



Mycotoxin contamination of maize (*Zea mays* L.) samples in Hungary, 2012–2017

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Abstract

Mycotoxin contamination of maize often raises risks for human and animal health. The most frequently detected mycotoxins in maize are trichothecenes, fumonisins, and aflatoxin. A total number of 17,011 maize samples were tested by SGS for their mycotoxin content between 2012 and 2017. The toxin results clearly show that the southern areas of the country had higher levels of toxin contamination than the average. According to the dataset, aflatoxin contamination has become regular but the appearance of fumonisins was also more frequent. Deoxynivalenol toxin accumulation in crops can also reach dangerous levels under favorable ecological conditions. The fluctuation between years and regions is decisively shaped by the weather conditions. However, the two pathogens with less virulence (*Fusarium verticillioides* and *Aspergillus flavus*) must be taken into account and the contribution of insect pests. 72.63% of the total fumonisin concentration was defined as fumonisin B₁, 20.34% as fumonisin B₂, and 7.03% as fumonisin B₃. The correlations between the three fumonisins analogs were highly significant ($P=0.001$), and correlation coefficient varied between 0.961 and 0.998 across the six years of evaluation. This is the first complex evaluation of deoxynivalenol, fumonisin, and aflatoxin contamination of maize samples in Hungary.

Keywords Mycotoxin · Maize · Hungary · Deoxynivalenol · Fumonisin · Aflatoxin

Introduction

Maize (*Zea mays* L.) is the most important ingredient of feeds and one of the most important agricultural export products of Hungary. Food and feed safety problems have increasing significance in maize production. Species of genus *Fusarium* and *Aspergillus* cause important animal and human health concerns worldwide, but their damage and danger vary in different parts of the world (Munkvold and White 2016). In the last decades, no such data were published from Hungary. As many years were with high temperatures and drought in the Mediterranean area, it was clear that fumonisins and aflatoxins might have a higher incidence

than found in the past (Battilani et al. 2016; Cotty and Jaime-Garcia 2007; Miedaner and Juroszek 2021).

Ni et al. (2011) showed a positive correlation between the degree of insect damage on the ear and aflatoxin contamination. Folcher et al. (2010) tested the fumonisin B₁ + B₂ (FB₁ + FB₂), deoxynivalenol (DON), and zearalenon (ZEA) content of the MON 810 Bt transgenic maize hybrid and its non-GMO isogenic pair. The Bt genotype presented reduced fumonisin concentrations by more than 90% and ZEA content by 50% confirming the earlier results (Munkvold et al. 1997).

After examination of maize samples from different maize growing areas of Hungary, nearly two thirds of the maize samples tested were found to be contaminated by *Aspergillus flavus*, and about one fifth of these were also able to produce aflatoxin (Dobolyi et al. 2013). These results were confirmed with the report of high incidence of aflatoxin in Serbia (Kos et al. 2013). In maize, many *Fusarium* spp. were identified from grains (Mesterházy and Vojtovics 1977, Goertz et al. 2010, Dorn et al. 2009, Ivić et al. 2009, Scauflaire et al. 2011).

In Hungary, the predominance of *F. verticillioides* was revealed, while the presence of *Fusarium graminearum*, *F.*

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proliferatum, *F. Sporotrichioides*, and *F. subglutinans* was rare. In warmer years, *Penicillium* and *Aspergillus* isolates also appeared in increasing proportion (Tóth et al. 2012).

Aflatoxin data are published from Serbia (Jakic-Dimic et al. 2009), fumonisin, DON, and ZEA data from Poland (Czembor et al. 2015). In Romania aflatoxin, DON, zearalenone, and fumonisin contamination were reported (Tabuc et al. 2009), while DON, ZEA, but no aflatoxin occurrence from maize samples were reported from Croatia (Pleadin et al. 2012). In data published in Italy, DON, ZEA, aflatoxins, and fumonisins occurred in a significant part of the samples (Leggieri et al. 2015). In Spain, mostly aflatoxin, fumonisins, and zearalenone were found in the samples examined (Tarazona et al. 2020). Multitoxin contamination of the samples is shown in early data of Borutova et al. (2012).

Aflatoxin production of *A. flavus* isolates was studied (Astoreca et al., 2012) at different water potential and temperature values, and their effect on mycotoxin concentration during storage was modeled by a predictive way. At a water potential value of 0.90, storage was only safe below 15 °C, while at 0.80, it was already 27 °C. With a water potential level of 0.77, storage was possible regardless of temperature.

To lower toxin contamination, the use of fungicides in maize is not widespread due to less effective technology. Among the various agrotechnical specifications, the advantage of early sowing and the precise timing of irrigation can be highlighted, but insecticide control and early harvesting are also of paramount importance. However, the most important factor is the resistance of the hybrid. The role of resistance breeding in prevention of mycotoxin contamination in maize is, therefore, particularly important (Munkvold, 2014).

The limit of total fumonisin concentration for unprocessed maize samples is 4000 µg/kg and 200–1000 µg/kg for processed foods. For DON, these values are 1750 µg/kg and 750 µg/kg, respectively. The prescribed limits for AFB₁ vary from 0.1 to 8 µg/kg, depending on the type of food (EU Commission Regulation No 1126/2007/EK). The limits for samples intended for animal feed depend on the animals kept and their age.

As in the last decades, no wide evaluation of the mycotoxins was published in Hungary, our aim was to present a long-term dataset for the most important mycotoxins in maize.

Materials and methods

17,011 samples were analyzed in maize between 2012 and 2017. SGS Hungária Ltd. was helpful in providing the toxin test results. Their mycotoxin-testing laboratories operate according to strict guidelines and accreditation to ISO 17025, ISO 9001:2008, so both sampling and the analytical

methods are validated (technical descriptions of the analysis of mycotoxins are available on the website of SGS).

The samples originated from farmers from all counties of Hungary who sent their grain samples for mycotoxin determination. Most of the samples were mixed, and a significant part of them were stored samples, so it is advisable to evaluate them in relation to the previous year. A significant part of the toxin concentration determinations of the grains harvested in September, October or later was performed next year when it was sold or used. There are no informations regarding the length of the storage period, and because of this, the preharvest or postharvest character of the toxin contamination is not specified. Higher degree of insect damage can also cause additional toxin contamination and this effect is included in the dataset.

Table 1 shows the number of samples tested in each year. Toxin concentrations for DON is indicated in mg/kg values, while in case of total aflatoxin (B₁ + B₂ + G₁ + G₂) µg/kg. In point of fumonisins, not only the sum of FB₁ and FB₂ concentrations was given but also FB₃ contamination in mg/kg.

Toxin data were grouped by county. Averages were shown in the figures per type of toxin and per year. The sum of these toxins is highlighted in the figures and tables shown.

Results

Average toxin contamination of maize samples between 2012–2017

The annual data are shown in Appendix 1–6.

Mean toxin data of the six years tested are shown in Table 2. In 2014 and 2015, DON was dominant toxin (The EU limit for adult pigs is 0.9 mg/kg, but for piglets only 0.2 mg/kg.). Higher concentrations of fumonisins and aflatoxins were found in 2013 and 2014. In other years, only sporadic occurrence was found. In the case of aflatoxin, positive values were observed every year except 2012, when no measurements for this toxin were performed. Many of the samples from harvest of 2012 were tested in 2013; therefore,

Table 1 Number of maize samples tested in the laboratory of SGS, Hungary, 2012–2017

Year	Number of samples
2012	429
2013	2009
2014	4743
2015	5713
2016	2010
2017	2107
Total	17,011

Table 2 Average toxin concentrations of the tested maize samples, 2012–2017

Years	Toxin concentrations		
	DON (mg/kg)	Total aflatoxin (µg/kg)	Total fumonisin (mg/kg)
2012	0.10	n. d. ^a	0.31
2013	0.14	1.20	1.00
2014	1.34	1.10	2.01
2015	1.20	0.39	0.75
2016	0.39	0.34	0.53
2017	0.25	1.20	0.30
Mean	0.57	0.71	0.82
LSD 5%	0.26	0.26	0.26

^aAflatoxin determination was not performed in 2012

higher concentrations were present. Aflatoxin concentrations were significantly lower in 2015 and 2016 but significantly higher in 2017. Total fumonisin contents of the samples in 2013 and 2014 were significantly higher than from other years. Toxin composition and maximum values differ significantly throughout the years and cannot be forecasted precisely. Climate change does not mean a continuous increase of toxin contamination, but higher differences can occur from year to year. Our conclusion is that resistance against all major pathogens is necessary to control one or more diseases effectively.

The two-way ANOVA (Table 3) shows highly significant differences between years and the year × toxin interactions indicating the influence of the yearly weather conditions on the toxin contamination.

Table 3 Two-way ANOVA of the tested maize samples (Years and Toxins), 2012–2017

Source of variance	SS	df	MS	F	p-value	F crit
Years A	59.21	5	11.84	10.97***	9.1E–10	2.23
Toxins B	3.49	2	1.74	1.61	0.20058	2.23
A × B	35.38	10	3.54	3.28***	0.00047	1.52
Within	349.87	324	1.08			
Total	447.95	341				

***p = 0.001

Table 4 Two-way ANOVA of the tested maize samples (Counties and Years), 2012–2017

Source of variance	SS	df	MS	F	p-value	F crit
Counties A	51.99	17	3.06	2.59***	0.000769	1.67
Year + Toxin B	80.03	14	5.72	4.83***	7.77E–08	1.73
Within	281.46	238	1.18			
Total	413.48	269				

***p = 0.001

Table 5 Three-way ANOVA from the results of toxin determinations, 2012–2017

Source of variance	SS	df	MS	F	LSD 5%
Counties	51.99	17	3.06	2.59***	0.85
Mycotoxins	3.51	2	1.76	1.49***	0.32
Year	39.96	4	9.99	8.45***	1.77
A × B	59.49	34	1.75	1.48**	
A × C	68.60	68	1.01	0.85	
B × C	36.55	8	4.57	3.86**	
A × B × C	153.36	136	1.13	0.95	
Within	281.46	238	1.18		
Total	413.48	269			

***p = 0.001, **p = 0.01.

Based on the results of two-way ANOVA (Table 4) regarding toxin concentrations, geographical location had a highly significant effect on distribution of all three toxins, while the effect of years was significant for DON and fumonisin, while the incidence of aflatoxin was much more unpredictable, further increasing the concern of aflatoxin. Based on the results of the three-way ANOVA, there are highly significant differences for all three main factors (LSD 5% for factor A is 0.85) similarly to the County × Toxin and Toxin × Year interactions (Table 5).

The maximum values (Table 6) of DON surpassed the EU limits each year. Two years showed higher than 100 µg/kg aflatoxin concentrations, while the EU limit for feeds is 20 µg/kg. We should also consider that the limit for human consumption is only 4 µg/kg which poses a threat also in years without *Aspergillus* epidemic. The distribution of

Table 6 Maximum toxin concentrations of maize samples in Hungary, 2012–2017

Years	DON (mg/kg)	Total aflatoxin (µg/kg)	Total fumonisin (mg/kg)
2012	1.61	n. d	1.71
2013	2.79	115.88	6.31
2014	5.36	109.40	11.89
2015	9.40	61.95	5.36
2016	4.83	18.31	5.59
2017	2.30	64.94	2.27

Table 7 Correlation between toxin concentrations of maize samples in Hungary, 2013–2017

	DON	Total aflatoxin	Total fumonisin
Total aflatoxin	0.0933		
Total fumonisin	0.4573*	0.4595*	

* $p=0.05$ **Table 8** Regional differences in toxin contamination of maize in Hungary, means for 2012–2017

Counties	Regions	DON (mg/kg)	Total aflatoxin (µg/kg)	Total fumonisin (mg/kg)
Veszprém	NW	0.87	2.17	0.63
Fejér	NW	0.71	0.43	1.06
Komárom-Esztergom	NW	0.90	0.12	0.72
Győr-Moson-Sopron	NW	0.62	0.36	0.75
Vas	NW	0.71	0.07	0.41
Mean		<i>0.76*</i>	0.63	0.71
Baranya	SW	0.86	1.15	1.82
Tolna	SW	1.17	0.63	1.44
Somogy	SW	0.97	0.75	1.11
Zala	SW	1.21	0.10	0.57
Mean		<i>1.05*</i>	<i>0.66*</i>	<i>1.24*</i>
Bács-Kiskun	SE	0.61	2.60	1.51
Csongrád-Csanád	SE	0.17	1.63	0.85
Békés	SE	0.17	1.38	0.91
Jász-Nagykun-Szolnok	SE	0.42	0.21	1.40
Mean		0.34	<i>1.46*</i>	<i>1.17*</i>
Pest	NE	0.57	1.16	0.72
Szabolcs-Szatmár-Bereg	NE	0.32	0.30	0.53
Borsod-Abaúj-Zemplén	NE	0.33	0.07	0.50
Hajdú-Bihar	NE	0.13	0.12	0.58
Heves	NE	0.10	0.17	0.04
Mean		0.29	0.36	0.47
LSD 5%				0.85

*Italic values Means of regions with the highest toxin contamination

maximum values prove the fact that only one year is not suitable to judge the potential risk of a mycotoxin.

The correlation between DON content and total aflatoxin concentration is not significant (Table 7). The correlation between DON and total fumonisin as well as total fumonisin and total aflatoxin is $r=0.45$, just above the limit of LSD 5%.

Regional differences in toxin contamination of maize in Hungary

Based on the DON toxin results, it can be concluded that the western part of the country is well separated from the eastern one, and the toxin concentrations were higher in that part of the country. This can be explained by the fact that in the vast majority of the years, the western part of the country has more precipitation and a lower average temperature, which favors the growth of *Fusarium graminearum* and the production of DON toxin (Table 8.).

In regard of aflatoxin, we only examined the period between 2013 and 2017, as no data were available from 2012. The spread of *Aspergillus flavus*, the main producer of aflatoxin, is controlled by hot and dry weather conditions. We generally obtained exceptionally high values

in the Southern Great Plain region, but Southern Transdanubia had also outstanding concentrations, which was joined by Pest county, presumably due to samples from the southern regions of the county (Table 8).

In case of fumonisins, the higher value range of the southern counties was common, but the regions of the Great Plain and Transdanubia were mixed. This was perhaps due to the general occurrence of fumonisins and the fact that *Fusarium verticillioides* is the most characteristic pathogenic species of maize and that warmer, drier climate favors its growth and mycotoxin production (Table 8).

Occurrence of fumonisin analogs in maize samples between 2012 and 2017

Among the 105 fumonisin data of different counties 31 (29.5%) have no detectable FB content. The highest FB₁ value was 3.54 mg/kg. The average concentrations of the examined FB derivatives were 0.63 mg/kg for FB₁, 0.17 mg/kg for FB₂, and 0.06 mg/kg for FB₃ (Fig. 1). FB₂ or FB₃ was never detected alone. The correlations between the three fumonisins analogs were highly significant ($p=0.001$), and correlation coefficient varied between 0.961 and 0.998 across the 6 years of evaluation. 72.63% of the total fumonisin concentration was defined as FB₁, 20.34% as FB₂, and 7.03% as FB₃. Isolates of *F. verticillioides* can produce fumonisin analogs in different composition. This means that the toxin composition in different isolates can be regulated differently.

Discussion

The aim of this study was a complex evaluation of natural DON, total fumonisin, and total aflatoxin contamination of maize samples derived from different geographical regions of Hungary. The six years of national dataset clearly show that all major mycotoxins occur in maize. The southern counties of the country, near the Romanian (Tabuc et al. 2009), Serbian (Jaksic et al. 2019), and Croatian border (Pleadin et al. 2012) show significantly higher toxin contamination than counties in the northern part of Hungary. In the case of countries, the north of Hungary fumonisin was present in all samples examined, while DON was present in 66.67% of the samples in Poland (Czembor et al., 2015). Regarding the results of countries to the south of Hungary, the concentration of DON and ZEA was extremely low each year in Italy (Leggieri et al., 2015). In contrast, the incidence of aflatoxins was 75%, while fumonisins occurred in all samples (field samples). Tarazona et al. (2020) have tested high number of stored maize samples for mycotoxin concentrations in Spain. 20.4%, 5.1%, 3%, and 3% of these maize samples had mycotoxin concentration exceeding the European Union permissible limits for total fumonisin, ZEA, AFB1, and total aflatoxins. There were samples in which co-occurrence of more than one mycotoxins was present. Quantifiable levels were observed in 33.5% of samples being the association of FB1, FB2, and DON, followed by the presence of FB1, FB2, ZEA, and DON. In accordance with these results, global climate change is increasing the incidence of *A. flavus* isolates as well as changes in the composition of mycobiota (Cotty et Jaime-Garcia 2007). Our data support that the production of aflatoxin can also be of field origin,

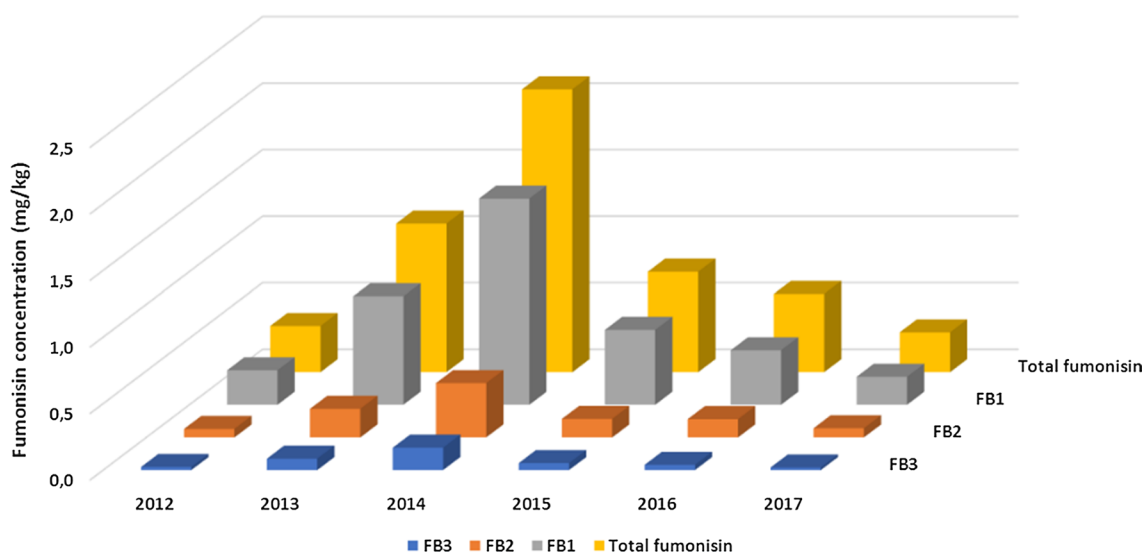


Fig. 1 Occurrence of fumonisin B analogs and the total fumonisin concentrations between 2012 and 2017

and its occurrence is becoming more pronounced as a result of climate change. The epidemic refers to one, two, or all three major toxins. The fluctuation between years is decisively shaped by the weather conditions, and this is true for the warmer and drier southern counties, where aflatoxin was also present. A part of the aflatoxin contamination could be of preharvest origin, but publications with clear data were not published yet. The correlation between DON and total fumonisin as well as total fumonisin and total aflatoxin concentration (2013–2017) is $r=0.45$, just above the limit of LSD 5%. There were some references previously supporting these data (Mesterhazy et al. 2012), but the significance of the correlations were not high enough to draw reliable conclusions. We should consider that the toxin content of the most contaminated lots is not tested by farmers, so the real toxin contamination data are most likely worse. As higher toxin contamination can occur across the whole country, higher plant resistance level is necessary to prevent larger ecological damages. Blaney et al. (2008) suggested also the same in Australia. Prevention is the cheapest way to avoid epidemics and raise food and feed safety. *F. verticillioides* isolates which may caused natural infection of maize belonged to the dominant FB chemotype, with higher amounts of FB₁ and FB₂ in the samples (Szécsi et al. 2010). Based on the evaluated data the mean ratios of FB₁:FB₂, FB₁:FB₃ and FB₁:total fumonisins were 3.7:1; 10.5:1; and 0.7:1, respectively. The overall ratio of FB₂ was higher and the concentration of FB₃ was lower than previously reported from Iran (Ghiasian et al., 2005).

Appendix 1 Toxin concentrations of maize samples in 2017, means for counties

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Bács-Kiskun	0.24	7.11	0.53	0.21	0.05	0.79
Baranya	0.33	1.21	1.05	0.31	0.09	1.45
Békés	0.03	2.36	0.00	0.00	0.00	0.00
Borsod-Abaúj-Zemplén	0.42	0.00	0.00	0.00	0.00	0.00
Csongrád-Csanád	0.03	0.13	0.00	0.00	0.00	0.00
Fejér	0.07	0.00	0.14	0.06	0.00	0.20
Győr-Moson-Sopron	0.59	0.00	0.63	0.21	0.06	0.90
Hajdú-Bihar	0.04	0.04	0.42	0.13	0.03	0.58
Heves	0.10	0.00	0.00	0.00	0.00	0.00
Jász-Nagykunszolnok	0.03	0.00	0.00	0.00	0.00	0.00

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Komárom-Esztergom	0.73	0.00	0.00	0.00	0.00	0.00
Nógrád	0.10	0.00	0.00	0.00	0.00	0.00
Pest	0.31	0.14	0.00	0.00	0.00	0.00
Somogy	0.25	0.20	0.66	0.18	0.06	0.90
Szabolcs-Szatmár-Bereg	0.10	0.00	0.06	0.02	0.00	0.08
Tolna	0.18	0.05	0.52	0.20	0.07	0.79
Vas	0.45	0.02	0.00	0.00	0.00	0.00
Veszprém	0.33	11.37	0.00	0.00	0.00	0.00
Zala	0.43	0.19	0.00	0.00	0.00	0.00
Mean	0.25	1.20	0.21	0.07	0.02	0.30

Appendix 2 Toxin concentrations of maize samples in 2016, means for counties

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Bács-Kiskun	0.51	0.13	1.74	0.63	0.16	2.53
Baranya	0.97	0.04	0.40	0.14	0.04	0.58
Békés	0.05	1.16	0.00	0.00	0.00	0.00
Borsod-Abaúj-Zemplén	0.19	0.00	0.72	0.20	0.06	0.98
Csongrád-Csanád	0.13	2.88	0.00	0.00	0.00	0.00
Fejér	0.46	0.00	0.40	0.13	0.04	0.57
Győr-Moson-Sopron	0.27	0.05	0.00	0.00	0.00	0.00
Hajdú-Bihar	0.09	0.00	0.43	0.10	0.05	0.58
Jász-Nagykunszolnok	0.79	0.11	0.00	0.00	0.00	0.00
Komárom-Esztergom	0.41	0.10	0.71	0.20	0.07	0.98
Pest	0.23	0.92	0.18	0.09	0.02	0.29
Somogy	0.46	0.31	0.49	0.16	0.05	0.70
Szabolcs-Szatmár-Bereg	0.10	0.56	0.37	0.08	0.04	0.49
Tolna	1.32	0.15	1.34	0.53	0.13	2.00
Vas	0.33	0.00	0.10	0.06	0.00	0.16
Veszprém	0.60	0.01	0.00	0.00	0.00	0.00
Zala	0.49	0.00	0.10	0.02	0.01	0.13
Mean	0.44	0.38	0.41	0.14	0.04	0.59

Appendix 3 Toxin concentrations fs maize samples in 2015, means for counties

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Bács-Kiskun	1.26	0.83	0.00	0.00	0.00	0.00
Baranya	1.72	0.03	1.97	0.54	0.21	2.72
Békés	0.30	1.04	1.58	0.39	0.16	2.13
Borsod-Abaúj-Zemplén	0.13	0.13	0.09	0.03	0.00	0.12
Csongrád-Csanád	0.09	3.22	0.00	0.00	0.00	0.00
Fejér	1.67	0.08	0.51	0.12	0.07	0.70
Győr-Moson-Sopron	1.14	0.20	0.31	0.07	0.01	0.39
Hajdú-Bihar	0.31	0.07	0.56	0.14	0.05	0.75
Heves	0.04	0.00	0.00	0.00	0.00	0.00
Jász-Nagykunszolnok	1.01	0.12	2.10	0.50	0.16	2.76
Komárom-Esztergom	1.76	0.03	0.49	0.14	0.04	0.67
Nógrád	0.03	0.00	0.00	0.00	0.00	0.00
Pest	1.56	0.08	1.23	0.24	0.10	1.57
Somogy	2.29	1.00	1.12	0.30	0.12	1.54
Szabolcs-Szatmár-Bereg	0.66	0.11	0.74	0.17	0.07	0.98
Tolna	3.03	0.14	0.00	0.00	0.00	0.00
Vas	1.38	0.01	0.00	0.00	0.00	0.00
Veszprém	2.00	0.32	0.00	0.00	0.00	0.00
Zala	2.38	0.06	0.00	0.00	0.00	0.00
Mean	1.20	0.39	0.56	0.14	0.05	0.75

Appendix 4 Toxin concentrations of maize samples in 2014, means for counties

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Bács-Kiskun	1.52	3.42	2.56	0.75	0.29	3.60
Baranya	1.94	1.72	2.66	0.80	0.30	3.76
Békés	0.47	2.03	1.27	0.34	0.14	1.75
Borsod-Abaúj-Zemplén	0.97	0.07	1.09	0.22	0.10	1.41
Csongrád-Csanád	0.72	3.56	3.54	1.06	0.49	5.09
Fejér	1.97	0.62	2.45	0.71	0.29	3.45

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Győr-Moson-Sopron	1.48	1.15	1.92	0.40	0.11	2.43
Hajdú-Bihar	0.17	0.27	0.93	0.26	0.08	1.27
Heves	0.17	1.03	0.00	0.00	0.00	0.00
Jász-Nagykunszolnok	0.43	0.15	2.27	0.62	0.28	3.17
Komárom-Esztergom	1.90	0.10	0.00	0.00	0.00	0.00
Pest	1.26	3.28	0.81	0.22	0.06	1.09
Somogy	2.51	1.18	2.20	0.57	0.22	2.99
Szabolcs-Szatmár-Bereg	0.49	0.59	0.75	0.16	0.07	0.98
Tolna	2.28	1.48	2.54	0.63	0.24	3.41
Vas	1.91	0.18	1.67	0.45	0.15	2.27
Veszprém	1.94	0.15	0.91	0.11	0.19	1.21
Zala	3.31	0.00	0.31	0.05	0.02	0.38
Mean	1.41	1.17	1.55	0.41	0.17	2.13

Appendix 5 Toxin concentrations of maize samples in 2013, means for counties

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Bács-Kiskun	0.02	4.09	1.13	0.31	0.12	1.56
Baranya	0.07	3.87	1.27	0.39	0.16	1.82
Békés	0.05	1.67	0.67	0.18	0.07	0.92
Borsod-Abaúj-Zemplén	0.13	0.22	0.30	0.06	0.02	0.38
Fejér	0.02	1.86	0.56	0.14	0.06	0.76
Győr-Moson-Sopron	0.08	0.76	0.57	0.17	0.06	0.8
Hajdú-Bihar	0.07	0.35	0.14	0.03	0.01	0.18
Heves	0.07	0.00	0.17	0.04	0.01	0.22
Jász-Nagykunszolnok	0.13	0.88	1.82	0.45	0.18	2.45
Komárom-Esztergom	0.22	0.50	1.54	0.23	0.15	1.92
Pest	0.06	2.54	0.95	0.30	0.10	1.35
Somogy	0.22	1.78	0.00	0.00	0.00	0.00
Szabolcs-Szatmár-Bereg	0.46	0.55	0.41	0.10	0.05	0.56
Tolna	0.11	1.98	1.40	0.43	0.18	2.01

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Vas	0.15	0.23	0.00	0.00	0.00	0.00
Veszprém	0.20	1.17	1.16	0.34	0.13	1.63
Zala	0.59	0.32	1.76	0.49	0.16	2.41
Mean	0.16	1.34	0.81	0.22	0.09	1.12

Appendix 6 Toxin concentrations of maize samples in 2012, means for counties

County	DON	Total aflatoxin	FB ₁	FB ₂	FB ₃	Total fumonisin
Bács-Kiskun	0.09	n.d	0.41	0.12	0.05	0.58
Baranya	0.11	n.d	0.43	0.09	0.06	0.58
Békés	0.11	n.d	0.52	0.09	0.04	0.65
Borsod-Abaúj-Zemplén	0.12	n.d	0.09	0.02	0.00	0.11
Csongrád-Csanád	0.06	n.d	0.00	0.00	0.00	0.00
Fejér	0.06	n.d	0.53	0.11	0.04	0.68
Győr-Moson-Sopron	0.15	n.d	0.00	0.00	0.00	0.00
Hajdú-Bihar	0.07	n.d	0.08	0.02	0.01	0.11
Heves	0.24	n.d	0.00	0.00	0.00	0.00
Jász-Nagykun-Szolnok	0.12	n.d	0.00	0.00	0.00	0.00
Komárom-Esztergom	0.35	n.d	0.59	0.12	0.04	0.75
Somogy	0.08	n.d	0.38	0.10	0.03	0.51
Szabolcs-Szatmár-Bereg	0.08	n.d	0.08	0.02	0.00	0.10
Tolna	0.08	n.d	0.35	0.06	0.02	0.43
Vas	0.04	n.d	0.00	0.00	0.00	0.00
Veszprém	0.16	n.d	0.60	0.24	0.07	0.91
Zala	0.06	n.d	0.36	0.10	0.03	0.49
Mean	0.12	n.d	0.26	0.06	0.02	0.35

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Declarations

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