Mycotoxins, Climate Change and Food Safety Workshop Report

Food Standards Scotland

Pilgrim House, Aberdeen

15 December 2015

13:00 – 17:00

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Introduction

Mycotoxins are toxic compounds produced by different types of fungus which can become an issue particularly when temperature and moisture conditions are favourable. They can enter the food chain through contaminated food and feed crops and consequently cause adverse health effects including cancer, gastrointestinal and kidney disorders as well as reducing resistance to infectious disease.

Much research has been carried out on mycotoxin risks and both domestic and EU guidance exists to encourage good practice, however there are still evidence gaps and little is known about the potential for climate change to influence the types, levels and incidence of mycotoxins in the future.

The European Commission has indicated that it is keen to engage with Member States on this issue and on 2 December 2015 the Food Standards Agency held a workshop on mycotoxins and Climate Change in London, which Food Standards Scotland attended.

In order to explore any Scotland-specific issues and provide an opportunity for Scottish researchers and industry to discuss this issue, Food Standards Scotland arranged this workshop in Aberdeen, attended by 9 researchers and 2 industry representatives.

This report will now be submitted to FSA for inclusion in their report and so will help form the UK position for on-going discussions on mycotoxins and climate change in the EU.

EU Legislation

EC Regulation 1881/2006/EC (as amended) regulates chemical contaminants in food laying down maximum levels (MLs) for contaminants including the following mycotoxins - aflatoxins, ochratoxin A, patulin, deoxynivalenol (DON), zearalenone (ZON), fumonisins and citrinin.

EC Directive 2002/32/EC (as amended) regulates undesirable substances in animal feed, laying down maximum permitted levels (MPLs) for aflatoxin B1. This is an acute toxin and genotoxic carcinogen which can also contaminate milk through contaminated feedstuffs.

EC Recommendation 2013/165/EU sets ‘indicative values’ for T-2 and HT-2 toxin in cereals and cereal product foods and EC Recommendation 2006/576/EC sets ‘guidance values’ in feed for deoxynivalenol, zearalenone, ochratoxin A and fumonisins B1 & B2. These values are not maximum levels but are intended to trigger data gathering and further investigation in order to mitigate factors which may cause higher levels.

With thanks to all those who attended the workshop:

Valerie Cockerell	SASA
Ruth Falconer	Abertay University
Silvia Gratz	University of Aberdeen
Archi Lamont	Scottish Quality Crops
Marian McEwan	SASA
Jessica Neal	Diageo (by TC)
Adrian Newton	James Hutton Institute
Karen Scott	University of Aberdeen
Derek Stewart	James Hutton Institute
Ian Toth	James Hutton Institute
Will Munro	FSS
Jacqui McElhiney	FSS
Josep Campins	FSS
Jacqui Angus	FSS
Claire Moni	FSS

Discussion sessions:

Which mycotoxins are of concern in Scottish agriculture and which mycotoxins may be expected to emerge?

Background – current situation

In Scotland, as well as some wheat production, the main cereals grown are barley (mainly for malting) and oats (for food & feed) – known as 'minor grains'. Other crops such as oilseed rape where mycotoxin risk is more likely related to the presence of *Alternaria* fungi are commercially important for both food and feed in Scotland but tend to be regarded as of a lower concern at the moment. Forage crops such as silage, hay and straw are also susceptible to mycotoxin risk.

The main mycotoxin producing fungi and toxins of concern in the field in Scotland (& the rest of the UK) are *Fusarium spp* which cause *Fusarium* head blight, producing primarily DON (deoxynivalenol) & ZON (zearalenone). In stored grain the fungi *Penicillium spp* and *Aspergillus spp* produce primarily aflatoxins & ochratoxins. Infection is more likely to be concentrated in outer layers of grain (husk) but mycotoxins can be expressed in any part of the grain. Research has shown that wheat tends to show higher contamination than barley - a survey of wheat and barley undertaken by Scotland' s Rural College (SRUC) found an incidence of *Fusarium* of 30-40% in wheat samples with DON the prevalent toxin; whereas incidence in barley was around half this level; barley also had consistently lower concentrations of mycotoxins than wheat. Although there are no legislative levels set for T-2 and HT-2 toxins, Scottish oats tend to have higher levels than in the rest of the UK.

Mycotoxin producing fungal infection is highly heterogeneous, varying widely between & within fields, and also over time with spikes of infection occurring during certain periods which makes the assessment of food safety risk problematic.

Different species or strains may also be introduced through imported grain for food/feed and as seed. Annual seed surveys undertaken by Science and Advice for Scottish Agriculture (SASA) have recorded a higher incidence of *Fusarium graminearum* and *F. lansethiae* in cereals in the last 5 years. The increase in *F. graminearum* is most likely linked to an increase in the area of maize being grown in the UK. Maize seed is also imported (mostly from Europe) into Scotland and the rest of the UK (mainly for feed) and some analyses have shown raised levels of T2 and DON in imported grain.

Mycotoxins are robust molecules and are generally resistant to denaturing by heat & different pH levels; they can pass into fermented products such as beer but not into distilled products such as whisky.

Industry requirements vary, with distillers preferring low protein barley varieties and feed manufacturers higher protein varieties. A particular concern for malting brewers/distillers is fungal contamination of grain which alters the quality and flavour characteristics of the final product.

Since fungi tend to infect the outer layers of the grain mycotoxin production can also affect feed manufacturers in Scotland. Around 90% of spent distillers' grain goes for animal feed, which in its 'raw' condition can be susceptible to mycotoxin contamination accumulated by fungal activity during storage.

Climate change has led to more sudden, less predictable weather events and altered temperatures and rainfall levels. There is potential for current fungal species to become more prevalent, for other species to be introduced or strains evolve; and for the rapid proliferation of infection.

Issues and risks

New fungal strains

Likelihood of different fungal strains becoming established due to favourable weather conditions and the possibility of new strains developing (including soil-borne fungi becoming air-borne and more virulent).

Mycotoxin expression

The relationship between fungal infection and toxin levels is uncertain. Mycotoxin levels cannot be inferred from fungal infection levels and mycotoxin levels can vary widely for the same level of infection.

Mycotoxin occurrence data

There appears to be a lack of baseline data on mycotoxin occurrence in Scotland at field, processor and retail level. Industry does carry out testing on farm (by buyer) and at intake (processor) but the focus tends to be on grain quality rather than mycotoxins *per se,* although the Malting Association of Great Britain has trend data from due diligence testing over the last 5 years (http://www.ukmalt.com/mycotoxins). A small amount of sampling for mycotoxin testing is carried out by Local Authorities but this is mainly focussed on imports with very little enforcement sampling undertaken of domestic grain or retail product.

Sampling methods

Achieving representative samples is a longstanding technical issue given the particulate nature of crops and the heterogeneity of fungal infection. The common industry method is dipstick testing which is sufficient for quality parameters such as protein and moisture content but not for mycotoxin assessment. The wide geographical spread of grain production also means that, unless obtained directly from the farm, grain is often bulked and mixed in store making sampling at this point useless for identifying the infection source.

Masked mycotoxins

'Masked' mycotoxins are formed as the plant's response to detoxify the toxins produced fungal infection by glucosylation; however this process can be reversed in the gut with the molecule reverting to its toxic form. Masked mycotoxins are not detectable by routine analytical methods and are currently not accounted for in the legislation. Little is known of what triggers the production of masked mycotoxins and there is a risk that crops and/or strains which appear resistant may simply be more efficient at converting toxins into masked mycotoxins as is known to be the case with barley.

Fungicide efficacy

Fungicides are available that can reduce infection rates in the field and in storage. It is likely, however, that some of these will be withdrawn from the market in future due to revised risk assessments and pressure to reduce the use of chemicals in the environment. Their efficacy may also be reduced by the evolution of resistant fungal strains.

New pests and diseases

It is likely that new pests and diseases will arise due to climate change and the plant damage that they cause can increase the likelihood of infection of crops with mycogenic fungi.

Potential mitigation approaches

Crop rotation

Crop rotation practices can reduce the risk of fungal infection, removing crop waste stubble as a source of infection and lowering the infectious fungal soil load. Practices may include longer rotations, avoiding consecutive planting of grain crops and avoiding planting adjacent fields with the same grain crop.

Mixed crops

Growing mixtures of different varieties of the same crop or different crops in the same field could limit the spread of fungal spores within the field, since each fungus is crop specific and different plants will have different levels of resistance. Mixed-variety plantings have also been shown to increase crop yield. One drawback of this technique is that whisky & flour/food producers especially prefer to select single varieties due to flavour and grain processing considerations whereas this is less of an issue for feed producers. Although not currently feasible for grain crops where the ears are intermingled, a potential future solution could be to explore the use of precision harvesting technology which is now becoming available and is capable of cropping of individual rows.

Harvest timing

Grain should be harvested at its optimum ripeness since grain which is past this point is more susceptible to fungal infection. It is also important when mixing grains to select those with the same maturity to minimise the risk of cross-contamination.

Cover crops

Inter-planting of cover crops within the main grain crop could help to reduce the spread of fungal spores and crop infection rates.

Farming techniques

There is some evidence (from the UK and Norway on barley, oats & wheat) that organic crops may be less susceptible to infection. The science behind these findings is uncertain but it has been postulated that factors involved could include the different agricultural practices employed such as longer crop rotations, minimum tillage and the use of different varieties with more natural resistance. Further work would therefore be required to verify these findings and how they translate to mycotoxin risk. It is also important to note that this work did not examine the potential for masked mycotoxins in organic varieties.

Some techniques, such as deep ploughing to control ergot, are already included in available guidance (e.g. Scottish Quality Crops Farm Assurance Guidance).

Targeted fungicide application

Fungicide application should be targeted at critical times such as flowering. The development of more accurate modelling and predictive techniques applicable at farm or field level could lead to more effective protection from fungal infection.

Risk assessment

Risk assessment tools have been developed for mycotoxins in wheat – for instance the Agriculture and Horticulture Development Board has produced one which allows the farmer to score his crop against various criteria. Assurance schemes also require that risk assessment is undertaken and is available in documentation. Overall, Scotland is classified as very low risk but climate change may alter this and there could be value in developing more targeted and smaller scale risk assessment methods.

Predictive modelling tools have also been developed, including one by the James Hutton Institute specifically aimed at predicting future *Fusarium* disease risk in Scotland, with rainfall during flowering being a major risk factor. There is scope to assess the linkage between the disease prevalence and mycotoxin expression[1] and for further model development to assist with planning mitigating strategies such as appropriate crop or variety choice.

Plant resistance breeding

Resistant crop varieties can be developed and there has been success in some Saharan countries but several aspects must be taken into account. Plant breeding is a long-term option which can take many years and commercial priorities tend to be to improve yield and quality factors rather than resistance. It should also be borne in mind that the resistance mechanism may be for the plant to detoxify the mycotoxin, so there is a possibility that masked mycotoxins could still present a food safety issue. The variety must also be tested and modelled to assess its effectiveness in the Scottish environment as the same varieties tend to exhibit different properties in different environments.

Detoxifying agents – enzymes & binders

Binders (e.g. clay compounds) are sometimes used in animal feed to block the absorption of some mycotoxins (DON, ZON, ochratoxin) although their efficacy may be questionable and they are not permitted for food products. For other mycotoxins the development of new binders would be needed and there could also be potential to develop new enzymes to denature the mycotoxins.

Bio-control

There may be potential to develop fungicidal bio-control agents, including exploiting the population dynamics of different fungal species to favour non-toxic forms.

Genetic modification

Genetically modified maize with fungal resistance is grown in Spain and has markedly reduced mycotoxin levels, however the UK's policy position means this is not currently an option here.

[1] Skelsey and Newton 2015 - Future environmental and geographic risks of *Fusarium* head blight of wheat in Scotland; European Journal of Plant Pathology, Volume 142, Issue 1, pp 133-147

Are there specific gaps in the scientific research on the impact of climate change on mycotoxin levels?

Uncertainty about toxicity

There are a large number of mycotoxins (~300-400) and the toxicity of some, such as T2 & HT2, is either uncertain or appears to be variable and further work is needed to clarify this.

Masked mycotoxins

The true risk from masked mycotoxins needs to be quantified particularly for 'minor' grains such as oats & barley; particularly in relation to the behaviour of masked mycotoxins in the human gut and the impact on human health.

Infection and mycotoxin expression correlation

There appears to be little correlation between fungal infection and mycotoxin production and we need to better understand the mechanisms involved in triggering mycotoxin production by fungi. This should include identifying key factors involved in toxin production in the field e.g. are these micro-scale or at larger climatic scale, how much does species/variety of both crop and fungus influence production, what influence do ecosystem dynamics have? For storage mycotoxins research could include examining conditions such as water content & temperature to develop an understanding of fungal infection mechanisms.

Baseline analysis

Sampling is carried out on farm and at processor intake but there is a lack of a coherent baseline of mycotoxin occurrence in Scotland, particularly for 'minor' grains. There is also no strategy for surveillance and monitoring which would enable trends to be reviewed and the identification of emerging toxins. There could be scope for Local Authorities to sample & analyse for mycotoxins under the LA grants scheme and SASA also has the potential to provide testing if baseline analysis is taken forward. It was also noted that the difficulties in sampling (due to health and safety concerns associated with accessing material and complicated sampling to ensure representativeness) could present a barrier. It was considered that there was scope to improve cooperation with industry and explore opportunities for them to share samples and results generated through the extensive sampling they already routinely take. This could be on an anonymised basis if necessary and initially it would be useful to gauge how much routine industry mycotoxin testing currently takes place. One caveat is that care is needed in ensuring samples are representative and that they are kept in the correct conditions prior to analysis.

Risk assessment

There is a lack of risk assessment data for mycotoxins, particularly for crops such as barley or oats. Risk assessment tools have been developed for wheat but not for these 'minor' crops.

Challenges to meeting legislative limits and possible solutions

EU engagement

It should be noted that legislative limits for mycotoxins are largely based on animal experiments and are set on a proportionate rather than precautionary basis. Scotland needs to be on the front foot in Europe and laws & guidance must be evidence and risk-based. There should be early engagement with the EU and the most toxic and prevalent toxins should be targeted to optimise risk management.

The toxins H2 & HT2 have indicative levels set by EC Recommendation, not legal limits. These are quite toxic compounds but the prevalence across Europe is lower so they are judged to be low risk; however raised levels have been found in Scotland and dietary intake may be different here which would alter the exposure risk. It is therefore important to ensure that local or regional variations in mycotoxin prevalence are taken into account when negotiating on legislative controls.

Different legislative levels are set for different stages in the production process i.e. unprocessed grain limit > processed grain limit > breakfast cereal limit. This can be problematic for industry and there may be scope to adjust these levels in future.

Allowing derogations on levels for short term exceedences is a currently a slow and uncertain process in the EU. There may be potential for negotiating a ‘fast-track’ regulatory process on the basis of *a priori* risk assessment of potential mycotoxin level exceedences.

Codes of practice & guidance

Government (FSA) best practice guidance for agriculture and storage exists. Some of this would benefit from being reviewed and there could be value in producing specific guidance for crops of importance to Scotland such as oats and barley.

Industry bodies such as Scottish Quality Crops (SQC), the Feed Materials Assurance Scheme (FEMAS), the Agricultural Industries Confederation (AIC) & the Trade Assurance Scheme for Combinable Crops (TASCC) provide guidance and assurance schemes which define standards according to customer requirements. These are regularly reviewed and so should take account of the potential impact of new issues such as climate change.

Red lines

Mixing of contaminated and clean crops to achieve compliance is not a viable option as contaminant dilution runs contrary to food and feed law principles.

The use of binders or enzymes in food crops is also unlikely to be an option for routine use but could feasibly be permitted in the short term in case of a large contamination event in the interests of food supply/food security.

Is an EU-wide strategy for managing mycotoxin formation feasible and what its possible components? Is a Scottish/UK strategy feasible?

Some work has been done at EU level on general mycotoxin reduction strategies (e.g. MycoRed, 2013) but combined EU mitigation approaches may not be possible due to Member States having different agricultural practices and hence different agendas. It is likely that a combination of approaches should be used as no single solution is likely to be practical.

As this is a commodity issue there may be scope to collaborate with other regions growing similar crops such as Scandinavia which could support Scotland in developing joint evidence gathering strategies which would produce data that was relevant to both countries. If strategies could be aligned between countries this would make for a more effective approach to EU.

It was considered that currently, even a major mycotoxin event in a single year would have a limited impact on the domestic market as the shortfall in supply could be made up for through imports. However it is important to view this issue on a global basis with regard to the sustainability of the food supply chains that may be affected by mycotoxin contamination since price increases could limit the availability of food to less developed countries. Additionally, contaminated grain diverted into the feed sector could have adverse effects on productivity, particularly in susceptible species such as pigs and poultry.