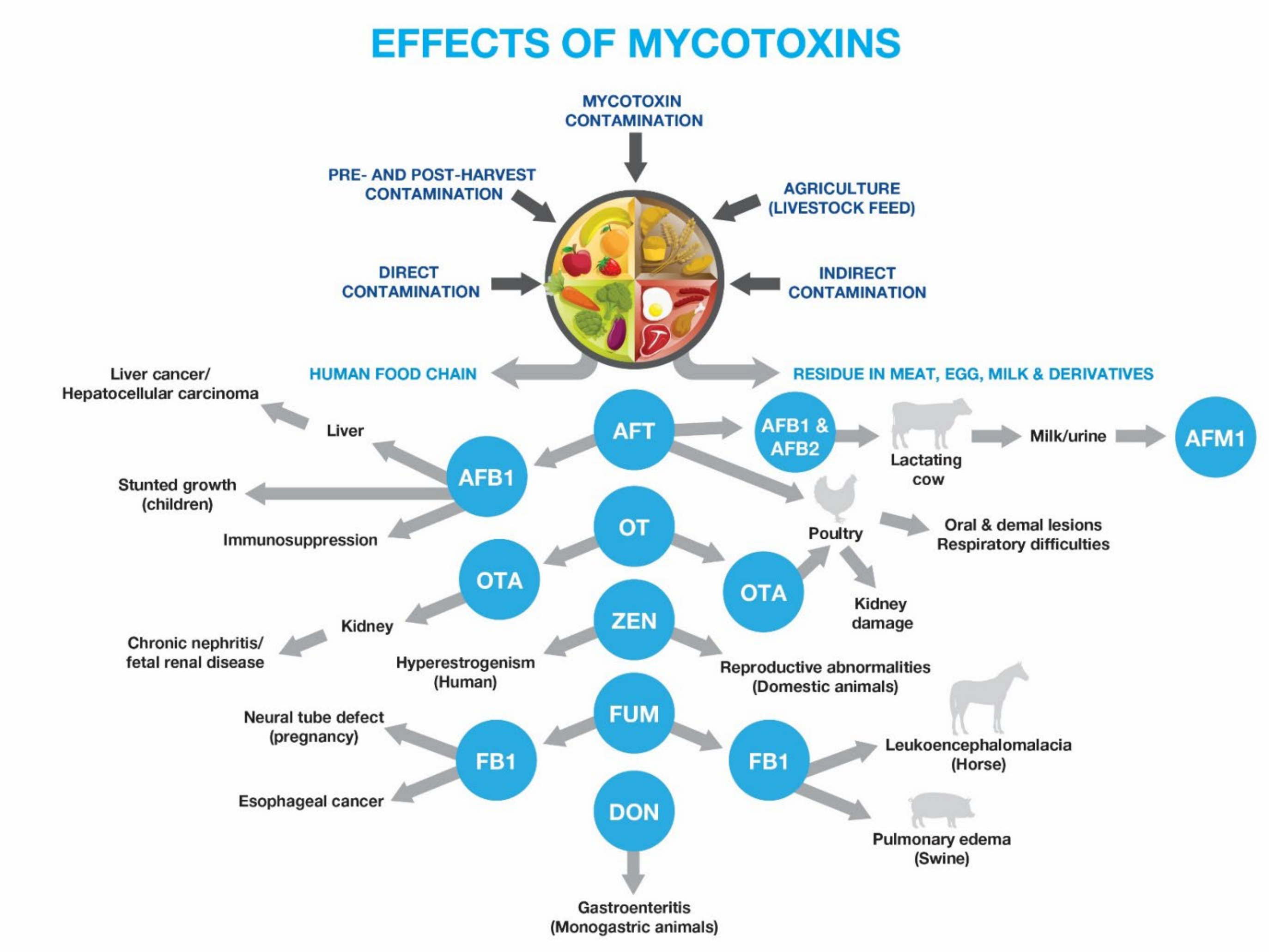
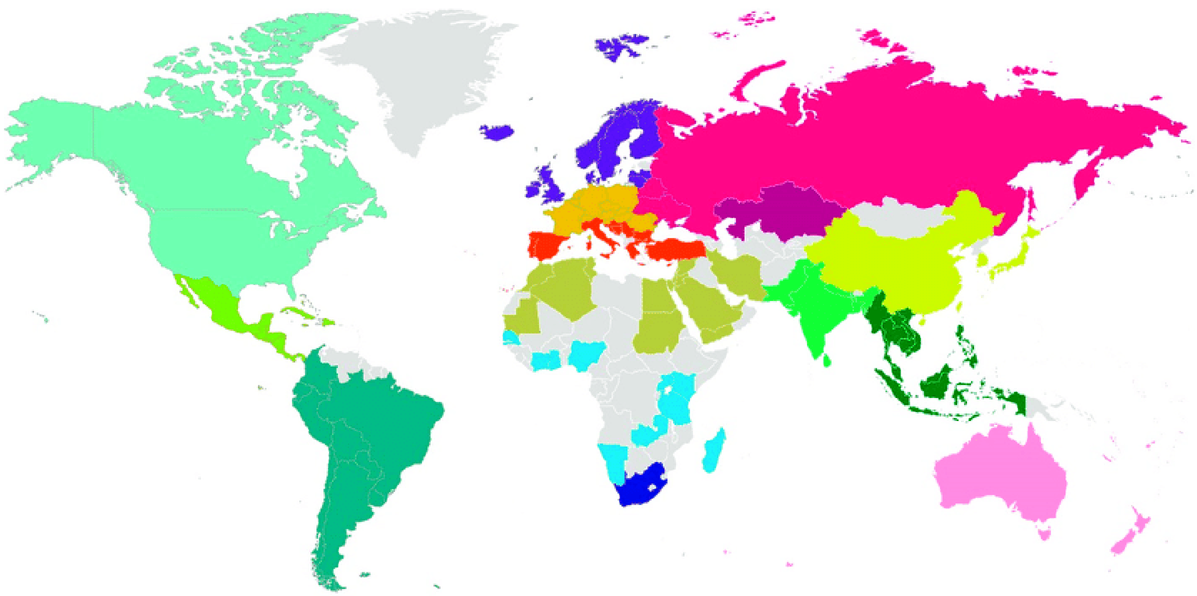
What Are Mycotoxins and How Do They Affect the Foods We Eat?

Mycotoxins (from the Greek μύκης *mykes*, "fungus" and τοξίνη *toxini*, "toxin") are toxic secondary metabolites produced by different types of fungus, belonging mainly to the *Aspergillus*, *Penicillium* and *Fusarium* genera. They commonly enter the food chain through contaminated food and feed crops, mainly cereal grains, corn and nuts and often under warm and humid conditions. This poses a huge risk worldwide as climate change is introducing more humid, warmer weather in food-growing regions. In addition, mycotoxins are difficult to control as they are stable compounds not destroyed during most food processing operations.

Mycotoxins can cause a variety of adverse health effects and pose a serious health threat to both humans and livestock. The adverse health effects of mycotoxins range from acute poisoning to long-term effects such as immune deficiency and cancer.



According to Food and Agricultural Organization (FAO) reports, it is estimated that mycotoxins affect nearly 25% of the world's crops each year. This number was recently confirmed in a global survey. Presently over 300 mycotoxins have been identified and reported; however, only a few regularly contaminate food and animal feedstuffs.



	ABF1	FUM	ZEN	DON	OTA	T-2
Northern Europe (n = 1,958)	5.9% 3.1 µg/kg	22.4% 186 µg/kg	28.9% 35 µg/kg	74.2% 504 µg/kg	8.1% 1.9 µg/kg	30.3% 34 µg/kg
Central Europe (n = 21,036)	12.7% 1.6 µg/kg	43.2% 187 µg/kg	45% 40 µg/kg	69.8% 428 µg/kg	11.9% 2.8 µg/kg	30.7% 11 µg/kg
Southern Europe (n = 3,527)	28.9% 2.1 µg/kg	74.9% 607 µg/kg	36.3% 44 µg/kg	52.9% 324 µg/kg	21.2% 2.6 µg/kg	11.7% 25 µg/kg
Eastern Europe (n = 2,382)	17.0% 3.4 µg/kg	33.6% 87 µg/kg	42.5% 15 µg/kg	59.9% 153 µg/kg	36.4% 3.6 µg/kg	48.2% 21 µg/kg
North America (n = 5,471)	10.5% 8.7 µg/kg	47.7% 652 µg/kg	31.7% 102 µg/kg	64.1% 505 µg/kg	4.3% 2.4 µg/kg	3.9% 29 µg/kg
Central America (n = 367)	8.6% 3.9 µg/kg	81.8% 929 µg/kg	38.2% 60 µg/kg	70.0% 316 µg/kg	3.8% 2.5 µg/kg	4.1% 3.1 µg/kg
South America (n = 17,332)	23.5% 3.2 µg/kg	75.3% 1,390 µg/kg	46.9% 51 µg/kg	26.9% 344 µg/kg	4.9% 17 µg/kg	21.5% 31 µg/kg
Middle East/North Africa (n = 1,075)	22.2% 2.4 µg/kg	66.8% 347 µg/kg	44.8% 31 µg/kg	47.8% 236 µg/kg	20.3% 3.1 µg/kg	8.5% 14 µg/kg
Sub-Saharan Africa (n = 208)	76.0% 23 µg/kg	72.6% 789 µg/kg	52.2% 38 µg/kg	49.5% 352 µg/kg	31.9% 7.2 µg/kg	3.0% 3.0 µg/kg
South Africa (n = 1,077)	9.0% 2.2 µg/kg	62.6% 266 µg/kg	41.6% 30 µg/kg	63.2% 363 µg/kg	5.6% 2.2 µg/kg	1.2% 4.4 µg/kg
Oceania (n = 1,695)	11.3% 2.0 µg/kg	22.2% 106 µg/kg	21.5% 105 µg/kg	34.5% 158 µg/kg	7.5% 3.6 µg/kg	2.0% 16 µg/kg
South Asia (n = 1,136)	82.2% 20 µg/kg	69.0% 288 µg/kg	19.6% 37 µg/kg	23.1% 96 µg/kg	60.4% 4.6 µg/kg	0.9% 13 µg/kg
Southeast Asia (n = 4,310)	57.4% 10 µg/kg	69.6% 573 µg/kg	45.9% 43 µg/kg	42.5% 137 µg/kg	15.2% 3.0 µg/kg	2.7% 26 µg/kg
East Asia (n = 13,232)	17.1% 10 µg/kg	60.7% 810 µg/kg	58.2% 90 µg/kg	84.8% 418 µg/kg	14.1% 2.9 µg/kg	11.0% 16 µg/kg
Central Asia (n = 15)	7.7% 1.4 µg/kg	25.0% 13 µg/kg	23.1% 1.5 µg/kg	26.7% 28 µg/kg	13.3% 22 µg/kg	6.7% 25 µg/kg

(Source: Gruber-Dorninger, et al., Global Mycotoxin Occurrence in Feed: A Ten-Year Survey, *Toxins* 2019, 11:375-400)

The main mycotoxins of concern are Aflatoxin, Deoxynivalenol (DON or Vomitoxin), Fumonisin (FUM), Ochratoxin (Ochra), Zearalenone (ZON or ZEA) and T-2 (type A trichothecenes) toxins.

Aflatoxin

Aflatoxin is produced by both *Aspergillus flavus* and *Aspergillus parasiticus*. These molds are common forms of 'weedy' molds widespread in nature. These molds can colonize and contaminate food before harvest or during storage, especially following prolonged exposure to a high-humidity environment or to stressful conditions such as drought. Aflatoxin M1 (AFM1) is the hydroxylated metabolite of Aflatoxin B1 (AFB1) and can be found in milk or milk products. AFM1 can be detected in milk 12–24 h after cows consume feed contaminated with AFB1. The concentration of AFM1 in milk is correlated to the levels of AFB1 in the raw milk. Aflatoxin is the most potent naturally occurring liver carcinogen known. Large doses of aflatoxins lead to acute poisoning (aflatoxicosis) that can be life-threatening, usually through damage to the liver.

Deoxynivalenol

Deoxynivalenol, also known as DON or Vomitoxin, is one of several mycotoxins produced by certain *Fusarium* species. The occurrence of DON is commonly associated with fusarium head blight; *Fusarium graminearum* and *Fusarium culmorum* being the primary molds producing this toxin. This mycotoxin occurs predominantly in grains such as wheat, barley, oats, rye and corn, and less often in rice, sorghum and triticale (wheat/rye hybrid). The incidence of fusarium head blight is strongly associated with moisture at the time of flowering (anthesis), and the timing of rainfall, rather than the amount, is the most critical factor. DON affects animal and human health, causing acute temporary nausea, vomiting, diarrhea, abdominal pain, headache, dizziness and fever; it can also have effects on reproduction.

Fumonisin

Fumonisin is a mycotoxin produced mainly by the fungus *Fusarium verticillioides*, a common contaminant of corn and corn products. Factors favoring fungal growth and toxin production include heat stress, insect damage, high humidity, and often a delay in harvest, as well as improper (wet) storage. Insects that damage corn, such as the European corn borer, provide a means for the fungus to invade the plant. Dietary exposure to Fumonisin in animals can lead to several harmful outcomes, including leukoencephalomalacia (neurologic damage) in horses, pulmonary edema syndrome in pigs, hepatotoxicity and nephrotoxicity in rats, and apoptosis in many other types of cells. There are also various health concerns in humans. Long-term Fumonisin exposure has been linked to possible carcinogenesis. Other effects have been observed, such as stunted growth and neural tube defects (NTD) in children.

Ochratoxin

Ochratoxins are secondary metabolites produced by multiple *Aspergillus* and *Penicillium* species. Ochratoxin is one of the most abundant food-contaminating mycotoxins. Ochratoxin A (OTA) is the single most potent member of this group of mycotoxins. OTA is most commonly found in cereal grains but can also be found in a range of other food commodities, including coffee, cocoa, wine, beer, pulses, spices, dried fruits, grape juice, pig kidney and other meat and meat products of non-ruminant animals exposed to feedstuffs contaminated with this mycotoxin. It is also a frequent contaminant of water-damaged houses and heating ducts. Ochratoxin A causes nephrotoxicity and renal tumors in a variety of animal species; however, human health effects are less well-characterized but include the risk of nephrotoxicity and renal tumors following long-term exposure.

Zearalenone

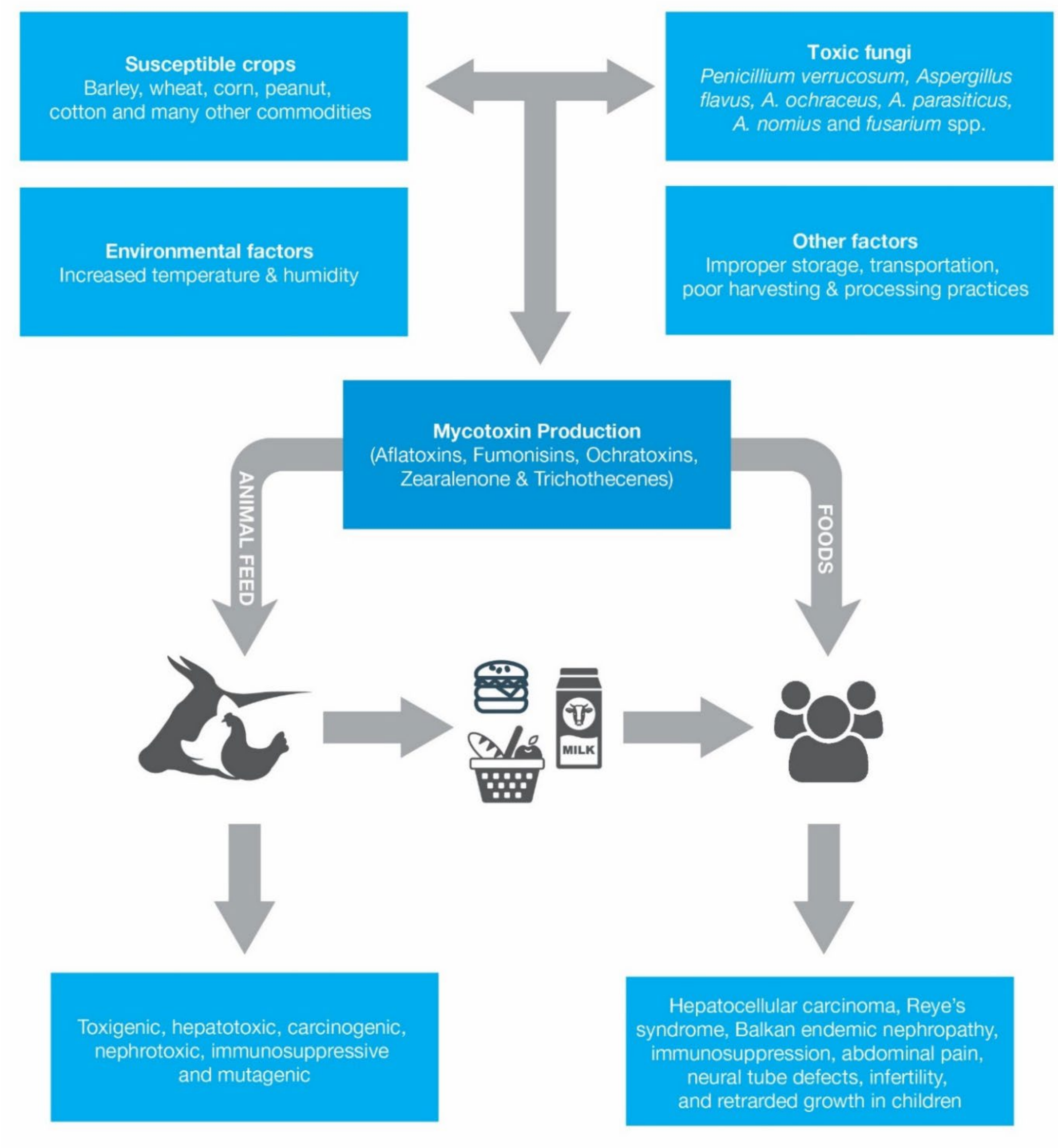
Zearalenone is found in maize and small grains and is primarily produced by *Fusarium graminearum* and some closely related species. It has a widespread occurrence wherever these crops are grown and is found in association with Deoxynivalenol, though its occurrence is less frequent. This mycotoxin can contaminate products made of corn, barley, wheat, oats, rice and sorghum. Zearalenone, an estrogenic mycotoxin, is a public health concern because of its toxicity and wide distribution; it can cause reproductive issues in both humans and animals.

T-2 toxins

T-2 toxin is the most toxic trichothecene, produced primarily by *Fusarium poae*, *Fusarium sporotrichioides* and *Fusarium tricinctum*. This toxin can be found in agricultural products such as oats, maize, barley and wheat. The occurrence and concentration are regional, but they vary significantly. It is structurally similar to DON but is much more toxic and less common than DON. The mycotoxins T-2 and its metabolite, HT-2, belong to a group of trichothecenes, type A, of which there are multiple metabolites that act via slightly different pathways. T-2 is highly toxic when inhaled or ingested as it is rapidly absorbed by cells due to its lipophilic nature. Its main target is the inhibition of protein synthesis, but it can affect multiple organs including the liver, kidneys, nervous system, reproductive system, immune system and skin, causing inflammation, edema and apoptosis. Acute toxic symptoms include vomiting, diarrhea, skin irritation, itching, rash, blisters, bleeding and dyspnea. If the animal or human is exposed to T-2 over a longer period, alimentary toxic aleukia (ATA) develops and can eventually lead to hemorrhaging and death.

What Causes Mycotoxins?

Multiple factors affect the level of mycotoxins in products. These include biological factors, environmental factors and conditions during storage and handling. Some factors are controllable – such as those involving human intervention. However, many factors must just be managed as they cannot be eliminated – such as temperature. Collectively, all these factors pose risks to food, animal and human safety.



Because of these potentially detrimental effects, it is critical that food and feed ingredients are tested regularly for the presence of mycotoxins. In addition, there are regulations regarding mycotoxin levels in almost every country worldwide. These regulations are in place to protect the safety and welfare of all – a focus on global One Health.

Mycotoxin Limits	United States	China	EU	CODEX
Aflatoxin Aflatoxin M1	20–300 ppb 0.5 ppb	0.5–20 ppb (B1) 0.5 ppb	4–20 ppb 0.025 to 0.05 ppb	10–15 ppb 0.05 ppb
Deoxynivalenol (DON)	5–10 ppm	1.3 or 5 ppm	0.2–12 ppm	200–2,000 ppb
Fumonisin	5–100 ppm	5 to 60 ppm	0.2–60 ppm	2,000–4,000 ppb
Ochratoxin A	-	2.5 or 10 ppb	0.5–250 ppb	5–50 ppb
T-2 Toxin	-	< 0.5 ppm	15–2,000 ppb (T-2 + HT-2)	-
Zearalenone (ZON)	-	0.1 – 60 ppm	20–2,000 ppb	200 ppb

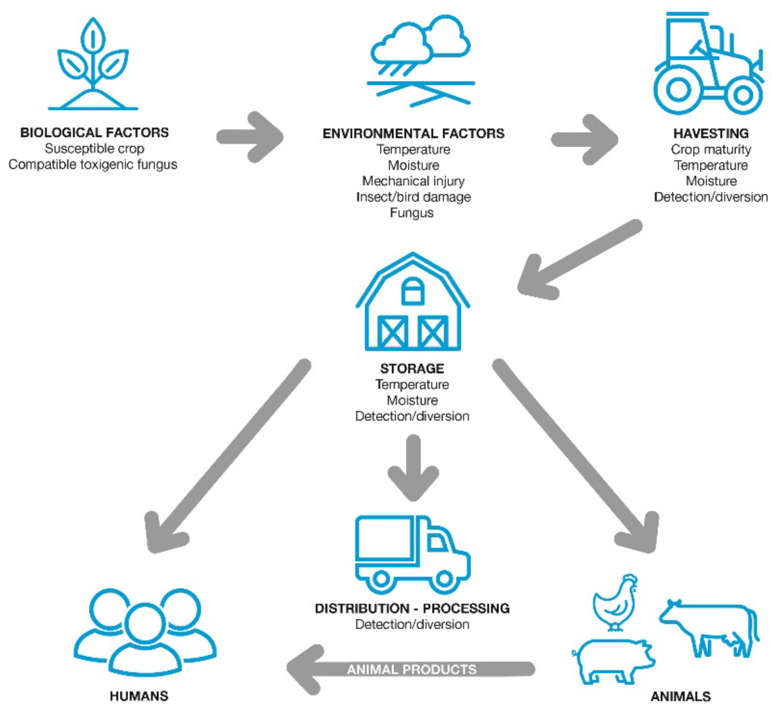
Indonesia, Malaysia, Korea, as well as most other countries in APAC have regulations in place for mycotoxin levels.

Food production companies must protect their brand by monitoring mycotoxins in their ingredients. The impacts of not monitoring their mycotoxin load can lead to product recalls, human and animal deaths or illness. This can decrease profits, increase food costs and prices and/or lead to a loss in revenue.

Testing for Mycotoxins

Mycotoxin testing should take place at multiple locations throughout the supply chain. Since mycotoxins are not homogenous and can arise throughout the food chain, monitoring for a full range of mycotoxins at multiple points throughout the supply chain is essential to keep the products that humans and animals consume safe.

Factors affecting Mycotoxin occurrence in the food chain



Testing for mycotoxins at the first point of reception can be an effective way to reduce mycotoxin loads. This mycotoxin load reduction is done by using a rapid onsite test for mycotoxins on every load or lot of product that is received. This allows the user to reject or segregate products at the point of reception before products are unloaded into the facility or comingled with other products. Samples are collected and tested, so results can be analyzed to determine rejection or segregation before the product is unloaded. The most rapid form of mycotoxin testing is employed at the first point of reception.

Currently, lateral flow device (LFD) technology is the fastest, easiest and most flexible tool that can be employed for mycotoxin testing. This technology provides results in ~10 minutes from a ground sample. The protocol steps can be taught easily to a user through a short training session. This allows facilities with short staffing, higher turnover rates or non-technical staff to have the ability to train personnel to perform the testing. These rapid tools can be employed throughout the field to reduce the mycotoxin load by reducing the amount of mycotoxin-contaminated products that enter the facility.

Throughout the supply chain, multiple platforms for testing mycotoxins can be employed. As products are transported to the next points in the supply chain, samples can be collected for analysis. These samples can be tested onsite with rapid platforms such as LFD or ELISA or sent to reference laboratories to be tested using platforms such as ELISA, HPLC or LC-MSMS. The technology being employed will be determined by the needs of the facility providing the product sample needing to be tested. The speed at which the sample needs to be analyzed, the level of detection needed, the sample type, or the capabilities of the laboratory are all factors that can contribute to the technology choice.

Hygiena offers competitive enzyme-linked immunoassays intended for the quantitative detection of mycotoxins in nuts, feed, grain, grain-by-products, milk and dairy products.