

Comparison of the amount of bioaccessible fumonisin B₁ and B₂ in maize and rice inoculated with *Fusarium verticillioides* (MRC 826) and determined by in vitro digestion—preliminary results

J. Szabó-Fodor¹ · I. Bors¹ · A. Szabó^{1,2} · M. Kovács¹

Received: 18 March 2016 / Revised: 8 June 2016 / Accepted: 9 June 2016 / Published online: 30 June 2016
© Society for Mycotoxin Research and Springer-Verlag Berlin Heidelberg 2016

Abstract In this study the occurrence of hidden fumonisin B₁ (FB₁) and fumonisin B₂ (FB₂) was analysed, on two cereal substrates (maize and rice), inoculated with *Fusarium verticillioides* (MRC 826), in order to determine the ratio of hidden FB₁ and FB₂. Two parallel methods were applied: an in vitro human digestion sample pre-treatment and the routine extraction procedure, in both cases with subsequent LC-MS analysis. It was found that all samples showed higher concentration of total fumonisin B₁ after digestion, as compared to that of free fumonisin analysed only after extraction. The percentage of the hidden form by maize was 18.8 % (±2.4) for FB₁ and 36.8 % (±3.8) for FB₂, while for rice it was 32.3 % (±11.3) and 58.0 (±6.8), respectively, expressed as the proportion to total fumonisin B₁, for the total dataset. Significant differences were found in the FB₁ and FB₂ concentration measured after the different digestion phases (saliva, gastric and duodenal) in case of both matrixes. The results are useful for human risk assessment, since both humans and animals may be exposed to markedly higher toxin load, as determined merely by conventional analytical methods.

Keywords Hidden fumonisin B₁ · Bioaccessibility · *Fusarium verticillioides* · Maize · Rice

Introduction

Fumonisin were discovered in South Africa in 1988 (Gelderblom et al. 1988; Marasas et al. 2000). They are known to be produced by *Fusarium verticillioides* (formerly known as *F. moniliforme*), *F. proliferatum*, *F. oxysporum*, *F. globosum*, several other *Fusarium spp.*, and *Alternaria alternata* f. sp. *lycopersici* (Scott 2012). Fumonisin are frequently found in corn and corn-based foods (Shephard et al. 1996; Weidenbörner 2001). Fumonisin B₁ (FB₁) is the most commonly found, not only in corn (maize) and corn-based foods but also in barley, rice, sorghum, triticale, cowpea seeds, beans, soybeans and asparagus. Fumonisin are responsible for several toxic effects in animals, and they have been associated with oesophageal cancer in humans (Voss et al. 2002).

The International Agency for Research on Cancer (IARC) designated FB₁ in Group 2B as ‘possibly carcinogenic to humans’ (International Agency for Research on Cancer (IARC) 1993).

According to a survey performed in 2011, 50 % of tested agriculture samples were found to be contaminated with fumonisin worldwide (Schatzmayr and Streit 2013).

Exposure assessments are based on the chemical analyses of foods and feeds to detect the exact quantity of mycotoxin contamination. From a food safety point of view, it is especially important to know not only the true initial amount of toxin entering the organism. The possible changes occurring during the digestion process (e.g. enzymatic hydrolysis, microbial metabolism) has also been taken into consideration.

Mycotoxins that are undetectable by conventional, extraction-based analytical methods are known as masked mycotoxins (Berthiller et al. 2013). While extractable mycotoxins can be easily detected, bound mycotoxins are not directly detectable; they have to be liberated from the matrix by chemical or enzymatic pre-treatment prior to chemical

✉ J. Szabó-Fodor
fodor.judit@ke.hu

¹ MTA-KE Mycotoxins in the Food Chain Research Group, Kaposvár University, Guba S. 40., Kaposvár H-7400, Hungary

² Faculty of Agricultural and Environmental Sciences, Institute of Diagnostic Imaging and Radiation Oncology, Kaposvár University, Kaposvár, Hungary

analysis. Fumonisin B₁ can bind to proteins and to other matrix components during food processing involving heat (Dall'Asta et al. 2009). The occurrence of bound fumonisins in processed corn foods is common. Another type of binding (or association) relates to observed instability of fumonisins in rice flour, corn starch and corn meal at room temperature; this can affect the immunoaffinity column clean-up procedure in analysis of naturally contaminated starch-containing corn foods for fumonisins (Scott 2012).

Dall'Asta et al. (2010) suggested an in vitro digestion model to evaluate the levels of bound fumonisin. With this method, after an enzymatic pre-treatment, significantly more (30–40 %) fumonisin was detected, compared to that measured after the conventional extraction method.

In the past decade, more studies have been published concerning the formation and role of matrix associated (hidden) mycotoxins in naturally infected and contaminated foods and feeds.

In the study of Szabó-Fodor et al. (2015), the hidden fumonisin B₁ was analysed in two cereal substrates (maize and wheat), which were inoculated with *F. verticillioides* (MRC 826). The study compared a routine extraction procedure with in vitro digestion sample pre-treatment. It was found that all samples showed a higher concentration of fumonisin B₁ after digestion, compared to the free fumonisin obtained merely by extraction. The percentage of the hidden form was 38.6 % (±18.5) in maize and 28.3 % (±17.8) in wheat, expressed as the proportion of total fumonisin B₁.

In this study rice, as an important, but from modified fumonisin point of view less investigated substrate to *F. verticillioides* was introduced into our in vitro digestibility (or bioaccessibility) study. Rice is the staple food for over half of the world's population. Almost a billion households in Asia, Africa and the Americas depend on rice systems for their main source of employment and livelihood. In 2001, the world's population consumed more rice than wheat and/or maize, the other two major cereals. In the same year, more than 3.1 billion people consumed 100 kg of rice or more (Nguyen and Ferrero 2006). People suffering from celiac disease are highly exposed to fumonisins due to the high contribution of gluten-free cereals (like corn and rice) in their diet (Dall'Asta et al. 2012).

Very little is known about the incidence and favourable conditions under which these toxins appear in rice. They have been most commonly studied in other cereals, and the research carried out upon them focused primarily on specific fumonisins B such as FB₁ and FB₂. The presence of these secondary metabolites in rice was described for the first time in two states in the USA; since then, they have been isolated in Russia, Argentina, Italy, Japan, Korea, Canada and Iran (Ferre 2016). Of the total rice production ca., 95 % is used for human nutrition. In the last three decades, the global rice consumption increased by 40 % (Nguyen and Ferrero 2006).

The aim of this study was to investigate the amount of hidden FB₁ and FB₂ present in maize and rice culture material inoculated with MRC 826 using in vitro gastrointestinal (GI) model. The GI model simulated human digestive conditions in order to determine the bioaccessibility of FB₁ and FB₂. The amount of fumonisin obtained this way was compared to the amount of FB₁ and B₂ obtained by a routine LC-MS analytical method (Fig. 1.).

Materials and methods

Chemicals

Romer MIX 3 (containing FB₁₋₂ at 50 mg/L) and U-[¹³C]-labelled FB₁ (25 mg/L in acetonitrile/water) primary stock solutions were used as references, which were obtained from Romer Labs GmbH (Tulln, Austria).

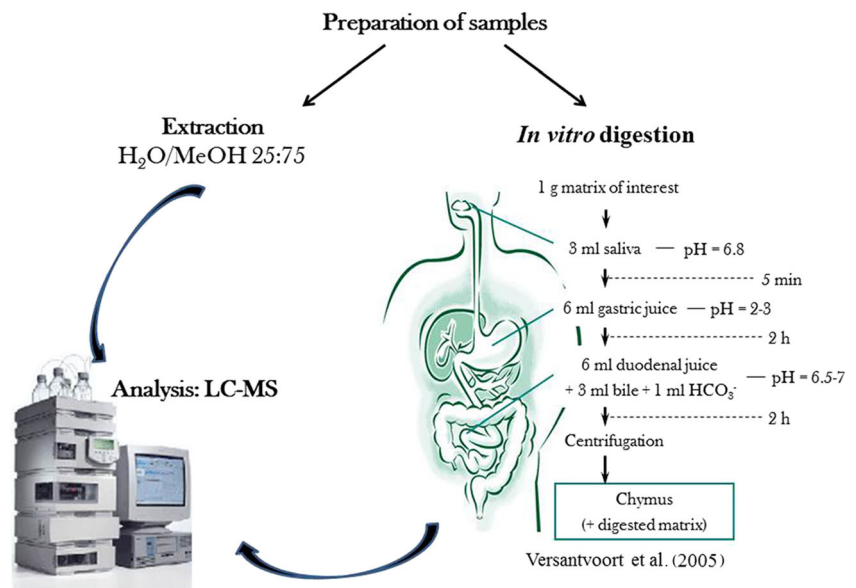
LC-MS grade methanol and acetonitrile were purchased from J.T. Baker (Mallinckrodt Baker, Phillipsburg, NJ, USA). Double distilled water was produced in our laboratory using Milli-Q system (Millipore, Marlborough, MA, USA). Every inorganic chemical (37 % hydrochloric acid, potassium hydroxide, potassium thiocyanate, potassium dihydrogen phosphate, potassium chloride, ammonium chloride, sodium sulphate, sodium dihydrogen phosphate monohydrate, sodium chloride, sodium hydrogen carbonate, calcium chloride, magnesium chloride hexahydrate) was supplied by VWR International (Debrecen, Hungary).

Urea (98 %), D-(+)-glucose (99.5 %), D-glucuronic acid, D-(+)-glucosamine hydrochloride (99 %), type III mucin from porcine stomach, uric acid, type VIII A alpha-amylase from barley malt, bovine serum albumin (BSA), pepsin from porcine gastric mucosa, pancreatin from porcine pancreas, type III lipase from porcine pancreas and bovine and ovine bile which were used for the preparation of the digestive juices were purchased from Sigma (Schnellendorf, Germany).

Fumonisin production, samplings

F. verticillioides (NRRL 20960 (=MRC 826) Syn. *F. moniliforme*) fungal culture (7 days old) was grown on 0.5 strength potato dextrose agar (PDA; Chemika-Biochemica, Basil, Switzerland). Agar discs (5 mm) were prepared with cork borer (Boeckel Scientifica, PA, USA), which were then stored at 10 °C in darkness in test tubes containing sterile distilled water (10 discs/10 ml distilled water).

For toxin production, maize or rice (40 g) was soaked in distilled water (40 ml) at room temperature for 1 h in Erlenmeyer flasks (500 ml), which were closed with cotton wool plugs. This was followed by the addition of the inoculated agar discs (10 agar discs per flask) to the autoclaved (20 min.) matrix. The cultures were then stored and incubated

Fig. 1 Preparation of samples

at 24 °C for 10 days. The flasks were shaken twice every day during the first week of incubation. When the incubation time was complete, the fungus-infected cereal was dried at room temperature and ground.

Chemical composition

In the frame of the proximate analysis, main chemical constituents were determined, in all instances the AOAC International (1995) protocols were followed. Dry matter: AOAC 934.01, vacuum oven; crude protein: Kjeldahl, AOAC 984.13; ether extract: AOAC 920.39; crude fiber: AOAC 978.10; Ash: AOAC 942.05; Nitrogen-free extract calculation: 100—(moisture + ash + protein + c. fiber + ether e.).

Sample preparation for conventional FB₁ analysis

Ground and homogenised samples (maize and rice) (1.00 ± 0.01 g) were weighed into 50-ml polypropylene tubes (VWR International, Bruchsal, Germany). Samples were extracted with 20 ml water/methanol (25:75 v/v) and blended for 3 min at 5000 rpm in an Edmund Bühler GmbH SM30 rotary shaker (Hechingen, Germany) and then centrifuged at 1500 g/5 min at room temperature (Model Janetzki T23 VEB MLW Zentrifugenbau Engeldorf, Germany). Supernatant (1 ml) was diluted (100- or 1000-fold) with water/acetonitrile (1:1 v/v), and these samples were then analysed by LC-MS.

In vitro digestion assay

The preparation of artificial digestion juices (saliva, gastric juice, duodenal juice and bile) were carried out according to

the protocol of Versantvoort et al. (2005). Before digestion, all digestion juices were heated to 37 ± 2 °C. The digestion started by adding 3 ml saliva to 1 g of ground sample, followed by an incubation step of 5 min. Then, 6 ml of gastric juice was added and the mixture was incubated for 2 h. Finally, 6 ml of duodenal juice, 3 ml of bile and 1 ml of 1 M NaHCO₃ solutions were added simultaneously to the mixture. The final incubation step lasted for 2 h. During the in vitro digestion, the mixture was stirred by a multiple (4) heating magnetic stirrer (Velp Scientifica, Usmate (MB)—Italy) to obtain a gentle mixing of the matrix with the digestive juices. This was followed by the addition of distilled water (1 ml) to the final chyme (19 ml). The samples were then centrifuged for 20 min at 4000 rpm, yielding the chyme as the supernatant and the digested matrix as the pellet. Raw chyme (200 µl) was diluted 10-fold with distilled water. This was followed by desalting step through Sep-Pak C18 cartridges (Waters Co., Milford, MA, USA). Briefly, after preconditioning the columns with 2 ml of methanol followed by 2 ml of water, 2 ml of the diluted chyme was loaded on the column, which was then washed again with 2 ml of water. Fumonisin B₁ was eluted using 2 ml of water/acetonitrile, 1:1 v/v. Prior to analysis, the eluent was diluted again 10- or 100-fold with water/acetonitrile (1:1 v/v). All corn and rice samples (4 samples each, all in 2 repetitions) underwent the entire digestion procedure, until the concentration after the duodenal phase; meanwhile, with the interruption of the procedure, the toxin concentration was checked after the saliva and after the gastric phase.

LC-MS analysis

LC-MS analysis was performed by a Shimadzu Prominence Ultra Fast Liquid Chromatograph (UFLC) separation system equipped with a LC-MS-2020 single quadrupole (ultra fast)

liquid chromatograph mass spectrometer (Shimadzu, Kyoto, Japan) with electrospray source. Samples were analysed on a Phenomenex Kinetex 2.6 μ X- C18 column (100 mm \times 2.1 mm). The column temperature was set to 50 °C, the flow rate was 0.3 ml/min and the injection volume was 1 μ l. The gradient elution was performed using double distilled water (eluent A) and methanol (eluent B), both acidified with 0.2 % formic acid; initial condition at 60 % A, 0–2 min isocratic step, 2–6 min linear gradient to 70 % B, 6–13 min linear gradient to 100 % B, 13–15 min isocratic step at 40 % B. Total analysis was 15 min. MS parameters are as follows: source block temperature 90 °C; desolvation temperature 250 °C; heat block temperature 200 °C; drying gas flow 15.0 l/min. Detection was performed using SIM mode.

The mass spectrometer was operating in the selective ion monitoring mode, at *m/z* 722.4 for FB1 and 756.5 for U-[13C]-labelled FB1.

Calibration curves using FB1 and U-[13C]-labelled FB1 standard in the range of 10–500 μ g/kg were prepared. U-[13C]-labelled FB1 (50 μ l, 100 μ g/kg) was used as internal standard. The internal standard was added to the analyte in case of the *in vitro* digestion after the clean-up procedure; while by the conventional extraction, it was added before the final dilution of the analyte. A further reason of the application of the internal standard was to overcome possible different matrix effects (e.g. ion suppression).

The limit of detection (LOD) for FB1 was 3 μ g/kg, while the limit of quantification was (LOQ) 10 μ g/kg.

Statistical analysis

Statistical analyses were performed using IBM SPSS 20.0 (2012) software. The data were expressed as mean \pm standard deviation (S.D.). Statistical significances of differences among treatments were determined by use of one-way analysis of variance (ANOVA) and followed by Tukey's pair-wise comparisons at significance level of 0.05.

Results and discussion

Table 1 shows FB₁ and FB₂ concentrations after water/methanol extraction for LC-MS analysis and at the different phases of *in vitro* digestion.

When comparing FB₁ concentration of rice and corn samples after the routine methanol/water extraction procedure to data received after the total digestion process, it can be established that 32 \pm 11.3 % and 18.8 \pm 2.4 % of the toxin was matrix associated in rice and maize, respectively. In rice, there was no significant difference between the extraction-based toxin concentrations, when compared to the post-salival phase, but when comparing latter results to the gastric or to the final phase, both differences were statistically

significant. In corn, however, a clear tendency could be observed; the concentration value gained with methanol/water extraction and those after the consecutive digestion steps were not significantly different.

For FB₂, the matrix associated proportion showed a higher value, as compared to FB₁, namely 58.0 \pm 6.8 % in rice and 36.8 \pm 3.8 % in corn. The significantly highest concentration in rice was measured after the saliva and thereafter the duodenal phase, while the post-salival results were not significantly different from the post-gastric ones. By this matrix, a significantly lower concentration was determined when applying the conventional methanol/water extraction. For maize, the lowest FB₂ concentrations were attained with the methanol/water extraction, meanwhile the concentration values determined after the consecutive steps of the digestion were not significantly different from each other.

Comparing the two matrices (i.e. rice and corn), rice provided the higher matrix associated toxin moiety in case of FB₁ as well as FB₂. In both matrices, the matrix associated proportion was higher in case of FB₂ than that of FB₁. During digestion, FB₂ was liberated from the matrix associated form at an earlier phase in maize; according to the concentrations measured in the different phases, this happened after the salivary digestion. Differences in the rate of the enzymatic liberation from the matrix may be as well explained with the differences in the rice proximate composition, namely (Table 2) the two matrices were strongly differing in ether extract, crude fiber and starch content.

The reason that FB₁ was more efficiently liberated in the gastric juice refers to the condition that its affinity is more pronounced towards proteins. In addition, the markedly higher starch content of rice (75 %) may as well be a factor behind the FB₁ liberation, as starch is partially hydrolyzed in the saliva, and its fragments (oligosaccharides, glucose and a part of the liberated FB₁) are recovered in the gastric juice. For both FB₁ and FB₂, it is worth mentioning that albeit in the gastric phase there is no lipolysis or starch hydrolysis, the low pH and the motility (here sample agitation by stirring) denaturates proteins and partly emulsifies and makes lipids and remnant polysaccharides more accessible for the latter, small intestinal enzymatic hydrolysis. Thus, some lipid and poly- or oligosaccharide-association may as well be 'destroyed' even in the gastric juice (Mead et al. 1986). It is worth mentioning that corn cell wall-originated crude fiber content is of rather high indigestible composition (lignin), which is a part of the acid detergent fiber fraction. Indeed this fraction is not decomposed at all in the stomach, but hemicellulose (and the probably associated mycotoxin moiety) is partly liberated; this is another partial breakdown step, where a certain toxin amount might be liberated.

It is clearly visible (even if in some cases statistical significance is lacking) that the consecutive digestion steps lead to the liberation of more and more toxin from the matrix associated form.

Table 1 FB₁ and FB₂ concentrations after water/methanol extraction for LC-MS analysis and in the different phases of the in vitro digestion process (4 samples/matrix and digestive phase, all in 2 repetitions)

	Extracted		After saliva phase		After gastric phase		After duodenal phase		Matrix associated ^a %
FB₁ (mg/kg)									
Rice	89.1±8.86	83.6*±20.7	89.6±10.95	72.2*±17.3	111.5±4.95	103.7*±9.1	117.6±15.04	122.1*±15.3	24.2
	53.3±4.99		58.6±3.58		93.8±3.29		104.9±0.09		49.2
	85.2±2.38		86.6±5.68		97.6±0.61		128.2±0.19		33.5
	106.7±8.00		103.9±4.57		111.8±5.5		137.5±12.48		22.4
									32.3±11.3
Maize	33.3±1.60	45.0*±9.0	33.8±2.00	44.5*±7.6	37.8±0.60	46.8*±6.2	39.5±1.60	53.7*±10.3	15.7
	40.6±0.98		45.3±6.76		47.6±4.54		51.6±0.20		21.3
	50.1±2.23		47.9±4.18		49.6±2.96		63.0±7.76		20.5
	50.01±0.02		50.77±2.21		51.93±2.63		60.9±1.28		17.9
									18.8±2.4
FB₂ (mg/kg)									
Rice	16.2±2.12	14.9*±3.4	22.7±1.54	22.6*±4.9	25.9±1.50	26.7*±5.0	33.3±4.27	35.4*±4.5	51.4
	11.3±0.46		15.7±1.10		23.8±0.31		30.9±0.20		63.4
	12.8±0.78		23.1±0.54		22.3±0.09		36.9±0.38		65.3
	19.4±0.25		28.9±1.24		34.6±0.48		40.4±3.74		51.9
									58.0±6.8
Maize	10.5±0.10	13.9*±2.5	13.6±0.31	18.6*±3.9	13.6±0.14	18.6*±3.8	17.0±0.90	22.0*±3.4	38.2
	13.2±1.72		16.4±0.13		16.7±1.80		22.6±0.33		41.5
	15.5±1.17		21.4±0.75		21.2±1.18		24.1±3.73		35.6
	16.4±0.46		23.1±0.12		22.7±1.77		24.1±1.25		31.9
									36.8±3.8

* Indicate significant differences within the same matrix ($P \leq 0.05$)

^a Matrix associated %: (the concentration after the duodenal phase – the concentration in the methanol/water extract) / the concentration after the duodenal phase

The determination coefficient (r^2) between extractable (concentration after the methanol/water extraction) and total FB₁ concentration (concentration after the duodenal phase) for corn and rice for FB₁ was 0.82 and 0.91, while for FB₂ it was 0.85 and 0.94, respectively.

As compared to literature data, it can be established that rice matrix is containing a higher proportion of matrix associated FB₁ form than corn (Dall'Asta et al. 2010; Szabó-Fodor et al. 2015).

Table 2 Main chemical components of the maize and rice matrices (results of the Weende analysis)

Chemical components/matrix	Maize	Rice
Moisture (%)	12.7	12.0
Crude protein (%)	7.4	6.7
Ether extract (%)	3.5	1.0
Crude fiber (%)	2.5	0.4
Crude ash (%)	1.4	0.5
Starch content (%)	61.2	75.5
Reducing sugar content (%)	1.2	0.8

Contamination of rice with fumonisin has been reported in the USA, and it has been studied extensively in the EU (Abbas et al. 1998; EC (European Commission) 2003); little information was published from Asia.

In a study carried out by Dall'Asta et al. (2010) using raw maize, results are presented as total, extractable and hidden forms, expressed in microgram per kilogram. From the published 31 results, the hidden percentage can be calculated ('hidden % = (hidden FB conc. / total FB conc. meaning FB conc. after digestion) × 100'); this calculated percentage of hidden fumonisins (FB₁, FB₂ and FB₃) was 35.6 ± 22.3 %.

In the study of Szabó-Fodor et al. (2015), calculating for the total dataset (pooling week 1 and 3), this proportion was 38.6 ± 18.5 %, while in the samples taken after 3 weeks of production this was 37.5 ± 15.5 % in maize.

In this case, corn contained a lower hidden toxin proportion, which can be explained by the relative short toxin production period, lasting only for 10 days, instead of 3 weeks. Anyhow, on the rice matrix during this shorter time ca. the same amount of matrix associated FB₁ and a ca. two-times higher matrix associated FB₂ proportion were detected.

This raises questions towards the applicability of the routine analysis, which strongly under-estimates the biologically accessible FB₁ and FB₂ moiety, due to the presence of matrix associated forms.

Acknowledgments The research was supported by the Hungarian Academy of Sciences (within the frame of the MTA-KE ‘Mycotoxins in the food chain’ Research Group) and János Bolyai Research Grants of the Hungarian Academy of Sciences (BO/499/13) to J.Sz. F.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest.

References

- Abbas HK, Cartwright RD, Shier WT, Abouzied MM, Bird CB, Tice LG, Ross PF, Sciombato GL, Meredith FI (1998) Natural occurrence of fumonisins in rice with sheath rot disease. *Plant Dis* 82:22–25. doi:10.1094/PDIS.1998.82.1.22
- AOAC International (1995) Official methods of analysis of AOAC International. 2 vols, 16th edn. Association of Analytical Communities, Arlington
- Berthiller F, Crews C, Dall’Asta C, De Saeger S, Haesaert G, Karlovsky P, Oswald IP, Seefelder W, Speijers G, Stroka J (2013) Masked mycotoxins: a review. *Mol Nutr Food Res* 57:165. doi:10.1002/mnfr.201100764
- Dall’Asta C, Mangia M, Berthiller F, Molinelli A, Sulyok M, Schuhmacher R, Krska R, Galaverna G, Dossena A, Marchelli R (2009) Difficulties in fumonisin determination: the issue of hidden fumonisins. *Anal Bioanal Chem* 395:1335–1345. doi:10.1007/s00216-009-2933-3
- Dall’Asta C, Falavigna C, Galaverna G, Dossena A, Marchelli R (2010) In vitro digestion assay for determination of hidden fumonisins in maize. *J Agric Food Chem* 58:12042–12047. doi:10.1021/jf103799q
- Dall’Asta C, Pia Scarlato A, Pia Scarlato G, Brighenti F, Pellegrini N (2012) Dietary exposure to fumonisins and evaluation of nutrient intake in a group of adult celiac patient on a gluten-free diet. *Mol Nutr Food Res* 56:632–640. doi:10.1002/mnfr.201100515
- EC (European Commission) (2003) SCOOP task 3.2.10. “Collection of occurrence data of Fusarium toxins in food and assessment of dietary intake by the population of EU member states”, Subtask III: Fumonizins. European Commission, Directorate-General Health and Consumer Protection, Brussels, 485–577. <http://europa.eu.int/comm/food/fs/scoop/task3210.pdf>
- Ferre FS (2016) Worldwide occurrence of mycotoxins in rice. *Food Control* 62:291–298. doi:10.1016/j.foodcont.2015.10.051
- Gelderblom WCA, Jaskiewicz K, Marasas WFO, Thiel PG, Horak RM, Vleggaar R, Kriek NPJ (1988) Fumonizins-novel mycotoxins with cancerpromoting activity produced by *Fusarium verticillioides*. *Appl Environ Microbiol* 54:1806–1811
- International Agency for Research on Cancer (IARC) (1993) Monographs on the evaluation of carcinogenic risks to humans No. 56. IARC Press, Lyon, pp 489–521
- Marasas WFO, Miller JD, Riley RT, Visconti A (eds) (2000) Fumonizins B₁, International Programme on Chemical Safety (IPCS, UNEP, ILO, and WHO). Environmental Health Criteria 219. WHO, Geneva
- Mead JF, Alfin-Slater RB, Howton DR, Popják G (1986) Lipids: chemistry, biochemistry and nutrition. Plenum Press, N.Y
- Nguyen VN, Ferrero A (2006) Meeting the challenges of global rice production. *Paddy Water Environ* 4:1–9. doi:10.1007/s10333-005-0031-5
- Schatzmayr G, Streit E (2013) Global occurrence of mycotoxins in the food and feed chain: facts and figures. *World Mycotoxin J* 6:213–222. doi:10.3920/WMJ2013.1572
- Scott PM (2012) Recent research on fumonisins: a review. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess* 29(2):242–8. doi:10.1080/19440049.2010.546000
- Shephard GS, Thiel PG, Stockenström S, Sydenham EW (1996) Worldwide survey of fumonisin contamination of corn and corn-based products. *J AOAC Int* 79:671–687
- Szabó-Fodor J, Dall’Asta C, Falavigna C, Kachlek M, Szécsi Á, Szabó A, Kovács M (2015) Determination of the amount of bioaccessible fumonisin B1 in different matrices after in vitro digestion. *World Mycotoxin J* 8(3):261–267. doi:10.3920/WMJ2014.1771
- Versantvoort CHM, Oomen AG, Van de Kamp E, Rempelberg CJM, Spis AJAM (2005) Applicability of an in vitro digestion model in assessing the bioaccessibility of mycotoxins from food. *Food Chem Toxicol* 43:31–40. doi:10.1016/j.fct.2004.08.007
- Voss KA, Howard PC, Riley RT, Sharma RP, Bucci TJ, Lorentzen RJ (2002) Carcinogenicity and mechanism of action of fumonisin B1: a mycotoxin produced by *Fusarium moniliforme* (= *F. verticillioides*). *Cancer Detect Prev* 26(1):1–9. doi:10.1016/S0361-090X(02)00011-9
- Weidenbömer M (2001) Foods and fumonisins. *Eur Food Res Technol* 212:262–273. doi:10.1007/s002170000259