Journal of Toxicology
TOXIN REVIEWS
Vol. 22, Nos. 2 & 3, pp. 139–152, 2003

The Costs of Mycotoxin Management to the USA: Management of Aflatoxins in the United States

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ABSTRACT

Mycotoxin losses and costs of mycotoxin management are overlapping areas of concern. Costs of mycotoxin management include research production practices, testing and research necessary to try to prevent the toxins from appearing in food and feed products of affected commodities. Mycotoxin losses result from (American Association of Veterinary Laboratory Diagnosticians (AAVLD), 1993) lowered animal

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DOI: 10.1081/TXR-120024089
0731-3837 (Print); 1525-6057 (Online)

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production and any human toxicity attributable to the presence of the toxin, (CAST (Council for Agricultural Science and Technology), 1989) the presence of the toxin in the affected commodity which lowers its market value, as well as (Hawk, 1998) secondary effects on agriculture production and agricultural communities.

INTRODUCTION

Losses from mycotoxins in the US are associated with regulatory losses, as opposed to lowered production, illness, and/or deaths from the effects of the toxins. This is particularly the case for human food, but increasingly it has become the case for animal feeds, as strict feed quality control programs become the norm for large-scale animal production units. The Stoloff papers from the 1980s infer that there is no aflatoxin-related toxicity or carcinogenicity in humans in the US (Stoloff, 1983, 1986, 1989). Mycotoxin management costs are incurred by both producers and the Federal and state governments to prevent mycotoxins from becoming a human and animal health threat. The Food and Drug Administration (FDA) has functioning mycotoxin regulatory programs for aflatoxin, fumonisins, and vomitoxin (American Association of Veterinary Laboratory Diagnosticians (AAVLD), 1993; US Food and Drug Administration, US Department of Health and Human Services, Public Health Service, 1993; US Food and Drug Administration, 1994, 2000).

Aflatoxin is the mycotoxin generating the greatest losses and the highest management costs due to its extremely high toxicity on a unit basis, and its long history of stringent regulation. The peanut, corn, cottonseed, and tree nut industries all recognize losses associated with meeting regulatory levels. The costs are inversely related to the regulatory level that must be met, and the necessity to meet lower concentration allowances will increase the costs of crop management. In the United States, the FDA has used a 20 ppb tolerance almost since the initiation of their mycotoxin regulatory program, but industries that sell to EU countries face regulatory allowances and buyer standards of much lower ppb concentrations (Hawk, 1998).

There have been few attempts to estimate, with accuracy, the mycotoxin related losses faced by various commodity groups in the US. The Council on Agricultural Science and Technology (CAST) report, Mycotoxins: Economics and Health Risks (1989) outlined the information regarding losses known at that time (CAST (Council for Agricultural Science and Technology), 1989). A chapter by the FDA's Peter Vardon, in the new CAST 2003 report on mycotoxins, analyzes the potential current economic cost of mycotoxins in the U.S. (Vardon, 2003). Vardon estimated an annual range of losses from $0.5 million to over $1.5 billion from aflatoxin (corn and peanuts), fumonisin (corn), and deoxynivalenol (DON) (wheat). Uncertainties were built into the cost model based on commodity outputs, prices, and contamination levels based on surveillance samples and compliance with FDA regulatory limits. Vardon assumed that the livestock loss was directly proportional to the percentage of feed that was contaminated above FDA standards, and he calculated small livestock losses from aflatoxin and DON. Costs of testing for the toxins, either to commodity producers or to the public through the FDA budget; costs of growing less valuable alternative crops; costs of handling affected crops; etc. were not included.

In some cases it is very difficult to determine what is a mycotoxin loss and what is not, because the buyer may maintain that it is the threat of mycotoxins that necessitates paying a lower price, while in fact, the buyer may not want to deal with small quantities of corn or other commodity available from certain suppliers. A food safety issue can be used in domestic trade negotiations just as it can in international trade.

RESEARCH COSTS

The investment in research programs by the Federal government, primarily to prevent mycotoxins in crops, can be considered a major cost of mycotoxin management. The USDA's Agricultural Research Service (ARS) has a mycotoxin research program, $17.7 million for approximately 60 scientists in fiscal year 2000, primarily focused on prevention of the fungus and toxin production in the crop. This level of support is the total appropriated amount; it includes the mycotoxin research share of administrative salaries, as well as the scientists and technicians and various support personnel, increasingly expensive energy costs, costs of services and building maintenance, etc. The USDA's Cooperative State Research Education and Extension Service (CSREES) reports $4.7 million for mycotoxin research, along with $5.1 million from states at their land grant institutions, and an additional $2.1 million from other Federal agencies at these institutions (William Wagner, CSREES, June 2001, *personal communication*).

The FDA also carries out research on mycotoxins at the Center for Food Safety and Applied Nutrition, primarily on methodology development, effects of processing, and toxicology. This activity is assessed for 14 to 15 scientists at $1.5 million. However, the FDA calculation includes only the scientists' salaries and some immediate laboratory costs and does not include the agency administrative costs and infrastructure as does the ARS amount (John Newland, Center for Food Safety and Applied Nutrition, FDA, June 2001, *personal communication*).

TESTING AND INSURANCE

Analysis of product samples is needed to assure that product offered to the market meets regulatory and market requirements. These considerable costs are incurred both by industry and by various government regulatory and action agencies. Industry costs, in particular, increase significantly during years when contamination of the crops is high. The average total value of commercial aflatoxin test kits on the market is approximately $10 million per year annually, about 2 million tests for an average year. Sales increase rapidly in outbreak years (Robert Elder, USDA-ARS, May 2001, *personal communication*). In addition to the test kit costs, the range of charges for testing by official agencies and cooperative services is from $10 to $20 per sample not including collection of the sample. For aflatoxin alone, testing will cost $30 to $50 million per year.

For example, testing costs associated with corn production and marketing comes from the Grain Inspection Packers and Stockyards Administration (GIPSA), which conducts aflatoxin and DON testing for exported grains. For aflatoxin, GIPSA analyses approximately 30,000 samples per year, which generates approximately $290,000 in revenues. State and private laboratories with official sanction from FGIS, analyse approximately 27,000 samples per year, which generates approximately $540,000 in revenues. For DON, FGIS analyses approximately 6000 samples per year, which generates approximately $100,000 in revenues, while official agencies analyse an additional 18,000 samples generating about $360,000 in revenues annually (John Giler, FGIS, May 2001, *personal communication*).

Grain sampling is part of the cost of testing commodities for mycotoxins. It is a part of the cost of testing corn for aflatoxin in southeast Texas,—a considerable expense at $20 to $30 per test and one test per truckload of 30,000 to 60,000 pounds of commodity. This equates to a testing cost of $2–3 per acre (Jeff Nunley, South Texas Cotton and Grain Association, May 2001, *personal communication*). Also in southeast Texas, every 100 tons of cottonseed requires a test for aflatoxin, at about $125 total costs (including sampling and transportation to the laboratory) per sample. Sample preparation for cottonseed costs more than for corn, which does not require dehulling or delinting. There is also a difference in the size of the sample that is generally used (Peter Cotty, USDA-ARS, June 2001, *personal communication*).

The cost of litigation may also be significant for cottonseed producers. The identity of cottonseed is generally maintained through the market

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chain. If contamination above 0.5 ppb is detected in milk, the product may be traced to the dairies where the cattle are being fed contaminated cottonseed. The sellers, producers, and any other party who can be identified are likely to be sued. Feedlots for fattening beef cattle are wary of feeding cottonseed containing >20 ppb aflatoxin even though it may be legal up to 150 ppb (Jeff Nunley, South Texas Cotton and Grain Association, May 2001, *personal communication*).

Insurance premiums, and compliance with the recommendations of the insurance company for those producers who chose it, is another major cost of managing mycotoxins. A private crop insurance company in Des Moines, IA, recommends that their insured producers sample a high percentage of their loads for the first 2 weeks of each season. Even if only a very small percentage of loads are found positive for the mycotoxin, they recommend that sampling continue on a random basis. This company states that testing costs for producers are $5 to $7 per test if carried out on a regular basis and $9 to $12 per test if done sporadically (David Frank, American Feed Industry Insurance Association, Des Moines, IA, June 2001, *personal communication*).

COMMODITY LOSS ESTIMATES FROM THE INDUSTRY

Peanuts

Marshall Lamb at the ARS National Peanut Research Laboratory in Dawson, GA, has prepared a recent paper addressing losses from aflatoxin (Lamb and Sternitske, 2001). This paper surveys and analyzes actual losses in peanuts during the 1993–1996 crop years. Lamb estimated the net cost of aflatoxin to the farmer, the peanut buying point, and the sheller segments of the Southeast peanut industry to be about $25 million per year. On a total Segregation I farmer stock basis, aflatoxin cost the Southeast peanut industry an average of $23.17 per ton while the net cost of aflatoxin on a per acre basis averaged $28.06 per acre. Peanuts are subject to a Federal marketing order that proscribes very strict and complicated procedures for testing, segregating, and handling peanuts to prevent peanuts that do not meet FDA requirements for aflatoxin from becoming a part of the human food supply. The costs of aflatoxin result from both the decreased value of the crop as calculated from the quota support price, and from costs incurred in handling contaminated peanuts, including blanching, re-milling, equipment, testing, and insurance. Lamb's calculation does not include costs of production practices, particularly irrigation, that may be used to help prevent aflatoxin in the crop.

Table 1. Reports of direct crop revenue losses due to mycotoxins.

Crop	Location/year	Ave ann prod. (Tons,000)	Toxin	Average contamination (%)	Est ann.[a] revenue loss US $ × 1,000	Source: personal communications
Cotton	AZ/1977–1999	397	AF	55	4,367 (at $20/ton)	Larry Antilla, Director of the Arizona Cotton Research and Protection Council, Phoenix AZ, April 2001
Cotton	TX/1999	502	AF	70	7,000 (at $20/ton)	Jeff Nunley, South TX Cotton & Grain Assoc., May 2001
Peanut	GA				25,000	Marshall Lamb (Lamb and Sternitske, 2001)
Corn	TX/1999 (4 districts S Texas)	2,100 tons (375 Bu)	AF	50	15,000 (at $0.4/Bu)	Jeff Nunley, South TX Cotton & Grain Assoc., May 2001
Corn	MS/1998	1,400 tons (50 Bu)	AF	20 discounted, 4 abandoned	2,000	Erick Larson, Mississippi Agricultural and Forestry Experiment Station, Personal communication, May 2001
Walnuts	CA/2000–1	236	AF	4	38,700	David Ramos, Davis California, March 2001.
Almonds	CA/1995–2001	366–830	AF	3	23,000–47,000	Merle Jacobs, Almond Board of California, Modesto CA
Barley	ND,SD,MN/ 1993–1998		DON		406,000[b] (5 years)	John Mittleider, North Dakota Barley Council, Fargo ND, June 2001
Wheat	ND,SD,MN/ 1993–1998		DON		1,000,000[b]	Jim Baer, North American Millers, Washington DC, June 2001

Notes to Table 1:
[a]Does not include abandoned acreage.
[b]Includes actual production losses.

Cotton

Cottonseed is a by-product of cotton fiber production, and thus cotton breeding and agronomic practices have not traditionally considered the need to prevent contamination of the seed. Aflatoxin contaminates cottonseed in Texas and in Arizona with sufficient frequency that it is a continuing concern of state regulatory officials in these states. The major market for cottonseed, either whole seed or meal, is feed for dairy cattle. In the late 1970s, aflatoxin from contaminated cottonseed fed to dairy cattle was detected in milk by state regulatory officials and the FDA. Dairy cattle excrete a much higher percentage of ingested aflatoxin in milk (metabolized to aflatoxin M_1) than is ever deposited in muscle meat of any species. In addition, the amounts of any residue allowed in milk are low and at the sensitivity of the method, in this case <1 ppb. Cottonseed is still fed to dairy cattle but it is tested and recognized contamination of milk is rare (CAST (Council for Agricultural Science and Technology), 1989).

Estimates for a single year do not provide a true picture of the extent of aflatoxin contamination because of its variability. Thus, the Arizona Cotton Research and Protection Council combined their estimates from 1977 to 1999. During this 22-year period, Arizona had an average annual cottonseed production of 397,000 tons, with an average annual value of $42,205,000 for a total value of $928,510,000. Discounts on cottonseed with aflatoxin levels above 20 ppb vary from $20 to $50 per ton with the majority falling in the $30 to $35 range. Based on these figures, the most conservative estimate of revenue lost due to aflatoxin contamination over the 22 year period is $96,074,000 or slightly over 10 percent (Table 1).

In addition to direct revenue losses due to aflatoxin discounts, regulatory restrictions prevent contaminated cottonseed from leaving the state (except under a restrictive permitting system), severely affecting marketing options for the Arizona growers. Costs of treatment to eliminate aflatoxin (ammoniation) plus interim shipping and/or storage fees would result in a cost benefit of $20 per ton or more if aflatoxin-free cottonseed could be shipped directly from gins to prime customers such as dairies.

In south Texas, Jeff Nunley estimated that testing costs alone could be as high as $150,000 for each of two major cottonseed processors that use cottonseed originating from south Texas. Cottonseed that contains high aflatoxin levels is segregated and processed separately leading to additional costs at the processor level. These increased costs are ultimately reflected in lower values for cottonseed at the producer level. During the 1999 crop year, only about 30 percent of the cottonseed tested at the major cottonseed processing mills in south Texas had acceptable levels of aflatoxin (Table 1).

While not all processors formally discounted their price for aflatoxin-contaminated cottonseed, discounts of $20 per ton for contaminated seed were common with some discounts being larger. Based on an average $20 per ton discount, the loss of value to south Texas cotton producers for the 1999 crop from aflatoxin-contaminated seed would be slightly over $7,000,000. With a harvested acreage estimated at 960,000 acres this loss equates to approximately $7.30 per harvested acre. In south Texas, contaminated cottonseed may be processed at an oil seed mill for crushing so that some value is recouped on the contaminated crop, or it may be sent to Indigo, California for ammoniation, or finally contaminated meal may be used for mushroom fertilizer.

Corn

In the Corn Belt states of Iowa, Illinois, Indiana, etc., corn is contaminated with aflatoxin only sporadically, primarily when droughts occur. Severe losses from aflatoxin in Midwest corn did occur in 1983 and again in 1988. Corn is contaminated every year at one or more locations in the southern states, that is North Carolina to Georgia, and across to Texas. In 1998, corn losses in Mississippi, Louisiana, and Texas were extremely severe. Corn is grown to a very limited degree in Arizona, but would be planted more frequently in many areas if it were not for aflatoxin contamination, which eliminates it as a potential rotation crop. The situation is similar in the south Texas Corpus Christi area, where corn could be a valuable rotation crop for the primary cash crop of cotton. However, in order to avoid aflatoxin contamination 300,000 acres are planted to sorghum each year rather than to corn (Jeff Nunley, South Texas Cotton and Grain Association, May 2001, *personal communication*).

In Mississippi in 1998 a severe drought resulted in high aflatoxin contamination. These losses were in irrigated as well as dryland corn, and were particularly onerous for farmers who had just planted corn for the first time. Twenty per cent of the 50 million bushel crop had aflatoxin levels of 20 to 150 ppb and was sold at a discounted price. Another 4 percent was abandoned because it contained over 150 ppb. However, initially, approximately 50 percent of the crop was contaminated to the extent that many samples exceeded legal limits. Half of that amount was eventually sold for feed by farmers. Little of Mississippi corn is used directly for human consumption. Probe samples taken from truckloads for aflatoxin analysis of corn are generally smaller than optimal, and more likely to be near 5 pounds than near 50 pounds. This is considered necessary to maintain the commercial flow of commodity (Erick Larson, Mississippi Agricultural and Forestry Experiment Station, May 2001, *personal communication*).

The Georgia corn producers consider their markets to be limited by the perception, if not the reality, of contamination by aflatoxin. The acreage of corn in Georgia has been shrinking during the last 10 years as swine farms have left the state and been replaced by larger operations elsewhere. Swine producers were more content to use local Georgia corn than are poultry producers. This is probably due to the greater concern among poultry producers that aflatoxin may be harmful to broiler growth and even immune competency; but also to the economics of corn transportation, handling and distribution. Poultry operations are large and integrated with their own feed mills, and they do not want to handle local corn in truckload quantities, but rather trainloads of corn from the Midwest. They will use local corn shortly after it has been produced in the fall, and when there is an interruption in the flow or arrival of trainloads of Midwest corn (Dewey Lee, UGA June 2001, Tifton GA, *personal communication*).

Tree Nuts

Tree nuts such as almonds, walnuts, and pistachios may be contaminated with aflatoxin, though at lower levels than for cottonseed and corn. However the problem is very significant to the producers both because (American Association of Veterinary Laboratory Diagnosticians (AAVLD), 1993) the crop has a high unit value, and (CAST (Council for Agricultural Science and Technology), 1989) much of the crop is sold to the European markets that enforce limits significantly lower than in the US.

In walnuts during the 2000–2001 crop year aflatoxin was found in 4 percent of the samples tested by the industry. Since the crop size for the year 2000 was 236,000 tons, the walnut industry lost an estimated 18,880,000 pounds of walnut kernels to alfatoxin for the year's harvest. There was short tonnage (production) and higher market prices for the 2000–1 crop year, and the cost of product lost is estimated at $2.05 per pound of product. Thus the total direct dollar market value lost to the walnut industry was $38,704,000.

It is difficult to estimate the cost of aflatoxin to the almond industry; however, there is a strong correlation in almonds between aflatoxin and insect damage to kernels which places the nuts into an inedible category and can be used as an estimate of loss due to aflatoxin. Almond production utilizes several sophisticated techniques to sort the good from the inedible kernels, and handlers remove and dispose of their inedible almonds to non-human consumption channels. In California, in the six crop years from 1995–96 to 2000–01, almond production ranged from 366,000,000 to

830,000,000 pounds, and exported almonds had a value of $623.8 million in 1999. If 3 percent of each year's production is considered inedible (aflatoxin contaminated), the value of 10,980,000 to 24,900,000 pounds of almonds is lost per year. Thus, based on a wholesale value of $1.50 to $3.00 per pound for uncontaminated, edible almonds, the lost market value to the producer for contaminated almonds ranged from $23,265,000 to $47,310,000 in this six-year time period. There are additional costs of transportation, sorting, and analytical tests for contaminated almonds that are not included in the above loss figures.

Barley

Contamination with deoxynivalenol (DON) or vomitoxin produced by Fusarium head blight infection with *F. graminearum*, has caused serious losses to the barley producers in the Tri-State area of Minnesota, North Dakota, and South Dakota. In barley the loss is primarily due to vomitoxin, while that in wheat is due to both lowered grain production and toxin production. Wheat flowers outside of the boot, and thus, is inherently more susceptible to being infected with the fungal spores.

Malters and brewers use a 0.5 ppm level of DON as a limit, but how it is used varies by company. DON-containing grain is discounted 5 to 10 cents per bushel for each 0.1 ppm that the grain exceeds 0.5 ppm. Anheuser-Busch is the most stringent and anything in excess of 0.5 ppm vomitoxin in the barley grain or in malt which they may buy from other malters is unacceptable. Some malters, however, will accept grain with 2 to 3 ppm vomitoxin, since in some cases the process of malting will lower levels of vomitoxin. However, if the malting is carried out too long, the fungus will regrow and the levels will increase again.

Serious contamination with DON has occurred in the Tri-State area each year since 1993. Prior to that, contamination was only sporadic. Barley growers believe that this was due to a change in long term weather patterns with the area now having higher rainfall and relative humidity. The acceptance rate for barley in the Tri-State has not been greater than 35 percent since 1983. When barley is not acceptable for malting, it is used for animal feed, which brings a lesser rate of return. Growers need approximately $160 per acre to break even and malting barley usually yields about $160 per acre while barley for animal feed yields only $100 per acre. The unavailability of barley as a reliable rotation crop is another loss to growers with the preferred 3-year rotation in being: 1st year, wheat; 2nd year, feed grain; 3rd year, oil seed; and back to wheat. In addition, there is the loss of the economic infrastructure that had grown up around handling and marketing the crop particularly in eastern North Dakota. The

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Tri-State barley producers have calculated a total loss of $406 million for the 6 years from 1993 through 1998. The total barley acreage has now declined over half from 1993, because the growers do not want to take the high risk of growing malting barley. In 1993 there were 4,250,000 acres of barley while in 2000 there were 1,950,000 acres of barley. (John Mittleider, North Dakota Barley Council, May 2001, *personal communication*)

Wheat

Losses from Fusarium Head Blight (FHB), also known as Scab, in wheat include both lowered grain yield and the presence of DON. In 1993, farm gate losses in the Red River Valley of North Dakota, South Dakota, and Minnesota were $200 to $400 million for this fungal infection and mycotoxin. In 1996, there was a $300 million loss to farmers alone raising soft wheat, and also in that year there were significant replacement costs to millers. Replacement costs include transportation of wheat from another area to meet contracted deliveries, as well as the higher price that must be paid for this wheat because of decreased availability. The industry estimates they have sustained total losses of $1 billion from wheat scab (Table 1) (Jim Baer, North American Millers Washington DC, June 2001, *personal communication*).

A North Dakota State University economist, has estimated losses based on grain yields and price (dollars per bushel) that might have been expected under normal conditions, in the absence of wheat head scab). Precipitation and temperature data were used to estimate ''normal'' production. The loss of production is calculated as the difference between actual and normal production, and then adjusted for acreage abandoned as a result of scab. Total direct and secondary economic losses from FHB in North Dakota for wheat and barley, and in Minnesota for wheat, were estimated at $545 million from 1998–2000. The finding that there is a significant secondary economic impact is as significant as the direct loss. For each dollar of lost net revenues for the producer, an additional $2.10, approximately, is lost in secondary economic activity, including households, retail trade, finance, insurance and real estate, and personal business and professional services (William Nganji, ND State University, Fargo ND June 2001, *personal communication).*

Animals

Paul Sundberg of the National Pork Board (June 2001, *personal communication*) stated that swine producers do not recognize on-going losses from aflatoxin, although they may occur in localized production areas in severely affected crop years. That there are only a very small number of cases of actual recognized toxicity in swine in the US is the direct result of our food safety regulatory system.

University scientists are apparently more concerned with the effects of aflatoxin in poultry feeds than are the poultry industries. Perhaps it is because they remember when there was a greater incidence of aflatoxin in corn at levels which could decrease growth and increase disease susceptibility. To prevent contamination with aflatoxin above FDA guidelines, the poultry industry now relies on sampling of corn by the feed mills, which are often a part of the same integrated production and marketing operation. The sampling rate of the feed mills varies greatly depending on industry reports of the occurrence of aflatoxin in corn from specific localities in that year. When contamination is reported by the corn industry in specific states or when positives are found during routine sampling, the rate of sampling by the poultry industry is greatly increased.

A large integrated turkey producer reported conducting 2200 non-ELISA assays for aflatoxin, at a cost of approximately \$2.67 per test for materials. They also reported conducting a total of 4200 tests for fumonisins, deoxynivalenol and zearalenone in 2001 in their company laboratory, which serves their feed mill and production facilities. In the latter case they used ELISA test kits at ~\$7 apiece. These numbers of tests, which were skewed to test a greater proportion of the local southeast corn bought than of Corn Belt corn, were used to assure the safety of approximately ~400,000 T of corn (Neal Allen, Carolina Turkeys, Mt Olive NC May 2002, *personal communication*).

DISCUSSION

In the US, there is an FDA established tolerance of 20 ppb of aflatoxin for foods other than milk, while European markets are striving for a lower CODEX importation standard of 2 ppb. Also in the USA, production of susceptible crops is being reliably managed to meet the current FDA aflatoxin guidelines, with export crops for human use meeting the more stringent European guidelines. The risk of exposure to aflatoxin and other mycotoxins under current handling practices is not considered to be a public health threat in the US. Conservative calculations of estimated lost crop revenues and the cost of research and monitoring activities, are between \$500 million and \$1.5 billion a year to manage mycotoxin producing fungi to achieve this level of security; and this does not include secondary industry and international trade losses. Thus, the management of

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aflatoxins and other mycotoxins costs millions of US dollars every year, and research into more definitive solutions must continue.

Suggested FDA advisory levels for Fusarium toxins range from 0–4 ppm, and higher for some animal species. The FDA guidelines for these toxins are achievable without a major disruption of the corn production and marketing system. However, as fumonisins are found in maize and trichothecenes, such as vomitoxin/DON, are found in maize, wheat, and barley, the costs of Fusarium toxins to the US could easily mount up as quickly as those of aflatoxin. Increased costs will be primarily related to fumonisin and vomitoxin testing at all levels of production and marketing and will of course vary greatly from year to year.

The most obvious cost of mycotoxins is their toxicity to humans and animals when they are present in food and feed in sufficient concentrations. Fortunately, this does not happen often in the US as possible toxic amounts are usually caught by one of the several levels of producer and government control. Where mycotoxins do not present a direct health threat to humans and/or animals, they can result in direct losses to producers when their crops exceed regulatory limits and the price is decreased, or the crop cannot be sold at all. Commodity handlers have costs of testing and insurance and the occasional cost of moving or disposing of commodity whose aflatoxin content was not initially recognized in time to prevent its acquisition. To society as a whole, there are also the costs of research to prevent mycotoxins as well as the costs of regulation at both Federal and state levels. For instance, for corn producers there could be losses of revenue from both reduced prices for high-mycotoxin grain, and for increased costs for testing at grain elevators. For both aflatoxin and the Fusarium toxins, the extent of losses to many producers depends in part on how willingly the elevator operators will accept high mycotoxin corn with the intent to handle it by commingling of loads; and this will vary with the overall level of contamination of the crop and the availability of clean corn. The existence of FDA guidelines has led to increased awareness of the possible presence of mycotoxins with resulting greater care taken by all producers and commodity handlers as well as livestock producers feeding their own animals on the farm.

For all the knowledge about the chemistry and modes of action, the toxic effects of mycotoxins on humans and animals, and for all the increased costs of production, solutions to the problems related to mycotoxins are still few and far between. Good agronomic practices may be helpful in marginal years but unless they include irrigation, they have little effect in years of even moderate drought. Reducing mycotoxin vulnerability of crops and competitively excluding toxic fungi are the most promising permanent solutions that have the potential to markedly reduce mycotoxin related costs of production. Appropriate sampling and testing protocols that are also less expensive are also critical to reducing costs while assuring that the FDA guidelines are being met.

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