

MULTIPLE MYCOTOXINS DETECTED

IN CORN

harvested on four continents
in 2020

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Livestock production destined for human consumption is critically influenced by the quality of the feed materials. This impacts on both food/feed safety and security.

- ▶ It is important to note that feed ingredients and integrated animal feeds can be contaminated with various chemical and biologically derived residues, including dioxins and heavy metals, spoilage microbes and mycotoxins.



Contamination with mycotoxins is amongst the most important “silent menace” which can have a spectrum of severe adverse health impacts on animals and subsequently enter the human food chain.

Mycotoxins are toxic secondary metabolites of specific spoilage molds (e.g., *Aspergillus*, *Penicillium*, *Fusarium species*) which can colonize carbohydrate and lipid-rich feeds made from peanuts, wheat, corn, sorghum, and other cereal grains.

They are very heat stable and thus difficult to destroy once formed.

The FAO declared that probably 25% of the worlds’ staple food/feed crops including cereals produced annually may be contaminated with mycotoxins.

However, this may be a significant underestimate, as the occurrence above the detectable levels suggests contamination with these toxins to be up to 60–80% (*Eskola et al., 2020*).



Mycotoxins are a major challenge for animal feed producers and, therefore, regular monitoring of these contaminants in feed commodities is essential to minimize impacts on key animal production chains.



The aim of the present study was to **screen corn samples** received from different countries and regions of the world, **between September 2020 and February 2021** in order to determine their level of contamination with mycotoxins.









In this survey, **50-60 samples per country** and a total of **1000+ samples** were analyzed for multiple mycotoxins.



The corn samples were collected from **Europe** (including Serbia, Bosnia, Spain, Croatia, Italy, and Russia), **Africa** (Algeria, Morocco, Ghana, Ivory Coast, Kenya and Cameroon), **Latin America** (Dominican Republic, Peru, Argentina and Colombia), and **Asia** (Vietnam, Malaysia, Turkey, and Thailand).

The corn samples were all analyzed by LC-MS/MS triple quad (Agilent 6460 series) using a **multi-mycotoxin method for quantification of all mycotoxins present**. These included the following mycotoxins that are regulated in the EU in feed by EU Directives 2002/32/EC, 2006/576/EC, and 2013/165/EU:

-  Aflatoxin B₁ (AFB₁), B₂, G₁ and G₂
-  Ochratoxin A (OTA)
-  Zearalenone (ZEN)
-  Deoxynivalenol (DON)
-  Fumonisin B₁ and B₂ (FB₁ and FB₂)
-  T-2 and HT-2 toxins



The results of this survey are presented in the following format:

- ▷ Country specific data
- ▷ Global conclusions for 2020
- ▷ Patterns of mycotoxins detected over the period 2018-2020
- ▷ Conclusions



COUNTRY SPECIFIC DATA FROM EACH CONTINENT EXAMINED

Average multi-mycotoxins detected in corn samples



Table 1 shows the average of each mycotoxin detected (ppb) in the corn samples in the survey on a country and continent basis.

🔍 **Fumonisin**s were the predominant mycotoxins detected with a high average level of contamination, especially in:

- ▲ Italy
- ▲ Cameroon
- ▲ Ivory Coast
- ▲ Kenya
- ▲ Thailand

🔍 DON and ZEN were found to be present at lower average contamination levels.





Table 1. Average multi-mycotoxin contamination levels detected (ppb) in corn samples in each country and continent in 2020. Bold numbers are indicative of the highest average contamination levels found. <LOQ, Below Limit of Quantification.

	Countries	AFB ₁	OTA	ZEN	DON	FB ₁	FB ₂	HT-2	T-2
Europe	Serbia	54	11	411	566	1396	447	906	81
	Croatia	4	11	968	872	1121	340	39	32
	Spain	<LOQ	<LOQ	<LOQ	<LOQ	683	287	<LOQ	<LOQ
	Russia	<LOQ	<LOQ	144	1181	442	142	109	132
	Italy	<LOQ	<LOQ	34	203	4592	1015	<LOQ	<LOQ
	Bosnia & Herzegovina	<LOQ	<LOQ	<LOQ	290	1358	371	45	68
Africa	Ivory Coast	264	<LOQ	<LOQ	<LOQ	2995	873	175	<LOQ
	Morocco	<LOQ	<LOQ	58	116	694	161	10	<LOQ
	Ghana	1	<LOQ	<LOQ	<LOQ	803	269	<LOQ	<LOQ
	Cameroon	38	<LOQ	<LOQ	<LOQ	2495	635	<LOQ	<LOQ
	Algeria	<LOQ	<LOQ	<LOQ	87	1128	262	<LOQ	<LOQ
	Kenya	<LOQ	<LOQ	521	749	2494	669	<LOQ	<LOQ
Latin America	Dominican Republic	1	<LOQ	36	134	1320	331	<LOQ	<LOQ
	Colombia	<LOQ	<LOQ	31	283	1472	313	24	<LOQ
	Argentina	<LOQ	<LOQ	63	442	1167	315	<LOQ	<LOQ
	Peru	<LOQ	<LOQ	62	462	1554	442	<LOQ	<LOQ
Asia	Turkey	<LOQ	<LOQ	<LOQ	<LOQ	69	<LOQ	<LOQ	<LOQ
	Malaysia	<LOQ	<LOQ	45	184	154	59	<LOQ	<LOQ
	Vietnam	<LOQ	<LOQ	46	353	737	185	<LOQ	<LOQ
	Thailand	6	<LOQ	30	<LOQ	2033	688	22161	<LOQ

Relative percentage of positive corn samples with mycotoxins








The percentage of positive samples with various mycotoxins is shown in **Table 2** for each of the countries.




	Countries	AFB ₁	OTA	ZEN	DON	FB ₁	FB ₂	HT-2	T-2
Europe	Serbia	2%	ND	ND	12%	68%	52%	5%	1%
	Croatia	1%	1%	42%	67%	89%	69%	21%	12%
	Spain	<LOQ	<LOQ	<LOQ	<LOQ	100%	83%	<LOQ	<LOQ
	Russia	<LOQ	<LOQ	35%	52%	32%	19%	58%	32%
	Italy	<LOQ	<LOQ	10%	33%	100%	100%	<LOQ	<LOQ
	Bosnia & Herzegovina	<LOQ	<LOQ	<LOQ	60%	100%	100%	45	68
Africa	Ivory Coast	86%	<LOQ	<LOQ	<LOQ	38%	86%	43%	<LOQ
	Morocco	<LOQ	<LOQ	8%	23%	100%	92%	8%	<LOQ
	Ghana	14%	<LOQ	<LOQ	<LOQ	100%	86%	<LOQ	<LOQ
	Cameroon	80%	<LOQ	<LOQ	<LOQ	80%	80%	<LOQ	<LOQ
	Algeria	<LOQ	<LOQ	<LOQ	67%	100%	100%	<LOQ	<LOQ
	Kenya	<LOQ	<LOQ	80%	100%	80%	80%	<LOQ	<LOQ
Latin America	Dominican Republic	33%	<LOQ	10%	10%	100%	100%	<LOQ	<LOQ
	Colombia	<LOQ	<LOQ	17%	70%	100%	93%	3%	<LOQ
	Argentina	<LOQ	<LOQ	28%	47%	100%	84%	<LOQ	<LOQ
	Peru	<LOQ	<LOQ	17%	33%	92%	92%	<LOQ	<LOQ
Asia	Turkey	<LOQ	<LOQ	<LOQ	<LOQ	69%	<LOQ	<LOQ	<LOQ
	Malaysia	<LOQ	<LOQ	17%	40%	100%	13%	<LOQ	<LOQ
	Vietnam	<LOQ	<LOQ	5%	32%	97%	68%	<LOQ	<LOQ
	Thailand	70%	<LOQ	21%	ND	95%	77%	2%	<LOQ

Table 2. The percentage (%) of positive corn samples from each country on each of the four Continents in 2020. Bold percentages highlight the importance of contamination with Fumonisin. The countries where DON was important are shown in green.

Relative % of positive corn samples

 **Fumonisin**
>80% in most countries

 **DON**
 67% of samples from Croatia and Algeria
 70% of samples from Colombia
 100% of samples from Kenya

 **Aflatoxins**
 80% of samples from Cameroon
 70% of samples from Thailand

Number of mycotoxins per sample

EUROPE

The number of mycotoxins per sample from the 6 European countries are shown in **Figure 1**.

Overall, **the corn harvested in 2020 was predominantly contaminated >1 mycotoxin**, regardless of the country or origin.

Indeed, the **Italian and Bosnian samples were all contaminated with multiple mycotoxins**.

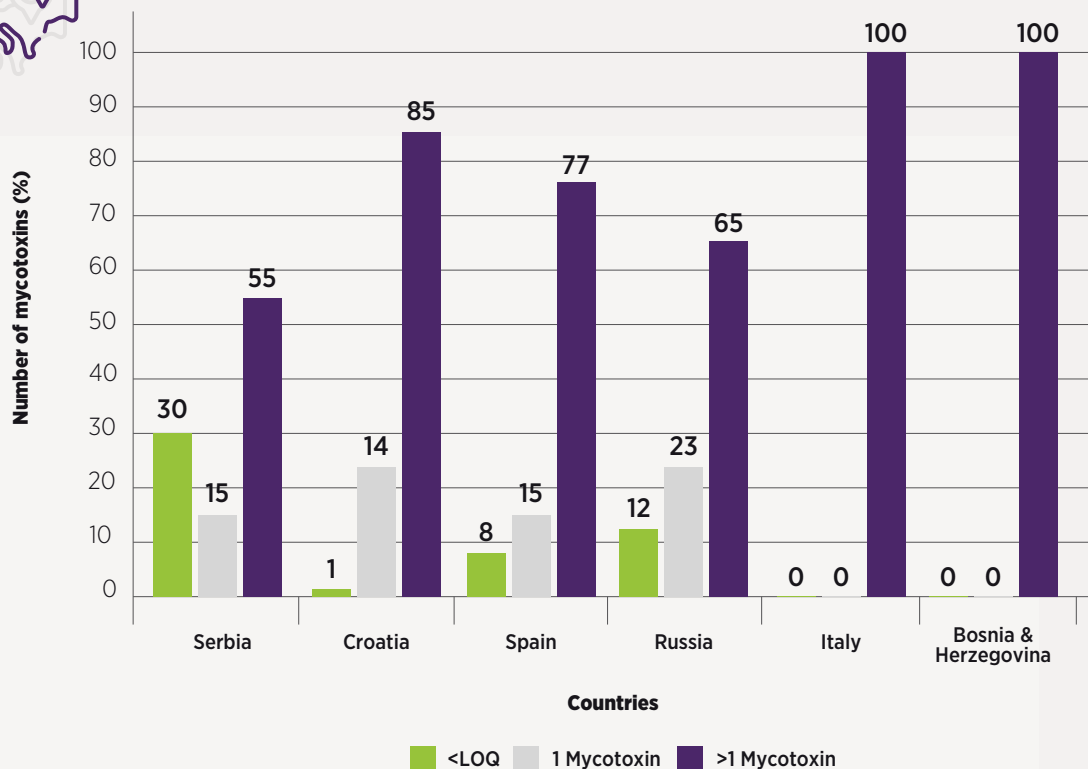


Figure 1. Summary of the percentage (%) of samples from different European countries contaminated with one or more mycotoxins.



AFRICA

Figure 2 summarizes the relative percentages of corn samples with mycotoxins from the 6 African countries sampled.

Again, in all these countries the feed samples were predominantly contaminated with multiple mycotoxins. Only $\leq 15\%$ of samples in these countries were contaminated with 1 mycotoxin.

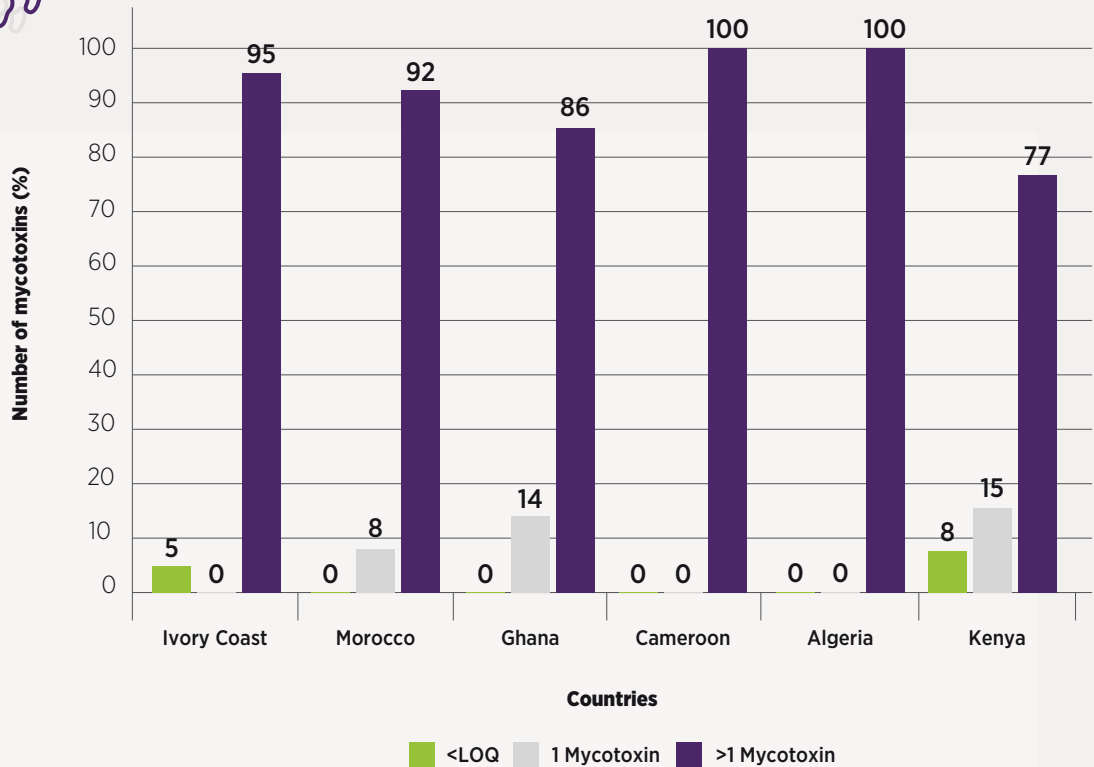
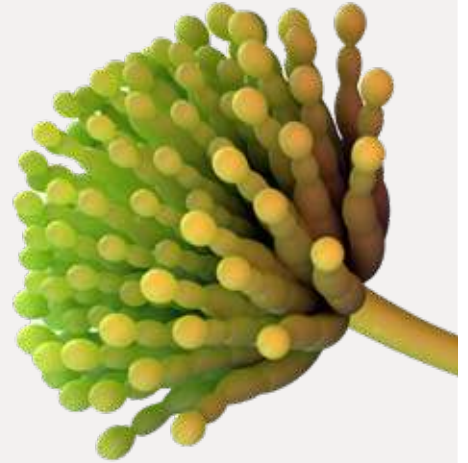


Figure 3. Comparison of the percentage (%) samples of corn contaminated with one or multiple mycotoxins in 6 African countries.

LATIN AMERICA

In Latin America, similar results were obtained with **almost all samples of corn for feed contaminated with ≥ 1 mycotoxin** and only **<8%** contained a single mycotoxin.

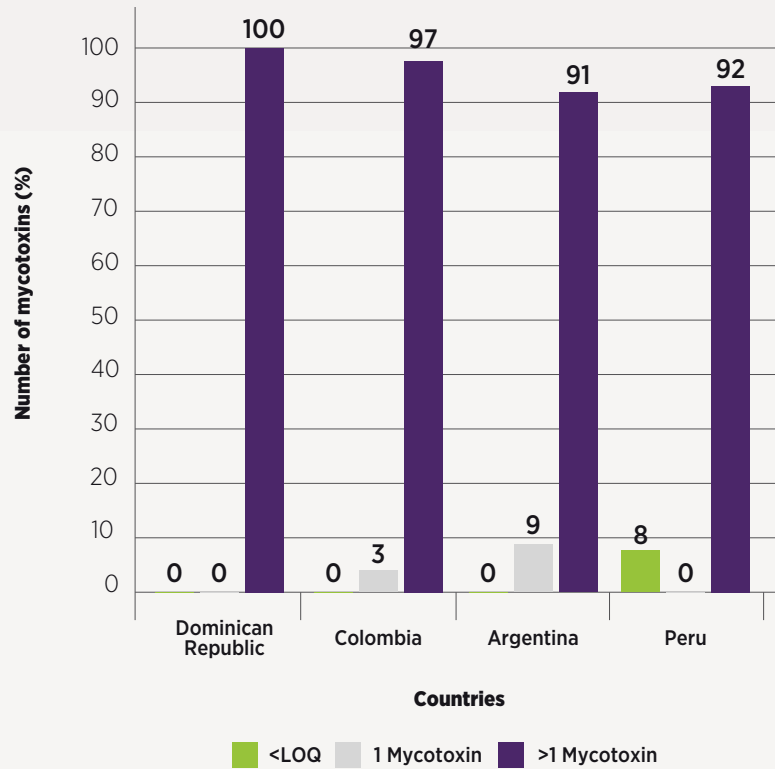


Figure 3. Relative contamination of corn samples with a single or mixture of mycotoxins in 4 different countries in Latin America.

ASIA

For the four countries where samples were analyzed in Asia, the pattern was slightly different (Figure 4).

- There was a **higher percentage of samples with only a single mycotoxin**, especially Malaysia (50%), Vietnam (25%) and Thailand (14%).
- Interestingly, in the **Turkish samples a quarter contained one mycotoxin and none were contaminated with multiple mycotoxins.**
- Overall, in three of the four countries there were still $\geq 50\%$ of samples with more than one mycotoxin.

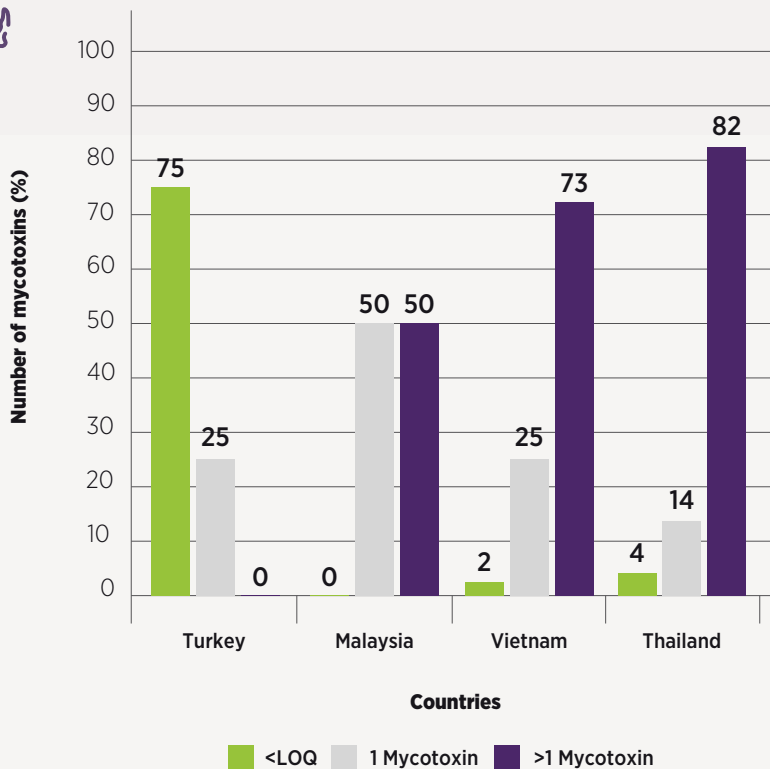
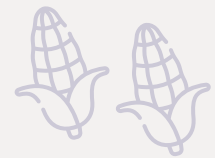
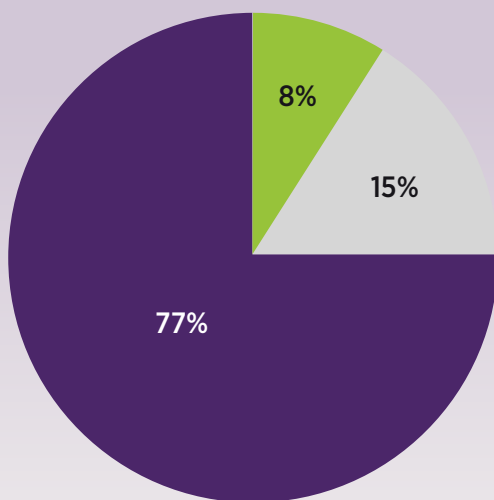


Figure 4. Relative contamination of corn samples with a single or mixture of mycotoxins in 4 different Asian countries.

GLOBAL CONCLUSIONS BASED ON THE CORN SURVEY CARRIED OUT IN 2020



In this survey in 2020, a total of 1000+ samples were received for analysis by PATENT CO. Of these, **92% of the samples were contaminated with at least one or multiple mycotoxins**, and only 8% found to contain no mycotoxins at all (**Figure 5**).






 <LOQ  1 Mycotoxin  >1 Mycotoxin

Figure 5. Summary of the relative percentages of samples contaminated with one or multiple mycotoxins in the 1000+ corn samples analyzed.





The predominant mycotoxins and their mean contamination levels in order of concentrations were:

- 🔍 FB₁ (1396 ppb)
- 🔍 FB₂ (447 ppb)
- 🔍 DON (566 ppb)
- 🔍 ZEN (411 ppb)
- 🔍 AFB₁ (54 ppb)
- 🔍 HT-2 (906 ppb)
- 🔍 T-2 (81 ppb)
- 🔍 OTA (11 ppb)

Fumonisins were detected in 85% of all samples, **DON** in 29%, **AFB₁** in 16%, **T-2/HT-2** in 9% and **ZEN** in 16% from the pooled data for all the countries in the four continents examined (**Table 3**).

These results certainly demonstrate that globally, the *Fusarium* mycotoxins (FB₁, FB₂, DON, ZEN,) were the most predominant ones contaminating the harvested corn samples destined for animal feed use.

	AFB ₁	OTA	ZEN	DON	FB ₁	FB ₂	HT-2	T-2
AVG	54	11	411	566	1396	447	906	81
Max	1947	11	25731	8827	14314	4369	44303	638
Median	3	11	43	298	770	248	44	26
% of positives	16	0	16	29	85	69	9	4

Table 3. Summary of the global contamination levels including the Mean, Maximum and Average contamination levels (PPB) and the relative number of positive samples based on the data from 20 countries globally in 2020.



COMPARISON OF PATTERNS OF CONTAMINATION OF CORN SAMPLES WITH MYCOTOXINS IN 2018, 2019 AND 2020

In all cases, the harvested corn samples in 2018, 2019 and 2020 were all analyzed for mycotoxins at PATENT CO using LC-MS/MS.

- ▶ The pattern of mycotoxins detected in these three years were compared for identifying any trends or patterns of contamination in the different regions.



Comparison of mycotoxin contamination levels in the three sampling years on a global basis in the corn samples

Figure 6 shows the comparison of the number of corn samples found to contain no mycotoxins, single or multiple mycotoxins in the three survey years.

It is worthwhile noting that the pattern in all three years is very consistent.

Corn contaminated with mycotoxins (2018-2020)

>75% contaminated with >1 mycotoxin

The corn samples found globally to be contaminated with just one mycotoxin were $\leq 15\%$.

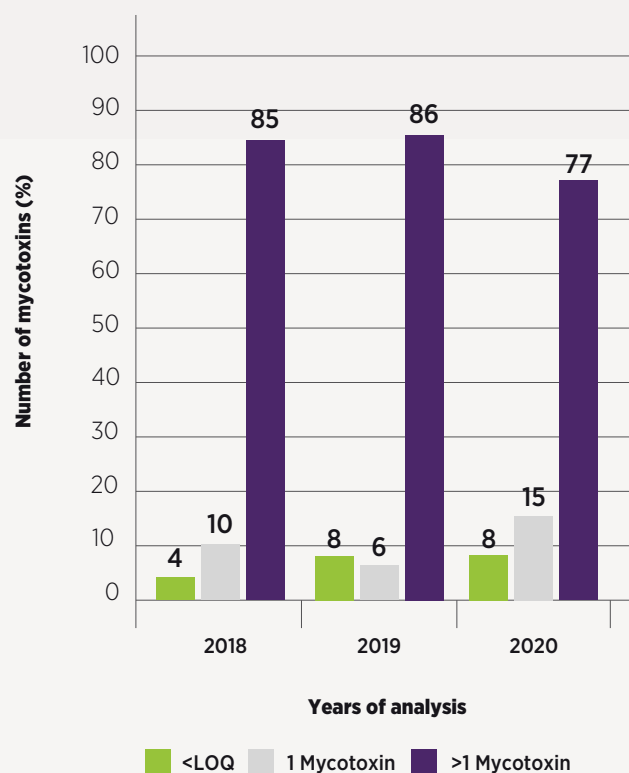


Figure 6. Comparison of the percentage samples of corn containing no mycotoxins, single or multiple mycotoxins in 2018, 2019 and 2020.

Average of mycotoxins (ppb) detected in corn samples in 2018–2020



Figure 7 compares the actual average contamination levels found for all samples in each of the three sampling years.

- ▶ This clearly shows the **consistently high levels of FB₁** in the corn samples in each of the three years. This was followed by **DON** and an **increase in 2020 of contamination with ZEN**.
- ▶ On the other hand, there has been a **decreasing trend in the contamination levels with AFB₁ and OTA** over the 3 years of the survey.

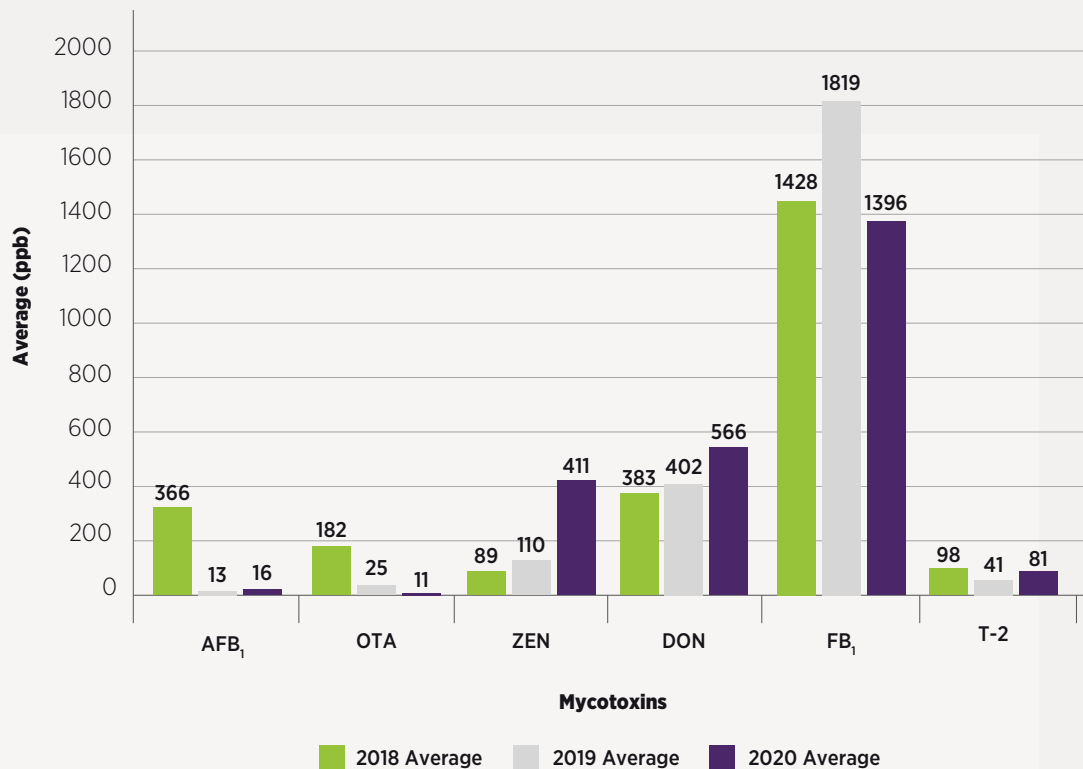


Figure 7. Comparison of the average for the different mycotoxins found contaminating the corn samples on a global level in each of the three years. AFB₁, Aflatoxin B₁; OTA, Ochratoxin A; ZEN, Zearalenone; DON, Deoxynivalenol; FB₁, Fumonisin B₁.

Percentage of mycotoxins (ppb) detected in corn samples in 2018–2020



Figure 8 also shows that, on a relative contamination percentage basis, **most samples were contaminated with FB₁ (>75%), followed by DON (>25%) and then ZEN and AFB₁ (<25%).**

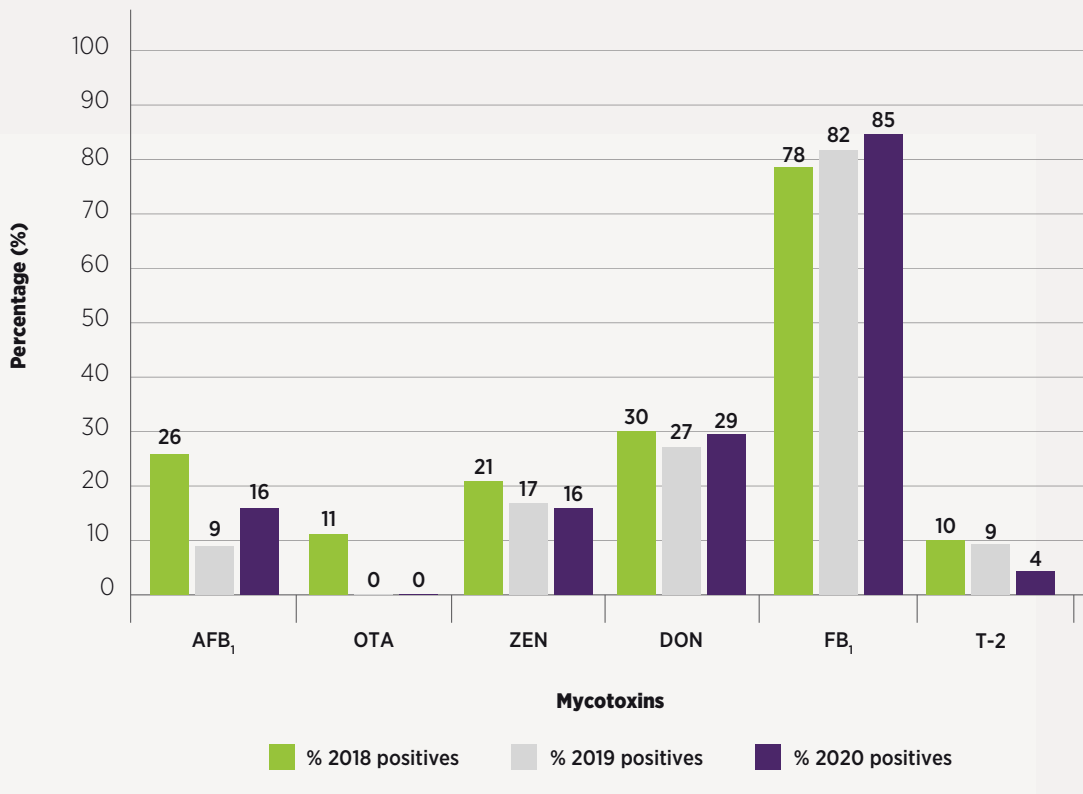


Figure 8. Comparison of the relative percentage (%) of positive corn samples globally contaminated with the different mycotoxins during the three sampling years.



CONCLUSIONS



The 2020 global survey of corn samples destined for use in feed showed that overall, in 1000+ samples, **fumonisin were the predominant mycotoxins** present. This appeared to be the case in samples from countries on all four Continents. **This was followed by DON and ZEN.**

- ▶ Only in some of the African countries (Ivory Coast and Cameroon) was AFB₁ found to be present at high contamination levels. In addition, >75% of samples were found with multiple mycotoxins, regardless of continent or country.

In terms of the pattern of contamination, it was clear that over the years 2018-2020 **the trend of the predominant contamination with Fumonisin and DON is consistent.**

- ▶ The number of samples contaminated with fumonisin has remained high in each of the three years.

However, there has been a **decrease in contamination with AFB₁ and OTA** when compared to previous years.

In addition, **the trend of corn feed samples being contaminated with mixtures of at least two mycotoxins is increasing.**

- ▶ The co-occurrence of two or, in some cases, three mycotoxins can lead to **additive or synergistic effects** when fed to sensitive animal species (e.g., swine and poultry amongst others).

This suggests that **technologies are required for the control of mixtures of such contaminants in feedstuffs predominantly based on corn to minimize impacts on animal development.**

It would be interesting to **superimpose these trends on to regional and global climate information including temperature, episodes of rainfall and drought stress** to examine whether these patterns will continue or whether they may change in the short and medium term.



- ▶ This would be beneficial in the development of **appropriate minimization strategies under changing climate regimes in the next 4-5 years.**