

■ DON (Vomitoxin) in Wheat

Basic Questions and Answers

■ What is DON?

Deoxynivalenol (DON), commonly referred to as vomitoxin, is a mycotoxin that may be produced in wheat and barley grain infected by *Fusarium* head blight (FHB) or scab. FHB may infect grain heads when wet weather occurs during the flowering and grain filling stages of plant development. The occurrence of FHB does not automatically mean that DON is present, but a high level of scabby kernels in the harvested grain means DON will likely be present. Levels of DON do not necessarily correlate with levels of physical damage in grain.

■ What are the critical levels of DON for use in food and feed?

The concentrations of DON in grain are expressed as parts per million (ppm). One ppm is equivalent to 1 pound in 1 million pounds, 1 penny in \$10,000, 1 minute in two years, or 1 wheat kernel in 80 pounds of wheat.

The U.S. Food and Drug Administration (FDA) has established DON advisory levels to provide safe food and feed. Unlike aflatoxin in corn, DON is not a known carcinogen. Furthermore, grain with DON would have to be ingested in very high amounts to pose a health risk to humans, but it can affect flavors in foods and processing performance.

Human food products are restricted to a 1-ppm level established by the FDA. This level is considered safe for human consumption. The food industry often sets standards that are more restrictive. DON causes feed refusal and poor weight gain in some livestock if fed above the advisory levels. FDA advisory levels are as follows:

1 ppm	Finished wheat products, such as flour, bran and germ, that potentially may be consumed by humans. The FDA does not set an advisory level for raw grain intended for milling because normal manufacturing practices and additional technology available to millers can substantially reduce DON levels in the finished wheat product. However, individual millers or food industries may have stricter requirements than 1 ppm.
10 ppm	Grains and byproducts destined for ruminating beef and feedlot cattle older than 4 months and for poultry, providing that these ingredients don't exceed 50 percent of the diet
5 ppm	Grains and grain byproducts destined for swine, providing that these ingredients don't exceed 20 percent of the diet
5 ppm	Grains and grain byproducts destined for all other animals, providing that these ingredients don't exceed 40 percent of the diet

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In cooperation with the N.D. Wheat Commission

■ How does DON impact wheat grain quality and product performance?

FHB infection during very early kernel development can reduce yield by decreasing kernel numbers. Slightly later infections cause shrunken, chalky white or discolored scabby kernels, which often are referred to as tombstones. Kernels infected late in their development by FHB may show no visible damage, but still have elevated levels of DON. A Canadian study (Sinha & Savard, 1997, Can. J. of Plant Path. 19:8-12) of DON in FHB infected wheat kernels found an average level of 1 to 1.2 ppm in normal appearing kernels, 2 to 5 ppm in shriveled kernels, 174 ppm in white tombstones, and 274 ppm in pink tombstones.

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The majority of the DON is present in the seed coat or bran in wheat. For the flour miller, shrunken kernels result in a loss of milling yield because damaged kernels are removed to improve flour quality and reduce DON content. Enzymes found on scabby kernels can break down protein and consequently reduce gluten strength and adversely affect the bread and pasta making properties of the flour. Processing and final product quality, however, are not significantly affected by DON *per se* when levels are below 1 ppm. In addition, the process of milling wheat into white flour or durum semolina typically results in the reduction of DON by approximately 50 percent. Therefore, many grain handlers or processors purchase grain with DON levels up to 2 ppm without discounts. Manufacturers of whole-grain foods will have specifications that are more rigid.

Most export markets have specifications built into their purchase agreements to limit DON levels. The typical standard used by the majority of world buyers is 2 ppm maximum. In Europe, some countries have lower limits, such as 1 ppm in the United Kingdom and 0.5 ppm in Norway, due to their own advisory levels. Japan has set a maximum DON level on imported wheat of 1.1 ppm. A complex formula was developed by the Japanese Department of Health to limit the per capita consumption of DON.

■ How is DON Measured?

DON is measured using several laboratory procedures. The most common method used by the Federal Grain Inspection Service (FGIS) and most grain handling and processing facilities is the immunological-antibody method called ELISA (Enzyme Linked Immunosorbent Assay) because it is relatively fast and cheap. The gas chromatography - electron capture (GC-EC) analytical method is quantitative and used to calibrate ELISA test kits. It also is the method used by the NDSU Veterinary Science Toxicology Laboratory for measuring DON presence in grain samples. Factors, such as sampling differences, wheat cleaning, sample preparation and test kit standard error, may cause differences in results between testing laboratories, but each lab and elevator follows approved methods that are periodically conformance tested.

■ Is the sampling procedure for DON analysis important?

The reliability of testing is greatly influenced by the sampling procedure. To achieve a more accurate DON level estimate, it is critical that the collected grain sample be representative of an entire truckload or bin of grain.

Grain and other particles separate based on particle size and density as it flows into a truck or bin. Typically, the

smaller, denser material is near the center and the larger, lighter material is near the outside of the container. Therefore, it is expected that there will be a variation in the concentration of affected kernels in various portions of a truckload. In addition, since DON levels can vary greatly between kernels of similar size and density, it is important to take several samples from various locations within the load.

Probe samples should not be taken from the center or outer portions of a load because these areas do not reflect a cross section of the load. The samples also must represent spatially distinct areas of the load. The probe should collect the sample from as much of the entire depth of the truck as possible. Four to five probes per truck are recommended.

To obtain an accurate sample from an end gate grain stream, samples from the entire width and depth of the grain stream should be collected, not just the first and last portion of the load. A Pelican sampler or other sampling device aids in proper sample collection. At least four samples of the entire grain stream should be collected at intervals to represent spatially different portions of the load.

■ What are possible strategies for using wheat with DON?

CLEANING

Is grain cleaning economically feasible for removing DON?

FHB blight affects the kernel in a variety of ways that permit the scabby kernels to be removed from good quality wheat. The kernels may be deformed enough that they can be removed by screening. The kernels typically have a

Wheat Cleaning Examples

Wheat Sample	Test Weight (lb/bu)	DON (ppm)
Whole Field Sample	54.2	7.0
Light Portion	55.7	5.0
Medium Portion	58.4	3.1
Heavy Portion	59.9	1.5
Screenings	41.2	26.1

Factors	Original sample	Clean-out	Cleaned Sample
Bushels	1,000	110	890
Test Weight (lbs/bu)	59-61	57	61-63
Damage	2-5%	Unchecked	<0.5%
DON level	8 ppm	Unchecked	0-2 ppm
Market Price	\$1.70	\$1.00	\$3.20
Value	\$1,700	\$110	\$2,848

Increase in income from cleaning this 1,000 bushels of wheat was \$858; \$110 value of clean out + \$2,848 value of cleaned sample - \$400 cost of cleaning - \$1,700 value of unclean sample. Cleaning cost in this example was \$0.40/bushel.

lighter test weight, so the very light kernels can be removed by airflow. If screening and aspiration do not adequately remove the scabby grain, the wheat can be sorted by density with a gravity table or fluidized bed separation. The amount of scabby grain and the amount of wheat lost during cleaning is different for each lot of grain, so a small quantity needs to be cleaned to determine the economics. The cost of cleaning will typically be about 40 cents per bushel. DON can occur on kernels of normal appearance and shriveled or tombstone kernels. Therefore, it is not always possible to reduce the DON level by cleaning the grain.

Is respiratory protection needed while handling infested grain?

All mold spores, not only those of the *Fusarium* fungus, may cause allergic reactions and breathing problems if inhaled. Appropriate personal protective gear, such as masks designed to keep out mold spores and grain dust, are recommended when handling grain. Generally, these masks are either N95 rated masks, which typically have two straps, or respirators with HEPA filters. Masks are available at most hardware stores for about \$2.50 each.

STORAGE

Does DON increase in storage?

After the grain dries below a moisture level of about 22 percent, fungal growth and DON production stops. Anytime the kernel is damaged, however, the potential for grain deterioration during storage increases. Damaged wheat should be stored at or below 12 percent moisture content. Studies show that the allowable storage time for scabby wheat is slightly less than for non-affected wheat. Therefore, recommended airflow rates to dry scabby wheat should be slightly increased above the rates recommended for good quality wheat. Affected wheat should be cooled by aeration soon after being placed in storage and further cooled periodically as outdoor temperatures decline until the wheat is about 25 F.

MARKETING

What is the best strategy for marketing wheat with DON?

The most cost effective way to market wheat with high DON levels depends on many factors, such as how much DON is in the wheat and the current discounts; ability and cost to segregate, clean and/or blend the wheat; cost of storage; contract obligations with the elevators; the loan deficiency payment (LDP); and the price outlook.

Elevator discounts generally are the most severe at harvest. Discounts usually decrease after harvest, as the marketing system is able to assimilate the lower quality grain over time. Market reaction to DON levels can vary depending on which market elevators are selling into,

how much of their local draw area was affected and the availability of blending stocks. Elevators and grain exporters risk outright rejection of shipments that exceed contract specifications.

At harvest, every attempt should be made to segregate and store on-farm DON-affected and nonaffected wheat. The possibility of deferring contracted wheat in the hope that discounts will lessen with time should be explored. On-farm storage also gives the producer time to improve quality before delivery by cleaning and/or blending. To be worthwhile, the combined value of the cleanout and clean grain, less cleaning costs, must be greater than the value of the original grain. The value of cleanout varies at elevators. A one-time in/out charge of about 8.5 cents per bushel is an additional storage cost that also should be considered.

A CCC loan on wheat being stored may offer benefits. Most importantly, it provides cash flow. It also may have a lower interest charge than a commercial loan. However, any LDP that might be available cannot be taken if a CCC loan is taken. Forfeiture on the loan usually is not the best alternative since the discounts on forfeited wheat would be 50 cents for 2.1 to 3 ppm, 75 cents for 3.1 to 4 ppm and \$1 for 4.1 to 5 ppm. Wheat more than 5 ppm would have a settlement value of zero.

For wheat in the bin, the cost of good quality on-farm storage is about 1.5 to 2.1 cents per month, based on interest rates of 4.5 to 7 percent, respectively. Storage into April/May could be profitable if distant futures prices are at least 12 to 15 cents higher and remain there, the basis does not deteriorate, and DON discounts are reduced or quality can be improved.

FEEDING

Can DON contaminated grain be used as a livestock feed?

In most cases, wheat containing DON can be used as a livestock feed. However, there are some classes of livestock that do not tolerate DON well.

Beef Cattle: FDA limits for cattle are similar to poultry (dietary levels of 5 ppm). Research conducted in North Dakota and Minnesota has suggested growing and finishing cattle can tolerate higher levels (up to 18 ppm based on research at the Carrington Research Extension Center).

Dairy Cattle: FDA limits the level to 2 ppm DON in the diets of lactating dairy cows.

Swine: Do not feed wheat containing DON to gestating or lactating sows or pigs weighing less than 50 pounds. Growing and finishing pigs may be fed grains containing DON, provided the level of DON in the diet does not exceed 1 ppm.

Poultry: Poultry can be fed grain containing DON. Total dietary levels should not exceed 5 ppm (e.g., 10 ppm DON in wheat could be fed at 50 percent of the diet).

Horses: No research data exists that has evaluated feeding grain containing DON to horses. Since monogastric animals tend to be more sensitive than ruminants to these type of toxins, horse owners should be extremely cautious about feeding DON containing grain to horses.

■ Recommendations for feeding wheat

In addition to the problems related to DON, feed wheat is a grain that requires diligent feeding management to be successfully included in a ration for cattle. Wheat ferments very rapidly, making it a difficult to feed at high levels. Here are a few pointers for making the most of this grain:

- Wheat is higher in protein and similar in energy to corn (see following table).
- Limit wheat to 40 percent or less of the ration in backgrounding and finishing diets.
- Limit durum to 30 percent or less of the ration in backgrounding and finishing diets.
- Gradually adapt cattle to wheat-based diets. Start with low levels (10 to 15 percent) and then gradually increasing the wheat level up to 30 percent (durum) or 40 percent (hard wheats).
- Wheat should be coarsely rolled or cracked, but not finely ground for optimum performance.
- Wheat should not be fed in self feeders.

For more detailed information on grain feeding, check out the following web sites:

- www.ext.nodak.edu/extpubs/ansci/beef/as1184w.htm
- www.ext.nodak.edu/extpubs/ansci/livestoc/as647w.htm
- www.extension.iastate.edu/Publications/PM1994.pdf

Nutrient content of various feed grains (NRC, 1996)^a

	Wheat	Barley	Corn	Oats	Sorghum
TDN (%)	88	88	90	77	82
NE _m (Mcal/kg)	2.18	2.06	2.24	1.85	2.00
NE _g (Mcal/kg)	1.50	1.40	1.55	1.22	1.35
CP (%)	14.2	13.2	9.8	13.6	12.6

^aNutrient analysis can vary. A laboratory analysis is recommended.

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■ What can I do to prevent DON in the future?

The environment plays a critical role in the development of FHB and the production of DON. Humid and warm conditions during flowering favor FHB and DON production. When environmental conditions are ideal, multiple control practices are needed to control this pernicious disease.

Crop rotation will not eliminate Fusarium head blight and DON accumulation, but will help reduce the severity, even in epidemic years. Research studies in other states show that infections have been 5 to 10 times higher when corn was the previous crop than when wheat was the previous crop. In 2005, a research study in Fargo showed that the field severity of FHB was 2 times higher with wheat planted into wheat stubble than when the same variety was planted the same day in an adjacent field of soybean stubble.

Variety resistance: No wheat varieties are totally resistant to Fusarium head blight, but some varieties show more tolerance to the disease and DON accumulation. Of varieties currently available, Glenn, Alsen and Freyr are among the most tolerant. For additional details go to www.cc.ndsu.nodak.edu/instruct/stack/FHB/FHB.html. Planting at least two or three tolerant wheat varieties with differing maturity dates will help minimize the risk of scab infection. In a wet year, large quantities of the fungus that causes scab are produced, subjecting virtually any wheat field to some degree of Fusarium infection. Check variety trial results from experimental plots to see which varieties perform best in the presence of the disease.

Fungicides can help reduce Fusarium head blight and DON levels by 50 percent to 70 percent in North Dakota in most years, when using the best available fungicides and appropriate application timings. Success is greatest when fungicides are applied to moderately susceptible to moderately resistant spring wheat varieties. Under severe epidemics, fungicides have not sufficiently reduced disease or DON levels to achieve a top market grade in barley or in very susceptible wheat and durum cultivars. For additional information on the use of fungicides to control FHB, go to www.ext.nodak.edu/extpubs/ageng/machine/ae1148w.htm. Seed treatments before planting may improve seed germination and seed vigor, but they will not prevent FHB infection or DON accumulation.

Tillage buries disease-carrying debris, allowing for microbial degradation of the Fusarium fungus and lowering the chance of fungal spore dispersal. Moldboard plowing is more successful at burying residue than chisel plowing. However, other factors such as soil or water erosion are important considerations for tillage practices and residue concerns may be more effectively dealt with by crop rotation.

For more information on this and other topics, see: www.ag.ndsu.edu

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