Food Safety Information Papers

CORN REFINERS ASSOCIATION, INC.

MYCOTOXINS

QUESTION: *All grain crops are susceptible to fungal infections when specific weather patterns occur during the growing season. These fungi are capable of producing toxins, known as mycotoxins. What procedures are in place to minimize the risk that food ingredients of the corn wet-milling industry will contain mycotoxins that might pose a significant health risk in food products?*

Summary

- The production of mycotoxins in growing corn is predictable under specific weather patterns. This predictability allows Corn Refiners Association (CRA) member companies to implement measures to prevent entry of contaminated grain into their manufacturing plants. While mycotoxins are predominately a function of growing conditions, their presence may be exacerbated by poor storage conditions.

- FDA has set action levels for aflatoxin and advisory or guidance levels for fumonisin and deoxynivalenol. FDA's general requirements for safe and wholesome food and feeds reduce the risk of other mycotoxins.

- Corn wet-millers utilize only about 10% of the U.S. corn crop. They can exercise control over the quality of grain entering wet-milling plants for processing, rejecting diseased and otherwise unacceptable corn.

- The low levels of mycotoxins that may enter corn wet-milling plants are removed from food ingredient products through the normal processing steps used in their manufacture.

- FDA acknowledges that wet-milling is an effective process for removing mycotoxins like aflatoxin and fumonisin from corn starch, corn-derived sweeteners and corn oil.

Prepared by WHITE *Technical Research* GROUP; Revised by DTB Associates, LLP
217/795-4437

1. U.S. Corn Production

Corn is used in animal feed compounding, corn dry-milling, distilling and corn wet-milling. Animal feed manufacturers grind corn and incorporate it into finished feeds for livestock and poultry. Corn dry millers grind corn to make corn meal, corn flour, grits, alcohol, corn oil and various feed ingredients. Distillers produce fuel, beverage and industrial alcohol, and feed ingredients.

The largest portion of the corn crop is used domestically for animal feeding, followed by use for fuel, beverage and industrial alcohol, exports and finally wet- and dry-corn milling for food production. In recent years, about 10-12% of the crop has been used by wet- and dry-corn millers. About 50% of the corn processed by wet millers is used for production of sweeteners, 30% used for production of alcohol and the remaining 20% used for production of food and industrial starches.[1]

2. Fungi Affecting Corn

The Food and Agriculture Organization (FAO) estimates that one quarter of the world's food crops are affected by mycotoxins.[2] The annual incidence of mycotoxins varies among commodities, years and geographic regions. The crops most affected economically in the United States are corn, peanuts and cottonseed. Economic losses from mycotoxins derive not only from crop and livestock losses, but also from costs associated with regulatory compliance programs.

Mycotoxins are most commonly produced by the fungal genera *Aspergillus*, *Fusarium and Penicillium.*[3] These fungi grow on corn in the field or in storage, and can produce a number of different mycotoxins. The common mycotoxins produced by *Aspergillus* and *Fusarium* are listed in Table 1.

Table 1: Common corn fungi and mycotoxins.

Fungus	Mycotoxin
Aspergillus	Aflatoxins – B_1, B_2, G_1, G_2 (M_1, M_2 metabolites)
Fusarium	Deoxynivalenol (vomitoxin) Fumonisins – B_1, B_2, B_3 Trichothecenes – deoxynivalenol, diacetoxyscirpenol, diacetylnivalenol, fusarenon X, neosolaniol, nivalenol, T-2 toxin, HT-2 toxin Zearalenone

[1] 2010 Corn Annual, Corn Refiners Association, Washington DC, and Renewable Fuels Association.
[2] CAST Task Force Report, Mycotoxins: economic and health risks, No. 116, November 1989.
[3] CAST Task Force Report, *ibid*.

Factors that influence mycotoxin production by fungi include cultivar susceptibility and growth stage, moisture, temperature, pH and crop stresses such as drought, insect damage and the presence of other fungi or microbes. Fungal outbreaks are predictable and proliferate under specific weather patterns. For example, drought, sustained high temperatures and late season rain support the growth of *Aspergillus*; cool and wet conditions promote *Fusarium* growth. Local, state and federal departments of agriculture evaluate each new corn crop and issue reports on mycotoxin levels. By reviewing these reports and monitoring weather conditions during the growing season, corn wet-millers can anticipate the risk of mycotoxin contamination and implement preventive measures.

3. Fate of Mycotoxins in Corn Wet-Milling

Several groups have investigated the distribution of mycotoxins during the corn wet-milling process and their recovery in various fractions. It is important to note that none of these studies reported significant levels of mycotoxins in the starch fraction. This is important since starch is the starting raw material for numerous food ingredients, including: starches, dextrins, maltodextrins, corn syrup and corn syrup solids, high fructose corn syrup, liquid and crystalline dextrose, crystalline fructose and many dextrose-based fermentation products.

Aflatoxin

Because of its relatively high water solubility, aflatoxin is primarily recovered in steepwater. For example, Romer[6] reported that 50% and approximately 30% of the initially present aflatoxin was found in steepwater solubles and the fiber stream, respectively— (Table 2). Corn starch contains only a minute amount of any aflatoxin found in the original corn.

Table 2: Recovery of aflatoxin in wet-milled corn fractions.

Fraction	Yahl[4]	Bennett[5]	Romer[6]
Steepwater & solubles	42%	40%	50%
Fiber	30%	38%	28%
Gluten	17%	13%	11%
Germ	10%	6%	11%
Starch	1%	1%	0.2%

[4] Yahl, K.R., S.A. Watson, R.J. Smith & R. Barabolok, Laboratory wet-milling of corn containing high levels of aflatoxin and a survey of commercial wet-milling products, *Cereal Chem.*, 48:385-391, 1971.
[5] Bennett, G.A. & R.A. Anderson, Distribution of aflatoxin and/or zearalenone in wet-milled corn products: a review, *J. Agric. Food Chem.*, 26(5): 1055-1060, 1978.
[6] Romer, T., Detecting mycotoxins in corn and corn-milling products, *Feedstuffs*, 56(37): 22-23, 1984.

Fumonisin

A joint USDA-University of Illinois wet-milling study found that about 40% of fumonisin B_1 & B_2 were recovered in the gluten and fiber fractions and that corn germ contained about 20% of the initial fumonisin (Table 3). Corn starch did not contain detectable residues of fumonisin B_1 & B_2 (Table 3). Saunders reported similar findings.[7]

Table 3: Recovery of fumonisin in wet-milled corn fractions.

Fraction	USDA-U. of Illinois[8] (% starting corn)
Solubles	2-15%
Fiber	19-41%
Germ	9-22%
Gluten	37-42%
Starch	None detected

Deoxynivalenol

Lauren and Ringrose followed the fate of deoxynivalenol, also known as vomitoxin, in fractions of corn after passage through a commercial wet-milling plant.[9] Due to its relative water solubility (similar to aflatoxin), the highest concentrations were found in concentrated steepwater. The lowest levels of deoxynivalenol were recovered in the germ, fiber and gluten fractions. These investigators noted that starch samples from the commercial plant had shown only trace levels of deoxynivalenol.

T-2 Toxin

Collins[10] studied the distribution of T-2 toxin in wet-milled corn fractions using bench scale wet-milling equipment (Table 4). Approximately two-thirds of the T-2 toxin initially present was recovered in the steep and process water (solubles fraction). The fiber, germ, and gluten fractions each contained approximately 10% of the original T-2 toxin. Only 4% was recovered in the starch.

---

[7] Saunders, D.F, Meredith, F.I. & Voss, K.A., Control of Fumonisin: effects of processing, *Environmental Health Perspectives*, [109]: 333-6, 2001.

[8] Bennett, G.A., J.L. Richard & S.R. Eckhoff, Distribution of fumonisins in food and feed products prepared from contaminated corn, in *Fumonisins in Food*, L. Jackson et al., eds., Plenum Press, New York, p. 317, 1996.

[9] Lauren, D.R. & M.A. Ringrose, Determination of the fate of three *Fusarium* mycotoxins through wet-milling of maize using an improved HPLC analytical technique, *Food Additives & Contaminants*, 14(5): 435-443, 1997.

Table 4: Recovery of T-2 toxin in wet-milled corn fractions.

Fraction	Collins[10]
Solubles	67%
Fiber	10%
Germ	10%
Gluten	9%
Starch	4%

Zearalenone

In contrast to the other mycotoxins discussed, zearalenone is relatively insoluble. Comparatively less is recovered in steepwater solubles and more is recovered in the solid gluten and fiber fractions of the corn wet-milling process (Table 5). Minor amounts are recovered in the germ fraction. Zearalenone was not measurable in the starch fraction.

Table 5: Recovery of zearalenone in wet-milled corn fractions.

Fraction	Bennett[11,12]	Romer[13]
Gluten	49-56%	45%
Solubles	17-26%	26%
Fiber	15-19%	18%
Germ	9-11%	11%
Starch	None detected	None detected

4. Human Health Risks and Regulatory Limits

Aflatoxin

The International Agency for Research on Cancer (IARC) working group on carcinogenicity risks for humans has classified aflatoxins as group I carcinogens: known human carcinogens.[14] Ingestion of extreme levels of aflatoxin has been reported to cause acute hepatotoxicity in developing

[10] Collins, G.J. & J.D. Rosen, Distribution of T-2 toxin in wet-milled corn products, *J. Food Sci*, 46:877, 1981.
[11] Bennett, G.A. & R.A. Anderson, *ibid.*
[12] Bennett, G.A., E.E. Vandegraft, O.L. Shotwell, S.A. Watson & B.J. Bocan, Zearalenone: distribution in wet-milling fractions from contaminated corn, *Cereal Chem.*, 55:455-461, 1978.
[13] Romer, T., *ibid.*
[14] International Agency for Research on Cancer, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 82; Some Traditional Herbal Medicines, Some Mycotoxins, Naphthalene and Styrene, Lyon, 2002.

countries.[15] It should be noted that such high levels have never been found in U.S. corn supplies.

FDA established an "action level" for aflatoxin of 20 parts per billion (ppb) in 1969. The action level is the maximum allowable residue level in food. Although action levels are not regulations enforced by the Agency, they do represent a level above which the Agency reserves the right to take action.

Based on new animal feeding studies, aflatoxin action levels for feed ingredients were revised in 1982 and again in 1989. Where import or domestic feed shipments are analyzed in accordance with valid methods and found to exceed applicable action levels, they are considered adulterated and may be seized and removed from interstate commerce by FDA.[16] Further, producers of adulterated product can face other penalties and liabilities.

Action levels for human food are 20 ppb total aflatoxin, except for milk where the limit is 0.5 ppb aflatoxin M_1. For corn-containing animal feed ingredients, the action level is also 20 ppb, with the following exceptions:

- 100 ppb for feeds used for breeding cattle and swine, and mature poultry;
- 200 ppb for finishing swine exceeding 100 lbs.;
- 300 ppb for finishing (feedlot) beef cattle.[17]

Ninety-nine countries around the world have established regulatory limits for total aflatoxins and, in many cases, specific regulations for aflatoxin B_1 or aflatoxin M_1 in milk.[18]

Fumonisin

The IARC working group on carcinogenicity risks for humans has placed *Fusarium* toxins within the Group 2B carcinogens: i.e., possibly

[15] Cullen J.M., Newberne, P.M. Acute hepatotoxicity of aflatoxins. In: Eaton, D.L., Groopman, J.D., eds. The toxicology of aflatoxins: human health, veterinary, and agricultural significance. London: Academic Press, 1993:1-26.
[16] FDA Compliance Policy Guide 7126.33: Section 683.100 Action levels for aflatoxins in animal feeds.
[17] Action Levels for Aflatoxins in Animal Feeds, Compliance Policy Guidance, Sections 555.400, 527.400 and 683.100 (CPGs 7120.26, 7106.10 and 7126.33).
[18] Worldwide regulations for mycotoxins in food and feed in 2003. FAO Food and Nutrition Paper (FAO). 1728-3264, no. 81. Van Egmond, H.P.; Jonker, M.A. FAO, Rome (Italy). Food and Nutrition Div.; WHO, Geneva (Switzerland), 2004

carcinogenic to humans.[19] Due to limited data, there is insufficient evidence to conclude that fumonisin B_1 is a human carcinogen.

In the United States, the FDA has not set action or other regulatory levels for fumonisins. However, FDA has published draft guidance for industry (Table 6). No corn wet-milled products for human consumption were included in the guidance.[20] The European Union has set maximum limits of 4 mg/kg (B_1 & B_2] for fumonisin in raw corn (except corn intended to be processed by wet-milling) and 1 mg/kg for dry milled corn products. Switzerland has set a limit of 1 mg/kg for fumonisin in dry corn-based foods for human consumption.

Table 6: FDA fumonisin guidelines for human foods and animal feeds.

Human Foods	**Total Fumonisins (FB_1+FB_2+FB_3)**
Degermed dry milled corn products (e.g., flaking grits, corn grits, corn meal, corn flour with fat content < 2.25 %, dry weight basis)	2 parts per million (ppm)
Whole or partially degermed dry milled corn products (e.g., flaking grits, corn grits, corn meal, corn flour with fat content of <2.25 %, dry weight basis)	4 ppm
Dry milled corn bran	4 ppm
Cleaned corn intended for mass production	4 ppm
Cleaned corn intended for popcorn	3 ppm
Animal Feeds	**Total Fumonisins (FB_1+FB_2+FB_3)**
Equids and rabbits	5 ppm (≤20% of diet)**
Swine and catfish	20 ppm (≤50% of diet)**
Breeding ruminants, poultry and mink*	30 ppm (≤50% of diet)**
Ruminants 3 months old raised for slaughter and mink being raised for pelt production	60 ppm (≤50% of diet)**
Poultry being raised for slaughter	100 ppm (≤50% of diet)**
All other species or classes of livestock and pet animals	10 ppm (≤50% of diet)**

*Includes lactating dairy cattle and hens laying eggs for human consumption
**Dry weight basis

[19] International Agency for Research on Cancer, IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 56; Some Naturally Occurring Substances: Food Items and Constituents, Heterocyclic Aromatic Amines and Mycotoxins, Lyon, 1993.
[20] U.S. Food and Drug Administration, Center for Food Safety and Applied Nutrition, Center for Veterinary Medicine, *Guidance for Industry: Fumonisin Levels in Human Foods and Animal Feeds,* June 6, 2000; revised November 9, 2001.

Deoxynivalenol

Deoxynivalenol (also known as DON or vomitoxin) has been linked to acute gastrointestinal illness in humans.[21] However, since human symptoms are common to other diseases, illnesses caused by this mycotoxin are difficult to definitively diagnose.[22]

While action levels for deoxynivalenol have not been established, FDA has published advisory levels for deoxynivalenol in finished wheat products intended for human consumption (flour, bran, germ, etc.) and "grain and grain products" destined for animal feeds (Table 7). FDA set no advisory level for raw, incoming wheat intended for milling, reasoning that normal manufacturing practices and additional technology would significantly reduce deoxynivalenol in finished wheat products.[23] The Canadian government regulates deoxynivalenol in wheat but not in corn. The European Union has established maximum levels for deoxynivalenol in wheat, corn (except corn intended to be processed by wet-milling), oats and dry milled corn products.[24]

Table 7: FDA advisory levels for deoxynivalenol

Human Foods	Deoxynivalenol
Finished wheat products, e.g. flour, bran, and germ, that may potentially be consumed by humans. FDA is not stating an advisory level for wheat intended for milling because normal manufacturing practices and additional technology available to millers can substantially reduce DON levels in the finished wheat product from those found in the original raw wheat. Because there is significant variability in manufacturing processes, an advisory level for raw wheat is not practical.	1 part per million (ppm)

[21] Advisory levels for Deoxynivalenol (DON) in Finished Wheat Products for Human Consumption and Grains and Grain By-Products used for Animal Feed, , July 7, 2010 http://www.fda.gov/Food/GuidanceComplianceRegulatoryInformation/GuidanceDocuments/NaturalToxins/ucm120184.htm
[22] Ranhotra, G., Vomitoxin in grains and public health concerns, American Institute of Baking *Research Department Technical Bulletin*, 19(3): 1-7, 1997.
[23] FDA 2010, Ibid
[24] Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Union L 364/5, December 12, 2006, as amended September 28, 2007, June 18, 2008, July 2, 2008 and February 26, 2010.

Continued: Table 7: FDA advisory levels for deoxnivalenol

Animal Feeds – Intended Use	
Grains and grain by-products (on an 88% dry matter basis) and in distillers grains, brewers grains, and gluten feeds and gluten meals derived from grains (on an 88% dry matter basis) destined for ruminating beef and feedlot cattle older than 4 months and ruminating dairy cattle older than 4 months, with the added recommendations that the total ration for ruminating beef and feedlot cattle older than 4 months not exceed 10 ppm DON, and the total ration for ruminating dairy cattle older than 4 months not exceed 5 ppm DON. For chickens, 10 ppm DON on grains and grain by-products with the added recommendation that these ingredients not exceed 50% of the diet of chickens	10 ppm on grains and grain byproducts 30 ppm on distillers grains, brewers grains, gluten feeds and gluten meals
Grains and grain by-products destined for swine with the added recommendation that these ingredients not exceed 20% of their diet.	5 ppm
Grains and grain by-products destined for all other animals with the added recommendation that these ingredients not exceed 40% of their diet.	5 ppm

T-2 Toxin

One of the trichothecene mycotoxins, T-2 toxin contains both water-soluble and non-water soluble components and is thought to interact with the outer phospholipid bilayer of the mammalian cell. T-2 toxin has been implicated along with other toxins in human outbreaks of alimentary toxic aleukia.[25] Neither T-2 toxin nor other trichothecene mycotoxins are specifically regulated in food and feed ingredients by FDA.

Zearalenone

This mycotoxin is an estrogen-related metabolite produced by *Fusarium roseum*. There are no FDA action levels or limits for zearalenone and related compounds. The European Union has a maximum limit of 0.35 mg/kg in unprocessed corn (except corn intended to be processed by wet-milling) and 0.4 mg/kg in refined corn oil.

5. Mycotoxins and Animal Feed

The studies cited in Section Three demonstrate that most known mycotoxins are water soluble and, if present in raw grain, are not found at significant levels in food products produced through wet-milling (i.e.

[25] CAST Task Force Report, *ibid*.

starch, syrups, oils). However, processing does not destroy these toxins and they may concentrate in wet milling fractions destined for use in animal feeding (i.e. steepwater, gluten, fiber and germ). For this reason, corn wet-millers generally establish purchase specifications below human health-based regulatory limits.

Excessive levels of mycotoxins in feed ingredients can have implications for human and animal health. If the toxin is carried over into animal products such as tissues and milk it must be controlled to ensure that toxin levels in food products are within health-based regulatory limits. If the toxin is not carried over to food products but is metabolized by the animal, consideration must be given to any potential effects on animal health and productivity.

In the case of aflatoxin, studies have demonstrated that aflatoxin B_1 is converted by dairy cattle into its less toxic metabolite aflatoxin M_1.[26] Levels of aflatoxin M_1 in milk have been found to be approximately 2.5 percent of the level of aflatoxin B_1 contained in feed.[27] Maximum limits for aflatoxin in milk have been established by various bodies (0.5 ppb by the U.S. and Codex Alimentarius Commission, and 0.05 ppb by the European Union).

Fumonisins have been shown to cause fatal leucoencephalo-malacia in horses ("crazy horse disease").[28] Fumonisins have also been linked to pulmonary edema and liver and pancreatic lesions in swine[29], and to cancer in male rats and female mice.[30] Fumonisin residues in food products derived from animals are insufficient to make them injurious to consumers.[31] However, because of the effect on animal health FDA has established advisory levels for fumonisins in feed for a variety of species.

A review by Hazel and Patel indicated there is negligible transmission of trichothecenes such as DON into foods of animal origin such as meat, dairy products and eggs.[32] However, due to animal health concerns FDA has established advisory levels for DON for a variety of animal species.

---

[26] FAO/WHO Joint Expert Committee on Food Additives, Food Additive Series 47, 2001.
[27] International Dairy Federation, Feed-associated Mycotoxins in the Dairy Chain: Occurrence and Control, Bulletin 444, 2010,
[28] Riley, R.T., W.P. Norred & C.W. Bacon, Fungal toxins in foods: Recent concerns, *Annu. Rev. Nutr.*, 13:167-189, 1993.
[29] Riley, R.T., et al., *ibid.*
[30] National Center for Toxicological Research, Toxicology and carcinogenesis studies of fumonisin B_1 in F344/N rats and B6C3F_1 mice (feed studies), Technical Report TR-496.
[31] FAO/WHO Joint Expert Committee on Food Additives, Food Additive Series 47, 2001.
[32] Hazel, C.M., Patel, S. Influence of Processing on tricothecene levels. *Toxicol Lett* 153: 51-59, 2004.

Symptoms of T-2 toxicity in animals include decreased feed consumption, weight loss, oral lesions, bloody diarrhea and decreased egg production.

At low levels, zearalenone is somewhat beneficial in some animal species, promoting growth of sheep, chickens and feedlot cattle. At high levels, however, it adversely affects swine, causing "estrogenic syndrome," and leads to similar problems in cattle. The primary result is the economic consequence of delayed estrus in breeder sows. It is thought that a level of more than 1000 ppb zearalenone must be present to affect the health of other animals.[33]

6. FDA Risk Assessment

It is important to note that no cases of illness or death from eating aflatoxin have been documented in the United States.[34] In a "Talk Paper" issued during the aflatoxin outbreak of 1988, FDA reassured the public that aflatoxin in corn was not reaching consumers:

> "The amount of aflatoxin in food intended for human consumption—including field corn to be used as a raw material for food products as well as the finished products themselves—is limited by FDA to 20 parts per billion, except for milk, which has an action level of 0.5 ppb. Studies show that the two general methods for processing corn—dry and wet-milling—remove a major portion of any aflatoxin that may have been present initially. For example, corn starch derived from wet-milling has been found to have only 1 percent of the aflatoxin present in the raw corn."[35]

In addition, FDA does not view exposure to fumonisin from corn wet-milled ingredients to be a significant health risk:

> "No fumonisins have been detected in the starch fraction obtained from wet-milling of fumonisin contaminated corn. The starch fraction is further processed for the production of high fructose corn syrups and other corn sweeteners.[36] Therefore, these types of products do not contain any detectable levels of fumonisins. Corn oil, extracted from corn germ and refined, does not contain any

---

[33] Bennett, G.A., E.E. Vandegraft, O.L. Shotwell, S.A. Watson & B.J. Bocan, *ibid.*
[34] Harmon, John W., Existing Detection and Control Programs Minimize Aflatoxin. U.S. Government Accounting Agency report GAO/RCED 91-109, May 22. 1991.
[35] FDA Talk Paper, Aflatoxin in corn not reaching consumers, No. T89-21, April 13, 1989.
[36] Bennett, G.A. & J.L. Richard, Influence of processing on *Fusarium* mycotoxins in contaminated grains, Food Technology, 50(5): 235, 1996.

> detectable levels of fumonisins.[37] The gluten and fiber fractions from the wet-milling process do contain fumonisins; however, these fractions are used to produce animal feed, such as corn gluten meal and corn gluten feed."[38]

7. Mycotoxin Management by the Corn Wet-Milling Industry

CRA member companies take seriously their responsibility to minimize consumer exposure to mycotoxins. CRA member companies follow practices for mycotoxin management that may include:

- Evaluating levels of mycotoxins in corn crop by reviewing agricultural reports and monitoring growing conditions;
- Testing both incoming corn and finished products for mycotoxins;
- Rejecting grain with mycotoxin levels above purchase specifications and/or government limits.

Early Warning and Effective Sampling

Mycotoxin-producing fungi appear only under specific and well-characterized weather conditions. For example, sustained high temperatures and late-season rain are indicators that elevated levels of mycotoxins may be present. Local, state and federal departments of agriculture routinely issue crop reports on the levels of the various mycotoxins in corn. These provide guidance to corn purchasers about which geographic regions should be subject to the highest testing levels. Depending on the results of testing in the first few months after harvest, crop testing can be maintained, intensified or diminished.

Effective Testing

Mycotoxin testing occurs at several stages after harvest using a variety of analytical methods. The development of rapid immunoassay test kits has made it possible for the grower to monitor mycotoxin levels on the farm without the need for complicated or costly test protocols and instruments. Testing by the grower can be the first point of segregation of contaminated grain.

[37] Patel, S., Hazel, C. M., Winterton, A. G. M., and Gleadle, A. E., Surveillance of fumonisins in UK maize-based foods and other cereals, *Food Additives and Contaminants*, 14(2): 187-191, 1997.

[38]Food and Drug Administration, Center for Food Safety and Applied Nutrition, Background Paper in Support of Fumonisin Levels in Corn and Corn Products Intended for Human Consumption, June 6, 2000.

Country elevators serve as the second point of segregation through their routine sampling and screening processes. Black light screening is a qualitative test used to detect the presumptive presence of *Aspergillus flavus* by its distinctive bright green-yellow fluorescence. This method is quick and easy to run at the site of unloading and positive results are generally confirmed by more quantitative methods. Similar sampling programs are used at sub-terminal and terminal elevator levels, backed up in many facilities by automatic grain samplers and more sophisticated testing methods.

Though the wet-milling process isolates mycotoxins from starch, sweeteners and oil ingredients, CRA member companies monitor corn, in-process streams and outbound feed products when there is reason to believe mycotoxins may be present in the grain supply. Critical locations for sampling and testing may include inbound unloading, steepwater and feed product streams. Since corn cleanings may contain mycotoxin levels above those of the original corn, they may be analyzed prior to reintroduction to any feed product stream.

Originally corn wet-milling laboratories relied on TLC (thin layer chromatography) and minicolumn analytical procedures to monitor mycotoxins. Newer ELISA (enzyme linked immuno-sorbant assay) and HPLC (high performance liquid chromatography) methods have been adopted due to their speed, sensitivity and ease of use. Using only USDA's Grain Inspection, Packers and Stockyards Agency certified mycotoxin test kits can ensure the suitability and accuracy of these rapid test kits.

FDA regulations apply directly to interstate grain sales, but also are generally applied to intrastate grain sales due to the likelihood that grain sold intrastate will enter interstate commerce. Acceptable mycotoxin limits are thus dictated by FDA requirements, by policies of individual purchasers or by agreements between buyer and seller. Many CRA member companies have established in-house aflatoxin standards below 20 ppb.

Since wet-milling companies use a relatively small percentage of the corn crop for production of food ingredients, they can exercise considerable control over specific lots of corn accepted for processing. Those with unacceptable levels of mycotoxins are rejected.

New Crop Varieties and Detoxification Strategies

CRA member companies support the efforts of the USDA Agricultural Research Service and other research groups to develop 1) crop varieties which are resistant to fungal invasion, and 2) bio-competitive organisms which could result in non-aflatoxin forming varieties of *Aspergillus flavus*. One application of this type of technology has been the recent introduction of a commercial product containing non-toxic strains of *Aspergillus flavus* that can displace toxic strains in agricultural fields[39]

Insect damage is a risk factor for contamination by a number of mycotoxins. Insect resistant maize hybrids produced using modern biotechnology have been demonstrated to lessen insect feeding on corn kernels and reduce concentrations of fumonisins in comparison with non-transgenic corn. These hybrids have also been shown to lower concentrations of deoxynivalenol and zearalenone. In some studies, Bt maize hybrids have shown lower aflatoxin levels than non-transgenic verities, but results are inconsistent across different growing regions[40]. Aflatoxin inoculation of corn hybrids damaged by Southwestern corn borer showed significantly higher levels of aflatoxin accumulation in non-Bt hybrids than in Bt hybrids when plants were both inoculated with an *Aspergillus flavus* spray and infested with Southwestern corn borer.[41]

It is possible that effective detoxification strategies will be developed in the future allowing better use to be made of contaminated corn. With the exception of chemical detoxification of cottonseed and use of chemisorbents few of these have found commercial application. Detoxification strategies under development include:

- Physical methods of detoxification—thermal inactivation, irradiation, solvent extraction and absorption from solution;
- Biological methods of detoxification—microbial inactivation and fermentation; and,
- Chemical methods of detoxification—structural degradation following chemical treatment, modification of toxicity by dietary chemicals and alteration of bioavailability by mycotoxin chemisorbents.[42]

---

[39] EPA Registration 75624-2, registered to Circle One Global Inc. for use on peanuts and corn.
[40] Munkvold, G. P. Cultural and Genetic Approaches to Managing Mycotoxins in Maize. Annual Review of Phytopathology 41:99–116, 2003.
[41] Williams, W.P., Windham, G.L., Buckley, P.M., Perkins, J.M., Southwestern corn borer damage and aflatoxin accumulation in conventional and transgenic corn hybrids, Field Crops Research; 91; 321-336, 2005.
[42] CAST Task Force Report, *ibid*.

The Member companies of the CRA are committed to providing safe products. Their monitoring and testing programs, in combination with the corn wet-milling process itself, ensure that consumers will not be exposed to mycotoxins in food products from the wet-milling industry.