Review on mycotoxin risk

Prandini, A., Sigolo, S. and Filippi, L.
Institute of Food Science and Nutrition - Catholic University of Piacenza
‘MYCOTOXIN’

Secondary toxic chemical substances produced by fungi
Potential threat to human and animal health (inhalation, absorption, ingestion of contaminated food products)

One or more fungal species ↔ one or more mycotoxin

Major mycotoxins

- Aflatoxins  
  Aspergilli – Penicillium verrucosum

- Ochratoxins  
  Aspergillus ochraceus – P. verrucosum

- Deoxynivalenol  
  F. graminearum – F. culmorum

- Fumonisins  
  Fusarium spp.
MYCOTOXIN EFFECTS

- Manifest effects with doses close to acute toxicity
- Belated symptoms
- Long-term effects after suspension

>> Symptoms frequently confused by multi-presence and conventional induced pathologies

SUSPECTED SYMPTOMS

- reduced ingestion
- reproductive problems
- nephropathy
- breathing syndrome
- worsening of performance
Other effects

Economic losses

- FAO values in many millions of $ per year the losses due to MYCOTOXIN contaminations (about 25% of world cereal harvests)
- Losses had been shown in the entire food chain, from field to production process and distribution, including losses in animal breedings
- Excluding sanitary costs for human health
Mycotoxins were associated to food problems in:

- France (16th)
- England (17th), Central-Eastern Europe
- Ethiopia and India (last 30 y), Africa, Asia
- Italy (1970’s)
- Denmark (mid-1980s)
- Malaysia and the Netherlands (1990’s)
- Eastern Kenia (2004) ....

The secondary toxic metabolites are formed in the final exponential growth phase of fungi

AFM$_1$  DON  FM B$_1$  OTA
Quality loss and mycotoxin formation is of particular concern when toxins enter human food chain by direct consumption.
MYCOTOXINS
Stable substances after the fungal death

PREVENTION OF CONTAMINATION
=
PREVENT FUNGAL GROWTH
=>
CONTROL THE EFFECTS
AFLATOXINS

FUMONISINS - AFLATOXINS

DEOXYNIVALENOL

ZEARALENONE

T2 TOXINS - HT2 - OCHRATOXINS

OTA

FUMONISINS - AFLATOXINS

T2 – HT2 - OCHRATOXINS  5 - 15
DON – ZEA  15 – 30
FUMONISINS  25 – 35
AFLATOXINS  15 - 35

From: Iller Campani, 2004; Logrieco, 2005
MYCOTOXIN RISK

- Limited effect of acute mycotoxin exposure
- Pre-harvest control of fungi growth during crop development
- Changes in global climatic conditions

FOOD QUALITY AND FEEDING NECESSITY

New EU Members States increase demand for food

- Adequate growth of agricultural industry in particular contexts
- Implementation of trading system inside an enlarged pan-European market

and .....
- Improvement of analytical methods to detect toxins

It is necessary to fulfill the requirements of CEN (European Committee for Standardization)

**LEGISLATION**

**EU REG. n. 1881/2006** set maximum limits for contaminants

*Article 3*

**Prohibitions on use, mixing and detoxification**

4. Foodstuffs containing contaminants listed in section 2 of the Annex (Mycotoxins) shall not be deliberately detoxified by chemical treatments

**EU RECC. n. 2006/576/EC** on the prevention and reduction of *Fusarium* toxins in cereals and cereal products
<table>
<thead>
<tr>
<th>Country</th>
<th>Mycotoxins:</th>
<th>2005</th>
<th>2006</th>
<th>RASFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iran</td>
<td>452 (440*)</td>
<td>892</td>
<td>240</td>
<td>*pistachios</td>
</tr>
<tr>
<td>China</td>
<td>80 (79**)</td>
<td>37</td>
<td>26</td>
<td>**peanuts &amp; deriv.</td>
</tr>
<tr>
<td>Brazil</td>
<td>37 (32**)</td>
<td>26</td>
<td>45</td>
<td>(42**)</td>
</tr>
<tr>
<td>Argentina</td>
<td>23 (22**)</td>
<td>45</td>
<td>45</td>
<td>(42**)</td>
</tr>
<tr>
<td>Ochratoxin A</td>
<td>16</td>
<td>12</td>
<td>26</td>
<td>dried vine fruits</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td></td>
<td>4</td>
<td>spices</td>
</tr>
<tr>
<td>Patulin</td>
<td>3</td>
<td>13</td>
<td>7</td>
<td>coffee &amp; its products</td>
</tr>
<tr>
<td>Fumonisin</td>
<td>2</td>
<td>11</td>
<td>17</td>
<td>cereals &amp; their products</td>
</tr>
<tr>
<td>Zearalenone</td>
<td>0</td>
<td></td>
<td>1</td>
<td>cereals</td>
</tr>
</tbody>
</table>

Note: * Indicates that the country is the source of the mycotoxin.
## Mycotoxins:

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mycotoxins:</strong></td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Aflatoxin</td>
<td>10</td>
<td>4 maize flour &amp; pistachio</td>
</tr>
<tr>
<td>Ochratoxin A</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Patulin</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Fumonisin</td>
<td>1</td>
<td>9 maize flour</td>
</tr>
<tr>
<td>Zearalenone</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

and Deoxynivalenol?

RASFF have began notification from 1st May 2007 (1 in maize flour, Italy)
<table>
<thead>
<tr>
<th>Country</th>
<th>Mycotoxin/Source</th>
<th>Level/Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>DON (cereals)</td>
<td>low level (2001)</td>
</tr>
<tr>
<td>Germany</td>
<td>AFs (dried fruits, spices)</td>
<td>50-70% (&lt;20%)</td>
</tr>
<tr>
<td></td>
<td>OTA (coffee, beer, sausages)</td>
<td>50-100% &gt; limits</td>
</tr>
<tr>
<td></td>
<td>DON (cereals in baby foods)</td>
<td>13% &gt; 100 µg/kg</td>
</tr>
<tr>
<td></td>
<td>ZEA (maize)</td>
<td>in trace</td>
</tr>
<tr>
<td>Portugal</td>
<td>AFs (dried fruits, spices)</td>
<td>exceeded allow. limits</td>
</tr>
<tr>
<td></td>
<td>OTA (spices, wine)</td>
<td>&lt; allow. limits</td>
</tr>
<tr>
<td>Spain</td>
<td>AFB₁,₂ (maize, dried fruits)</td>
<td>+ &gt; allow. limits</td>
</tr>
<tr>
<td></td>
<td>DON, ZEA (maize)</td>
<td>&lt; allow. limits</td>
</tr>
<tr>
<td></td>
<td>OTA (coffee, wine, beer)</td>
<td>100% &gt; allow. limits</td>
</tr>
<tr>
<td>UK</td>
<td>DON, ZEA (breakfast cereals)</td>
<td>80% &lt; limits</td>
</tr>
<tr>
<td></td>
<td>OTA (wheat, barley)</td>
<td>2-3% &gt; limits</td>
</tr>
</tbody>
</table>
Awareness to reduce occurrence of mycotoxin in the years to come (National authorities should educate producers)

Good Agricultural Practices (GAPs) represent the primary line of defense against contamination of cereals with mycotoxins

‘Know how’ of the storage conditions to limit mycotoxin production may make it possible to control further increases in mycotoxin levels during storage (GMPs)
... more information

European Mycotoxins Awareness Network (EMAN)
http://www.mycotoxins.org

Scientific Committee for Food (SCF)
http://europa.eu.int/comm/food/fs/sc/scf/reports/

Codex Alimentarius Commission
www.codexalimentarius.net/download/report/28/Al03_12e.pdf

European Food Safety Authority (EFSA)

Scientific Cooperation (SCOOP)
http://ec.europa.eu/food/fs/scoop/index_en.html

http://europa.eu.int/eur-lex/lex/JOIndex.do?

year 2006 OJ series L OJ number (mandatory) 364
A case study on the occurrence of Aflatoxin $M_1$ in milk and dairy products

Prandini, A., Sigolo, S. and Filippi, L.
Institute of Food Science and Nutrition - Catholic University of Piacenza
# AFLATOXINS

- *Aspergillus flavus*
- *Aspergillus parasiticus*
- *A. nomius, Penicillium verrucosum*

<table>
<thead>
<tr>
<th>FUNGUS SPECIES</th>
<th>MYCOTOXINS</th>
<th>TEMPERATURE RANGE (°C)</th>
<th>WATER ACTIVITY ($a_w$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Aspergillus flavus</em></td>
<td>AFB₁, AFB₂</td>
<td>6 - 48 optimum 36 - 38</td>
<td>&gt;0.78</td>
</tr>
<tr>
<td><em>Aspergillus parasiticus</em></td>
<td>AFB₁, AFB₂, AFG₁, AFG₂</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Contaminated commodities: cereals, tree nuts, spices, oilseeds

Major hazard: most widely occurrence (CAST, 1989) and our inability to detect them biologically.
CONTAMINATION

Direct:
- Fungal growth for fermentation (cheese, *Penicillium*)
- Unintentional fungal growth (uncorrected manufacturing)

Indirect:
- Contaminated rations for cows (AFM$_1$ in milk)

AF: immunosuppressive, liver tumor inducing and carcinogenic potency
AFB$_1$: class 1 (human carcinogenic IARC, 1993)
AFM$_1$: class 2B (possible human carcinogenic IARC, 1993)
- Continued low-dose exposure brings to chronic effects
Milking animals that ingest aflatoxin B₁ (AFB₁) by contaminated diets, excrete the 4-hydroxylated metabolite aflatoxin M₁ (AFM₁) into milk with a proportion of 1-3%.

**LEGISLATION**

The Commission set limit for AFB₁ of 5 µg/kg for supplementary feedstuffs for lactating dairy cattle (European Commission, 1991)

**tolerance level is difficult to be observed**

to produce bulk milk <50 ng AFM₁ per kg = the daily average individual intake in a herd is <40 µg AFB₁ per cow
The EU Commission fixed a limit for AFM$_1$ of 50 ng/kg for milk and a variable limit for cheese.

In particular to protect babies and children: AFB$_1$ transfer directly in breast milk.

**Aflatoxins** in milk are **stable** during heating treatments i.e. pasteurization and sterilization.

- EU limit: 50 ng/kg of AFM$_1$

Variation of pH during fermentation (yoghurts, cheeses) cause coagulation of proteins that adsorb or occlude the toxins.

- EU limit: variable
RISK FACTORS ANALYSIS

AFB₁ analysis in corn is necessary to evaluate risk of AFM₁ contamination in milk and dairy products.

If stresses affect plant growth during pollination, Aspergillus fungi increase AF level.

Risk factors of AFB₁ contamination in corn:

- To prevent fungi and AFB₁: maize
- To reduce AFB₁: feedstuffs
- To control AFM₁: milk
Risk factors of AFB₁ contamination in corn silage production

<table>
<thead>
<tr>
<th>PRE-HARVEST</th>
<th>HARVEST</th>
<th>SILAGE AND STORAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Choice of seeding time and density</td>
<td>▪ Low silage moisture</td>
<td>▪ Unsuitable filling and closing of storage silo</td>
</tr>
<tr>
<td>▪ Lack of irrigation and weed killing</td>
<td>▪ Long and irregular cutting up</td>
<td>▪ No use of organic acids and/or preservatives</td>
</tr>
<tr>
<td>▪ Phytophagous damages</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▪ Excessive or not balanced fertilization</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Risk factors of AFB\(_1\) contamination in corn grain production

<table>
<thead>
<tr>
<th>PRE-HARVEST</th>
<th>HARVEST</th>
<th>POST-HARVEST</th>
<th>PRE-PROCESSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Such as corn silage production and</td>
<td>▪ Mechanical damages</td>
<td>▪ Wet grain storage before drying process</td>
<td>▪ Grain heating</td>
</tr>
<tr>
<td>▪ Drought and high temperature ((&gt;25-30^\circ)C)</td>
<td>▪ Prolonged drying in field</td>
<td>▪ Grains storage with moisture &gt; 14%</td>
<td>▪ Grains re-humidification</td>
</tr>
<tr>
<td>▪ Minimum tillage or sod seeding</td>
<td></td>
<td>▪ Unsuitable driers</td>
<td></td>
</tr>
<tr>
<td>▪ Choice of hybrids</td>
<td></td>
<td>▪ No kernels cleaning</td>
<td></td>
</tr>
<tr>
<td>▪ Unsuitable crop rotation</td>
<td></td>
<td>▪ No refrigeration</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>▪ No phytophagous control</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Particular climatic conditions \((0.78 \ a_w\) hour: closely interrelated with \(\text{AFB}_1\) incidence and contamination levels) for the first time in Italy during summer 2003 conduced to a significant diffusion of aflatoxins:

<table>
<thead>
<tr>
<th>Year</th>
<th>(\text{AFB}_1 (&gt;0.2 \ \text{ppb}))</th>
<th>Year</th>
<th>(\text{AFB}_1 (&gt;0.2 \ \text{ppb}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>1.9</td>
<td>2000</td>
<td>0.0</td>
</tr>
<tr>
<td>1996</td>
<td>0.3</td>
<td>2001</td>
<td>6.3</td>
</tr>
<tr>
<td>1997</td>
<td>1.5</td>
<td>2002</td>
<td>2.1</td>
</tr>
<tr>
<td>1998</td>
<td>1.5</td>
<td>2003</td>
<td><strong>14.3</strong></td>
</tr>
<tr>
<td>1999</td>
<td>4.1</td>
<td>2004</td>
<td>3.3</td>
</tr>
</tbody>
</table>

\% contaminated corn samples superior to the instrumental limit in Pianura Padana (Po Valley)

(Pietri et al, 2004; Reyneri, 2006)
PREVENTION OF RISK IN MILK

With high temperature and high humidity in field it is difficult to prevent the formation of aflatoxins

- **SCOUTING**: land control of ‘stressed’ culture
- Essential to be careful in post-harvest storage (12-12.5% RH)
- Suppliers careful of mycotoxin risk, in particular of aflatoxin risk (HACCP)
- Choice alternative feedstuffs without hazardous raw materials
What can we do with contaminated material?

Detoxification (elusive goal)

- Feedstuffs
  - ammonia (gaseous phase): alteration of molecular structure
  - sodium bentonite and aluminosilicates: binding agents
  - sodium-, potassium-, calcium-hydroxide (with formaldehyde)
  - ADSORBENT

- Milk
  - acidification of milk with organic acid (lactic, citric or acetic)
  - addition of formaldehyde (0.5%)
  - via Nocardiaceae (Flavobacterium aurantiacum = Nocardia corynebacterioides)

New utilization

- corn: production of ethanol or wet milling
- milk: meal for swine

Destruction (following national impositions, Italy – 2003)
WORST CASE SITUATION
for ruminants (cattle, buffalos, sheep, goats)

- Occurrence of AFB$_1$ at maximum permissible level in feed concentrates
- Maximum concentrate intake of high yielding dairy cow
- Contamination of basic feedstuffs in rations of dairy cows at maximum permissible level

Climate change in Southern Europe
AFM$_1$ - CONCLUSION

- Controlling critical point for fungal growth and mycotoxins production such as cultural phases (HACCP)

- Primary strategy to protect: monitoring by reliable analyses → surveillance in field could be appropriate

- Spreading news about risks linked to unsuitable farming management systems
On the occurrence of Deoxynivalenol and Ochratoxin A in wheat

Prandini, A., Sigolo, S. and Filippi, L.
Institute of Food Science and Nutrition - Catholic University of Piacenza
DEOXYNIVALENOL (DON)

- *Fusarium graminearum* (maize)
- *Fusarium culmorum* (wheat)

<table>
<thead>
<tr>
<th>FUNGUS SPECIES</th>
<th>TEMPERATURE RANGE (°C)</th>
<th>WATER ACTIVITY ($a_w$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Fusarium graminearum</em></td>
<td>25 - 30</td>
<td>&gt;0.88</td>
</tr>
<tr>
<td><em>Fusarium culmorum</em></td>
<td>21 - 25</td>
<td>&gt;0.87 → &gt;0.88</td>
</tr>
</tbody>
</table>

Contaminated commodities: all species of cereals

Major hazard: occurrence at undetectable level in a wide variety of food
CONTAMINATION

Direct:

Ingestion of contaminated cereals and grains

The exposure varies with supplies in different geographical regions:

- in Europe major source is wheat
- in Asia major sources are rice and wheat

DON: strongly immunosuppressive, neural disturbance, haemorrhaging, necrosis of tissue, vomiting and feed refusal (= vomitoxin)

DON: a class 3 (not classifiable as to its carcinogenicity to humans) IARC, 1993
Stable during the processing of cereal products (bread, noodles, infant food, beer)

DON contamination is located at the surface of the kernel: milling practice is a physical technique accepted from **EU REGULATION n. 1881/2006**

### LEGISLATION

- The Commission **EU** set limit of DON μg/kg:
  - 500 (bread) - 1750 (not manufacturated wheat and corn)
- Canada **Canada**, Russia **Russia** and the USA **USA** set statutory or guideline limits:
  - 500 – 2000 μg/kg (wheat)
DON analysis in wheat is necessary to evaluate risk of DON contamination in by-products.

Infection depend on:
- Rainfall and relative humidity (RH)
- Duration of canopy wetness
- Temperature related to the stage of wheat development

To prevent in field, condition for DON contamination.
### Risk factors of DON contamination in wheat and bread

<table>
<thead>
<tr>
<th>WEATHER</th>
<th>AGRICULTURAL PRACTICES</th>
<th>POST-HARVEST</th>
<th>MILLING AND BREAD PROCESSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>High temperature</td>
<td>Unsuitable crop rotation</td>
<td>Unsuitable conditions of conservation (SMC)</td>
<td>Wholemeal bread production</td>
</tr>
<tr>
<td>High moisture</td>
<td>No removal of crop debris</td>
<td>Damaged kernels</td>
<td></td>
</tr>
<tr>
<td>Rainfall</td>
<td>Excessive N fertilization</td>
<td>No chemical or alternative control</td>
<td></td>
</tr>
<tr>
<td>(among flowering and early dough stage)</td>
<td>Choice of variety</td>
<td>Unsuitable conditions of transport</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No chemical or biological control</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Prevention of Risk in Field

Conventional as well as organic agriculture

Good agricultural, handling, and storage practices

Minimize the risk of mould growth and mycotoxin contamination

- Long crop rotations (crop/species-specific mould)
- Low/different nitrogen fertilization rates (rough plants)
- Tilling as weed control (minor fungal inoculum)
Scouting critical points during most sensitive crop period (among flowering and early dough stage) to reduce the risk of FHB outbreaks

Under good condition of storage (25°C, 62% RH) seeds maintain good quality and *Fusarium* species do not compete with other storage-fungi
**OCHRATOXIN A (OTA)**

- *Penicillium verrucosum* (temperate climate)
- *Aspergillus ochraceus, A. carbonarius* (warm climate)

<table>
<thead>
<tr>
<th>FUNGUS SPECIES</th>
<th>TEMPERATURE RANGE (°C)</th>
<th>WATER ACTIVITY ($a_w$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Penicillium verrucosum</em></td>
<td>0 - 31</td>
<td>&lt; 0.80</td>
</tr>
<tr>
<td></td>
<td>Optimum 20</td>
<td></td>
</tr>
<tr>
<td><em>Aspergillus ochraceus</em></td>
<td>12 - 37</td>
<td>&gt; 0.80</td>
</tr>
<tr>
<td></td>
<td>Optimum 24-31</td>
<td>Optimum 0.95 – 0.99</td>
</tr>
</tbody>
</table>

Contaminated commodities: cereals, grapes, dried and stored foods

Major hazard: occurrence at low level in a wide variety of food
**CONTAMINATION**

Direct:
- Ingestion of contaminated cereals, juices
- Inhalation in people working on waste fields (rarely)

Indirect:
- Contaminated feed for monogastric animals (OTA in meat, liver paté)

OTA: **immunosuppressive**, embriotoxic, carcinogenic and teratogenic, genotoxic, nephrotoxic in mammalian species (BEN = Balkan Endemic Nephropaty, 1991)
OTA: class 2B (possible human carcinogenic IARC, 1993)
Carry-over:

- limited in ruminant probably due to detoxification activities of microflora
- depend on tissue in meat production (swine, poultry)

Longest half-life of OTA (35 days) known for living mammals

**LEGISLATION**

The Commission set limit for OTA of 2 - 10 μg/kg from not manufacturated wheat and maize to soluble coffee

- EU limit: 5 μg/kg of OTA (wheat and corn)
- EU limit: 5 μg/kg of OTA (roasted coffee)
According to the occurrence in many foods a provisional Tolerable Daily Intake (TDI) was established of:

- 14 ng OTA /kg b.w./day (JECFA, accumulation)
- 5 ng OTA /kg b.w./day (EU SCF, carcinogenity)

**Ochratoxin A** is stable to heat (bread-making), to roast (coffee), to fermentation (wine, beer):

- EU limit: 2 μg/kg of OTA (wheat and corn by-products)
- EU limit: 0.5 μg/kg of OTA (baby food, infant formula with cereals)
OTA analysis in wheat is necessary to evaluate risk of OTA contamination in bread

\[ \text{A. ochraceus} \quad \text{OTA occurrence in stored grains} \]
\[ \text{P. verrucosum} \]

Infection depends on:
- Moisture of grains at harvest: \(0.77 \ a_w\)
- Temperature
- Controlled atmosphere during storage

A good storage practice to prevent OTA production
# Risk factors of OTA contamination in bread

<table>
<thead>
<tr>
<th>POST-HARVEST</th>
<th>WHEAT MEAL PRODUCTION</th>
<th>BREAD PROCESSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsuitable conditions of conservation:</td>
<td></td>
<td>Wholemeal bread production</td>
</tr>
<tr>
<td>• Insufficient drying</td>
<td>• No cleaning of kernels</td>
<td></td>
</tr>
<tr>
<td>• Over-long storage before drying</td>
<td>• No scouring of kernels</td>
<td></td>
</tr>
<tr>
<td>• No chemical or alternative control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Damaged kernels</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WHAT COULD WE DO WITH CONTAMINATED MATERIAL?

- Detoxification of
  
  SOLID MEDIA / AGRICULTURAL PRODUCTS
  
  - a strain of *A. niger* (normally use in fermentation of food) and *A. fumigatus*
  
  - ADSORBENT (stop carry-over in pig and chick)

  LIQUID MEDIA / MILK
  
  - *Lactobacillus*, *Streptococcus* and *Bifidobacterium* detoxify milk
  
  - *A. Nigri* and *A. fumigatus*

Such methods must be:

- compatible with existing national and european food safety legislation (Reg. CE 1881/2006)
- protective of the functionality/quality of cereals
Exposure to OTA is worldwide (detected in human sera in many countries) with high incidence, at low level

Difficulty of eliminating OTA from food chain makes it essential avoidance in raw materials, and protection from further contamination occurs

Controlling critical points for fungal growth and mycotoxin production such as storing techniques
Prediction of mycotoxins using models

Prandini¹, A., Sigolo¹, S., Filippi¹, L. and Battilani², P.
¹Institute of Food Science and Nutrition
²Institute of Entomology and Plant Pathology
Catholic University of Piacenza
Forecasting AFB$_1$ and AFM$_1$ contamination

- Linear relationships to estimated the carry-over

\[
\text{AFM}_1 \text{ (ng/kg milk)} = [1.19 \times \text{AFB}_1 \text{ intake (µg cow}^{-1} \text{ day}^{-1})] + 1.9
\]
\[
\text{AFM}_1 \text{ (ng/kg milk)} = 10.95 + 0.787 \times \text{AFB}_1 \text{ intake (µg day}^{-1})
\]

(Veldman)

(Pettersson)

No predictive models for the risk of AFB$_1$ contamination in corn or AFM$_1$ contamination in milk and dairy products

Prevention in field

1. Control insects and weeds
2. Scouting (EC Recc. 2006/576)
3. Minimize damage kernels
Forecasting FHB epidemics

FHB is an IDEAL disease, given:
- prevalence of FHB epidemics in wet growing season
- short period (anthesis) of susceptibility to infection

A generalized forecasting system is difficult to apply in a field situation

Measures of control as:
- use of cultural control techniques
- growing of resistant cultivars
- use of fungicides or biological antagonists
to reduce the risk of FHB epidemic
OTA production in grains is a IDEAL phenomenon, given:
- occurrence of *A. ochraceus* and *P. verrucosum*
  primarily in stored grains

In a predictive model based on:

\[
\text{temperature} \times a_w \leftrightarrow \text{different species}
\]

Measures of control as:
- Cleaning and removal of damaged kernels
- Use of chemical control (fumigants)
ARGENTINA (2001)

Empirical equation for predicting FHB incidence:
- Temperature
- Moisture variable

associated to head blight in many wheat cultivars

The equations should be carefully used for prediction in other geographic areas, with few changes in temperature thresholds.
ITALY (2002)

FHB dynamic simulation model:
daily infection risk based on
- Sporulation
- Spore dispersal
- Infection of host tissue

Main factors affecting the risk for DON and ZEA
- Air temperature
- Relative humidity and rainfall
- Fungal species and host growth stage

Model produce one index for FHB risk, and one for mycotoxin level in grain
DON prediction in mature grain using:
- Rainfall
- Temperature (4 - 7 days before heading and from 7 days before to 10 days after heading)

Predictive model for timing use of fungicides

A web site (http://www.ownweb.ca) provide predictions of DON across the province of Ontario in Canada (Hooker et al., 2002; Hooker et al., 2003).
Model for FHB disease based on:
- Weather (hourly temperature, humidity and rainfall)
- Crop growth stage
- Disease observations

Predict the risk of disease severity greater than 10% (model accuracy ~ 80% using validation data)

With integration of empirical observation, the model is given for prediction of DON level in grain.

A web site (www.wheatscab.psu.edu) provide data from 23 states both spring and winter wheat areas.
Predictive model about ochratoxin A production in stored grain (OTA PREV project)

Fungal growth and OTA production are influenced by:
abiotic (mainly water availability and temperature) and biotic factors.

Mathematical model use:
- numbers of \textit{P. verrucosum} colonies
- moisture content during storage

They are significantly related to the risk of exceeding the ‘5 μg OTA kg\(^{-1}\) grain’ legislative limit
Predictive models on *Fusarium verticillioides* and fumonisin contamination in maize

Variables used:
* air temperature
* relative humidity
* wetness
* free water in plant tissue
* cornc growth stage

and mathematical equations related to spore production, infection, invasion and mycotoxin production.

Italy: conceptual model for the dynamic simulation of the life cycle of *F. verticillioides* in maize and production of fumonisin B₁ in grain in dry and warm climates of southern Europe.

To produce an operative model, some aspects of the disease cycle need to be investigated further
Implementation of food safety measures (GAPs, GMPs, HACCP system) to reduction of mycotoxins in first steps of commodities production

Timing use of fungicides (to reduce hazards for human and animal health) could be improve with better meteorological predictive models
OVERALL CONCLUSIONS

- Mycotoxins can be produced in field as well as during food storage, and a variety of climatic, environmental and agronomic factors determine their production.

- Prevention of growth and mycotoxin production of fungi on plants and in feedstuffs is the best approach to impede the harmful effects on animal and human health.

- Contribute to frequency and worldwide diffusion of mycotoxin contamination is the global transportation and food conservation systems.
OVERALL CONCLUSIONS (continued)

- It’s difficult to forecast the occurrence of fungal diseases and toxins contamination in food grains
- Predictive models are limited to climatic variables (no use of field specific effects such as crop rotation, crop variety, tillage, etc)
- They are usually site-specific and do not provide acceptable accuracy when applied to diverse and complex environments (also human behaviour influence mycotoxin problem but is difficult to quantify)
IN THE FUTURE?

- Researches about genetic resources for improvement of resistance or less susceptibility of plants to contamination
- Integration of predictive models with GAPs and GMPs to prevent contamination risk
- Disclosure of guidelines (‘know how’) to harmonize the storage centres about the best way for managing and storing commodities
- National storage centres have due to follow guidelines for good conservation of commodities

Bigger pertaining areas are favourable for better management
Thank you for your attention