



Fusarium Mycotoxins – a manageable risk for the cereals food chain

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Where do mycotoxins go in cereal milling?

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Agenda

- Introduction
- Milling processes
 - Oats
 - Wheat
 - Maize
 - For each consider the occurrence of fusarium toxins in unprocessed cereals and fate during milling
- Conclusions



Milling Studies



- **Focus on:**

Commonly occurring mycotoxins in UK cereals

- Fusarium toxins
 - Trichothecenes DON/NIV/T2/HT2, acetylated DON derivatives
 - Zearalenone (ZON)
 - Fumonisin (maize only)

Focus on:

**Production of milling intermediates frequently consumed in UK foods
Commercial scale**

MAIZE	WHEAT	OATS
• Milling (Dry)	• Milling	• Milling
➢ Breakfast cereals	➢ Bread	➢ Oat breakfast cereals, biscuits etc
➢ Snacks	➢ Cakes	
	➢ Biscuits	




Approach




- For all processes studied:
 - Investigation conducted over multiple harvest years
 - Sampling points and sampling plans agreed at the outset
 - Analytical requirements defined
 - Studied same process on multiple occasions

Key question: Are all toxins presented in the raw cereal accounted for at the end of processing?



= **Process mass balance**



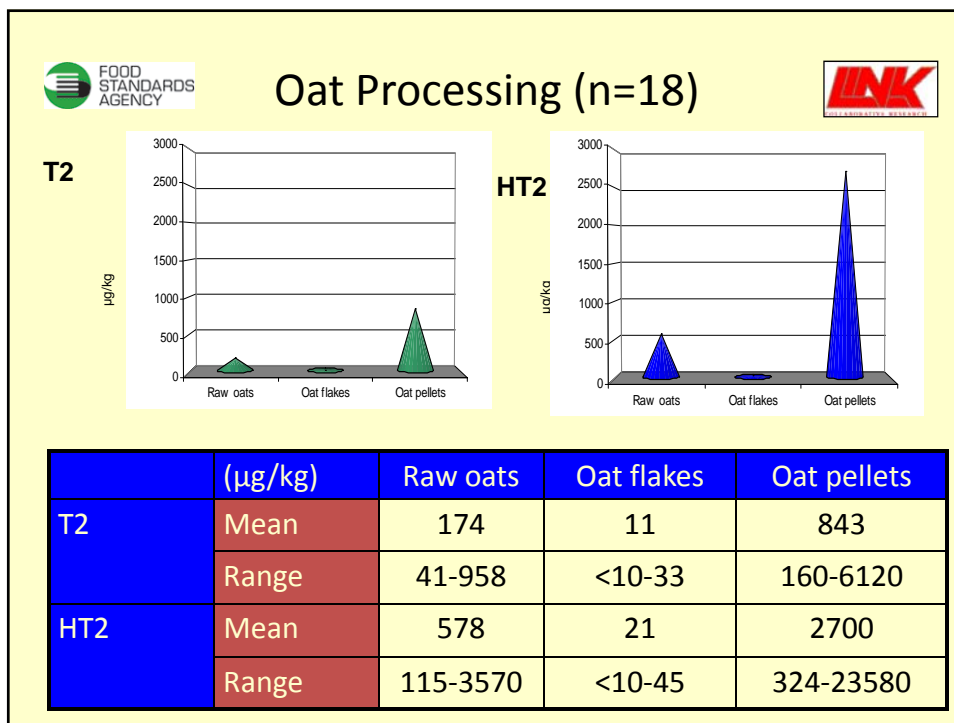
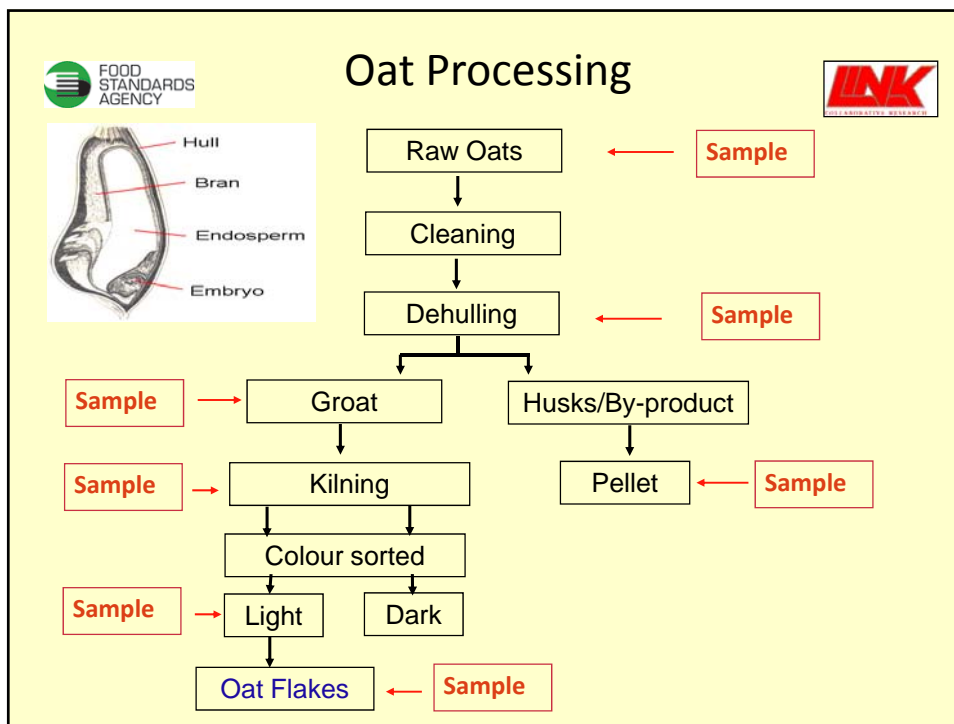
Sampling and Analysis



Sampling and Traceability	<p>Critical that:</p> <ul style="list-style-type: none"> • the samples taken are representative of the lot being processed • the raw material lot can be traced through the process <ul style="list-style-type: none"> ➢ Sample points based on chemical and physical processes that may affect mycotoxins ➢ Sampling plans agreed with the UK FSA for each process ➢ Plans are as close as possible to EU sampling plans 										
Mycotoxin Analysis	<p>Two analytical labs participated in the project</p> <p>Steps taken to ensure all results are accurate, comparable with no bias</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr style="background-color: #e0e0e0;"> <th colspan="2" style="text-align: left; padding: 2px;">CONSIDERATIONS</th> </tr> </thead> <tbody> <tr> <td style="padding: 2px;">Standard quantification</td> <td style="padding: 2px;">Sample treatment at the laboratory to achieve homogeneity (grinding/particle size/mixing)</td> </tr> <tr> <td style="padding: 2px;">Extraction (-solvent/time)</td> <td style="padding: 2px;">Clean-Up</td> </tr> <tr> <td style="padding: 2px;">End determination techniques</td> <td style="padding: 2px;">Method performance parameters</td> </tr> <tr> <td style="padding: 2px;">Accreditation status – all ISO 17025</td> <td style="padding: 2px;">Proficiency testing carried out (FAPAS)</td> </tr> </tbody> </table>	CONSIDERATIONS		Standard quantification	Sample treatment at the laboratory to achieve homogeneity (grinding/particle size/mixing)	Extraction (-solvent/time)	Clean-Up	End determination techniques	Method performance parameters	Accreditation status – all ISO 17025	Proficiency testing carried out (FAPAS)
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OAT MILLING





Oat Summary



RAW OATS

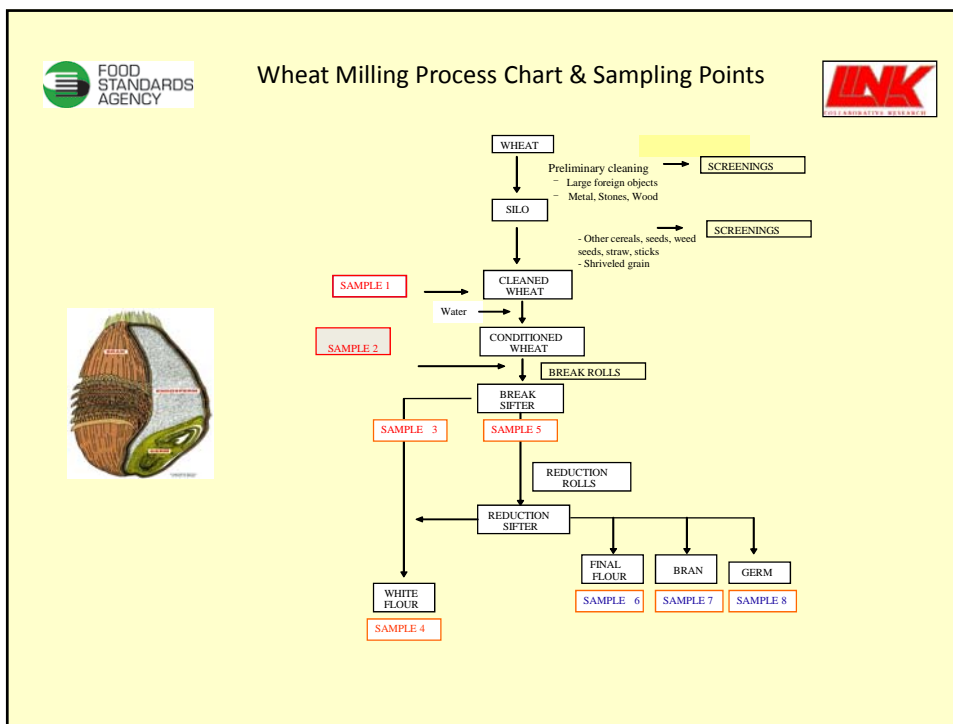
- T2 and HT2 occur in all samples
- Maximum 4,500µg/kg combined
- DON and NIV occur but at lower levels, DON higher in Scandinavian oats than UK oats
- Very low ZON

PROCESSING

- Processing of oats highly effective in reducing the level of all trichothecenes in the oat flakes
- **Reductions of >95% consistently achieved**
- Oat flakes maximum HT2=45µg/kg
- Mycotoxins concentrated in the pellet by-products for animal feed
- All toxins accounted for in process streams (mass balance)



WHEAT MILLING



Wheat Deoxynivalenol Levels

HARVEST	NUMBER OF SAMPLES	MEAN LEVEL (µg/kg)	RANGE (µg/kg)	MEDIAN (µg/kg)
2004	2	91	63-118	-
2005	12	140	22-481	109
2006	15	45	16-113	43
2007	6	292	208-382	280
TOTAL	35	122	16-481	63

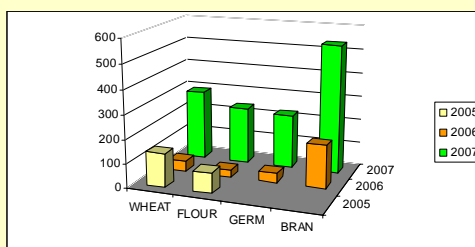


Wheat Milling: Deoxynivalenol

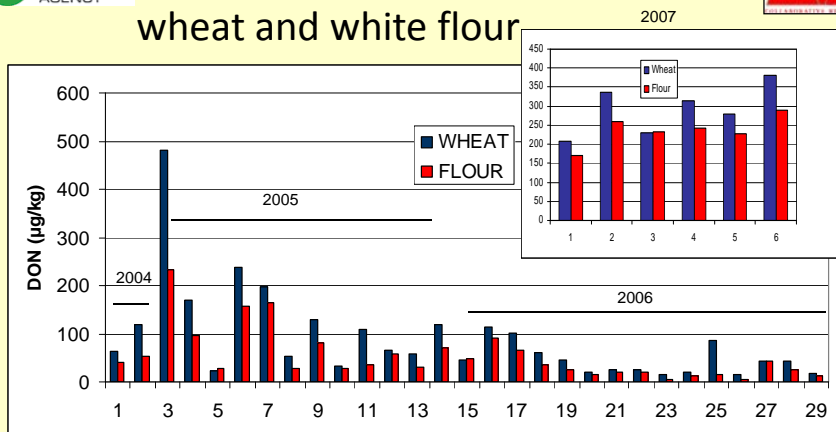


	Cleaned Wheat (n=35)	White Flour (n=35)	Germ (n=21)	Bran (n=22)
	µg/kg			
Mean	122	85	114	326
Range	16-481	<10-289	21-374	41-1080
Median	63	41	53	168

Mean reduction
cleaned wheat → flour
= 30%
All DON accounted for
in the process streams



Occurrence of DON in cleaned wheat and white flour



Key findings:

- Mean DON reduction (cleaned wheat to flour) = 30% (range 0-67%)
- 2007 Mean reduction 18%



Wheat Milling: Nivalenol



	Cleaned Wheat (n=35)	White Flour (n=35)	Bran (n=22)	Germ (n=21)
	µg/kg			
Incidence	43%	1%	100%	57%
Mean (of positives)	16	10	37	12
Median (of positives)	15	10	39	13
Range	<10-29	10	10-72	<10-15



Wheat Milling: T2



	Cleaned Wheat (n=35)	White Flour (n=35)	Bran (n=22)	Germ (n=21)
	µg/kg			
Incidence	11%	0%	68%	52%
Mean (of positives)	11	<10	40	20
Median (of positives)	11	-	41	16
Range	<10-12	-	<10-77	<10-34



Wheat Milling: HT2



	Cleaned Wheat (n=29)	White Flour (n=29)	Bran (n=15)	Germ (n=15)
	µg/kg			
Incidence	11%	0%	68%	38%
Mean (of positives)	11	<10	49	20
Median (of positives)	12	-	44	17
Range	<10-13	-	<10-95	<10-29



Wheat Milling: ZON



	Cleaned Wheat (n=6)	White Flour (n=6)	Bran (n=6)	Germ (n=6)
	µg/kg			
Incidence	66%	66%	100%	80%
Mean (of positives)	9	3	35	11
Median (of positives)	6.9	4.1	25.1	6.8
Range	<3-33.8	<3-5.7	14.5-70.7	<3-25.8



Legislation



- All wheat samples below the regulatory limit for DON & ZON

	Unprocessed Cereals	
	Maximum level 1881/2006 ($\mu\text{g}/\text{kg}$)	Maximum level in FQS64 ($\mu\text{g}/\text{kg}$)
DON	1250	481
ZON	100	33.8

	Cereal Flour and Germ		
	Maximum level 1881/2006 ($\mu\text{g}/\text{kg}$)	Maximum level in FQS64 ($\mu\text{g}/\text{kg}$)	
		Flour	Germ
DON	750	288	374
ZON	75	<10	25.8

- Bran can have high levels of DON (max 1080 $\mu\text{g}/\text{kg}$)



Wheat Milling: Overview



CLEANED WHEAT

- DON detected in all samples, ZON detected in 2007 harvest samples
- Other toxins at low incidence and levels in each harvest

EFFECT OF MILLING

- DON is reduced in white flour (mean 30%, range 0-67%).
- Increased in bran
- Other trichothecenes show the same pattern*
- All toxins accounted for in the milling stream
- Levels of all toxins below EU regulatory limits



MAIZE MILLING





Occurrence in Raw Maize





µg/kg		Origin = FRENCH 1 (n=17)	Origin = FRENCH 2 (n=14)	Origin = ARGENT. (n=14)
DON	Range	13-519	27-420	16-166
	Mean	112	150	87
	Median	38	92	72
FB1	Range	73-482	19-1027	237-3813*
	Mean	262	316	1563
	Median	220	225	1362

*B1+B2 = 5202


Occurrence in Raw Maize

µg/kg		Origin = FRENCH 1 (n=17)	Origin = FRENCH 2 (n=14)	Origin = ARGENTINIAN (n=14)
ZON	Range	<3-86	<3-52	<3-42
	Mean	18	17	14
	Median	<3	12.6	9
Data also for:				
	Nivalenol	HT-2 toxin	T2-toxin	3Ac-DON
	15 Ac-DON	Fus X	Neosolaniol	DAS





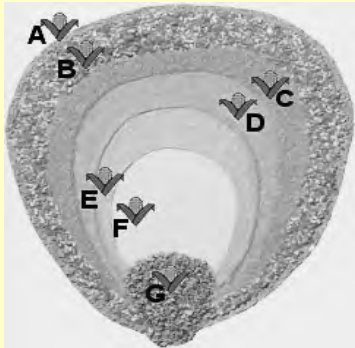
Mycotoxins in Raw Maize Summary

- Maize subject to contamination with a range of mycotoxins
- DON and FB1 occurred in all consignments
- Occurrence varies depending on:
 - Origin
 - Fumonisins higher in South American maize than French maize
 - T2 and HT2 not detected in South American maize
 - Season
 - French consignments from 2004 had higher DON and ZON levels than samples from 2005




Schematic view of a maize seed Origin of different milled products






A	Bran	B	Flaking grits
C	Coarse grits	D	Fine grits
E	Polenta	F	Flour
G	Germ	H	Maize meal (not labelled, composition varies)

- Coarse and flaking grits <1000-5000μ
- Medium to fine grits 300-1000μ
- Polenta 200-300μ
- Flour 200μ and less
- Other products (maize meal, germ, bran, broken grains)



Dry Milling of Maize



82 consignments studied

```

    graph TD
      Raw[Raw maize] --> Clean[Clean]
      Clean --> Temper[Temper]
      Temper --> De-germ[De-germ]
      De-germ --> Mill[Mill]
      Mill --> Products[Range of products depending on final food product]
      Products --> Flour[Flour]
      Products --> Grits[Maize grits/flour]
      Products --> Flaking[Flaking grits]
      Flour --> Tortilla[Tortilla]
      Grits --> Snacks[Extruded snacks]
      Flaking --> Cereals[Breakfast cereals]
      
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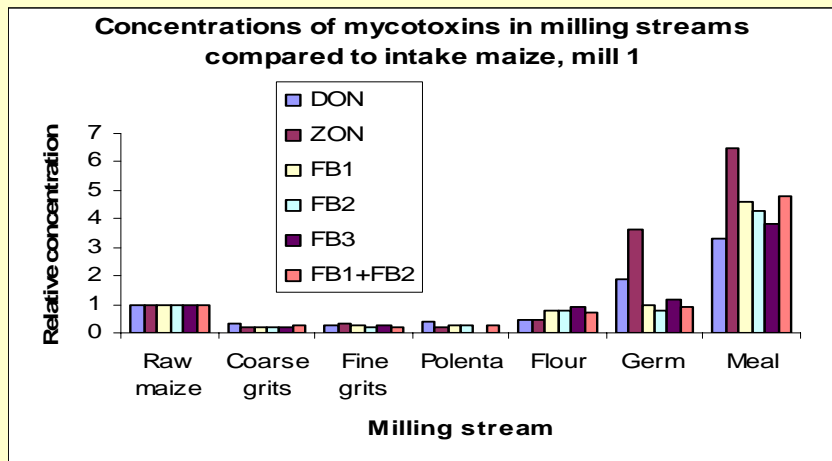
Mill 1 : French (SW)

Mill 2 : French (Loire)

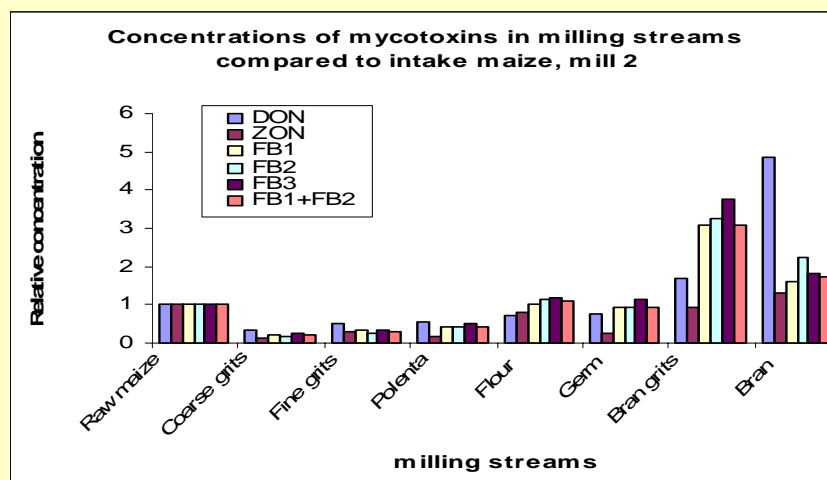
Mill 3 : Argentinean

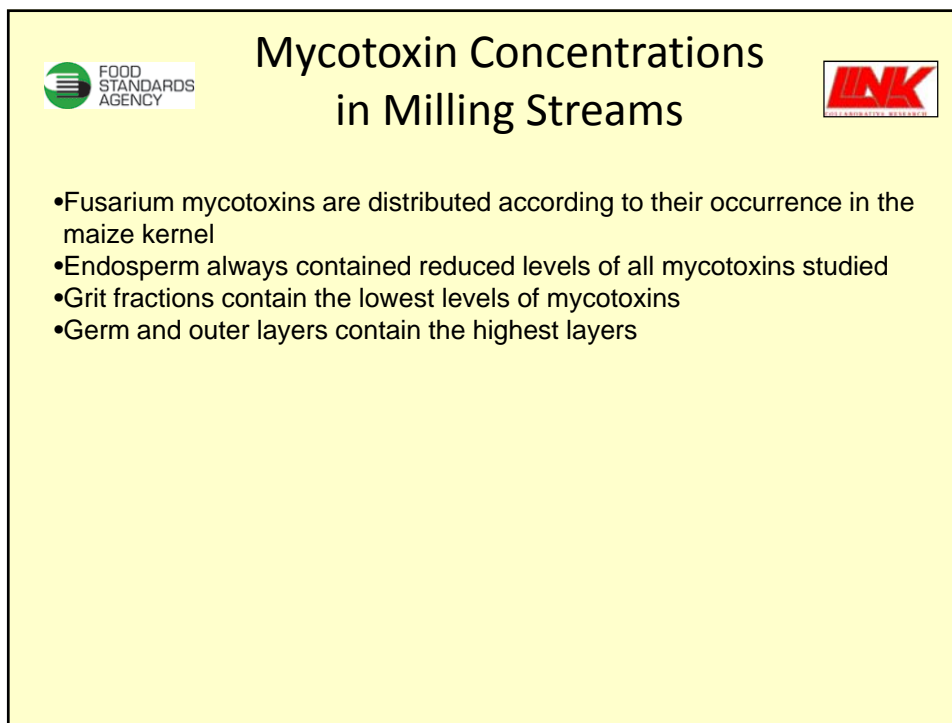
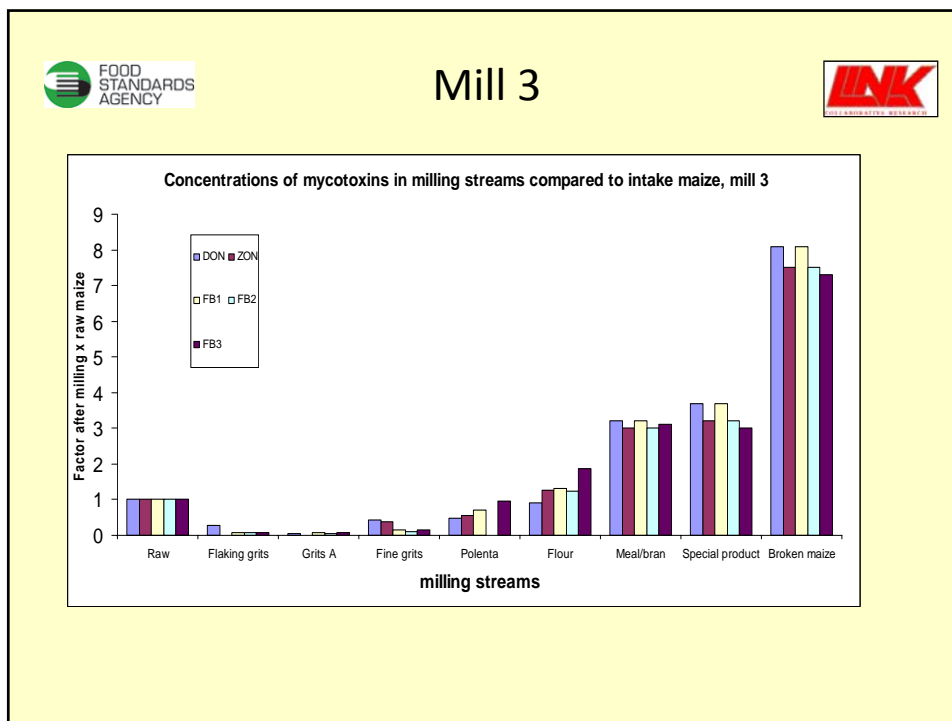


Mill 1



Mill 2







Key Conclusions



- Where do mycotoxins go in cereal milling?
 - Fusarium mycotoxins are not lost during milling but merely redistributed into different milling streams
 - Fusarium mycotoxins tend to follow the same distribution patterns
 - In general levels are highest in the outer layers of the grain and the germ, they are lowest in the endosperm
 - The exact distribution in milling streams is variable (between mills, milling process set up) and need to be understood for the milling process being used



Acknowledgements



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