

dsm-firmenich

World Mycotoxin Survey

The Global Threat

January – December 2023



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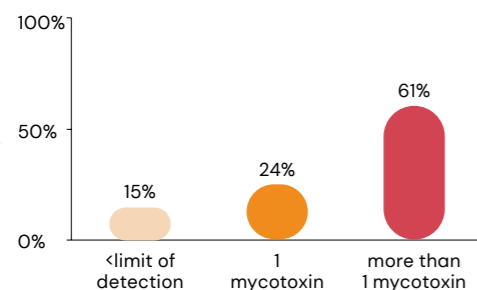
World Overview

23 808
Samples

113 558
Analyses

95
Countries

Co-contamination



Number of mycotoxins per sample based on samples tested for 3 or more mycotoxins.

Risk Level

The risk level expresses the percentage of samples testing positive for at least one mycotoxin above the threshold level in parts per billion (ppb).

Recommended risk threshold of major mycotoxins in ppb

Afla	ZEN	DON	T2	FUM	OTA
2	50	150	50	500	10

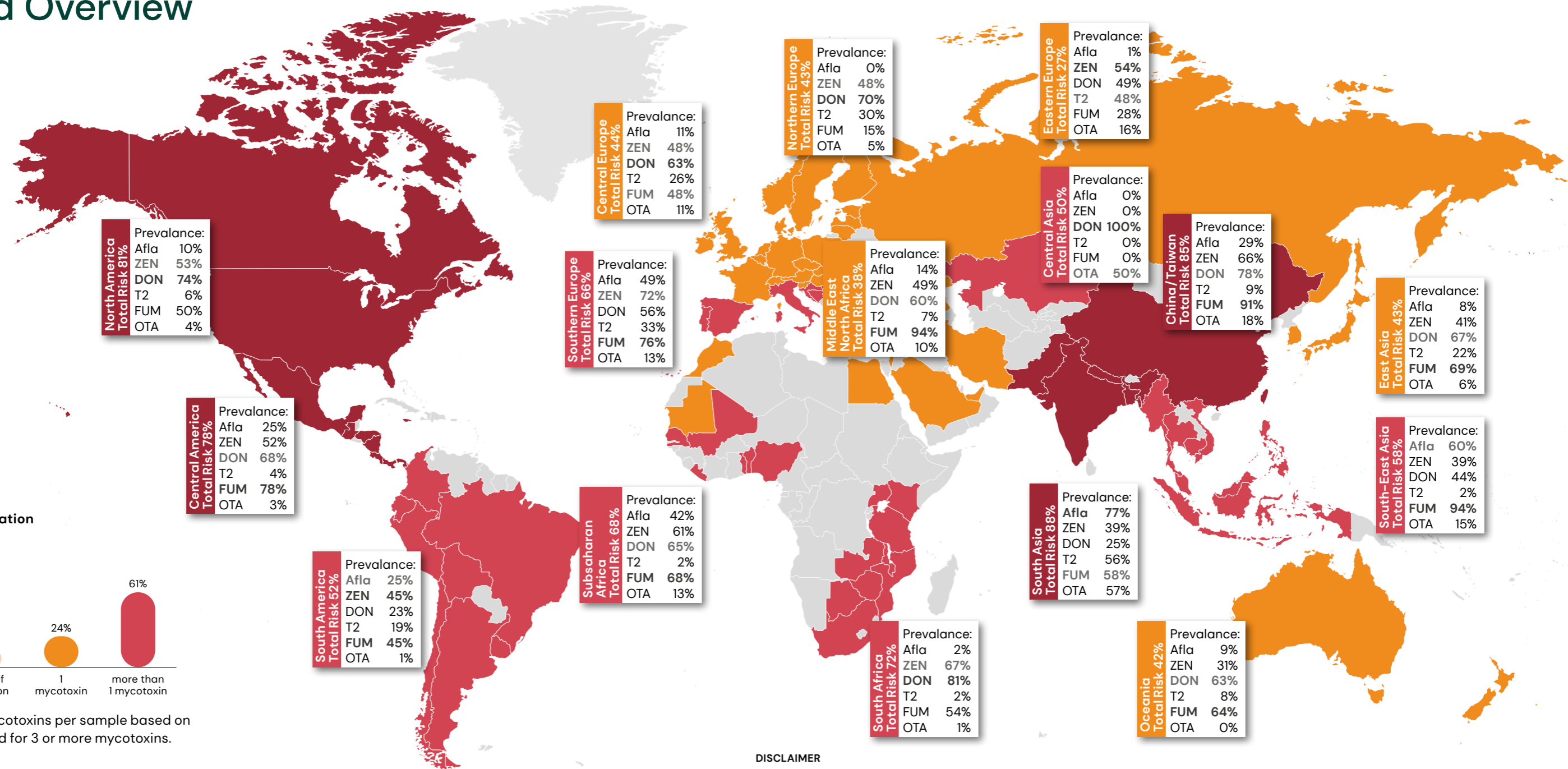
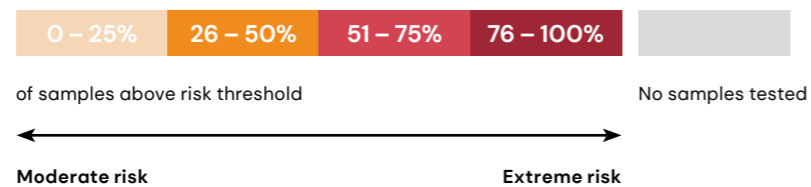


Figure 1. Global map of mycotoxin prevalence and risk in different regions.



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Mycofix® is not available in the US and Canada.

ACKNOWLEDGEMENTS

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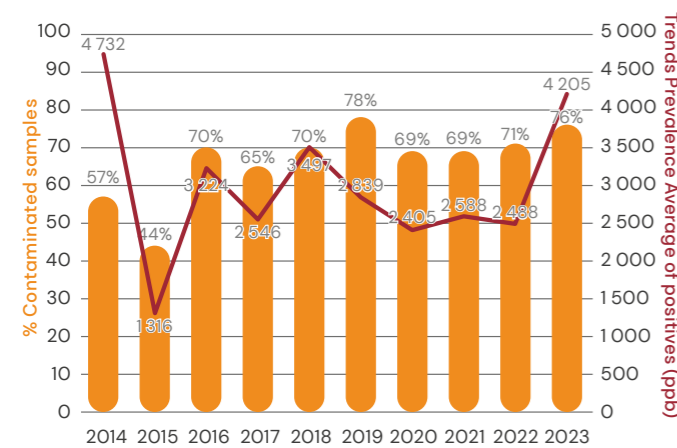
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Mycotoxin Trends

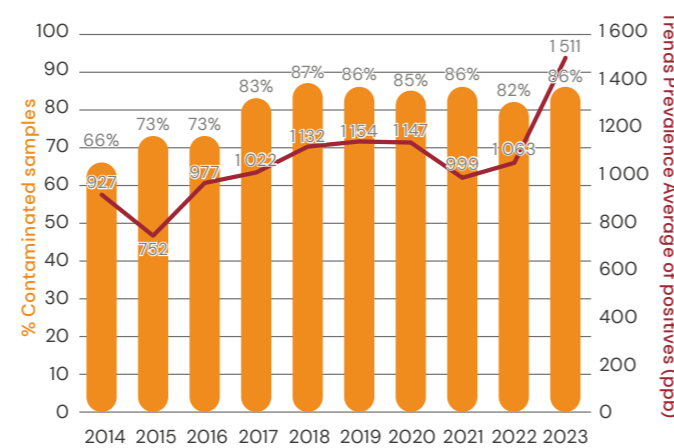
Starting already in 2004, the DSM Mycotoxin Survey is the longest running Mycotoxin Survey. This huge dataset allows us to look at variations in contamination levels of the mycotoxins over the years. In the last 10 years contamination with the six main mycotoxins in all commodities (raw materials as well as finished feed) seems to be stable on a global perspective. The yearly average of positives concentration levels of the

Fusarium mycotoxin FUM shows a slight increase over the past 10 years in Finished Feed. FUM prevalence in North American corn kernel samples vary more widely with peak values in 2007, 2012, 2019 and 2023, whereas FUM concentration in ppb shows an constant increase over the past 10 years (despite a peak in 2014, where an enormous average of 4732ppb FUM was found).

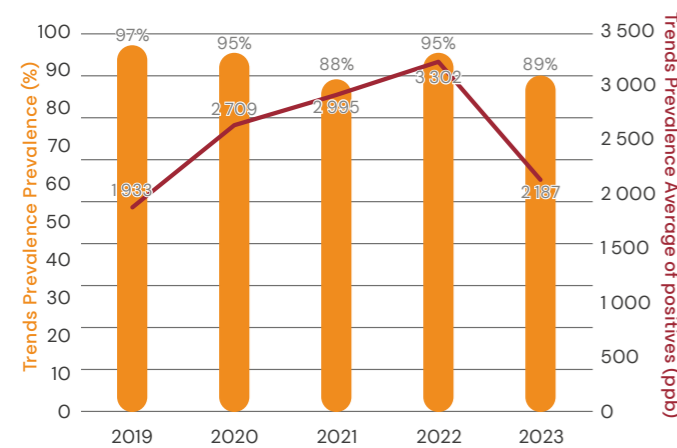
FUM on North American corn kernels



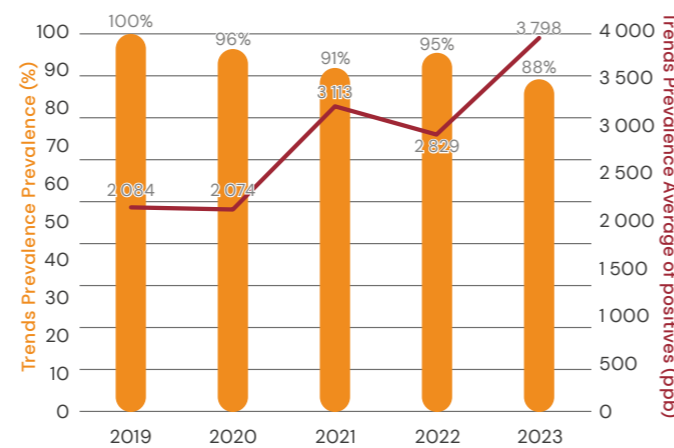
FUM in Finished Feed World



DON in DDGS in Asia



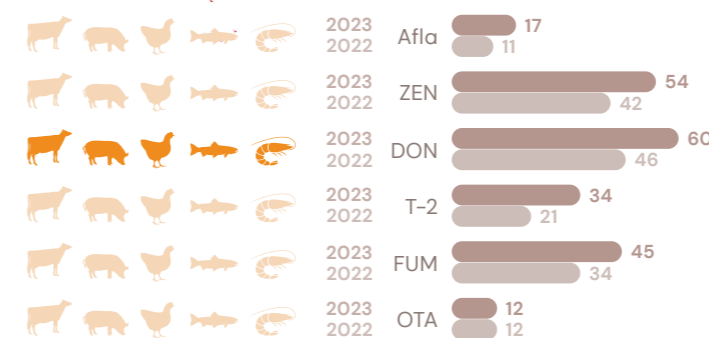
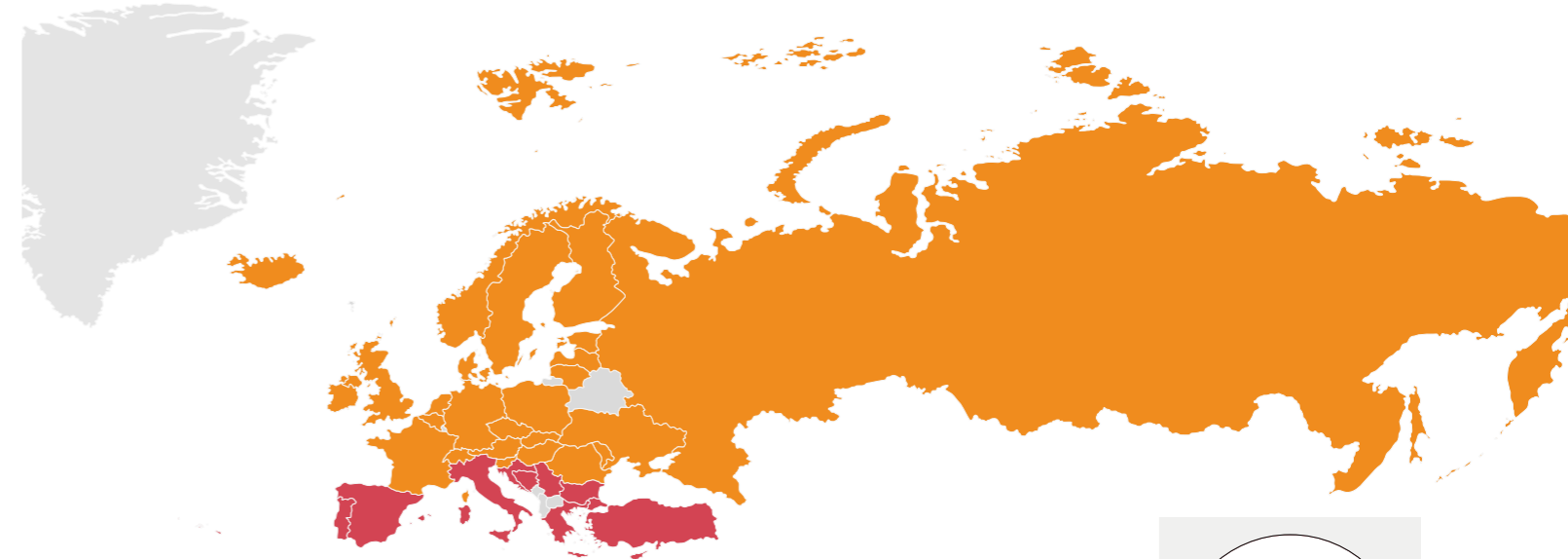
FUM in corn kernels in Asia



Prevalence of FUM in Asian corn kernels and DON in Asian DDGS seems to be quite stable, whereas average of positives show an increase over the past 5 years. While there is high variation by looking at different

raw materials in specific regions and sub-regions, the global perspective shows the consistent presence of mycotoxins in animal feed and its ingredients.

Europe



Animal colours indicate the risk posed to this species by the prevalence and concentration of each mycotoxin in all samples from this region (light orange=moderate to red=extreme see color code page 2)
% Contaminated samples January–December 2023 ■ and January–December 2022 ■

	Total samples: 10 188	Afla	ZEN	DON	T-2	FUM	OTA
Wheat grains	Number of samples tested	637	1 338	1 369	872	636	615
	% Contaminated samples	5%	24%	41%	19%	9%	4%
	Average of positive (ppb)	5	50	297	18	199	21
	Median of positive (ppb)	4	12	77	12	42	6
	Maximum (ppb)	23	5 474	8 459	150	1 272	162
Corn kernels	Number of samples tested	926	1 073	1 093	679	882	649
	% Contaminated samples	22%	66%	77%	47%	77%	7%
	Average of positive (ppb)	17	112	882	75	1 266	37
	Maximum (ppb)	1 362	3 937	20 440	2 534	37 540	386
Corn silage**	Number of samples tested	792	1 191	1 195	766	779	767
	% Contaminated samples	4%	70%	79%	6%	46%	2%
	Average of positive (ppb)	9	200	968	67	598	5
	Maximum (ppb)	57	13 187	25 275	955	15 962	14

** Mycotoxin concentrations are expressed on dry matter basis. If mycotoxin concentrations were not available on DM basis, they were corrected assuming a standard of 33% DM content in the silage samples.

Corn
DON and FUM in 77% of samples, followed by ZEN (66%)

77%

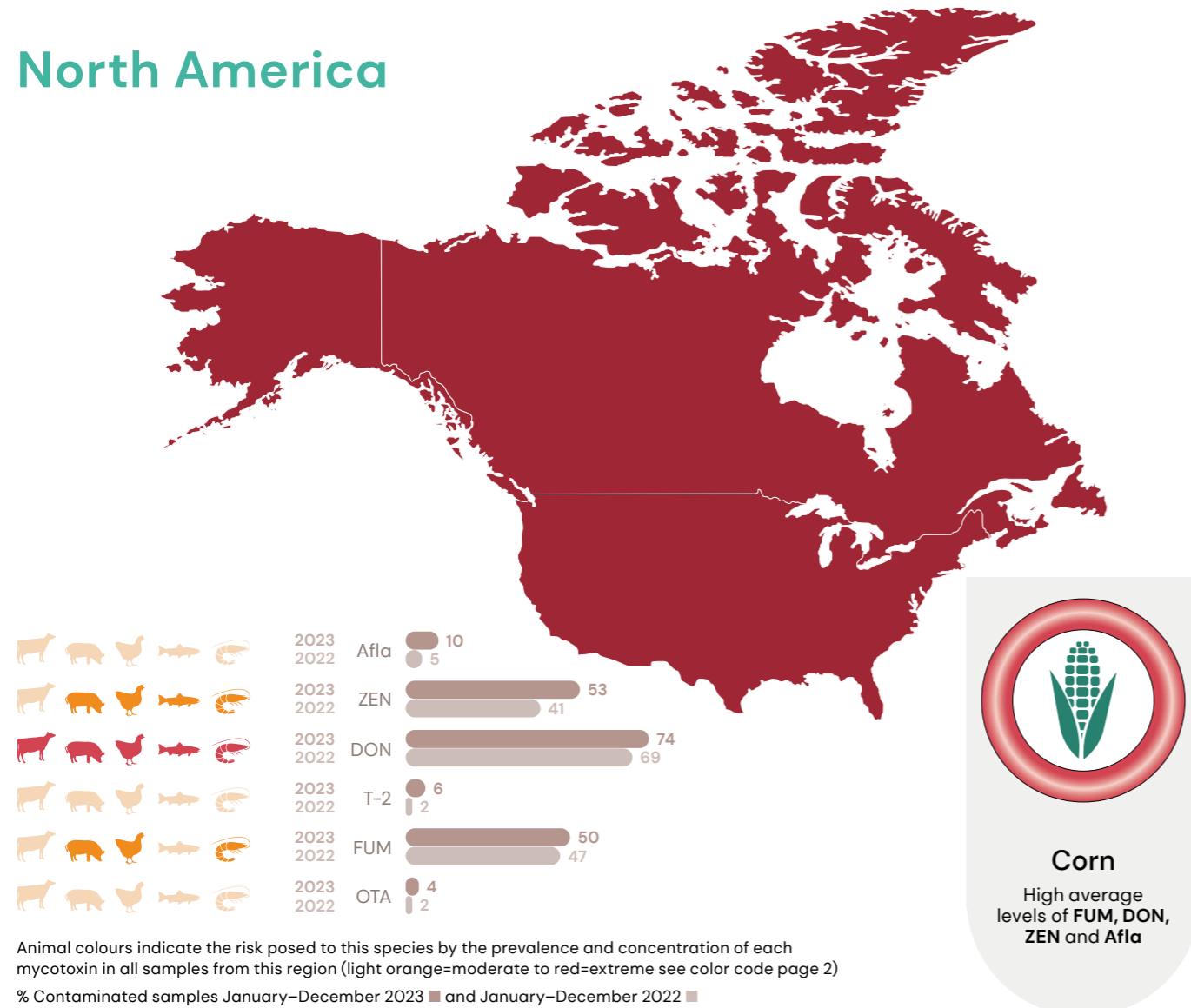
Straw
79% positive for DON with >850 ppb on average

79%

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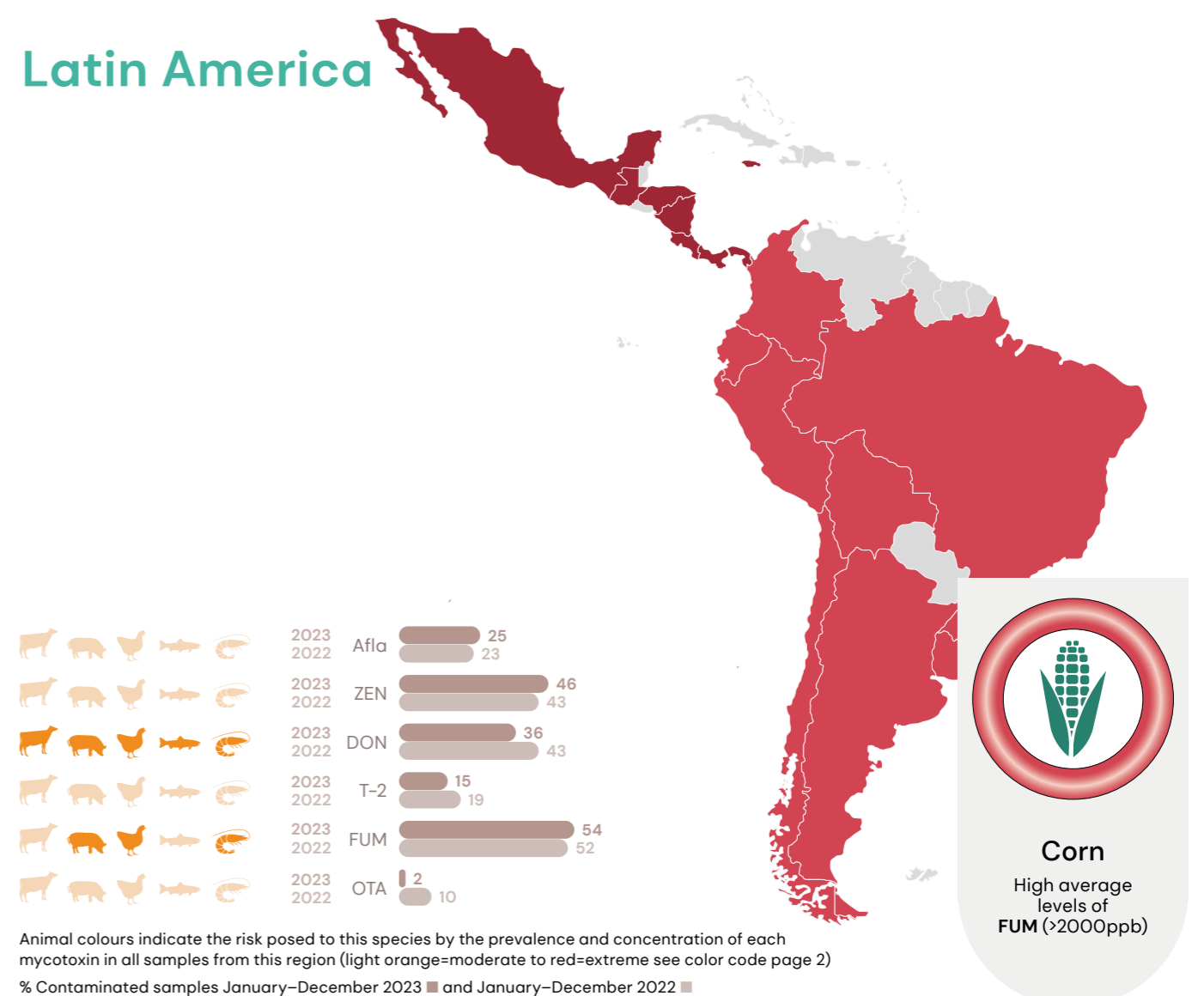
North America



	Total samples: 1928	Afla	ZEN	DON	T-2	FUM	OTA
Wheat grains							
Number of samples tested	22	22	22	22	22	22	22
% Contaminated samples	0%	9%	23%	0%	5%	5%	
Average of positive (ppb)	-	1 042	2 821	-	4 575	12	
Median of positive (ppb)	-	1042	213	-	4 575	12	
Maximum (ppb)	-	2 080	13210	-	4 575	12	
Corn kernels							
Number of samples tested	479	481	481	477	481	475	
% Contaminated samples	9%	51%	68%	6%	76%	0%	
Average of positive (ppb)	40	218	1 371	23	4 205	3	
Median of positive (ppb)	9	66	555	11	1 383	3	
Maximum (ppb)	327	4 310	11 300	100	83 175	3	
Corn silage**							
Number of samples tested	285	285	285	285	285	285	
% Contaminated samples	3%	60%	89%	0%	19%	3%	
Average of positive (ppb)	2	456	2 123		910	8	
Median of positive (ppb)	2	204	1 260		392	5	
Maximum (ppb)	5	10 440	27 700		11 918	34	

** Mycotoxin concentrations are expressed on dry matter basis. If mycotoxin concentrations were not available on DM basis, they were corrected assuming a standard of 33% DM content in the silage samples.

Latin America



	Total samples: 7 374	Afla	ZEN	DON	T-2	FUM	OTA
Wheat grains							
Number of samples tested	71	64	34	60	38	44	
% Contaminated samples	37%	55%	32%	38%	29%	5%	
Average of positive (ppb)	2	51	403	47	289	326	
Median of positive (ppb)	2	31	340	50	290	326	
Maximum (ppb)	7	135	1102	73	820	649	
Corn kernels							
Number of samples tested	2 923	2 797	1 844	1 730	2 377	1 145	
% Contaminated samples	19%	34%	35%	11%	64%	1%	
Average of positive (ppb)	16	85	654	44	2 049	5	
Median of positive (ppb)	2	43	463	36	1 200	3	
Maximum (ppb)	9 846	2 612	5 200	254	24 730	19	
Corn silage**							
Number of samples tested	150	152	96	72	96	63	
% Contaminated samples	21%	69%	35%	1%	34%	0%	
Average of positive (ppb)	20	424	1 328	354	874	0	
Median of positive (ppb)	19	198	781	354	494	-	
Maximum (ppb)	78	2 517	6 000	354	9 420	-	

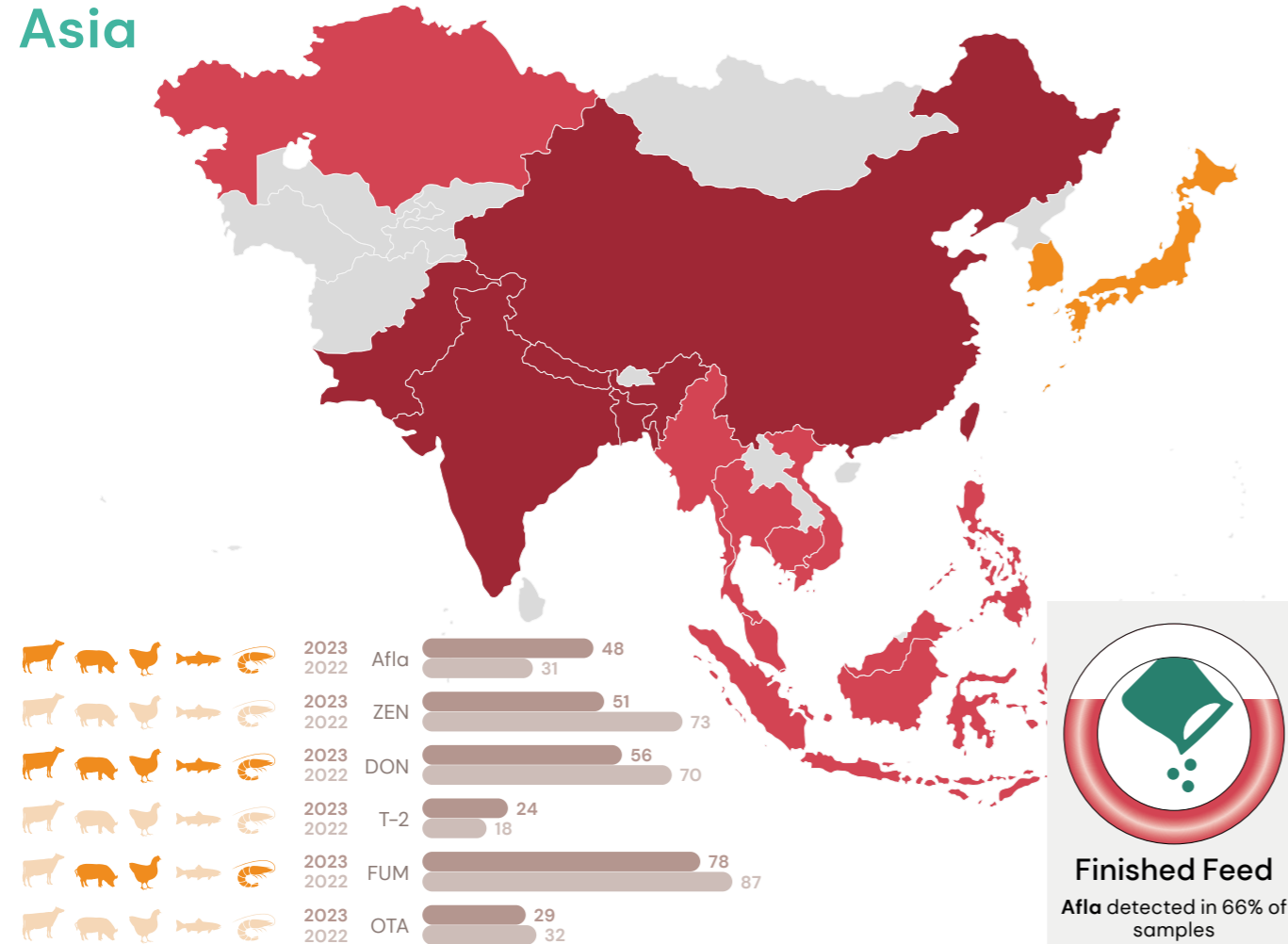
** Mycotoxin concentrations are expressed on dry matter basis. If mycotoxin concentrations were not available on DM basis, they were corrected assuming a standard of 33% DM content in the silage samples.

Corn DDGS
High levels of *Fusarium* mycotoxins
97% of samples contain >1 mycotoxin
97%

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Asia



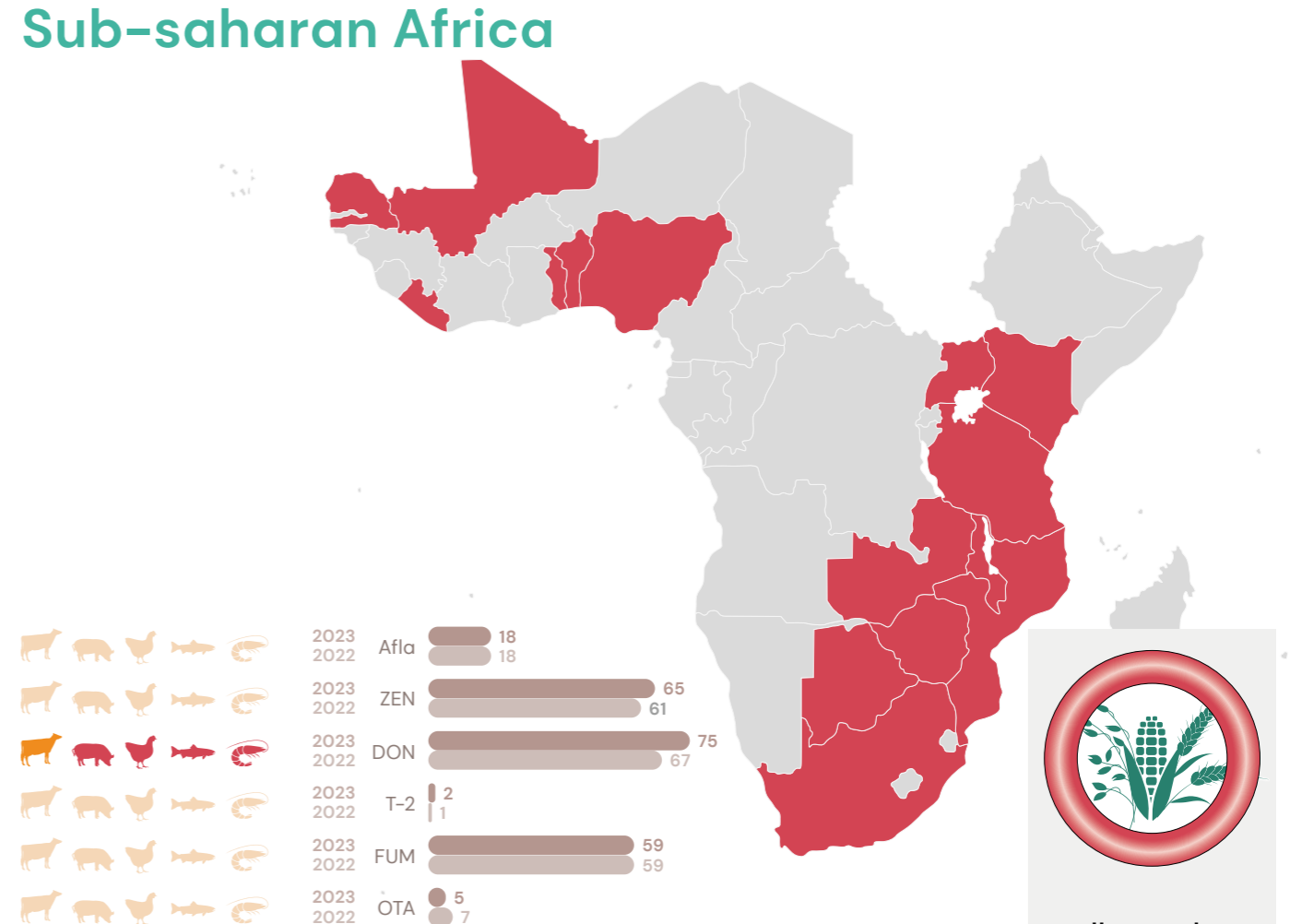
Animal colours indicate the risk posed to this species by the prevalence and concentration of each mycotoxin in all samples from this region (light orange=moderate to red=extreme see color code page 2)

% Contaminated samples January–December 2023 ■ and January–December 2022 ■

	Total samples: 2 948	Afla	ZEN	DON	T-2	FUM	OTA
Wheat grains	Number of samples tested	114	242	245	110	111	110
	% Contaminated samples	2%	62%	65%	9%	59%	8%
	Average of positive (ppb)	2	48	909	14	63	3
	Median of positive (ppb)	2	43	421	12	34	2
	Maximum (ppb)	3	276	10 556	22	490	9
Corn kernels	Number of samples tested	551	743	743	474	739	474
	% Contaminated samples	40%	41%	63%	20%	88%	28%
	Average of positive (ppb)	55	135	711	20	3 798	7
	Median of positive (ppb)	22	49	480	17	1 800	3
	Maximum (ppb)	1 392	2 803	9 037	61	142 773	100
Corn silage**	Number of samples tested	95	95	95	95	95	95
	% Contaminated samples	9%	43%	39%	15%	86%	6%
	Average of positive (ppb)	18	313	1 313	69	924	4
	Median of positive (ppb)	13	94	372	52	195	3
	Maximum (ppb)	55	2 537	12 059	274	2 6143	8

** Mycotoxin concentrations are expressed on dry matter basis. If mycotoxin concentrations were not available on DM basis, they were corrected assuming a standard of 33% DM content in the silage samples.

Sub-saharan Africa



Animal colours indicate the risk posed to this species by the prevalence and concentration of each mycotoxin in all samples from this region (light orange=moderate to red=extreme see color code page 2)

% Contaminated samples January–December 2023 ■ and January–December 2022 ■

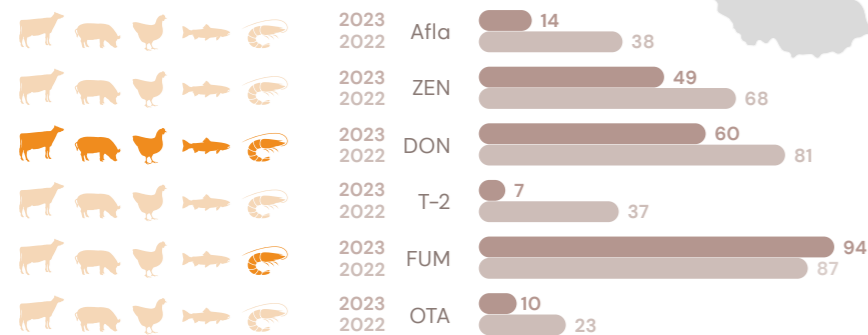
	Total samples: 1 179	Afla	ZEN	DON	T-2	FUM	OTA
Wheat grains	Number of samples tested	10	10	10	10	10	10
	% Contaminated samples	0%	60%	100%	0%	30%	0%
	Average of positive (ppb)	-	32	861	-	126	-
	Median of positive (ppb)	-	29	483	-	135	-
	Maximum (ppb)	-	65	2 898	-	213	-
Corn	Number of samples tested	363	322	322	322	362	322
	% Contaminated samples	10%	48%	90%	1%	63%	1%
	Average of positive (ppb)	210	70	683	19	920	498
	Median of positive (ppb)	30	14	335	20	257	12
	Maximum (ppb)	2 899	2 156	14 611	27	12 772	1 963
Corn silage**	Number of samples tested	40	40	40	40	40	40
	% Contaminated samples	0%	73%	83%	0%	30%	0%
	Average of positive (ppb)	-	196	1 698	-	172	-
	Median of positive (ppb)	-	56	786	-	104	-
	Maximum (ppb)	-	1 905	7 679	-	753	-

** Mycotoxin concentrations are expressed on dry matter basis. If mycotoxin concentrations were not available on DM basis, they were corrected assuming a standard of 33% DM content in the silage samples.

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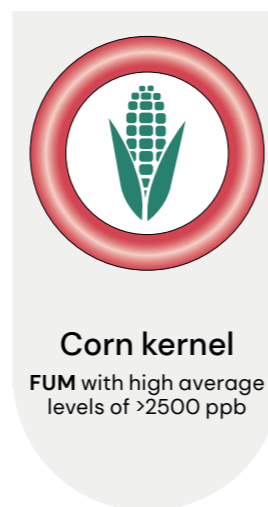
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Middle East & North Africa



Animal colours indicate the risk posed to this species by the prevalence and concentration of each mycotoxin in all samples from this region (light orange=moderate to red=extreme see color code page 2)
% Contaminated samples January–December 2023 ■ and January–December 2022 ■

	Total samples: 191	Afla	ZEN	DON	T-2	FUM	OTA
All samples	Number of samples tested	102	68	68	68	191	68
	% Contaminated samples	14%	49%	60%	7%	94%	10%
	Average of positive (ppb)	25	41	656	30	942	6
	Median of positive (ppb)	6	25	133	17	153	7
	Maximum (ppb)	142	193	5 857	86	48 778	11
Corn kernels	Number of samples tested	38	21	21	21	58	21
	% Contaminated samples	18%	24%	71%	14%	95%	5%
	Average of positive (ppb)	44	84	546	42	2 507	10
	Median of positive (ppb)	24	81	87	23	1 035	10
	Maximum (ppb)	142	193	3 177	86	48 778	10
Finished Feed	Number of samples tested	28	28	28	28	28	28
	% Contaminated samples	18%	86%	79%	7%	89%	14%
	Average of positive (ppb)	4	36	810	12	495	4
	Median of positive (ppb)	2	10	403	12	321	3
	Maximum (ppb)	6	174	5 857	13	1 413	8



Focus: major grain & soy producing countries



Country		Afla	ZEN	DON	T2	FUM	OTA
USA	Number of samples	453	453	453	449	453	449
	% Contaminated samples	9%	52%	66%	6%	79%	0%
	Average of positives (ppb)	40	221	1374	20	4 259	3
	Median of positives (ppb)	9	67	555	10	1419	3
Argentina	Number of samples	1 630	1 565	545	1 024	1 072	785
	% Contaminated samples	28%	30%	28%	18%	67%	0%
	Average of positives (ppb)	5	56	974	44	2 463	3
	Median of positives (ppb)	2	35	655	36	1 420	3
Brazil	Number of samples	902	842	909	316	915	46
	% Contaminated samples	2%	38%	29%	1%	51%	4%
	Average of positives (ppb)	19	118	489	46	1 097	11
	Median of positives (ppb)	8	65	400	46	750	11
Ukraine	Number of samples	40	44	44	35	44	35
	% Contaminated samples	10%	77%	98%	57%	86%	0%
	Average of positives (ppb)	17	137	1 248	36	706	
	Median of positives (ppb)	3	99	928	26	171	
	Maximum (ppb)	60	608	6 522	132	3 754	0



Country		Afla	ZEN	DON	T2	FUM	OTA
Russia	Number of samples	212	212	212	206	212	206
	% Contaminated samples	0%	14%	40%	22%	2%	4%
	Average of positives (ppb)		19	125	17	11	23
	Median of positives (ppb)		5	59	8	11	6
Australia	Number of samples	56	56	56	56	56	56
	% Contaminated samples	2%	25%	71%	5%	59%	0%
	Average of positives (ppb)	1	18	1 007	14	35	
	Median of positives (ppb)	1	10	197	11	33	
France	Number of samples	114	199	199	147	114	114
	% Contaminated samples	0%	22%	44%	18%	0%	1%
	Average of positives (ppb)		18	514	7		5
	Median of positives (ppb)		8	100	4		5
	Maximum (ppb)	0	98	8 459	27	0	5



Country		Afla	ZEN	DON	T2	FUM	OTA
Argentina	Number of samples	1 189	1 245	328	1 038	312	751
	% Contaminated samples	57%	72%	9%	37%	21%	1%
	Average of positives (ppb)	3	75	293	42	1 264	4
	Median of positives (ppb)	2	48	215	33	1 080	3
Brazil	Number of samples	439	430	441	166	444	18
	% Contaminated samples	2%	34%	8%	2%	4%	0%
	Average of positives (ppb)	7	39	419	34	487	
	Median of positives (ppb)	3	35	365	33	420	
USA	Number of samples	26	218	1 700	59	1 710	0
	% Contaminated samples	39%	39%	39%	39%	39%	39%
	Average of positives (ppb)	1	16	100	8	60	3
	Median of positives (ppb)	1	10	34	8	28	3
	Maximum (ppb)	1	38	309	11	205	5

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Spectrum 380® and Spectrum Top®50



Only analyzing for single mycotoxins can lead to underestimation of the detrimental effects of mycotoxins on animal health and performance. Our long-term monitoring of mycotoxins in different commodities shows that co-occurrence of mycotoxins is the rule and not the exception. Here we need support of state-of-the-art analytical methods based on LC-MS/MS. These allow to detect multiple mycotoxins in one run. The high sensitivity of the method is important, as already moderate levels of mycotoxins can have a detrimental effect. This is especially true in case of co-contamination.

Spectrum 380®:

The most advanced and comprehensive mycotoxin analysis available

It detects > 800 different mycotoxins (including masked and modified forms and emerging mycotoxins), fungal metabolites as well as plant and bacterial toxins and metabolites.

This is not a routine analysis but it is done in special cases and/or also of course as part of research of future objectives.

Spectrum 380® is developed and conducted by the world's leading independent mycotoxin research lab at the Department of Agrobiotechnology (IFA-Tulln) at the University of Natural Resources and Life Sciences Vienna and offered through cooperation with Performance Solutions plus Biomin.

Spectrum Top®50:

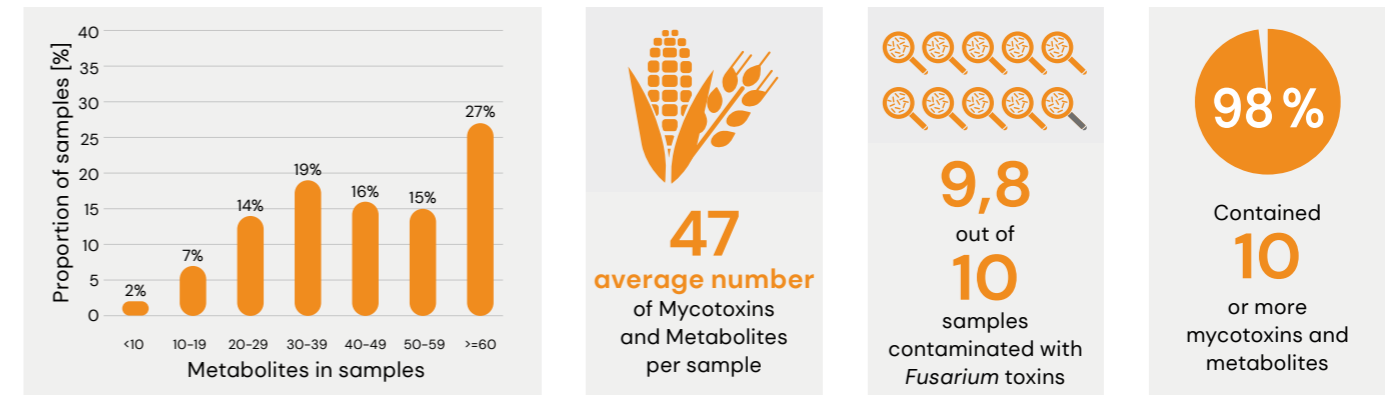
The most comprehensive mycotoxin analysis commercially available

It detects > 50 different mycotoxins (including masked and modified forms), emerging mycotoxins and fungal metabolites.

The Spectrum Top® 50 method was developed by scientists of Romer Labs, a leading global supplier of diagnostic solutions for food and feed safety.

Multiple mycotoxin occurrence

Spectrum 380® results January to December 2023: the most comprehensive mycotoxin analysis available



Total 980 samples from 32 countries; 784 000 points of analysis

Mycotoxins & metabolites

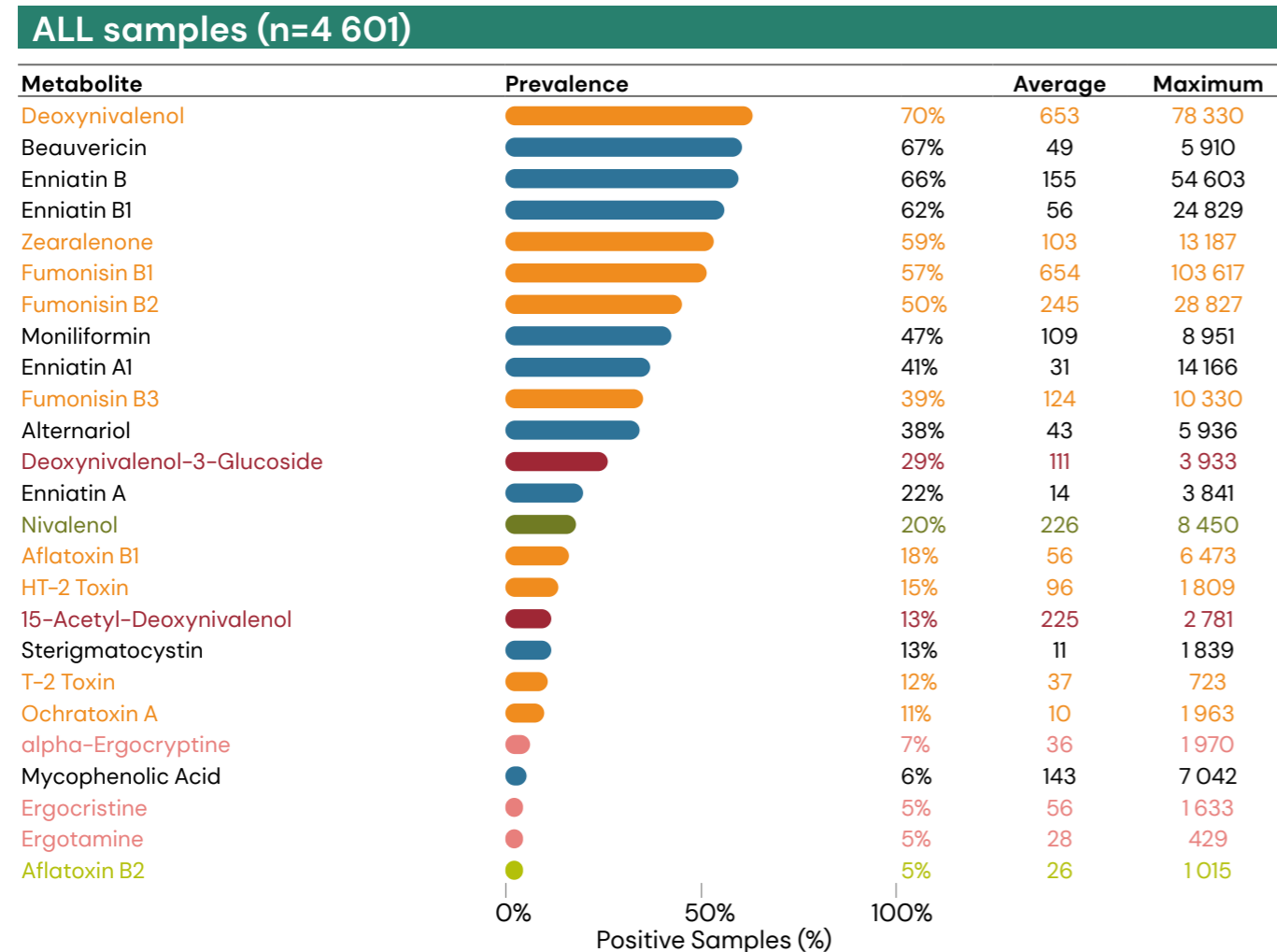
Metabolite	Prevalence	Average	Maximum
Tryptophol	95%	263	31 360
Aurofusarin	80%	1 088	560 960
Abscisic acid	75%	232	5 902
Infectopyron	74%	11 207	194 496
Enniatin B	72%	89	3 016
Culmorin	72%	283	28 244
Enniatin B1	68%	56	1 829
Deoxynivalenol	64%	3 547	1 833 600
Moniliformin	64%	79	1 971
15-Hydroxyculmorin	63%	601	42 840
Asperphenamate	62%	235	24 066
Siccanol	61%	768	63 072
Asperglucide	60%	206	30 955
Brevianamid F	58%	137	2 240
Beauvericin	58%	22	650
Flavoglucin	58%	214	18 029
Altersetin	56%	79	6 163
Fellutanine A	56%	57	1 901
Zearalenone	56%	62	3 675
Enniatin A1	55%	24	957
Apicidin	54%	46	1 637
Equisetin	54%	85	2 889
Chrysogin	53%	35	1 712
Rugulosovin	52%	85	2 509
Genistin	51%	35 438	366 400
Daidzin	51%	24 104	287 600
Emodin	51%	66	4 312

Positive Samples [%] for metabolites present in >50% of samples (orange bars indicate regulated or guideline mycotoxins; red bar indicates a masked mycotoxin). Cut off for all metabolites 1 ppb (except for aflatoxins 0.5 ppb). Average of positives and Maximum are presented in ppb.

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Overview of the most frequently found mycotoxins, their masked and modified forms as well as emerging mycotoxins in all samples and finished feed



Top25 metabolites are presented according to their prevalence. Cut off for all metabolites 1 ppb (except for aflatoxins 0.5 ppb). Average of positive samples and maximum levels found are reported in ppb.

- **Ergot alkaloids**
- **Regulated or guideline mycotoxins**
- **Masked and modified mycotoxins**

15-Acetyl-DON: fungal metabolite of DON; shown to be converted to DON in intestinal tract of pigs and chickens

DON-3-glucoside: plant metabolite of DON (masked DON); less toxic than DON, but it converted back to DON in the gastrointestinal tract of mammals.

- **Aflatoxin B2:** Aflatoxins, less toxic than Aflatoxin B1, not regulated
- **Nivalenol:** Type B trichothecene, more cytotoxic than DON in intestinal cells of pigs and ruminants (*in vitro*)

4 601

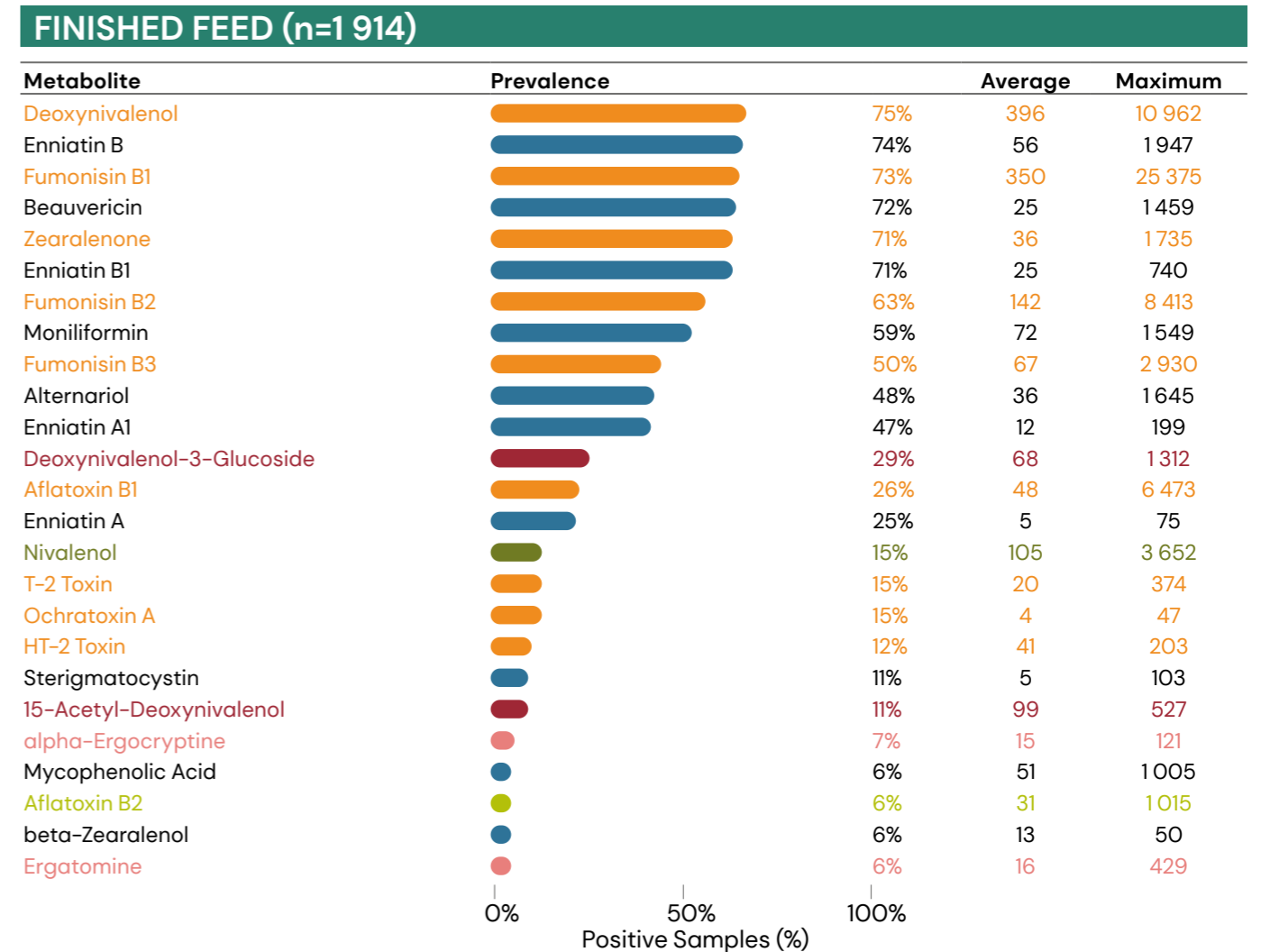
Samples

243 853

Analysis points

78

Countries



Top25 metabolites are presented according to their prevalence. Cut off for all metabolites 1 ppb (except for aflatoxins 0.5 ppb). Average of positive samples and maximum levels found are reported in ppb.

- **Emerging mycotoxins**

Emerging mycotoxins: frequently found on agricultural commodities, not regulated; toxicity is under investigation, but toxic effects suggested in some scientific literature; EFSA started to publish reports to do a risk assessment for these toxins.

Moniliformin: broiler very susceptible, genotoxic, immunosuppressive; causes heart damage, muscular weakness, respiratory distress

Alternariol: no acute toxicity, cytotoxic and mutagenic *in vitro*, effects on reproductive & immune system *in vitro*.

Beauvericin and Enniatins: effects on immune system: accumulation in fat-rich tissue.

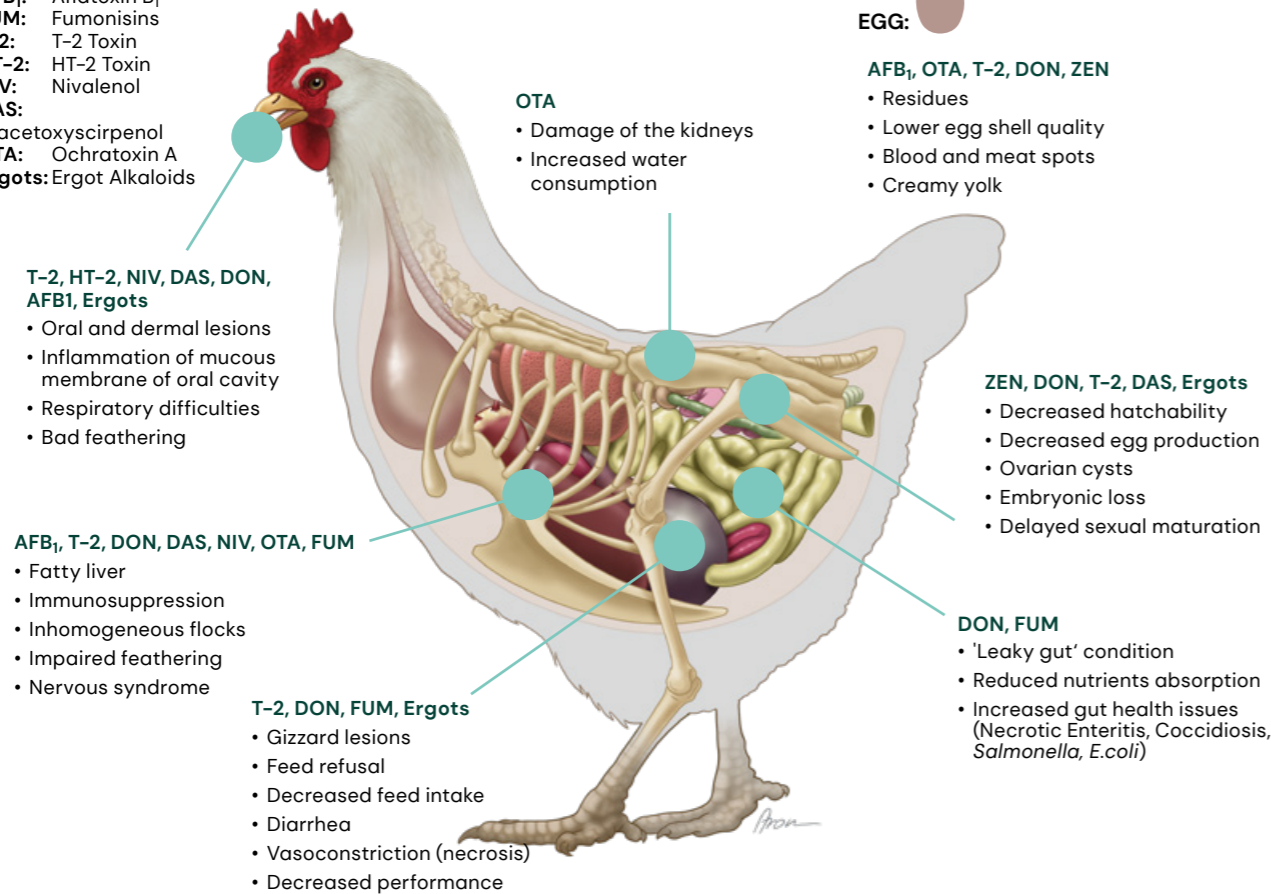
Sterigmatocystin: precursor of aflatoxins; causes similar effects as aflatoxin B₁ in animals, but lower acute toxicity; negative effects incl. bloody diarrhea, less milk production, less feed intake, hepatotoxicity, nephrotoxicity

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Meaning of abbreviations:

DON: Deoxynivalenol
ZEN: Zearalenone
AFB₁: Aflatoxin B₁
FUM: Fumonisin
T-2: T-2 Toxin
HT-2: HT-2 Toxin
NIV: Nivalenol
DAS: Diacetoxyscirpenol
OTA: Ochratoxin A
Ergots: Ergot Alkaloids



ZEN, Ergot alkaloids, Trichothecenes (DON, T-2, etc.), Afla

- Irregular heats
- Low conception rates
- Ovarian cysts
- Embryonic Loss
- Abortions
- Low testicular development
- Low sperm production

DON, NIV, T-2, Afla, ZEN, Ergot alkaloids, etc.

- Impaired rumen function
- Diarrhea
- Lower volatile fatty acid production
- Lower microbial protein production
- Decreased rumen pH

Ergot alkaloids

- Impaired thermoregulation
- Convulsions

Afla, DON, NIV, T-2, HT-2, among others.

- Milk contamination
- Decreased milk production
- Mastitis

Meaning of abbreviations:

Afla: Aflatoxins
DON: Deoxynivalenol
FUM: Fumonisin
HT-2: HT-2 toxin
NIV: Nivalenol
T-2: T-2 toxin

Trichothecenes (NIV, DON, etc.), FUM

- Leaky gut
- Decreased nutrient absorption
- Inflammation

DON, NIV, T-2

- Decreased feed intake
- Decreased feed efficiency

DON, FUM, Afla, etc.

- Increased liver enzymes
- Liver toxicity

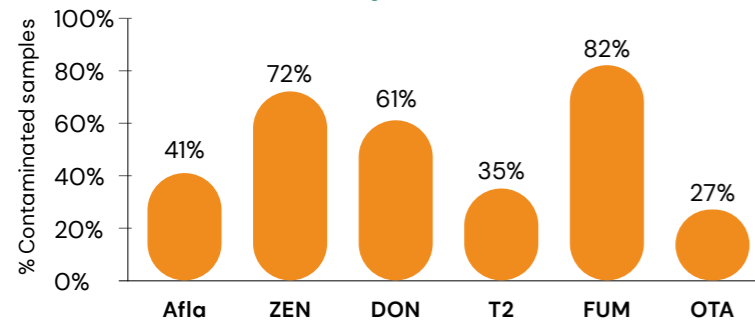
Ergot alkaloids, endotoxins, DON

- Laminitis (lameness)

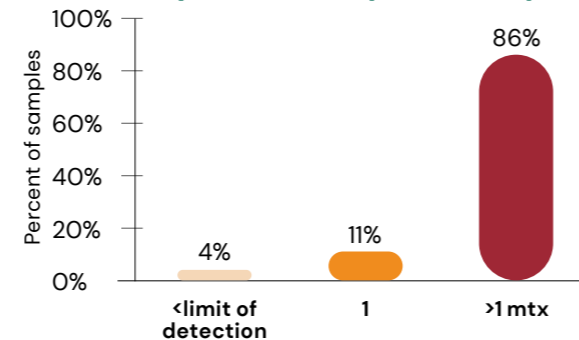
Summary for Finished Feed Poultry in World from Jan 2023 to Dec 2023

	Afla	ZEN	DON	T-2	FUM	OTA
Number of samples	2 053	2 016	2 097	1 873	2 045	1 759
% Contaminated samples	41%	72%	61%	35%	82%	27%
Average of positive (ppb)	18	48	360	22	911	12
Median of positive (ppb)	8	26	266	19	435	5
Maximum (ppb)	511	2 985	5 857	110	36 719	506

Prevalence of Mycotoxin Detected



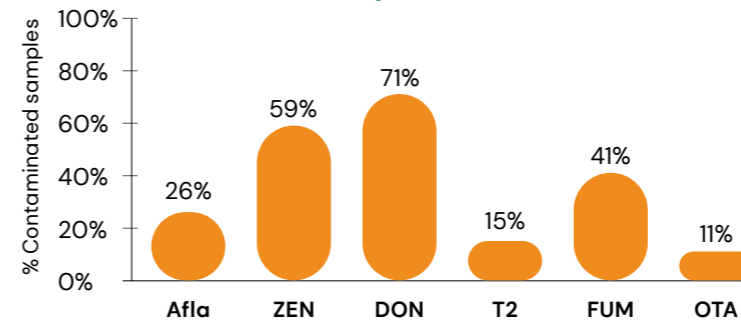
No. of Mycotoxins per sample



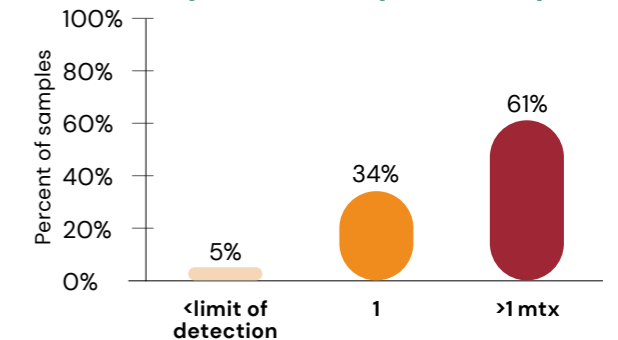
Summary for Finished Feed Ruminants in World from Jan 2023 to Dec 2023

	Afla	ZEN	DON	T-2	FUM	OTA
Number of samples	981	995	989	833	911	840
% Contaminated samples	26%	59%	71%	15%	41%	11%
Average of positive (ppb)	27	129	746	35	503	10
Median of positive (ppb)	9	50	466	21	209	4
Maximum (ppb)	445	10 932	7 031	374	16 970	200

Prevalence of Mycotoxin Detected

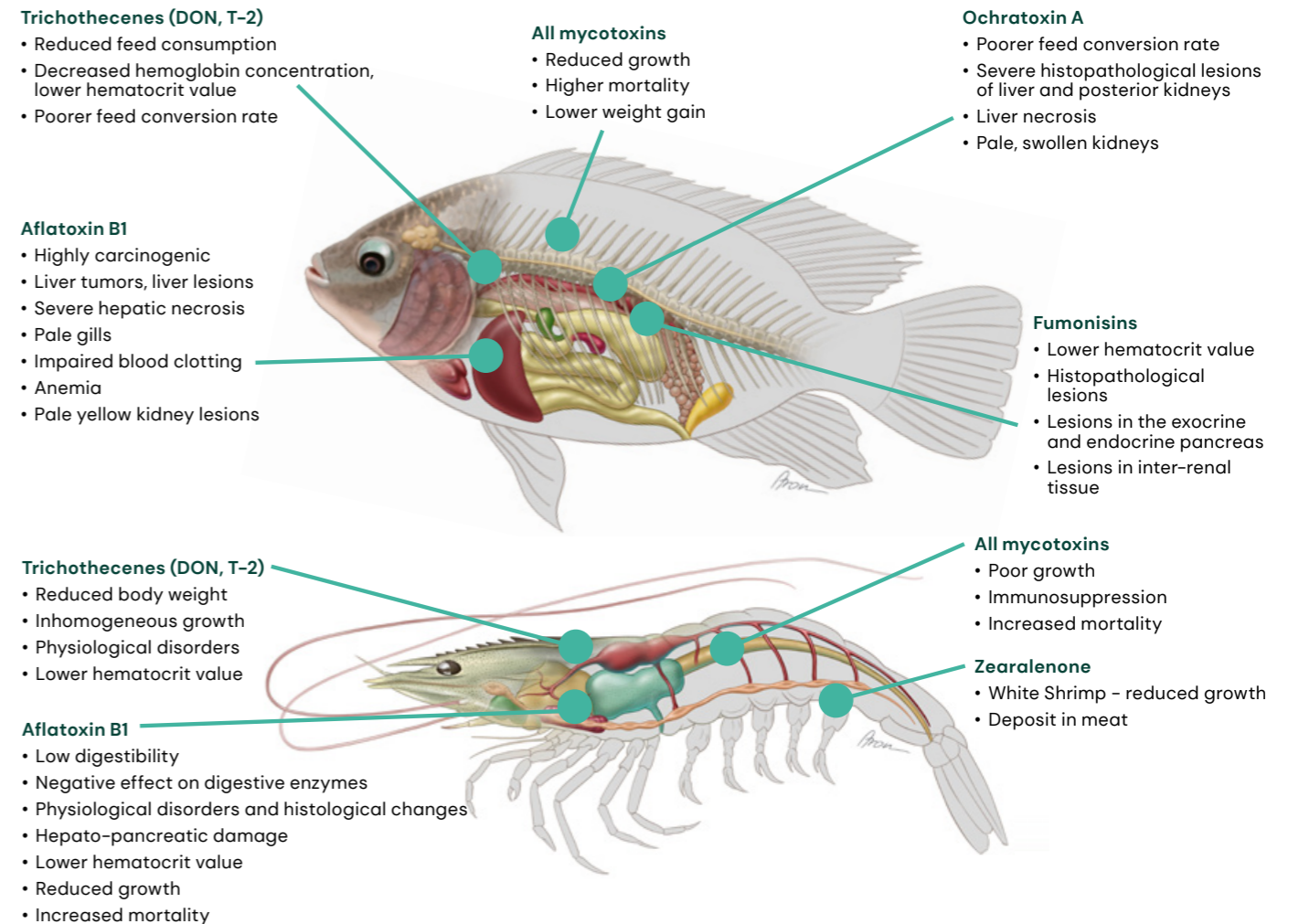
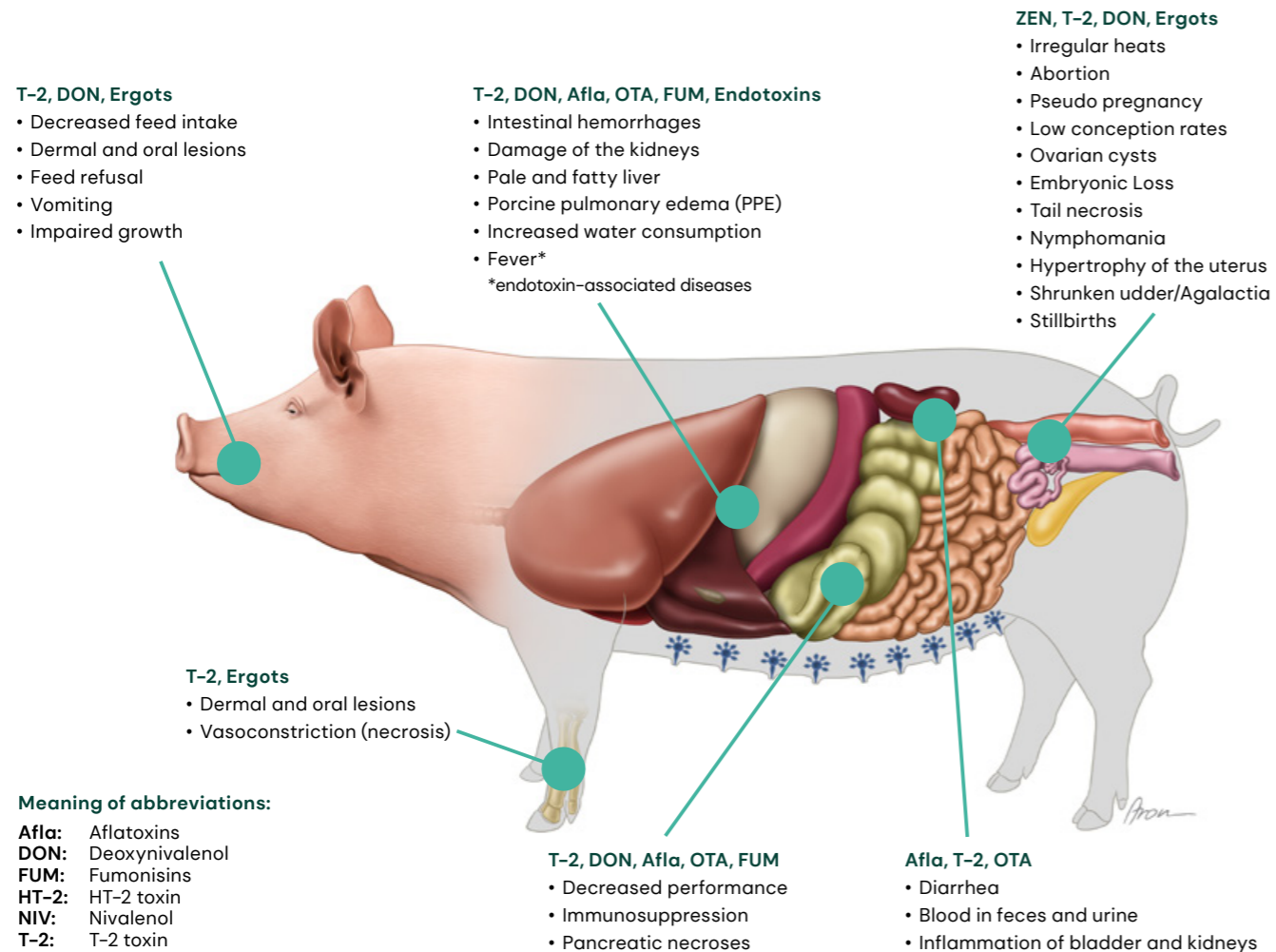


No. of Mycotoxins per sample



dsm-firmenich World Mycotoxin Survey

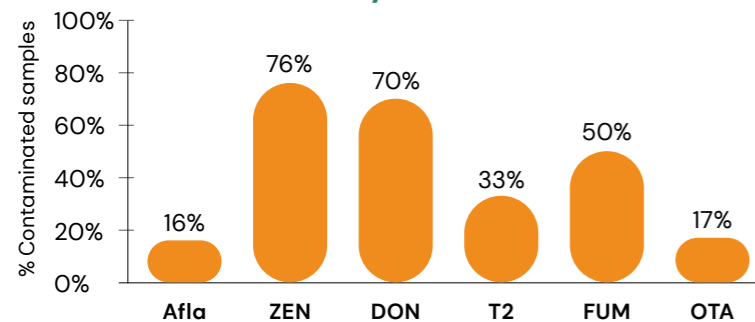
The Global Threat – January to December 2023



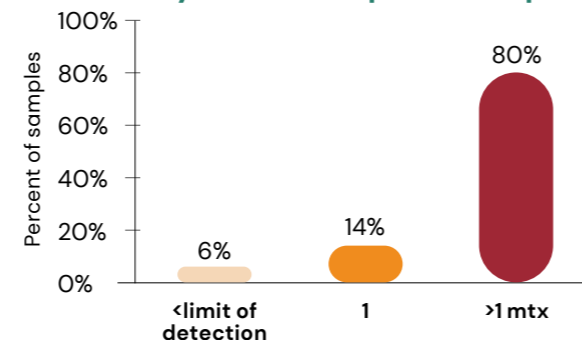
Summary for Finished Feed Swine in World from Jan 2023 to Dec 2023

	Afla	ZEN	DON	T-2	FUM	OTA
Number of samples	1 499	1 696	1 671	1 385	1 484	1 384
% Contaminated samples	16%	76%	70%	33%	50%	17%
Average of positive (ppb)	18	32	290	17	299	6
Median of positive (ppb)	3	17	152	11	119	3
Maximum (ppb)	864	1 020	10 962	654	5 393	200

Prevalence of Mycotoxin Detected



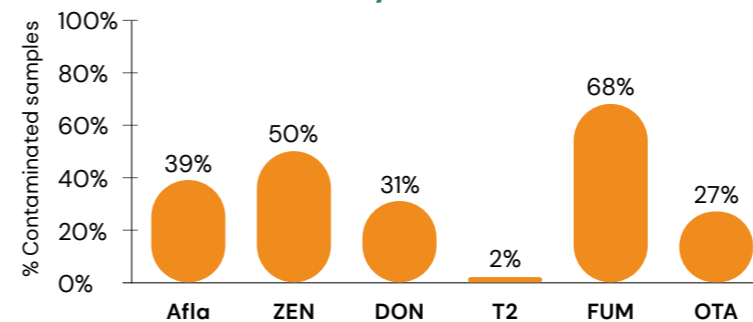
No. of Mycotoxins per sample



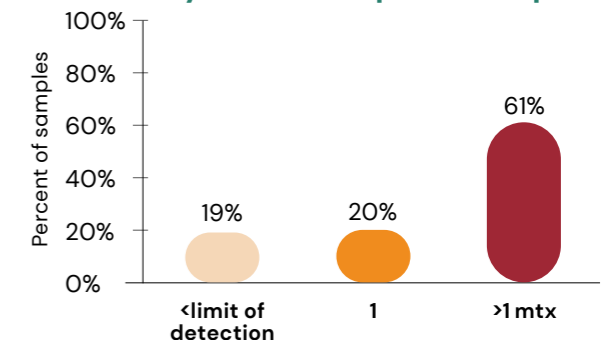
Summary for Finished Feed Aqua in World from Jan 2023 to Dec 2023

	Afla	ZEN	DON	T-2	FUM	OTA
Number of samples	163	163	163	131	163	131
% Contaminated samples	39%	50%	31%	2%	68%	27%
Average of positive (ppb)	297	39	192	28	474	6
Median of positive (ppb)	5	18	110	28	171	2
Maximum (ppb)	8 023	358	781	56	14 920	47

Prevalence of Mycotoxin Detected



No. of Mycotoxins per sample



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