

# Dry Matter Loss in Yellow Dent Corn Resulting from Invasion by Storage Fungi

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## ABSTRACT

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Samples of high-temperature-dried yellow dent corn stored in the laboratory at moisture contents of 14.5–19.5% suffered increasing invasion by storage fungi, increasing loss in dry matter, and an increasing percentage of damaged (brown to black) germs with increasing moisture content and increasing time of storage. Invasion of the germs by storage fungi (especially *Aspergillus glaucus*) preceded any detectable weight loss and change in germ color. By the time the dry matter loss had reached 0.5–1.0% the germs of the corn kernels had been extensively invaded by storage fungi.

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Respiration, as determined by amount of carbon dioxide produced, has long been used as a laboratory measure of weight loss and progressing deterioration of moist stored grains and seeds

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(1,4,8–10). Depending on the moisture content of the seed, the viability (dead seeds do not respire), and the number and kinds of microflora developing during the tests, the respiration may be from the seeds or from the microflora, or both. Seitz et al (9), working with high-moisture corn (*Zea mays* L.) essentially free of internal fungi, found that “respiration of the grain itself was a major contributor” to dry matter loss, whereas Hummel et al (4), working with wheat free of storage fungi, stated, “The respiratory rates of mold-free wheat at

35 C and moisture levels ranging from 15–31% were low and constant with time.”

Weight loss in moist grains undergoing fungus invasion in storage can be measured directly by determining the dry matter present at the beginning of the tests and periodically thereafter. The aim of our study was to determine the dry matter loss and germ discoloration resulting from invasion of yellow dent corn by storage fungi at moisture contents likely to be encountered in farm and commercial storage.

## MATERIALS AND METHODS

**Corn.** High-temperature-dried yellow dent corn, dried in a stage batch drier with an average temperature of 200 F, was obtained from the University of Minnesota bins at Rosemount. The corn had an initial moisture content of 9–10% and 2% damaged (dark brown to black) germs. Its germination was only 1–3%. Low germinability is characteristic of many samples of grade no. 2 corn from commercial channels (2,5,7), presumably

**Table 1.** Dry matter loss resulting from invasion by storage fungi on corn held 30, 60, and 90 days at beginning moisture contents of 15.5–18.5%

Days stored	Moisture content (%)			Dry matter loss (%)	
	At start (av.)	At test period		Av.	SD
		Av.	SD		
30	15.5 <sup>a</sup>	15.4	0.11	ND <sup>b</sup>	...
	16.5	16.8	0.19	0.25	0.14
	17.5	18.3	0.18	1.08	0.12
	18.5	19.6	0.23	1.60	0.07
60	15.5	15.7	0.20	ND	...
	16.5	17.5	0.15	1.17	0.05
	17.5	18.5	0.23	1.48	0.10
	18.5	21.1	0.08	3.68	0.19
90	15.5	15.9	0.09	0.63	0.07
	16.5	18.2	0.03	1.85	0.07
	17.5	19.7	0.11	2.87	0.08
	18.5	26.0	0.19	8.93	0.07

<sup>a</sup> Initial moisture content of all samples was within  $\pm 0.3\%$  of those indicated.

<sup>b</sup> Not detectable.

**Table 2.** Dry matter loss resulting from invasion by storage fungi on corn held 180 days at beginning moisture contents of 14.5–19.5%

Days stored	Moisture content (%)			Dry matter loss (%)	
	At start (av.)	At test period		Av.	SD
		Av.	SD		
30	14.5 <sup>a</sup>	14.6	0.11	ND <sup>b</sup>	...
	15.5	15.7	0.09	0.37	0.18
	16.5	17.1	0.31	0.82	0.37
	17.5	18.2	0.05	1.06	0.09
	18.5	19.4	0.07	1.29	0.11
	19.5	20.5	0.16	1.56	0.21
					$r^2 = 0.949^c$
60	14.5	14.6	0.24	ND	...
	15.5	15.7	0.22	0.18	0.35
	16.5	17.7	0.12	1.66	0.03
	17.5	18.8	0.25	2.03	0.29
	18.5	20.2	0.22	2.61	0.31
	19.5	21.3	0.24	3.58	0.94
					$r^2 = 0.978$
90	14.5	14.5	0.06	ND	...
	15.5	15.9	0.20	0.46	0.17
	16.5	17.6	0.20	1.76	0.18
	17.5	19.3	0.22	2.86	0.37
	18.5	20.9	0.23	3.69	0.37
	19.5	22.4	0.23	4.55	0.37
					$r^2 = 0.994$
120	14.5	14.4	0.10	ND	...
	15.5	15.9	0.18	0.55	0.16
	16.5	17.8	0.46	2.17	0.35
	17.5	19.9	0.50	3.69	0.68
	18.5	21.5	0.52	4.80	0.90
	19.5	22.7	0.34	5.37	0.37
					$r^2 = 0.992$
150	14.5	14.6	0.13	ND	...
	15.5	16.1	0.12	0.73	0.14
	16.5	18.4	0.29	2.88	0.28
	17.5	20.4	0.11	4.54	0.38
	18.5	22.4	3.52	5.80	0.74
	19.5	23.7	0.65	6.66	0.57
					$r^2 = 0.994$
180	14.5	14.6	0.09	0.24	0.28
	15.5	16.3	0.17	1.00	0.23
	16.5	18.7	0.41	3.30	0.39
	17.5	21.9	1.46	5.44	0.75
	18.5	23.0	0.04	6.78	0.35
	19.5	24.8	0.22	7.96	0.51
					$r^2 = 0.994$

<sup>a</sup> Initial moisture content of all samples was within  $\pm 0.3\%$  of those indicated.

<sup>b</sup> Not detectable.

<sup>c</sup> Regression analysis ( $r^2$  value) of the average moisture content at the test period on the average dry matter loss.

from lethal temperatures to which the corn has been exposed during drying.

**Moisture content.** Moisture content was determined on a wet weight basis by drying samples of 5–6 g at 103 C for 72 hr in a circulating air oven.

**Detection of fungi.** Fifty kernels were shaken for 1 min in 1.5% NaOCl and then were sectioned lengthwise through the germs in a sterile air hood. One set of halves was used for microscopic examination and the other set was again shaken for 1 min in 1.5% NaOCl. The individual halves were plated on T-6 agar (3), 25 per plate, with the cut side of the halves up. The plates were incubated at 25 C until the fungi grew out and could be identified. This permitted us to determine from what tissues the fungi grew.

**Storage test samples.** The corn to be used for each set of tests was well mixed before samples were removed from it. Four initial samples were taken for determination of moisture content and, at the same time, 100 or 200 g of the corn was placed in each of the requisite number of plastic bottles (Seedburo grain sample bottles) of approximately 300-g capacity. The bottles were closed immediately with screw caps equipped with plastic-coated paper liners.

The average moisture content of the four initial samples was used as the basis for adjusting the moisture content of the corn in each bottle. The bottle containing corn was put on the pan of an electronic balance sensitive to 0.01 g. Water was added first by pipette to bring the weight up to within less than 1 g of that desired, and then by means of a 1-ml syringe to get the exact weight desired. Immediately after the water had been added, and several times in the next several hours, each bottle was shaken in such a manner as to circulate and mix the corn thoroughly. Three replicates were made of each moisture content treatment.

**Storage.** In test 1, the bottles containing the corn at each moisture content were stored in a plastic box, along with a piece of moist sponge. The cover of the box was put on and taped shut. The box was then put into a polyethylene bag, along with another moistened sponge. The mouth of the bag was twisted shut, doubled over, and fastened with a rubber band. In test 2, the bottles at each moisture content were placed into a polyethylene bag. Then the bag with samples at 14.5 and 15.5% moisture content were put in a tightly closed plastic box above a saturated solution of NaCl to maintain a relative humidity of 75%. Those at 16.5 and 17.5% moisture content were put in a similar box above a saturated solution of  $(\text{NH}_4)_2\text{SO}_4$  to maintain a relative humidity of 80%. Those at 18.5 and 19.5% moisture content were put in a box above a saturated solution of KCl to maintain a relative humidity of 85%. All were stored at 25 C. At each sampling period,

the bottles were shaken well to mix the corn before samples were removed.

**Replicates and sampling.** In test 1, three replicate samples of 100 g each were adjusted to each moisture content (15.5, 16.5, 17.5, and 18.5%), stored at 25 C, and tested after 30, 60, and 90 days. In test 2, three samples of 200 g each were adjusted to moisture content (14.5, 15.5, 16.5, 17.5, 18.5, and 19.5%), stored at 25 C, and tested every 30 days for 180 days. At each test period, two portions were removed from each bottle for determination of moisture content. At several test periods, an additional 50 kernels were removed from each sample for culturing and microscopic examination of the split halves, as described above.

**Determining dry matter loss.** At the start of each series of tests, the dry matter of the corn in each bottle was the oven-dry weight of the corn. At the end of the first test period (30 days), each bottle plus corn was weighed, and the weight of the bottle was subtracted to give the net weight of the corn. Two samples were removed for moisture content determinations. The average moisture content of these two served to determine the dry matter of the corn in each bottle. This procedure was repeated at each test period. The total dry matter removed in previous tests was added to the dry matter remaining at any test period to give the total dry matter up to that time.

## RESULTS AND DISCUSSION

Total dry matter losses in the two tests are summarized in Tables 1 and 2. Because the conditions in the two tests were similar, the results will be discussed together.

Loss in dry matter was detectable in the samples with moisture content of 16.5% and above after storage for 30 days and increased with increasing moisture content and increasing time of storage.

In the samples at 15.5% moisture content, dry matter loss was first detected after 90 and 30 days in trial 1 and 2, respectively, and increased slowly but consistently thereafter in trial 2 (Tables 1 and 2). In the samples at 14.5% moisture content, dry matter loss was first detected after 180 days (Table 2). At that time, none of the germs in the sample were visibly discolored, but masses of conidia of the group species *Aspergillus glaucus* were detected by microscopic examination in 35% of the kernels. The same fungus grew from 74% of the kernel halves plated on T-6 agar.

In the samples at 15.5% moisture content stored for 180 days, the germs of 28% of the kernels were light to medium brown, masses of conidia or cleistothecia of the group species *A. glaucus* (6) were detected microscopically in 94% of the germs, and this fungus grew from 100% of the kernel halves plated on T-6 agar. Thorough invasion of the germ tissues preceded any discoloration of the germ tissues.

In the samples at 16.5% moisture content and above, heavy invasion by storage fungi was rapid and was followed by increasing development of dark brown to black germs typical of "damaged" kernels encountered in commerce. In all of the samples of both tests, after 90 days the only fungus detected up to and including the initial moisture content of 16.5% was the *A. glaucus* group. This same group species predominated in the samples with initial moisture content of 17.5 and 18.5%, but these samples also were gradually invaded by the group species *A. candidus*, *A. ochraceus*, and *A. flavus*. At 90 days and beyond, *Penicillium* also was recovered from the germ tissues of many of the kernel halves from samples with initial moisture contents of 16.5% and above. By that time, as shown in Tables 1 and 2, the moisture content of the samples had increased considerably,

presumably from the water of respiration produced by the fungi.

In these tests, by the time the dry matter loss had reached 0.5–1.0% the germs of most kernels had been moderately to heavily invaded by *A. glaucus*. It seems probable that corn in farm or commercial storage that had suffered a loss of that amount from invasion by storage fungi would be a poor risk for continued storage at any combination of moisture content and temperature that would permit continued growth of the fungi.

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