Mycotoxins in Oats: What are They, Where are They, and Why They Matter

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Grain Research Laboratory, Canadian Grain Commission
Winnipeg, MB, Canada
- Federal government agency that certifies the quality, safety and weight of Canadian grain
- Grain Research Laboratory works on factors affecting grain quality and safety
What are they?

- fungal secondary metabolites
  - chemical signals
  - chemical defense
  - chemical offense
What are they?

- there is a wide variety of mycotoxins in grain
- internationally, most issues centre around:
  - aflatoxins
  - fumonisins
  - zearalenone (ZEA)
  - ochratoxin A (OTA)
  - deoxynivalenol (DON)
  - ergot alkaloids

- CGC monitors mycotoxins in grain
  - approximately 35 mycotoxins are routinely monitored
- Canadian grain routinely meets regulations regarding DON and OTA in grain exports
Why do they matter?

- can cause food-borne and feed-borne illness
  - immunosupression, kidney toxin, feed refusal, decreased milk production, decreased blood flow, etc.

fusarium head blight in wheat is related to DON

ergot sclerotia in wheat contain ergot alkaloids

Pieter Breugel, 16th century Flemish painter
Art History Museum, Vienna
### Why do they matter?

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Commodity</th>
<th>Mycotoxin</th>
<th>Maximum level</th>
</tr>
</thead>
<tbody>
<tr>
<td>international</td>
<td>cereal-based foods for infants and young children</td>
<td>deoxynivalenol</td>
<td>200 µg/kg</td>
</tr>
<tr>
<td>Canada</td>
<td>raw cereals</td>
<td>ochratoxin A</td>
<td>5 µg/kg (proposed guideline)</td>
</tr>
<tr>
<td>Canada</td>
<td>directly consumed cereal grains and cereal-derived products</td>
<td>ochratoxin A</td>
<td>3 µg/kg (proposed guideline)</td>
</tr>
<tr>
<td>European Union</td>
<td>processed cereal-based foods for infants and young children</td>
<td>aflatoxins</td>
<td>0.10 µg/kg</td>
</tr>
<tr>
<td>European Union</td>
<td>unprocessed cereals</td>
<td>ochratoxin A</td>
<td>5 µg/kg</td>
</tr>
<tr>
<td>European Union</td>
<td>unprocessed oats</td>
<td>deoxynivalenol</td>
<td>1750 µg/kg</td>
</tr>
<tr>
<td>European Union</td>
<td>oats (with husk)</td>
<td>T-2/HT-2</td>
<td>1000 µg/kg (indicative level)</td>
</tr>
</tbody>
</table>
Why do they matter?

- In 2009, the topic of ochratoxin A in infant food was in the news.

Heinz recalls baby cereal

JILL MAHONEY
Globe and Mail Update
Published Friday, Dec. 11, 2009 7:10AM EST
Last updated Thursday, Aug. 23, 2012 12:17PM EDT
## Where are they?

<table>
<thead>
<tr>
<th>Grain</th>
<th>DON +</th>
<th>NIV +</th>
<th>MON +</th>
<th>15-ADON +</th>
<th>ZEAR +</th>
<th>Others +</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley</td>
<td>15%</td>
<td>15%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Corn</td>
<td>100%</td>
<td>0</td>
<td>22%</td>
<td>56%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Oats</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rye</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Durum</td>
<td>68%</td>
<td>0</td>
<td>100%</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Wheat</td>
<td>86%</td>
<td>0</td>
<td>17%</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Soybeans</td>
<td>2%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Canola</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Peas</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Journal of Agricultural and Food Chemistry, 2013, 62:7412
Research in collaboration with POGA

- Activity 1. Occurrence of toxigenic *Fusarium* and *Penicillium* fungi and their associated mycotoxins
  - Activity 2. Investigation of the fate of *Fusarium* and *Penicillium* species and their associated mycotoxins during processing of oats

- Funding from CGC, POGA, Saskatchewan Ministry of Agriculture, and Canada-Saskatchewan Growing Forward 2 bi-lateral agreement
Oat deliveries to mills and shipments from primary elevators

- Emerson Milling, Emerson MB
- Grain Millers, Yorkton SK
- Cargill
- Viterra
- Paterson
CGC Harvest Sample Program

- voluntary program for producers to submit a harvest sample and receive a free, unofficial CGC grade and protein content measurement
- samples inspected and graded by CGC inspectors
Fungal pathogens in 2013-2014

- Mildew-causing fungi predominant
- Fusarium species less frequently detected (mainly in the eastern Prairies)
Fungal pathogens in HSP oats 2015

- Mildew-causing fungi predominant
- *Fusarium* species less frequently detected (mainly *F. poae*)

- **Alternaria triticia**
- **Alternaria alternata**
- **Fusarium poae**

- **Alternaria triticia**
- **Alternaria alternata**
- **Fusarium poae**
- **Fusarium graminearum**

- **A. alternata & triticina**
- **Fusarium poae**
- **Fusarium graminearum**

Map showing distribution in Alberta, Saskatchewan, and Manitoba.
Mould load in oats 2013-14

- Total fungal biomass on kernels
- Depends on precipitation during the season
- Indicate origin of grain

- Alberta: ~6.5 ppm
- Saskatchewan: 2.8-4.9 ppm, 6.7-17 ppm, 3.6-5.8 ppm, 8-12.4 ppm
- Manitoba: 9.3-35 ppm
Mould load in oats 2015

- Alberta: 0.8 – 19 ppm
- Saskatchewan: 1.8 – 23 ppm
- Manitoba: 5.4 – 22 ppm
% of oat samples containing mycotoxins

<table>
<thead>
<tr>
<th></th>
<th>OTA  6%</th>
<th>citrinin 0%</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Storage-related</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aflatoxins</td>
<td>AFB₁ 0%</td>
<td>AFB₂ 0%</td>
<td>AFG₁ 0%</td>
<td>AFG₂ 0%</td>
</tr>
<tr>
<td><strong>Fusarium graminearum</strong></td>
<td>DON 67%</td>
<td>D₃G 24%</td>
<td>3-ADON 2%</td>
<td>15-ADON 0%</td>
</tr>
<tr>
<td>other Fusarium compounds</td>
<td>nivalenol 16%</td>
<td>zearalenone 5%</td>
<td>HT₂ 5%</td>
<td>T₂ 4%</td>
</tr>
<tr>
<td>other Fusarium compounds</td>
<td>beauvericin 96%</td>
<td>enniatin A 11%</td>
<td>enniatin A₁ 10%</td>
<td>enniatin B 49%</td>
</tr>
<tr>
<td>Fumonisins</td>
<td>FB₁ 0%</td>
<td>FB₂ 0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Alternaria compounds</strong></td>
<td>alternariol 85%</td>
<td>AME 83%</td>
<td>altenuene 0.4%</td>
<td>tentoxin 92%</td>
</tr>
</tbody>
</table>
## Mycotoxin concentrations observed in oats

<table>
<thead>
<tr>
<th>Storage-related</th>
<th>Mycotoxin</th>
<th>Median + (µg/kg)</th>
<th>% +</th>
<th>% + N. Europe</th>
<th>Maximum (µg/kg)</th>
<th>Maximum N. Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OTA</td>
<td>2.2</td>
<td>6%</td>
<td>29%</td>
<td>13.2</td>
<td>2.2</td>
</tr>
<tr>
<td><strong>Fusarium graminearum</strong></td>
<td>DON</td>
<td>188</td>
<td>67%</td>
<td>32-94%</td>
<td>4100</td>
<td>21608</td>
</tr>
<tr>
<td>Other Fusarium compounds</td>
<td>HT2</td>
<td>74</td>
<td>5%</td>
<td>71-92%</td>
<td>256</td>
<td>7584</td>
</tr>
<tr>
<td>Other Fusarium compounds</td>
<td>T2</td>
<td>50</td>
<td>4%</td>
<td>71-84%</td>
<td>99</td>
<td>2406</td>
</tr>
<tr>
<td><strong>Alternaria compounds</strong></td>
<td>beauvericin</td>
<td>20</td>
<td>96%</td>
<td>100%</td>
<td>271</td>
<td>220</td>
</tr>
<tr>
<td></td>
<td>alternariol</td>
<td>30</td>
<td>85%</td>
<td>93%</td>
<td>5760</td>
<td>449</td>
</tr>
<tr>
<td></td>
<td>AME</td>
<td>46</td>
<td>83%</td>
<td>100%</td>
<td>7870</td>
<td>177</td>
</tr>
<tr>
<td></td>
<td>tentoxin</td>
<td>55</td>
<td>92%</td>
<td>93%</td>
<td>322</td>
<td>4</td>
</tr>
</tbody>
</table>
DON in 2014 and 2015 harvest samples

Alberta  Saskatchewan  Manitoba
Presence of FUSARIUM DAMAGE has increased over time

FUS DMG was reason for downgrade

% of samples

Harvest year


POGA

2016 12 01

Journal of Agricultural and Food Chemistry, 2013, 61:5438
Susceptibility of oats to *Fusarium*

- “under conditions favourable for disease, all small grain cereals will sustain damage”

Most susceptible

- durum
- soft white spring
- Prairie Spring
- winter
- extra strong
- Red Spring
- triticale
- 6 row barley
- 2 row barley
- oats

Least susceptible
Ochratoxin A in oats

- OTA was measured in deliveries to milling facilities and in composite rail car loadings over the first two years of the project
- occurrence of OTA peaks in late summer/early fall in oat deliveries and railcar loadings
- this is consistent with what has been observed for wheat exports
OTA in wheat exports varies throughout a year.

<table>
<thead>
<tr>
<th>Date of shipment</th>
<th>Monthly mean OTA (µg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 2010</td>
<td>0.0</td>
</tr>
<tr>
<td>Sept 2011</td>
<td>0.5</td>
</tr>
<tr>
<td>Aug/Sept 2012</td>
<td>1.0</td>
</tr>
<tr>
<td>Aug 2013</td>
<td>1.5</td>
</tr>
<tr>
<td>Sept 2014</td>
<td>2.0</td>
</tr>
<tr>
<td>July 2015</td>
<td>2.5</td>
</tr>
<tr>
<td>Aug 2016</td>
<td>3.0</td>
</tr>
</tbody>
</table>

POGA
2016 12 01
Managing fusarium head blight and DON production

- integrated approach
  - plant healthy seed
  - crop rotation
  - stubble management
  - variety selection
  - risk maps and foliar fungicides

Preventing formation of OTA

- **Grains storage** is an essential part of managing OTA. Keep temperature and moisture content low and aerate grain regularly.

- CGC Official Grain Grading Guide's specifications for dry grain are:
  - Oats (all classes): 13.5% moisture or less
Acknowledgements

- Producers submitting to the Harvest Sample Program
- Emerson Milling, Grain Millers in Yorkton, Cargill, Viterra, Paterson
- POGA, Saskatchewan Ministry of Agriculture, and Canada-Saskatchewan Growing Forward 2 bi-lateral agreement
- Tom Gräfenhan + Microbiology group, Mike Roscoe, Don Gaba, Richard Blagden, Jason Chan