FRI Briefings

Fusarium Mycotoxins

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Despite intensive research, efforts to control *Fusarium* fungal infections and prevent or eliminate the presence of its mycotoxins in foods have not met with a great deal of success. Fusaria cause diseases, such as ear rot in corn and head blight and scab in wheat, that affect growth and yield of crops and were estimated to cause a loss of a billion dollars to wheat farmers in the USA in 1993. In addition, toxins produced by these fungi can be present, particularly in grains and grain products, in human foods and animal feeds. While animals may become sick from mycotoxin-contaminated feed, *Fusarium* toxins are apparently not carried over into milk, meat, and eggs.

At the Fifth European *Fusarium* Seminar, held in Hungary in August–September 1997, recent data on *Fusarium* infections in crops, the effects of *Fusarium* toxins on human and animal health, and different approaches to dealing with them were shared and discussed (*1*). In addition, a comprehensive, collaborative project involving investigators at a number of state universities in the north-central region of the USA has been established to explore methods to control *Fusarium* blight (scab) in wheat and barley and production of deoxynivalenol (DON) in these grains (*2*). Research areas will include: conventional and molecular approaches to plant breeding; monitoring of grain for contamination with DON and methods for post-harvest management of grain and detoxification; epidemiology and crop management to reduce the occurrence of scab; and enhancement of research and outreach information network.

Although they are not the most toxic of the many *Fusarium* mycotoxins, fumonisins (Fm) and DON are the most frequently detected and, therefore, most often associated with illness in farm animals or humans. Fumonisins cause a neurological disease, equine leucoencephalomalacia in horses, pulmonary edema in swine, hepatotoxic and nephrotoxic effects in other domestic animals, and carcinogenesis in laboratory animals. The American Association of Veterinary Laboratory Diagnosticians has recommended maximum levels of 5, 10, and 50 ppm fumonisin B1 (the most commonly detected of more than 11 structurally related fumonisins) in feed for horses, swine, and beef and poultry, respectively. Although relatively high levels of fumonisins have been detected in corn in some areas of the world with high rates of esophageal cancer in humans, it has not been determined whether fumonisins are causally related to development of this cancer. A recent report from India described an acute but self-limiting foodborne disease outbreak in villagers consuming moldy corn containing up to 64.7 mg fumonisins/kg (*3*). It is not known whether lower mycotoxin concentrations, chronically consumed, cause other detrimental effects in humans, and tolerance levels for fumonisins have not been set for fumonisins in grains for human consumption (with the exception of Switzerland, which has set a level of 1 ppm).

DON is sometimes called vomitoxin because of its toxic effects on swine and other animals. Humans consuming flour made from scabby wheat or moldy corn containing DON also have been reported to suffer nausea and headaches which lasted 2–4 days. DON is frequently present at high concentrations (usually >1 ppm, sometimes as high as 20 ppm) in wheat and corn. Although no U.S. government regulation has been made regarding levels of *Fusarium* toxins in human foods, a recommended tolerance level of 1 ppm DON in grains for human use has been set by several countries, including the USA, while higher concentrations are permitted in animal feeds (*4*).

Fusarium mycotoxins found in food are generated primarily in the field although some toxin synthesis may occur during storage. Temperature and moisture conditions during the growing season and insect infestations are critical factors affecting fungal infection and toxin synthesis. Wet and cool weather during flowering of wheat is conducive to infection with *F. graminearum* which produces DON, while late season rainfall increases infection of corn silk with *F.*

moniliforme, the main producer of fumonisins. Incidence of DON contamination of Canadian soft winter wheat has been reported to vary from 22 to 100% according to surveys conducted during 1980–1994, with a higher incidence correlating with unfavorable climatic conditions. Mycotoxin concentrations were generally low, averaging 0.06–0.75 ppm, but some samples contained 5.67 ppm DON (*5*). Even normal-looking wheat kernels may contain DON although concentrations are generally quite low (*6*). Surveys have demonstrated the worldwide occurrence of fumonisins in corn. Levels of 29–63 ppm fumonisin B1 were detected in corn-based feeds associated with animal disease outbreaks and averages of 1–3 ppm in apparently healthy corn kernels (*7*). Therefore, food processors should expect that many corn and wheat shipments will contain low but detectable levels of fumonisins and DON, respectively. However, mycotoxin concentrations will vary greatly depending on climatic conditions and insect damage.

Although climate can't be controlled, investigators are exploring various approaches to influence rates of infection and toxin production in the field. Breeding for resistance to *Fusarium* infection has been carried out by traditional methods, with several varieties of wheat developed in China showing some degree of resistance to these fungi (*1*). Breeding programs in Canada have produced varieties of corn with resistance to infection by fungal growth through the corn silk. More recently, genetic engineering techniques have been utilized to transfer antifungal genes from plants or microbes into wheat and potatoes (*1*). Some preliminary experiments demonstrated that these plants have an enhanced resistance to *Fusarium* spp.

Other field conditions affecting the infection process and fungal growth may also be amenable to change. Evidence is accumulating that infection rates are higher in crops planted in fields previously planted in corn, particularly when crop residues are left in the field. Fungicide treatments were found to reduce the incidence of *Fusarium* infections in wheat but as yet there are no fungicides approved for use late enough in the season (at flowering). Research into the potential for using microbes antagonistic to *Fusarium* spp. is being conducted with rice plants susceptible to *F. moniliforme (8)*. Preliminary results indicate that some species may suppress growth of toxigenic fungi.

Since these toxins are heat-stable, ordinary cooking and procedures for heat processing do not substantially reduce toxin levels. However, other processing steps may decrease toxin levels. Recent data from Kansas (*9*) and the U.K. (*10*) demonstrated that certain corn products contain relatively high levels of fumonisins: corn meal (up to 349 ng/g), polenta (up to 2124 ng/g), and corn flour (up to 167.7 ng/g). Other corn-based foods generally had low mycotoxin levels but some individual samples contained significantly higher levels. Still other products, including corn oils, corn syrups, tortilla shells, and canned corn had little or no detectable fumonisins. Some of these differences in toxin levels in different products result from some physical or mechanical steps during processing. Since fumonisins are present at higher concentrations in rice husks and in corn screenings from infected plants, polishing of rice and removal of small particles from corn processing can significantly reduce toxin levels. Aqueous extraction of fumonisin-contaminated material also removes significant amounts of this water-soluble toxin and thereby reduces toxicity of the material (*11*). Wet-milling of contaminated corn produces a starch fraction with very little or no fumonisins while the steep water, gluten, germ, and fiber fractions contain most of the toxin (*7*).

Removal or destruction of mycotoxins by means of chemical reactions has also been investigated. The low incidence of fumonisins in tortillas suggested that nixtamalization (treatment of corn flour with calcium hydroxide) prior to making of tortillas might detoxify fumonisins. However, although nixtamalization does hydrolyze fumonisins, experiments with rats demonstrated that the fumonisin compounds are not completely detoxified and still exert hepatotoxic and nephrotoxic effects (*11*).Ammoniation (which can detoxify aflatoxins) and fermentation are not effective in detoxifying fumonisins. A recently described procedure for reacting the amine group of fumonisin B1 with fructose in a non-enzymatic browning reaction has been shown to eliminate the hepatotoxicity and cancer-promoting ability of this toxin (*12*). Further experiments are underway to determine the stability of this conjugate and the possible practical applications of this technique.

DON, another water-soluble toxin, can also be removed to a significant extent by wet milling of corn (*13*). Wheat, however, is usually dry-milled and little reduction in toxin levels occurs during flour production. Further processing into bread does remove some mycotoxins. Data on DON contamination in wheat, flour, and bakery products from the 1993/94 season (which was rainier than usual) in Argentina showed average DON concentrations of 1.8, 1.3, and 0.46 ppm in wheat, flour, and bakery products, respectively (*14*). A further evaluation of steps in the bread-making process indicated a decrease in DON of about 21.6% during fermentation of dough and a further decrease of 28.9% during production and baking of the final product (*15*). However, data from other experiments indicated that DON levels are not reduced significantly by baking. Experiments with microbes from different sources demonstrated that some organisms present in cattle rumen fluid (*16*) and soil (*17*) can detoxify DON by deepoxidation. It may be possible to use one or more of these microbes to reduce toxin levels in feeds or some foods.

Fusarium spp. continue to pose a threat to farmers, by destroying crops or dramatically reducing yields, and to animal and human health, by the production of mycotoxins. Liquid chromatography and gas–liquid chromatography are the most commonly used methods for determination of fumonisins and DON, respectively (*4,7*). Sensitivity of these methods is in the range of 50 ppb or less. More recently, antibodies raised to these mycotoxins have been used in radioimmunoassays with even lower detection limits. At this point, there is no good way to eliminate the *Fusarium* problem, and farmers and food processors should remain alert to changing field conditions which will affect toxin levels in grains.

References

1. Mesterházy, Á., ed. 1997. Proceedings of the 5th European *Fusarium* Seminar. *Cereal Res. Commun.* 25(3, Parts 1 and 2):231–857.

2. Securing the Food Safety and Sustainability of the Wheat and Barley Industries in the North Central Region of the U.S. http://35.8.1.112/scabtalk/fhb_1d.html

3. Bhat, R.V., P.H. Shetty, R.P. Amruth, and R.V. Sudershan. 1997. A foodborne disease outbreak due to the consumption of moldy sorghum and maize containing fumonisin mycotoxins. *Clin. Toxicol.* 35(3):249–255.

4. Chu, F.S. Trichothecene mycotoxins. 1997. In *Encyclopedia of Human Biology, Second Edition*, vol.8, pp. 511–522. Academic Press.

5. Scott, P.M. 1997. Multi-year monitoring of Canadian grains and grain-based foods for trichothecenes and zearalenone. *Food Addit. Contam.* 14(4):333–339.

6. Sinha, R.C., and M.E. Savard. 1997. Concentration of deoxynivalenol in single kernels and various tissues of wheat heads. *Can. J. Plant Pathol.* 19(1):8–12.

7. Munkvold, G.P., and A.E. Desjardins. 1997. Fumonisins in maize. *Plant Disease* 81(6):556–565.

8. Rosales, A.M., and T.W. Mew. 1997. Suppression of *Fusarium moniliforme* in rice by rice-associated antagonistic bacteria. *Plant Disease* 81:49–52.

9. Rumbeiha, W.K., and F.W. Oehme. 1997. Fumonisin exposure to Kansans through consumption of corn-based market foods. *Vet. Human Toxicol.* 39(4):220–225.

10. Patel, S., C.M. Hazel, A.G.M. Winterton, and A.E. Gleadle. 1997. Surveillance of fumonisins in UK maize-based foods and cereals. *Food Addit. Contam.* 14(2) 187–191.

11. Voss, K.A., C.W. Bacon, F.I. Meredith, and W.P. Norred. 1996. Comparative subchronic toxicity studies of nixtamalized and water-extracted *Fusarium moniliforme* culture material. *Food Chem. Toxicol.* 34:623–632.

12. Lu, Z., W.R. Dantzer, E.C. Hopmans, V. Prisk, J.E. Cunnick, P.A. Murphy, and S. Hendrich. 1997. Reaction with fructose detoxifies fumonisin B1 while stimulating liver associated natural killer cell activity in rats. *J. Agric. Food Chem.* 45(3):803–809.

13. Lauren, D.R., and M.A. Ringrose. 1997. Determination of the fate of three *Fusarium* mycotoxins through wet-milling of maize using an improved HPLC analytical technique. *Food Addit. Contam.* 14(5):435–443.

14. Pacin, A.M., S.L. Resnik, M.S. Neira, G. Moltó, and E. Martínez. Natural occurrence of deoxynivalenol in wheat, wheat flour and bakery products in Argentina. *Food Addit. Contam.* 14(4):327–331 (1997).

15. Neira, M.S., A.M. Pacin, E.J. Martínez, G. Moltó, and S.L. Resnik. 1997. The effects of bakery processing on natural deoxynivalenol contamination. *Int. J. Micrbiol.* 37:21–25.

16. Hedman, R, and H. Pettersson. 1997. Transformation of nivalenol by gastrointestinal microbes. *Arch. Anim. Nutr.* 50:321–329.

17. Shima, J., S. Takase, Y. Takahashi, Y. Iwai, H. Fujimoto, M. Yamazaki, and K. Ochi. 1997. Novel detoxification of the trichothecene mycotoxin deoxynivalenol by a soil bacterium isolated by enrichment culture. *Appl. Environ. Microbiol.* 63(10):3825–3830.

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