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ROTS AND GERM DAMAGE OF SMALL GRAINS IN STORAGE

Figure 1. Small grain storage mold - heat damage. (Courtesy C.M. Christensen).

Rots and germ damage may develop in stored small-grain seeds when storage fungi (commonly called storage molds) are present and when the moisture content is above 13 percent. As the moisture content increases above 13 percent, the likelihood of invasion of the kernel germ or embryo by storage fungi increases with increasing temperature and time. In wheat, oats, and barley having a moisture content of 13.5 to 14.5 percent, slow invasion by storage molds can cause germ and heat damage without any temperature increase (Figure 1). In the absence of insects and mites, heating in stored small grains generally indicates that the moisture content is above 15 percent. Seasonal or even diurnal temperature fluctuations in storage bins cause moisture migration and condensation that permit the growth of storage molds on and in grain that is otherwise suitably dry.

Nonseed debris, mostly dirt and chaff, is a reservoir for storage fungi, stored grain insects, and moisture. Mechanically damaged and broken kernels are more prone to invasion by these fungi than are seeds which are intact. Samples of wheat and other small grains free of storage molds have been dried to 16- to 18-percent moisture and stored at temperatures of 60° to 80°F (16° to 27°C) for more than 8 months without any germ damage developing. This indicates that normal processes within the seeds themselves do not cause germ damage during storage.

In the temperature range of 40° to 50°F (5° to 10°C), storage molds grow very slowly; while at 80° to 110°F (27° to 44°C), growth is very rapid. Grain that is to be stored for only a few weeks before processing may contain a higher moisture content, have more extensive invasion by storage molds, and be kept at a higher temperature without serious problems than can grain stored for longer periods. However, grain stored for only a few weeks at any combination of moisture content and temperature that permits even moderate invasion by storage fungi (usually not detectable by grain inspectors, but easily seen with the aid of a microscope) will be a high risk if kept in continued storage.

Grain moderately invaded by storage fungi or molds develops damage at lower combinations of moisture content and temperature and in a shorter time than grain free or almost free of storage fungi. Once storage molds become established, they continue to develop at moisture and temperature levels **below** those required for the initial invasion of sound grain.

For further information contact your nearest Extension office or an Extension Specialist, Department of Crop Sciences, University of Illinois, Urbana-Champaign.

We gratefully acknowledge the help of Drs. Clyde M. Christensen and Richard A. Meronuck, Department of Plant Pathology, University of Minnesota, for much of the subject matter and photographs.

The damage done by fungi growing in stored grain is the **end** product of storage conditions. The responsibility for it lies with those who store the grain. Storage rots and germ damage reduce the feeding value of grain and lower the market grade. Occasionally, certain storage molds may produce toxins that seriously affect poultry and livestock. Wheat with discolored and damaged embryos is discounted by millers because the germs are brittle and crumble easily. Such embryos show up in the flour as unsightly, black specks. Flour milled from wheat containing more than 20 percent "sick" kernels may yield "off-flavor" bread that is also smaller in loaf volume.

CAUSE

More than 25 different species of fungi cause germ damage and spoilage and are known to invade stored, small-grain seed. With the exception of *Fusarium (Gibberella)*–fungi that cause head blight or scab of wheat, barley, oats, and rye as well as ear and kernel rots of corn–storage molds do not normally enter undamaged seed until the seed matures. If the seed is sound at harvest, *Fusarium* will not attack it in storage, although *Fusarium* may invade corn of high-moisture content stored on the cob in cribs.

The fungi responsible for most of the damage in stored grain are species of *Aspergillus* and *Penicillium*. *Aspergillus glaucus* and *A. restrictus* colonize grain with over 13.5 percent moisture. At 15 percent moisture and above, *A. candidus, A. ochraceus* and *A. flavus* begin to develop. Species of *Penicillium* begin to grow once the grain moisture exceeds 16 percent. These fungi are common to and destructive in stored grain when the moisture content is 14 to 17 percent or more, and the temperature is above 50°F (10°C). At least one species of *Aspergillus* can grow slowly on and in wheat, oats, and barley that has a moisture content of only 13 percent. Small-grain seed stored at a relative humidity (RH) of 70 percent will have an equilibrium moisture content of 13.5 percent. At 85 percent RH, the moisture increases to 18 percent. Within a moisture range of 13.5 to 18 percent, the majority of storage molds grow most rapidly at 85° to 91°F (30° to 33°C)–although *Aspergillus flavus* develops quickly on and in moist grain at 113°F (45°C); and *A. candidus*, at 131°F (54°C). Most of these fungi can grow between 41° and 104°F (5° and 40°C). A few species of *Penicillium* can grow slowly at temperatures lower than 32°F (0°C).

Storage molds work like a "bucket brigade" at a fire. Each fungus is active within rather narrow limits. When those limits are reached, another fungi or other fungi begin to colonize the grain quickly, resulting in a succession of organisms colonizing the grain.

All storage molds give off heat and moisture–utilized, in turn, by their successors. This accelerates the rotting process. Increased temperature and moisture content (within limits) leads to more rapid rotting. Insects and mites are often present in spoiled grain. They take advantage of and contribute to the heat and moisture given off by the molds. Insects and mites also bring in and promote the development of storage molds.

Determining the number and kinds of fungi in a given lot of grain often indicates the moisture content and temperature at which the grain has been stored; and sometimes, the approximate length of the storage time.

SYMPTOMS

Storage fungi produce a sharp decrease in germination; dark germs (also called "sick" or germ-"damaged"); toxins that may be a health hazard for man and animals; musty or sour odors; heating; "caking";

and bin burning. These are the **end** results, caused by storage molds invading the grain. However, a complete invasion and killing of the embryo commonly occurs within the kernel **before** growth or symptoms are visible from the outside. Germ discoloration can be detected by removing the pericarp (germ covering) and examining the embryo (Figures 2, 3, 4). Germs that are lightly discolored throughout (or discolored only on the tip) are likely to be moldy (Figures 5 and 6), and may later turn dark brown to black. The mold growth may be tan, white, black, blue, bluish green, or pinkish red.

Figure 2. The seeds as observed before pericarps covering the germs were removed; no damage is evident.

Production of Mycotoxins

Under conditions of high relative humidity and high temperatures, fungi commonly found colonizing grain may produce a variety of mycotoxins. These fungal metabolites cause a number of diseases (mycotoxicoses) in animals and man brought about by consuming food and feed that have been invaded by toxin-producing fungi. Some of these mycotoxicoses result in feed refusal; vomiting and diarrhea; stunting or “poor growth” and performance; infertility; abortion; tremors and convulsions; edema; lesions in the liver, brain, and kidney tissues; teratogenic and hepatocarcinogenic effects; hemorrhaging of the liver and lung; and even death–especially in young animals. Mycotoxins consumed in the feed may lower the animal’s resistance to infection by parasites. Ten parts per billion (ppb) of aflatoxin consumed regularly by sensitive animals (chickens, ducks, and turkeys) can result in fatal liver cancer. (By way of analogy, 1 ppb is equivalent to 1 inch in nearly 1,600 miles). For 1 ppb of alflatoxin to appear in the milk or meat of dairy cows, edible organs and flesh of beef and pigs, and eggs and flesh of poultry, the feed must contain several hundred to several thousand ppb of aflatoxin.

Figure 3. Germs of wheat with the pericarps removed. Left, sound germ, white or off-white in color. Right, dark and damaged or “sick” (dead and decayed) germ.

Toxins produced chiefly by *Fusarium (Gibberella)* cause (1) the estrogenic syndrome, externally characterized by a swollen edematous vulva in females and enlarged mammary glands in young males and (2) the “refusal factor” or vomitoxin (deoxynivalenol), in the trichothecene mycotoxin group. If the feed ration contains more than about 5 percent of grain that is visibly damaged and containing one or more toxins, pigs may refuse to eat it.

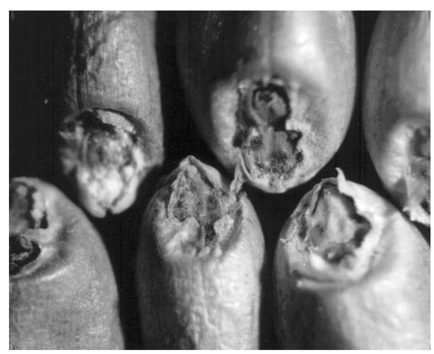

Figure 4. The same seeds with pericarps removed to expose the dark germs covered with storage fungi. The warehouseman claimed that none of the grain had a moisture content over 12.5 percent at any time during storage. But the particular kinds of storage fungi that grew from this seed proved conclusively that the grain had a moisture content of 15 to 16 percent for at least some months or these fungi could not have invaded it as they did.

Clinical signs and lesions in affected swine in Illinois in late 1981 and 1982 included feed refusal, a few instances of vomiting, lack of weight gain, poor feed efficiency, failure of mature sows to return to estrus, reduced fertility, high mortality of nursing pigs, intestinal-tract inflammation, and acute diarrhea in young pigs. Examinations of dead young pigs revealed hemorrhaging into the abdominal cavities, and pale, friable livers.

Figure 5. Storage fungi (Aspergillus species) fruiting on the germ ends of wheat kernels.

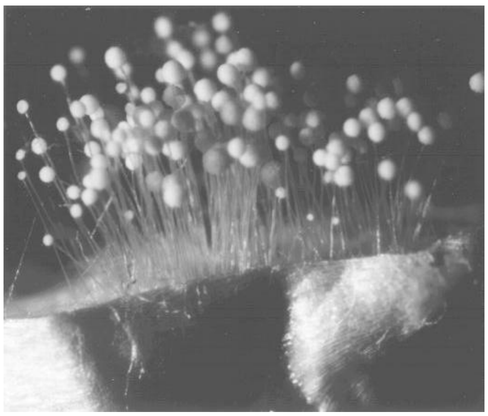

Figure 6. A storage fungus (Aspergillus ochraceus) growing from the germ of a split kernel of wheat.

The production of toxins by storage molds is highly variable–depending on the strain and species of fungus, storage temperature and moisture content, type of grain, length and type of storage, and probably other still-unknown factors. Once a toxin is produced in grain, it is extremely durable under most conditions of storage, handling, and processing of grain or other plant parts, or in foods and feeds made from them.

Toxins ingested with the feed by dairy cattle may be excreted in the milk. Their effects on humans are largely unknown, although aflatoxin has been implicated in primary liver cancer. *Aspergillus flavus* produces aflatoxins at moisture contents greater than 18 percent in equilibrium with 85 percent RH and temperatures of 54° to 108°F (12° and 48°C) with an optimum of 81° to 86°F (27° and 30°C). Under optimum conditions for growth *A flavus* can produce some aflatoxin within 24 hours and a biologically significant amount in a few days. Other mycotoxin-producing storage molds generally grow in the moisture range of 17 to 40 percent and at temperatures of 32° to 131°F (0° to 55°C). The U.S. Food and Drug Administration has set a maximum level of 20 ppb for aflatoxin in food or feed shipped in interstate commerce. The aflatoxin metabolite M_1 tolerance for milk is 0.5 part per billion.

Sources of Error in Determining the Moisture Content of Grain

Many warehousemen take an "average" sample from each lot of grain as it goes into storage and determine its moisture content with an electric or electronic moisture meter. The overall or weighted average of these samples is then considered to be the average moisture content of the grain throughout its storage life. This assumption has several sources of error.

1. An average sample from a given lot of grain does not indicate the **range** in the moisture content of the entire bulk. A range of ± 1 to 2 percent may be expected in the moisture content of any carload, truckload, or small bin. In large bins, the range may be greater. For safe storage, it is essential to know the **highest** moisture content of any portion of a given lot. Grain is only as dry as the wettest grain in terms of the risk of damage from storage molds.

2. The accuracy of the moisture meter should be checked frequently–determining the moisture content of check samples by oven-drying, or by submitting samples to federally licensed grain inspectors. The figure obtained by some types of electric moisture meters may be 1 percent below that obtained by oven-drying the same sample in the laboratory. The standard Motomco meter is quite sensitive but even under ideal conditions, it probably is not possible to determine the moisture content of a given sample by machine more precisely than ± 0.4 percent.

3. The moisture content will change and fluctuate with time and from place to place within a bin. If the temperature is not uniform throughout the bulk, a slow movement or circulation of air causes moisture to accumulate in the colder portions of the grain. Large and rapid shifts in moisture are likely when the moisture content of the grain is between 13 and 15 percent, when the temperature

of the grain is 75° to 80°F (24° to 27°C), and when the grain going into storage is heavily invaded by actively growing storage fungi. The migration of moisture is usually greatest in the winter when the cool, upper layers of grain in the center of a bin may accumulate a moisture content 5 to 10 percent or more above that in the bulk (shown on the elevator operator's record books) (Figure 7).

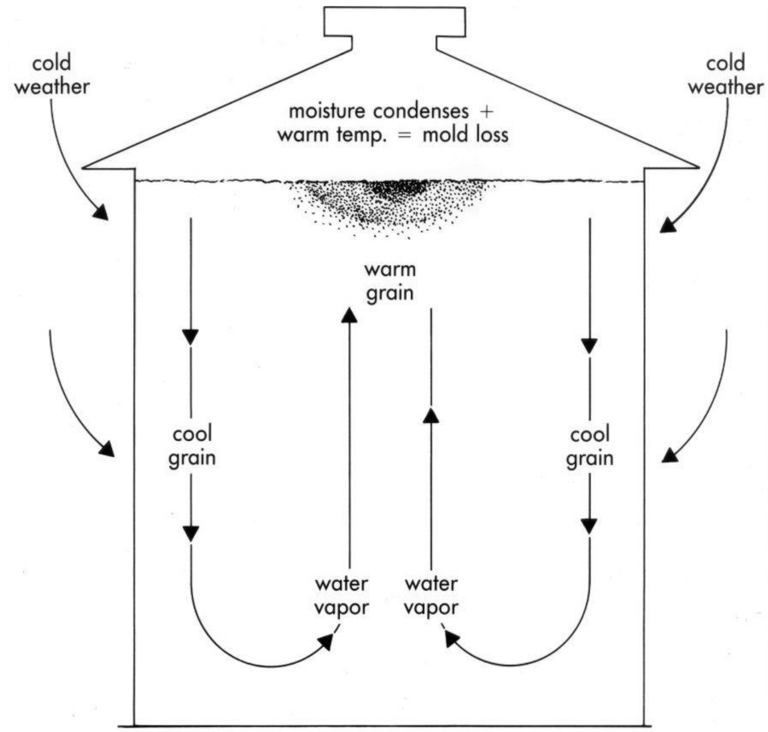

Figure 7. When warm grain is put into a bin followed by cold weather, migration of moisture takes place, resulting in grain loss from storage molds commonly in the center and upper layers (drawing by L.Gray).

4. When different lots of grain with high and low moisture contents are blended to achieve an average (**presumed** to be safe for storage, or to meet a certain grade), the moisture content may never equalize. Many such mixes are a very poor storage risk.

5. In a supposedly uniform lot of grain, the moisture content may vary from seed to seed by as much as 1 percent.

6. Activities of grain-infesting insects and mites can rapidly increase the moisture content of grain–up to 1 percent a week, and 10 percent in a few months. Fumigation may rid the grain of insects (some grain fumigants do not kill mites), but storage molds continue to develop. The amount of grain damaged by the molds may considerably exceed the amount infested by the insects or mites.

All of these factors combined explain why the moisture-content figure in an elevator operator's books often bears little relation to the **actual** moisture content of the grain being stored.

CONTROL

1. **Be certain that harvesting equipment is operating properly and set correctly. Cylinder speed and settings should be checked to insure the lowest possible damage to harvested grain.**

2. **Wherever possible, store grain (free of dirt, debris, chaff, and broken kernels) in a clean, tight bin at a moisture content below 13 percent and a temperature below 50°F (10°C).** If the grain is sound and dry when stored, it can be kept for years under these conditions without damage.

3. **Aerate high-moisture grain as soon as possible to provide a temperature of 35° to 50°F (2° to 10°C) throughout the bulk.** At such temperatures, insects and mites are dormant; and most storage fungi grow very slowly if at all.

4. **After the grain has been stored, take probe samples at weekly to monthly intervals from different portions.** Use calibrated moisture meters, "official" drying ovens, or the distillation methods of determining moisture. Avoid taking several samples from a bin and averaging them.

The **highest** moisture content, not the average, determines storability. Examine each sample for moisture content, damage, and the number and kinds of fungi. No germ or heat damage will develop in grain when the moisture content is below 13 percent.

5. **Measure and keep a record of temperatures in different parts of the grain.** Even a slight rise in temperature means that some spoilage is occurring. Only vigorously feeding insects or rapidly growing storage fungi can cause stored grain to heat up. If a "hot spot" is found, determine its size and location, as well as the condition of the grain in and near it. Do this by sampling and examining the grain. Temperature detection cables or other devices to measure the temperature at various places within bulk grain are an aid to–but not a substitute for–the intelligent handling of stored grain. Relatively dry grain is a good insulator. A rise in temperature of even a few degrees (as indicated by a thermo-couple) may mean that the grain in the region of highest temperature is already spoiled.

6. **When "hot spots" or a crust of moldy grain are found, take the following corrective measures:**

   a. **The rotted and moldy grain should be removed and dried, and either fed or sold.**

      Moldy grain should be fed with extreme caution to all classes of poultry and livestock, but if mixed with sound grain, it can be fed with less risk to livestock being finished for market. Moldy grain is considered unsafe for **lactating cows** and all breeding and potential breeding animals.

   b. **The moisture content of the remaining grain should be checked.**

   c. **The remaining grain should be turned and thoroughly mixed to redistribute moisture and allow heat to escape.**

7. **Aeration fans should be installed to move small quantities of air through the grain**. Doing this will maintain a uniform temperature and help prevent "wet" spots. It is cheaper and more effective to maintain the temperature and moisture throughout a bin with aeration than to transfer the grain from bin to bin. Such transfers also increase the amount of cracked and broken kernels.

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