The Wonderful World of Fungal Toxins: What We Know About Mold, Plant, and Animal Interaction

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Mycotoxins

- Naturally occurring toxins produced by molds (fungi)
- The molds grow on a variety of different crops and foodstuffs including cereals, nuts, spices, dried fruits, apples and coffee beans, often under warm and humid conditions
- Mycotoxins can cause a variety of adverse health effects and pose a serious health threat to both humans and livestock
- The adverse health effects of mycotoxins range from acute poisoning to long-term effects such as immune deficiency and cancer
- A scientific expert committee jointly convened by WHO and the Food and Agriculture Organization of the United Nations (FAO) – called JECFA – is the international body responsible for evaluating the health risk from natural toxins including mycotoxins
- International standards and codes of practice to limit exposure to mycotoxins from certain foods are established by the Codex Alimentarius Commission based on JECFA assessments

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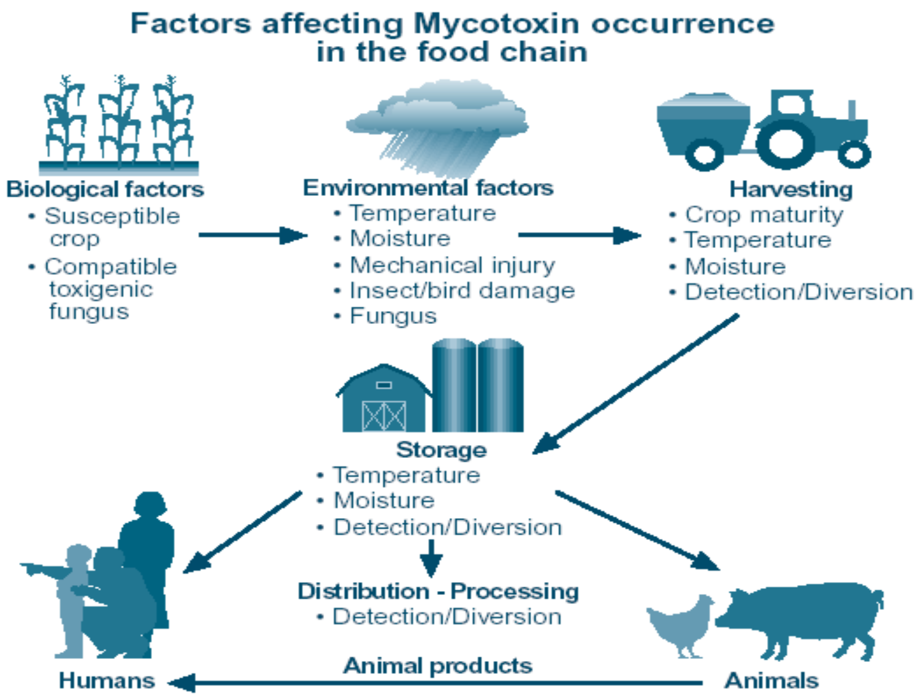

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Historical Importance

Gangrenous ergotism in the 16th century
The Beggars by Pieter Bruegel the Elder (1525-1569)

Examination of a Witch (1853) by T. H. Matteson, inspired by the Salem trials

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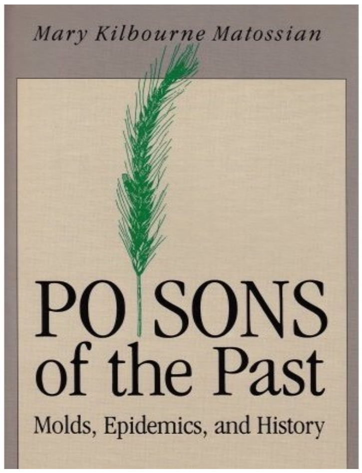
Historical importance



Evidence that food poisoning from microfungi in rye bread may have caused widespread hallucinations, low fertility and witch-like behavior during the 14th through the 18th centuries.

Argues that epidemics, sporadic outbursts of bizarre behavior and low fertility and high death rates from the 14th to the 18th centuries may have been caused by food poisoning from microfungi in bread, the staple food in Europe and America during this period.

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Human diseases suspected to be related to mycotoxins

Disease	*Food*	*Etiological agent*	*Toxin*
Alimentary toxic aleukia	Cereal grains	*Fusarium* spp.	Trichothecenes
Balkan nephropathy and chronic interstitial nephropathy	Cereal grains	*Penicillium*	Ochratoxin A
Cardiac beriberi	Rice	*Aspergillus* and *Penicillium* spp.	Citreoviridin
Ergotism	Rye, cereal grains	*Claviceps purpurea*	Ergot alkaloids
Oesophageal tumors	Corn	*Fusarium verticillioides*	Fumonisin B_1
Hepatocarcinoma (acute aflatoxicosis)	Cereal grains, peanuts	*Aspergillus flavus A. parasiticus*	Aflatoxin B_1
Human neural tube defects	Corn	*Fusarium verticillioides*	Fumonisin B_1
Kashin Beck disease or 'Urov disease'	Cereal grains	*Fusarium spp.*	Trichothecenes
Kwashiorkor	Cereal grains	*Aspergillus flavus* and *A. parasiticus*	Aflatoxin B_1
Onyalai	Millet	*Phoma sorghina*	Undefined
Reye's syndrome	Cereal grains	*Aspergillus*	Aflatoxin B_1
Testicular cancer	Various	*Penicillium*	Ochratoxin A

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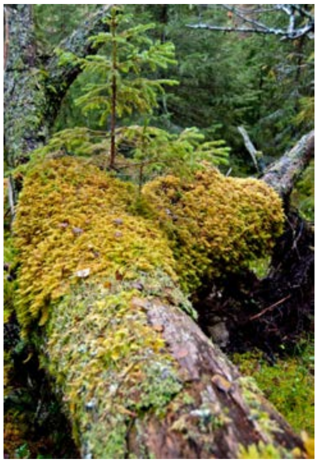
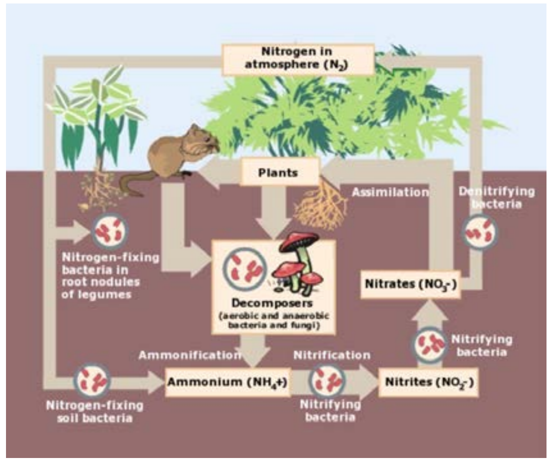
Ecology/Decomposition





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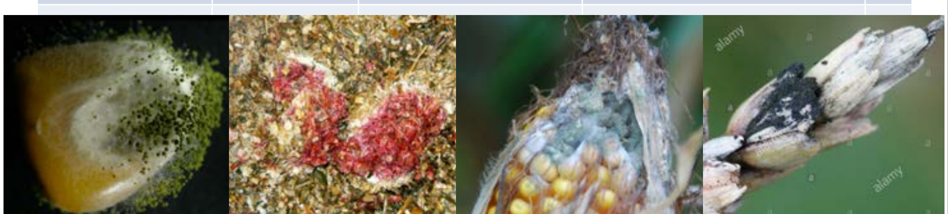
Mold	Cond.	Color	toxins	
Aspergillus	Storage /field	White/yellow/ green/blue	AF-OTA	
Fusarium	Field	Red/white/pink	ZEA, FB, Fusaric Acid, Trich (DON, T-2)	
Penicillium	Storage /field	Blue/green	OTA, Citrinin, Patulin	
Alternaria	Field	Black	tenuazonic acid, alternariol, alternariol altenuene, altertoxin etc.	
Mucor	Storage	White/gray/Black spores	???????	



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Mold	Cond.	Color	toxins	
Byssochlamys	Storage	Fluffy, powdery white	Patulin ?	
Cladosporium	-	White	-	
Claviceps	Field	Black	Ergot alcaloids	
Giberella	Field	Red-orange spore Red mold	Trichotecenes DON	
Ustulago maydis	Field	Black/Gray	None	

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Environmental Factors Affecting Mold Growth

- Suitable Substrate - Feed
- pH 4 to 8, depending on mold
- Temperature 5 to 44 C (40 to 110 F)
- Moisture > 13%, variable requirements
- Relative humidity > 70%
- Water activity above a_w of 0.75
- Oxygen (Moisture excludes air)

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Mold Growth

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Consequences of mold growth

- **nutritional losses**
- **losses in material specific weight**

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Nutritional value after 60 days in storage

Treatments	Fat (%/MS)	Protein (%/MS)	Specific weight (Kg/M^3)
12%U*	4,6a	8,7b	689a
12%U + AF**	4,6a	8,6b	691a
15%U	4,0b	8,9b	622b
15%U + AF	4,5a	8,9b	670a

* Humidity

** Antifungicide

(Krabbe, 2000)

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Consequences of mold growth

- nutritional losses
- losses in material specific weight
- presence of mycotoxins

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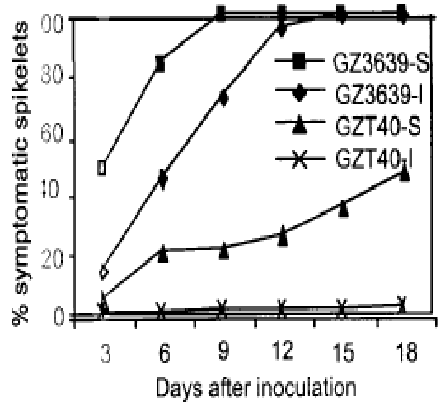
Biological significance

- Response to stress
- Competitive advantage (ecological)
- Mechanisms for propagation



Bai et. al Mycopathologia 2001

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Factors Associated with Mycotoxin Formation

- **Field Stress** - Plant stress - Infertility, Insect damage, Drought, Excess moisture, Temperature Extremes, Open husk, Lodging, Diseases (Stalk Rot, Ear Rot, Scab)
- **Harvest stress** - Late harvest, Harvest too wet (grain and hay), Harvest too dry (silage), Slow silo filling
- **Storage stress** - Grain or hay stored too wet, Silage stored too dry, without adequate cover, with excess surface exposure, inadequate fermentation
- **Feeding conditions** - Unclean bunks and equipment, Slow feeding of moist grains, Silage =>Slow feedout, Large feeding face

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Mycotoxin Analysis

Analytical Methods

- Fully quantitative
- Semi-quantitative
- Rapid monitoring




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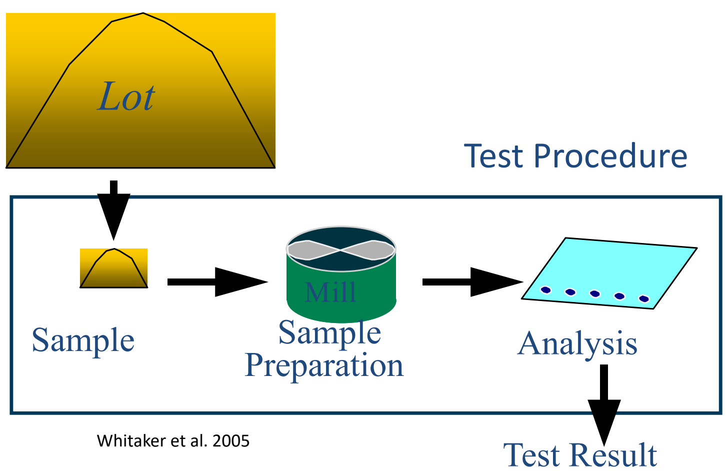
Mycotoxin Specific Sampling Protocols



Whitaker et al. 2005

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Mycotoxin Specific Sampling Protocols

The variability measured by the variance associated with a 0.91 kg sample, 50 g subsample, measuring aflatoxin in 1 aliquot by immunoassay in a lot of shelled corn at 20 ppb aflatoxin.

	Variance	Ratio %
Sample = 0.91 kg	268.1	75.5
Sub S^2, 50g	56.3	15.9
Immunoassay, 1 aliquot	30.4	8.6
Total	354.8	100

Sampling, sample preparation and analysis errors account for about 75.5, 15.9 and 8.6% of the total error, respectively.

Whitaker et al. 2005

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Mold and Toxin Distribution

Protein

12	13	12	14
13	13	14	12
15	11	12	12
13	14	11	9
13	12	12	13

Aflatoxin

0	0	0	0
0	0	200	0
0	0	0	0
0	0	0	0
0	0	0	0

Mean Protein Concentration 13%
(USDA)

Mean Aflatoxin Concentration 10ppb
(USDA)

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Sampling Recommendations

Table 6. Effect of increasing sample size on reducing the sampling variability[1].

	Sample size (kg)	
	0.91 kg	*4.54 kg*
Variance	266.5	53.3
Subsample[2], 50 g	56.3	56.3
TLC, 1 aliquot	27.9	27.9
Total	**350.7**	**137.5**
Range	20 ± 37	20 ± 23

Increasing sample size by a factor of five from 0.91 to 4.54 kg will cut the sampling variance in by a factor of five from 266.3 to 53.3 (80%). The total variance is reduced from 350.7 to 137.5 (60%).

Whitaker et al. 2005

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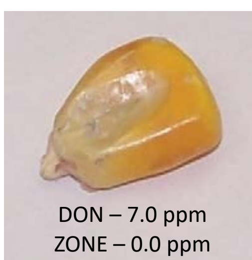
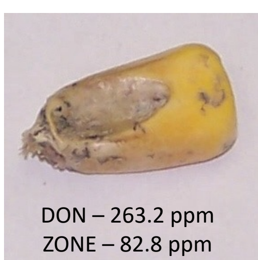
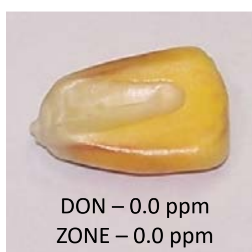
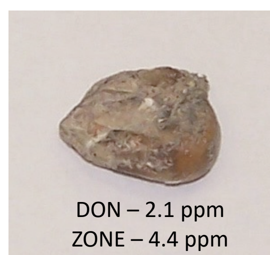
Visual Biases









Courtesy of Trilogy Labs

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Is there more mycotoxins now than before/ever

- Better analytical methods
- Understanding of their occurrence and effects
- Increased incidence in some years
  - Environmental stresses
  - Agronomic practices
- Higher production levels (animals)
  - More general stress
  - Genetic vulnerability
  - Animal production changes/challenges

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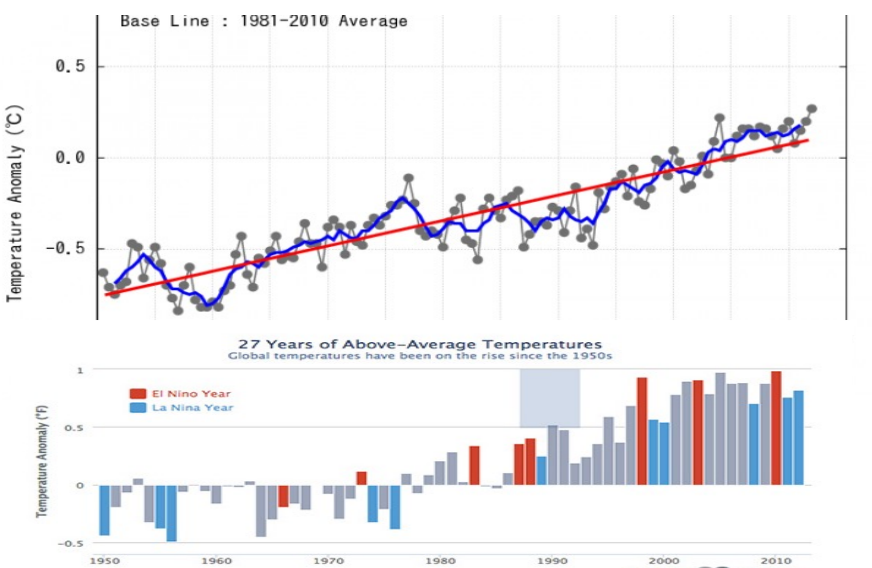
A Tale of 5 years



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Impact of Agronomic Practices

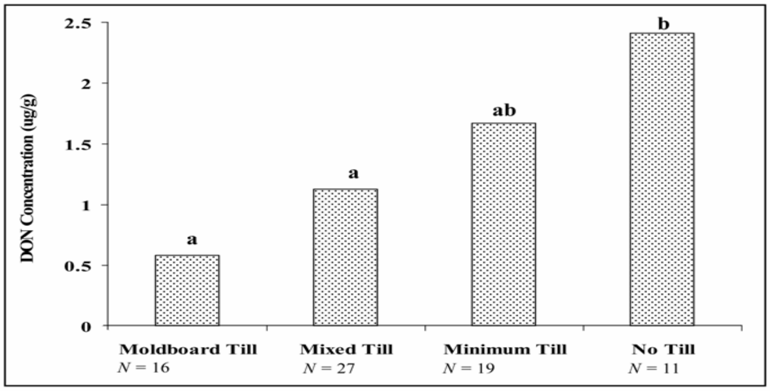

Fig. 6. Average deoxynivalenol (DON) concentration in 2001 and 2002 silage samples managed under different tillage systems. Mixed tillage refers to systems where more than one tillage type was used. Letters over bars indicate significant differences in DON concentration between tillage systems detected by the Tukey-Kramer test. Bars marked by the same letter are not significantly different.

Mansfield et. al. Plant Disease 2005

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Why have mycotoxin concerns increased?

- Better analytical methods
- Understanding of their occurrence and effects
- Increased incidence in some years
- Higher production levels (animals)

More general stress

Genetic vulnerability

Animal production changes/challenges

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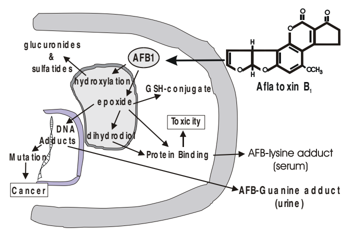
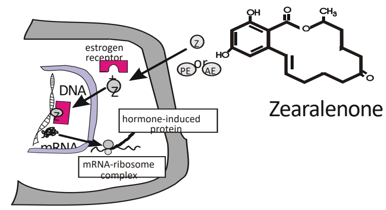
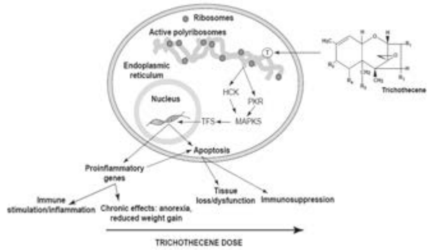
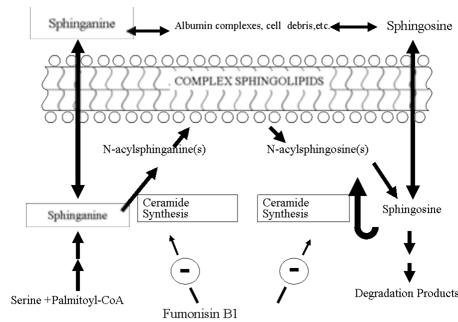
Toxicology









Riley and Pestka, 2005 in The Mycotoxin Blue Book

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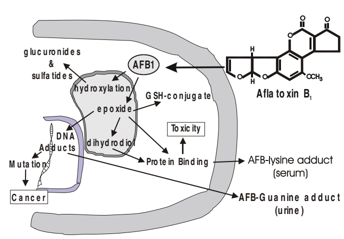

Riley and Pestka, 2005 in The Mycotoxin Blue Book

Research | Environmental Medicine

Case–Control Study of an Acute Aflatoxicosis Outbreak, Kenya, 2004

*Eduardo Azziz-Baumgartner,[1] Kimberly Lindblade,[2] Karen Gieseker,[3] Helen Schurz Rogers,[1] Stephanie Kieszak,[1] Henry Njapau,[4] Rosemary Schleicher,[1] Leslie F. McCoy,[1] Ambrose Misore,[5] Kevin DeCock,[6] Carol Rubin,[1] Laurence Slutsker,[7] and the Aflatoxin Investigative Group**

[1]National Center for Environmental Health, [2]National Center for Infectious Diseases, and [3]Epidemiology Program Office, Centers for Disease Control and Prevention, Atlanta, Georgia, USA; [4]Food and Drug Administration, Washington, DC, USA; [5]Preventive and Promotive Health Services, Kenya Ministry of Health, Nairobi, Kenya; [6]Centers for Disease Control and Prevention, Kenya Field Office, Nairobi, Kenya; [7]Centers for Disease Control and Prevention, Kenya Field Office, Kisumu, Kenya

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Aflatoxin Control in Milk

Animal (2007), **1:9**, pp 1344–1350 © The Animal Consortium 2007
doi: 10.1017/S1751731107000663

animal

Carryover of aflatoxin from feed to milk in dairy cows with low or high somatic cell counts

F. Masoero[1†], A. Gallo[1], M. Moschini[1], G. Piva[1] and D. Diaz[2]

[1]*Istituto di Scienze degli Alimenti e della Nutrizione, Facoltà di Agraria, Università Cattolica del Sacro Cuore, Via Emilia Parmense 84, 29100 Piacenza, Italy;* [2]*Department of Animal Dairy and Veterinary Sciences, Utah State University, Logan, UT 84322-4815, USA*

(Received 18 January 2007; Accepted 2 July 2007)

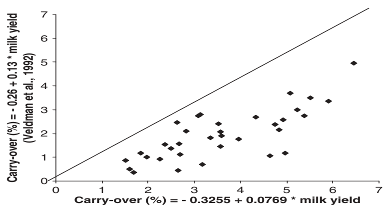

Figure 4 Plot of the predicted carry-over according to the obtained equation *v.* the predicted carry over as proposed by Veldman *et al.* (1992).

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Effects of the procedure of inclusion of a sequestering agent in the total mixed ration on proportional aflatoxin M1 excretion into milk of lactating dairy cows

F. Masoero[a,*], A. Gallo[a], D. Diaz[b], G. Piva[a], M. Moschini[a]

Table 3. DIM (kg/d), milk yield (kg/d), fat, protein and lactose (g/kg) milk contents, aflatoxin B1 (AFB1) intake (μg/d), aflatoxin M1 (AFM1) milk concentration (ng/kg) and carryover in milk (%) at plateau condition (7th and 9th day on AFB1 ingestion period) in trial 1

Item	Diet[1]				SEM
	Diet 1	Diet 2	Diet 3	Diet 4	
DMI, kg/d	23.06	22.73	23.09	23.42	0.27
Milk, kg/d	29.29	30.09	29.93	29.37	0.42
Fat, g/kg	37.8	36.6	36.7	37.8	0.88
Protein, g/kg	34.1	33.9	34.4	34.3	0.29
Lactose, g/kg	51	51.2	51	49.9	0.73
AFB1 intake, μg/d	172.42	170.42	170.39	171.85	0.72
AFM1, ng/kg	97.3[b]	75.7[c]	111.1[a]	120.4[a]	3.65
Carryover, %	1.63[b]	1.3[c]	1.95[a]	2.03[a]	0.07

[a-c] Means in rows with different superscripts differ ($P < 0.05$).

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Aflatoxin Control in Milk

Mycopathologia **156:** 223–226, 2002.

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Aflatoxin Binders I: *In vitro* binding assay for aflatoxin B1 by several potential sequestering agents

Duarte E. Diaz[1], Winston M. Hagler Jr.[2], Brinton A. Hopkins[1] & Lon W. Whitlow[1]
[1]*Department of Animal Science;* [2]*Department of Poultry Science, College of Agriculture and Life Sciences, Nort Carolina State University, Raleigh, NC USA*

Received 20 July 2000; accepted 2 October 2002

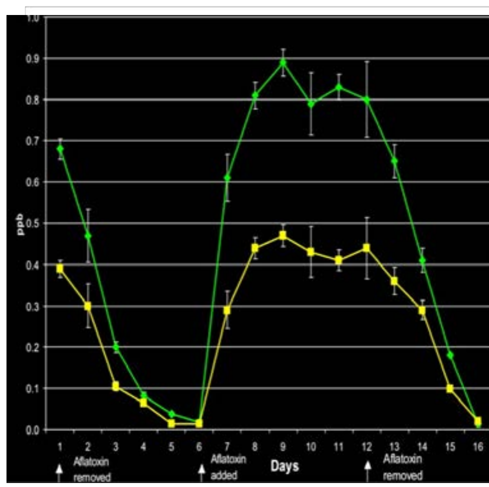
Mycopathologia **157:** 233–241, 2004.

2:

Aflatoxin Binders II: Reduction of aflatoxin M1 in milk by sequestering agents of cows consuming aflatoxin in feed

Duarte E. Diaz[1], Winston M. Hagler Jr.[2], John T. Blackwelder[1], Julie A. Eve[1], Brinton A Hopkins[1], Kevin L. Anderson[3], Frank T. Jones[4] & Lon W. Whitlow[1]
[1]*Department of Animal Science;* [2]*Department of Poultry Science, College of Agriculture and Life Science* [3]*College of Veterinary Medicine, North Carolina State University, Raleigh, NC, USA;* [4]*Current addres Department of Poultry Science, University of Arkansas, Fayetteville, AR, USA*

Received 20 July 2000; accepted in final form 15 March 2002



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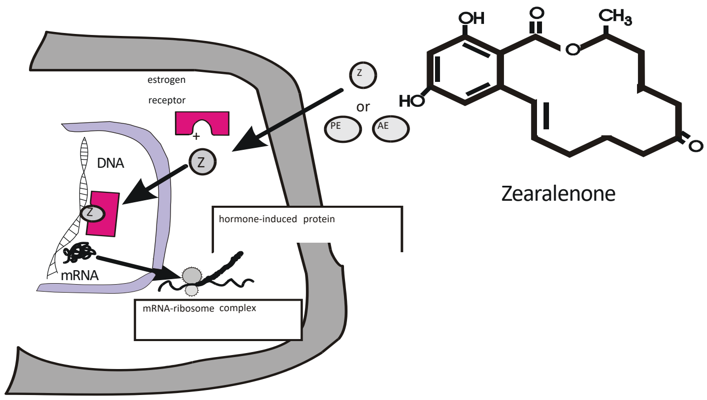

Riley and Pestka, 2005 in The Mycotoxin Blue Book

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Toxicology


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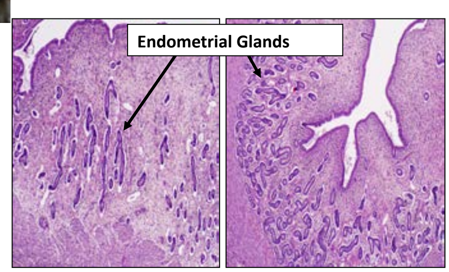
Zearalenone enhances reproductive tract development, but does not alter skeletal muscle signaling in prepubertal gilts☆

W.T. Oliver[a,*], J.R. Miles[a], D.E. Diaz[b], J.J. Dibner[b], G.E. Rottinghaus[c], R.J. Harrell[b]



Control: Sparse Endometrial Gland Development

Treated: Increased Endometrial Gland Development

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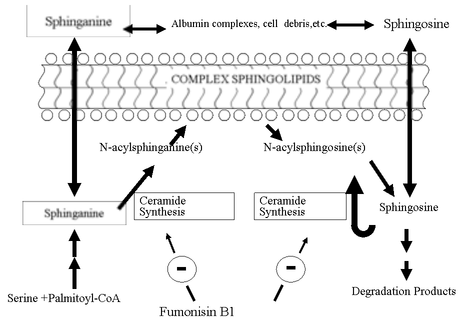

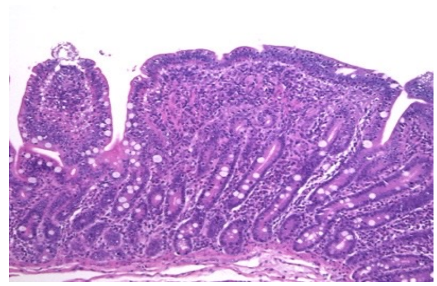

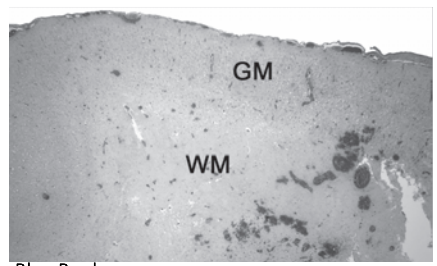

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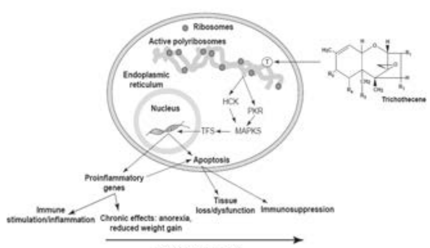

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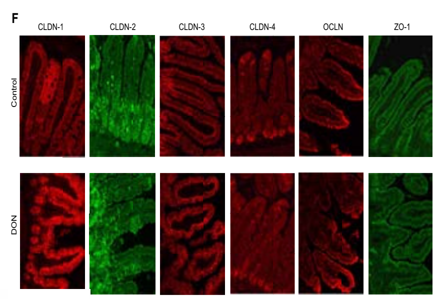

molecules MDPI

Review

Trichothecenes in Food and Feed, Relevance to Human and Animal Health and Methods of Detection: A Systematic Review

Magdalena Polak-Śliwińska * and Beata Paszczyk

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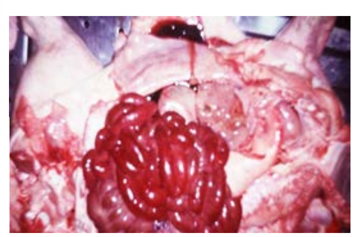
* Correspondence: m.polak@uwm.edu.pl; Tel.: +48-89-523-45-84



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Toxicology Letters 143 (2003) 97–107
Toxicology Letters
www.elsevier.com/locate/toxlet

Minireview

Trichothecenes in the environment: relevance to human health

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Received 16 December 2002; received in revised form 3 February 2003; accepted 4 February 2003

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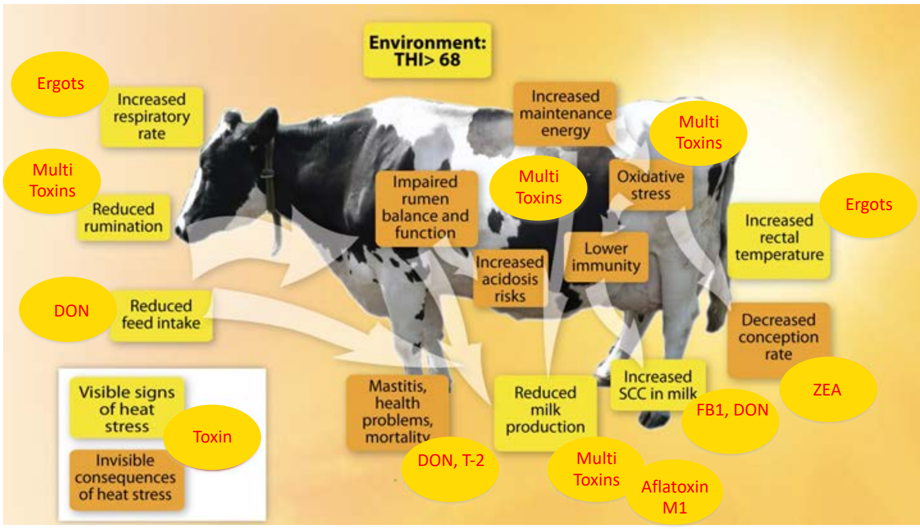
New Area - Heat Stress - Mycotoxin



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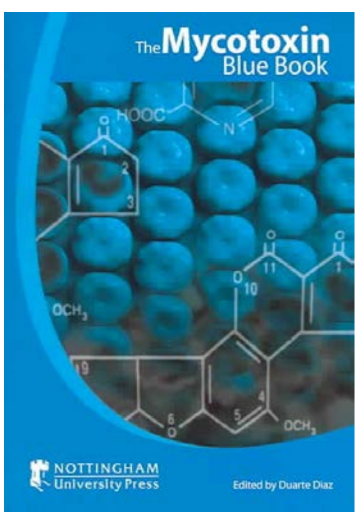
Publications



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