been set at 50 ppb and 100 ppb respectively.

¹ http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_364/l_36420061220en00050024.pdf
This Regulation applies from 1/03/2007, and replaces Commission Regulation (EC) 466/2001 (http://eur-lex.europa.eu/LexUriServ/site/en/oj/2005/l_025/l_02520050128en00030005.pdf)
² <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:229:0007:0009:EN:PDF>

4. Risk Assessment

Ochratoxin A can occur in wheat, barley and oats. All areas of the UK are at risk from ochratoxin A formation in stored cereal grains.

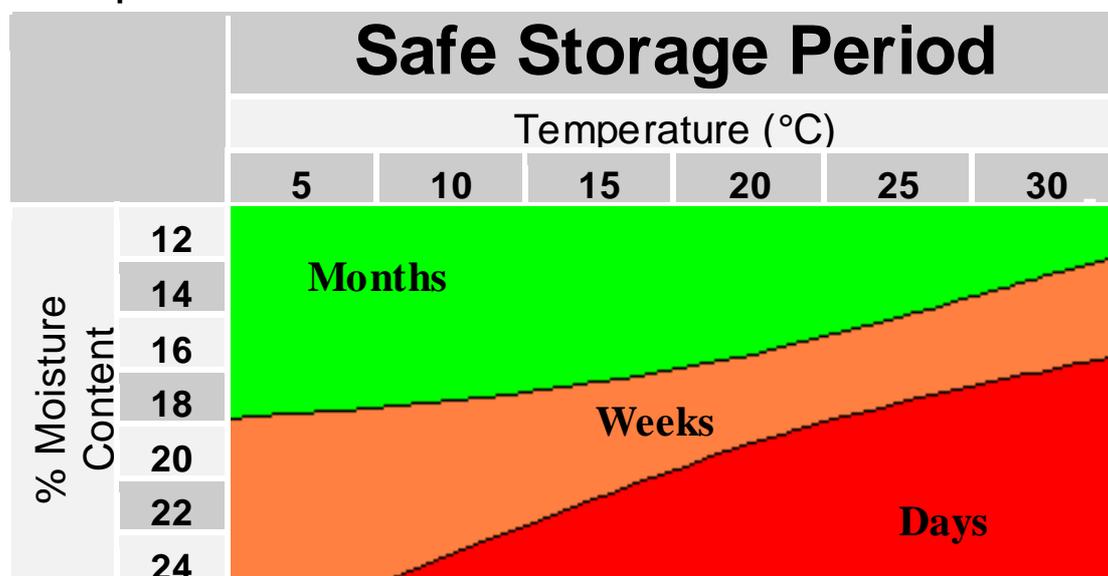
Risk of a harvested crop exceeding the legal limit for ochratoxin A is dependent on the presence of *Penicillium verrucosum* and environmental conditions conducive to ochratoxin A production (*i.e.* moisture and temperature). As *Penicillium verrucosum* is routinely found in grain stores it should be assumed to be present and a risk assessment performed based on temperature and moisture content.

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.

The figure below indicates the period of time that grain can be safely stored at a range of temperature and moisture conditions. The figure clearly demonstrates that if damp grain cannot be dried promptly, then cooling the grain can extend the safe storage period until damp grain can be dried.

As storage conditions change over time it is more accurate to use a computer model such as the HGCA Safe Storage Time Calculator¹ which predicts safe storage time for stored grain based on moisture content and temperature measured over time. If grain is stored longer than the predicted safe storage period it should be tested for ochratoxin A.

Ochratoxin A safe storage period for grains at a range of temperatures and moisture contents



Note: This storage period does not account for time taken to reach these conditions. This is the safe storage period for grain at risk from ochratoxin A contamination. Other storage problems, such as insect infestation can lead to shorter safe storage periods.

¹ <http://www.hgca.com/content.output/996/996/Tools/Tools/Safe Storage Time Calculator.msp>

5. Good Storage Practice

The amount of ochratoxin A present in stored grain is dependent on the amount of *Penicillium verrucosum* present and storage conditions. Cleaning of stores and equipment reduces the amount of *Penicillium verrucosum* that can transfer to newly stored grain. If grain is rapidly dried to below 18% moisture content, then further dried to 15% moisture content and maintained below this level then the risk of ochratoxin A contamination is reduced. If conditions are not conducive to bulk drying of grain or there is a backlog of damp grain to be dried using a hot-air drier then grain should be cooled to increase the safe storage period until the grain can be dried.

Good Storage Practice	Impact
Good Store Design and Condition Ensure stores are well designed and maintained	High
Good Harvest and Store Hygiene Clean harvest and store machinery	High
Timely Harvest Service and maintain equipment	High
Adequate Drying Capacity Ensure adequate drying capacity is available	High
Rapidly Dry Grain Rapidly dry grain to below 18% moisture content	High
Rapidly Cool Grain Rapidly cool grain to below 15°C	High
Continued Drying Dry to 15% moisture content for long-term storage	Medium
Continued Cooling Cool grain in winter months to below 5°C	Medium
Monitor Temperature and Moisture Content Continue monitoring temperature and moisture content	Low
Monitor Insect and Mite Activity Use traps and sieving to monitor insects and mites	Low

5.1. Good Store Design and Condition

High

Stores should be designed with adequate drying capacity for the volume of grain held. Stores should have adequate head space and ventilation to avoid re-absorption of moisture by dried grain at the surface.

Perforations in ducts/flooring should be kept clean to ensure adequate airflow.

Stores should be maintained in good order to ensure that water/moisture is prevented from entering the store. At high moisture content grain can become visibly mouldy. Grain with visible mould is likely to have a very high mycotoxin content and should be removed and disposed of safely.

5.2. Good Harvest and Store Hygiene

High

Penicillium verrucosum survives between crops on grain and dust remaining on machinery and in stores. Efficient cleaning of machinery and stores will reduce the “carry over” of this fungus between seasons. Machinery and stores should be cleaned thoroughly at the end of use each season, this will minimise the multiplication of *Penicillium verrucosum* between seasons.

Levels of dust in the environment should be minimised during all grain operations, including cleaning, as this will minimise deposits of dust in store and reduce hazards to operator health. HSE guidelines should be followed to minimise operator exposure to dust.¹

5.3. Timely Harvest

High

Harvest capacity should match the acreage to be harvested and machinery should be maintained in good order to avoid delays.

5.4. Adequate Drying Capacity

High

The drying capacity on farm should equal the harvest capacity to avoid a backlog of grain held at high moisture content (>18%). For bulk drying, the storage capacity should match acreage without having to exceed the grain depth which can be dried quickly (See Section 5.5 on **Rapidly Dry Grain** below)

5.5. Rapidly Dry Grain

High

Grain should be rapidly dried to below 18% moisture content to minimise the risk of ochratoxin A occurrence in storage.

For hot-air drying:

Hot air drying is a low risk system as grain can be quickly dried and drying time is independent of weather. Care must be taken not to overheat grain. Drying temperature should be set according to manufacturer’s instructions to meet end-user specifications.

¹ <http://www.hse.gov.uk/pubns/ais3.pdf>

For bulk drying:

Bulk grain can be dried in store using dry ambient air. Drying time is dependant on weather conditions although drying time can be reduced by using additional heat (about 5°C above ambient).

It is important that grain does not enter a store at a moisture content that cannot be dried to below 18% moisture content within days. Time required will depend on the moisture content of grain entering store, the weather conditions, the availability of additional heating, the airflow capacity of the fan and the depth of grain.

The most efficient drying procedure is to run the fan continuously and provide additional heat when the relative humidity is above 70-80%

Grain depth is important in bulk drying as drying occurs in a layer which progresses through the grain (the drying zone). The deeper the grain then the slower the air flow and hence slower the drying zone moves. Also, the deeper the grain then the further the drying zone must move to reach the grain at the surface. An airflow of at least 180 m³/hour/tonne is recommended.

Grain depth should be based on fan capacity and availability of added heat. Grain depth should be reduced when grain entering store has high moisture content (>20% moisture content).

The grain surface should be levelled so that grain depth is uniform.

Grain stirrers can be used to increase airflow and mix grain from different drying zones. This reduces the time taken for all grain to be dried below 18% moisture content and therefore reduces risk of ochratoxin A production occurring near the surface.

The HGCA Project Progress 13 provides further details on bulk drying strategies to reduce ochratoxin A risk.¹

5.6. Rapidly Cool Grain

High

For hot-air drying:

Grain should be cooled back to near-ambient temperature after hot-air drying.

For bulk drying:

Cool night time temperatures should be used to cool grain. An airflow of 10 m³/hour/tonne is recommended for cooling grain. Grain is quickly cooled when ambient air temperature is at least 5°C below grain temperature. Further details on grain cooling are contained in the HGCA Topic Sheet 78.²

If conditions are not conducive for bulk drying of grain then the safe storage period for grain can be extended by cooling grain.

¹ http://www.hgca.com/document.aspx?fn=load&media_id=2783&publicationId=3300

² http://www.hgca.com/document.aspx?fn=load&media_id=794&publicationId=1303

5.7. Continued Drying

Medium

Grain should be dried to below 15% moisture content for long-term storage. Although ochratoxin A production does not occur below 18% moisture content it is important to store grain below 15% moisture content to reduce insect and mite activity as these store pests generate heat, moisture and damaged grain providing conditions for *Penicillium verrucosum* growth.

5.8. Continued Cooling

Medium

Growers should continue to cool grain in winter months. Lower temperatures reduce the activity (directly and by lowering the water availability) of *Penicillium verrucosum*, mites and insects.

5.9. Monitor Temperature and Moisture Content

Low

Temperature and moisture content should be frequently monitored at several depths until these have stabilised for long-term storage. Grain should then be monitored regularly and any problems acted on immediately. There are several aids available to help monitor and record storage conditions. These include the HGCA Safe Storage Time Calculator¹ which uses temperature and moisture content data collected over time to calculate the safe storage period of cereals in store; and the HGCA GrainPlan² store management software. Both aids provide warnings as to potential risks and provide necessary actions to remove the risks.

5.10. Monitor Insect and Mite Activity

Low

Insect and mite activity generates heat, moisture and damaged grain providing conditions for fungal activity. Insect and mite populations should be monitored using traps and/or grain sieving and controlled where necessary.

¹ [http://www.hgca.com/content.output/996/996/Tools/Tools/Safe Storage Time Calculator.msp](http://www.hgca.com/content.output/996/996/Tools/Tools/Safe%20Storage%20Time%20Calculator.msp)

² <http://www.hgca.com/content.output/1248/1248/Resources/Tools/GrainPlan%20CD.msp>

6. Testing Grain for Ochratoxin A

You should consider testing grain for ochratoxin A if any of the good storage practices have been compromised. Diagnostic test kits are available; these allow growers to perform an on-site assessment of their grain. Alternatively, grain samples can be sent for analysis by a laboratory.

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 low weight samples from a single lot of grain are collected and mixed to form a composite sample. For further information on sampling, please see the HGCA grain sampling guide.¹

Using results from mycotoxin analysis, grain should be marketed accordingly, based on legislative and guideline limits detailed in 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 ochratoxin A. It is prohibited to mix products complying with the maximum levels with products known to exceed the maximum levels.

7. Organic Cereal Production

Methods detailed in this Code of Practice are appropriate for organic cereals. The Soil Association has published a technical guide which covers all aspects of storing organic combinable crops.²

8. Other Quality Parameters

This Code of Practice is specifically targeted at reducing ochratoxin A in cereal production. Other aspects of cereal production, in particular maintaining other end-user quality parameters are not covered. Users should consult other documentation such as the HGCA Grain Storage Guide³ to identify Good Storage Practice for storage issues other than reducing ochratoxin A.

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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 at Harper Adams University College.

¹ http://www.hgca.com/cms_publications.output/2/2/Publications/Publication/Grain%20sampling%20-%20a%20farmers%20guide.aspx?fn=show&pubcon=1261

² <http://www.soilassociation.org/web/sa/saweb.nsf/5f473da5a76ca15b80256b4400428a12/d1ea6ab170abb86d80256bf90034eb78!OpenDocument>

³ http://www.hgca.com/cms_publications.output/2/2/Publications/Publication/Grain Storage Guide - 2nd Edition.aspx?fn=show&pubcon=820