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Agricultural raw commodity foodstuffs, such as grains, vegetables and fruits, are subject to microbiological contamination during harvesting, storage and transport. Various molds and fungi are the most prevalent creating toxins that can contaminate foods. The toxins of concern are the 4 Aflatoxins, DON (Deoxynivalenol), Ochratoxin A, Zearalenone and the 3 Fumonisin.

Aflatoxins are produced by several species of *Aspergillus*: *A. flavus*, *A. parasiticus*, and *A. nomius* mold on peanuts and corn. *Aspergillus ochraceus* and *Penicillium verrucosum* molds yields ochratoxin in peanuts, corn and other grain staples. *Fusarium graminearum* and *F. culmorum* molds produce a heat stable Vomitoxin, also called DON (Deoxynivalenol) in cereal grains such as wheat, barley, oats, rice, and corn. Different species of *Fusarium*, especially *F. culmorum* and *F. crookwellense* produce Zearalenone. Several species of mold produce 15 closely related compounds of Fumonisin, Fumonisin B₁, B₂ being the most abundant. Fumonisin often occur together with other the mycotoxins.

Because these mycotoxins can potential invade many of the primary raw food ingredients, and affecting food safety, the analysis of these toxins in the raw food stuff is critical. The consequences are liver cancer, kidney failure and intestinal distress, amongst their potential teratogenic and reproductive effects. This is why sensitive, validated LC methods have been established for their analysis.

This is a worldwide issue with varying degrees of acceptance. The acceptable concentrations for mycotoxins are country dependant, as shown in Table 1.

	US	(in ppb, ng/g)	World
Total Aflatoxins	20		0 - 20
Ochratoxin A	4		5 - 200
Zearalenone	—		60 -1000
Vomitoxin (DON)	1000		500 - 750
Total Fumonisin	2000 - 4000		2 -1000

Table 1. Different countries have differing Mycotoxin action limits.

Currently, there are numerous methods for mycotoxin analysis, several for the four Aflatoxins, another for the Fumonisin, a third for Ochratoxin A, and a fourth for Zearalenone. Refer to Figure 1 for mycotoxin structures. Recently, for cost and expediency, it has become desirable to integrate several mycotoxins into a single analytical method.

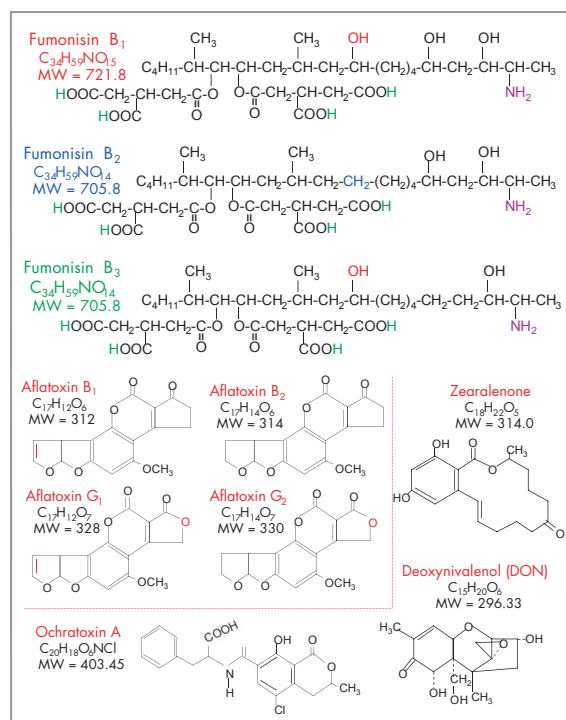


Figure 1. Mycotoxin structures.

Aflatoxin Analysis

Aflatoxin analysis has been an HPLC method for decades with numerous methods published. Of the many derivitization methods for aflatoxins found in the literature, three tend to stand out: post column iodine addition, which is the basis of the official AOAC method, electrochemically generated bromine using the Kobra Cell, and photochemical UV (Phred). Response comparison of the three methods is shown in Figure 2 with detection limits given in Table 2.

While each derivitization method for aflatoxins has its advantages, incorporation into a mixed mycotoxin scheme presents complications.

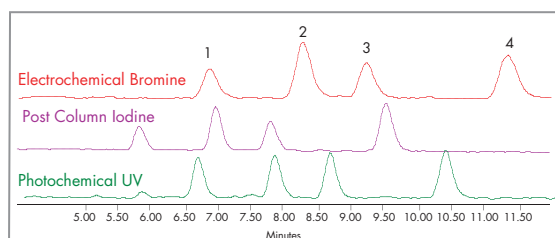


Figure 2. Response comparison 1: 12 ppt G₂, 2: 40 ppt G₁, 3: 12 ppt B₂, 4: 40 ppt B₁.

Analyte/Method	Iodine	Bromine	Photochemical
G ₂	1.26	1.26	0.94
G ₁	4.08	2.20	1.57
B ₂	1.88	0.94	0.63
B ₁	2.51	3.46	4.08

Table 2. Detection limits calculated as 3.14 times standard derivitization of peak area for 7 replicates.

Fumonisin require a post column addition of o-phthaldehyde—2-mercaptoethanol for derivitization. This reagent interferes with Iodine addition for aflatoxins. On the other hand, the KBr - HNO₃ required for electrochemical bromine generation introduce UV active species into the eluent which can diminish the response of DON at 220 nm. This leaves photochemical UV as the suitable alternative for aflatoxin derivitization in a mixed mycotoxin analysis.

Other Mycotoxins

DON, Deoxynivalenol, does not have fluorescence activity and hence the only means of detection is low wavelength UV, 220 nm. At this wavelength, many other organics will also be detected and requires sample preparation for optimal results. Use of photodiode array detection (PDA) will provide a UV spectra which can be compared against a spectral library for identification, and PDA peak purity calculations aids in assessing peak homogeneity.

Alfatoxins G₂ and B₂, Ochratoxin-A and Zearalenone are naturally fluorescent, whereas the Alfatoxins G₁ and B₁ require pre-column derivitization as described earlier, and the fumonisins require an o-Phthaldehyde post-column derivitization to make these analytes fluorescent. The fumonisins have a primary amine functionality that can be derivitized as shown in Figure 3.

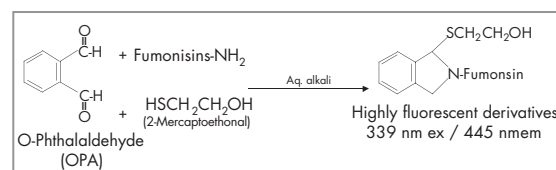


Figure 3. Post-column derivitization chemistry for any primary amine.

The Solution

Through use of UV detection at 220 nm for DON, a PHRED unit (Photochemical Reactor for Enhanced Detection) for aflatoxins, and post column addition pump for fumonisins, the analysis for DON, the four Aflatoxins G₂, G₁, B₂, B₁, three Fumonisins B₁, B₂, and B₃, Zearalenone and Ochratoxin-A has been condensed into a single 30 minute analysis, Figure 4.

This multi analyte method uses a Waters® Alliance® HPLC System with a Post Column Reaction Module, integrating fluorescence detection for UV derivitized aflatoxins, post column derivitization for fumonisins, and natural fluorescence for Zearalenone and Ochratoxin-A. A Waters 2996 Photodiode Array Detector was placed in series before the post-column hardware for the simultaneous UV detection and confirmation of Vomitoxin (DON).

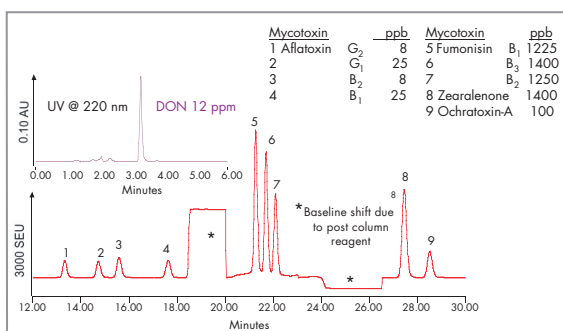


Figure 4. Chromatogram of multi-analyte mycotoxins.

The above approach requires the post column addition of OPA be initiated after the elution of Aflatoxin B₁ and terminated before the elution of Zearalenone. This is accomplished using the system control capabilities of the Waters Alliance HPLC System and Empower™ Software. Reagent Manager flow is initiated at 18.5 minutes and stopped at 24.5 minutes. The 2475 Fluorescence Detector was timed programmed to change excitation and emission wavelengths for analyte response optimization.

This multi-analyte, multi-detection method shows excellent linearity within the typical calibration range for these analytes, shown in Figure 5. The detection limits, Table 3, are well below the analytes action limit suggesting that this approach is excellent for analyte screening.

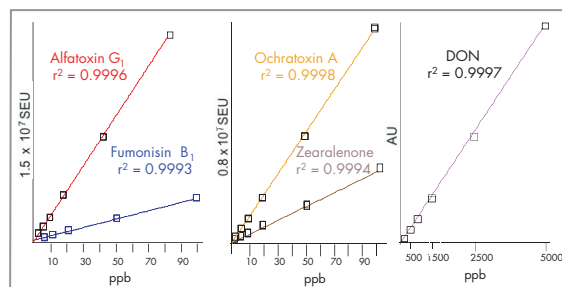


Figure 5. Multi-analyte, multi-detection linearity.

Method Detection Limits (ppb) with 50 µL Injection

DON	5.76	Fumonisin B ₁	2.0
Aflatoxin G ₂	0.003	Fumonisin B ₂	2.0
Aflatoxin G ₁	0.004	Fumonisin B ₃	2.0
Aflatoxin B ₂	0.002	Zearalenone	0.56
Aflatoxin B ₁	0.004	Ochratoxin- A	0.03

MDL calculated per EPA 40 CFR Ch 1 Pt 136 Appendix B

Table 3. Multi-analyte, multi-detection detection limits.

Sample Preparation

Sample preparation is strongly recommended when doing mycotoxin analysis. Vicam, a leader in immunoaffinity chemistries, markets several sample preparation kits, the AflaTest for aflatoxins, FumoniTest for fumonisins, ZearalaTest, OchraTest and DONtest HPLC. As a result of the trend to perform multi-analyte analysis, Vicam is developing a new test cartridge containing monoclonal antibodies for all the mycotoxins (DAFZO), and should be commercially available in early 2005.

Beer, spirits, and wine use various cereal grains and fruits as the substrate for the fermentation process. These agricultural raw materials are also the prime substrate for mold and bacterial growth and mycotoxin contamination. The Alcohol section of the Bureau of Alcohol and Tobacco Tax and Trade Bureau in Walnut Creek CA monitors alcoholic beverages for mycotoxins, and desires a multi-toxin method to maximize throughput and minimize costs. Dr. Darsa Siantar is collaborating with the chemists at Vicam and Waters to develop the appropriate sample prep for this analysis method. Figures 6 and 7 are representative chromatograms of beer and white wine respectively.

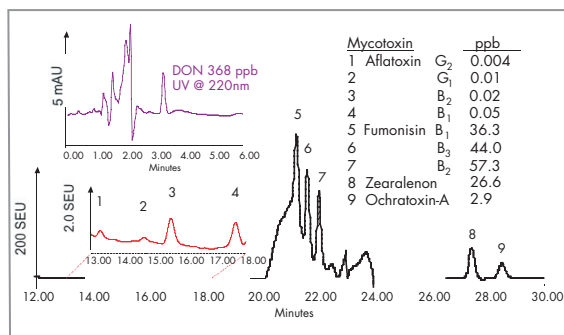


Figure 6. Chromatogram of multi-mycotoxins in spiked beer after Vicam DAFZO sample prep.

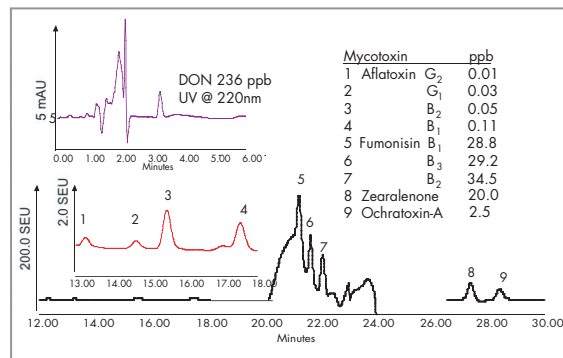


Figure 7. Chromatogram of multi-mycotoxins in spiked white wine after Vicam DAFZO sample prep.

Summary

DON, Aflatoxins, Fumonisin, Zearalenone, and Ochratoxin can now be analyzed in a single analysis. This method is not limited to these analytes, but can also be used to detect Aflatoxins M₁ and M₂, or the metabolites of DON. This method was accomplished using the Waters Carbamate Analyzer which has been optimized for post column derivatization using OPA. Add to this a UV detector, preferably a photodiode array detector because of its spectral analysis capability, and several applications can be run utilizing the same HPLC System. With the system control of gradients, the on/off of the post column reagent pumps, simultaneous detection from two detectors, fluorometer auto zero with all changes in excitation and emission wavelength, and processing of all the data, the Waters Empower Software is the focal point of all HPLC work.

The key to this multi-analyte, multi-detector method is the sample preparation using the high selectivity of Vicam's immuno-affinity cartridges. Without sample prep, numerous other matrix components will be detected by UV possibly compromising accuracy for DON, or other primary amines reacting with OPA and co-eluting with the fumonisins.

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