

SOME CHANGES IN NO. 2 CORN STORED TWO YEARS AT MOISTURE CONTENTS OF 14.5 AND 15.2% AND TEMPERATURES OF 12°, 20°, AND 25°C.¹

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ABSTRACT

Samples of No. 2 corn stored at 14.5% moisture content (m.c.) retained essentially their original condition, as judged by appearance, invasion by storage fungi, germination percentage, and final fat acidity value, when kept at 12°C. for 2 years, and changed only slightly in 1.5 years at 20°C. In the samples kept at 15.2% m.c., changes in the characteristics measured were slight in 6 months at 12°C. but appreciable after 2 years. Differences in condition of the samples kept at 14.5 and 15.2% m.c. and 20°C. were relatively large after 1 to 2 years. The samples stored at 25°C. deteriorated rapidly at both moisture contents.

Most of the work dealing with relation of fungi to the deterioration of stored corn has been done with seed-grade grain (1), although samples of No. 2 corn from commercial bins have been included in some of the reported tests (1,2,3). Moisture content of kiln-dried corn in equilibrium with constant relative humidities is lower than that of naturally dried corn (4), and supposedly, therefore, kiln-dried corn might be invaded and damaged by fungi at somewhat lower moisture contents and temperatures than seed-grade corn. That occasional shiploads of corn and other grains suffer serious deterioration during ocean transport seems to be common knowledge among grain exporters, importers, and insurance companies, although this information, understandably enough, is not published. The problem unquestionably is important, and probably complex. The work here reported aimed to follow the progress of some of the changes that occur in samples of kiln-dried corn of No. 2 grade stored for 2 years at moisture contents (m.c.) between 14.5 and 15.2% and at temperatures that might be expected to prevail during commercial storage and transport.

Materials and Methods

Corn. Approximately a bushel of No. 2 kiln-dried yellow corn was obtained from Cargill, Inc., from one of their bins in Minneapolis, in February 1964; presumably it was of the 1963 crop. The corn when received had 15.2% m.c., as determined by oven drying of several samples, and contained 4% damaged kernels. In our experience it represented a fairly average sample of No. 2 yellow corn.

Storage. Portions of about 200 g. of the corn were put in double polyethylene bags of 6-mil wall thickness, and the open ends of the bags were

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folded over and fastened securely. Part of the grain was spread out in a thin layer on a table in the laboratory and dried to 14.5% m.c., and subsamples of this were also put in polyethylene bags. Replicate bags were stored at 12°, 20°, and 25°C. Occasionally throughout the test period a recording thermometer was kept for a week in each incubator, and in most cases the temperature did not fluctuate more than $\pm 1.0^\circ\text{C}$.

Moisture content was determined by the two-stage air-oven method (5) on each of the samples at each test period. All moisture contents are given on a wet-weight basis.

Fat acidity value (FAV) was determined as described in *Cereal Laboratory Methods*, 02-01 (5).

Percentage of Seeds Invaded by Storage Fungi. At each test period, 50 kernels of each sample were shaken in 2% NaOCl for 1 min., rinsed in sterile distilled water, and cultured on weak tomato juice agar containing 10% NaCl. The dishes were incubated at 20°–25°C. until the percentage of kernels yielding fungi could be counted and the fungi identified, usually 7 to 10 days.

Results and Discussion

The major results are presented in Table I. For convenience the samples of different moisture contents will be referred to at their original figures of 14.5 and 15.2% respectively, although in those stored at 12° and at 20°C. there was some variation in moisture content from one test period to the next, and in those stored at 25°C. the moisture contents increased gradually; presumably this was due to metabolic water produced by the fungi.

The only fungi that invaded the samples during storage were members of the *Aspergillus glaucus* group, chiefly *A. restrictus* Smith and *A. repens* (Cda.) DeBary. The percentages of surface-disinfected kernels yielding these two species were recorded separately at each test period. However, in the samples stored 2 years at 15.2% m.c. and 12°C., 50 surface-disinfected kernels were split and cultured with the split surface up, on weak tomato juice agar containing 10% NaCl. After incubation for 3 days, part or all of the split surface of about 35% of the kernels was covered with a dense turf of sporophores of *A. restrictus*. From the whole surface-disinfected kernels of the same sample, only *A. repens* was cultured. The same was true of the kernels stored at 14.5% m.c. and 20°C. for 2 years. From this it seems that *A. restrictus* might have been detected, in culturing whole kernels, only when it was present alone, and that it might have been much more prevalent in some of the samples at some of the sampling periods than was indicated by culturing whole kernels. Because of this, the two major species of the *A. glaucus* group present are reported together as *A. glaucus*.

Samples Stored at 12°C. The corn stored at 12°C. and 14.5% m.c. decreased in germination percentage but otherwise changed very little in 2 years. The percentage of surface-disinfected kernels yielding storage fungi was lower after 2 years than after 1.5 years, but this may have been because the number of kernels cultured was not large enough. Percentage of brown

TABLE I
 INVASION BY STORAGE FUNGI, AND CHANGES IN EMBRYO COLOR,
 GERMINATION PERCENTAGE, AND FAT ACIDITY VALUES OF GRADE 2
 KILN-DRIED CORN STORED TWO YEARS (BEGINNING MOISTURE CONTENTS,
 14.5 AND 15.2%; 12°, 20°, AND 25°C.)

Temperature	Moisture Content	Surface-Disinfected Kernels Yielding <i>Aspergillus glaucus</i>	Embryos		Germination	Fat Acidity Value
			Brown	With Clumps of Sporo- phores in Cavities		
°C.	% wet wt.	%	%	%	%	
at start of test—		48	4	0	60	38
Stored 1/2 year						
12	14.6	62	6	0	52	
	15.5	68	6	0	42	
20	14.5	58	2	0	56	
	15.3	86	18	0	22	
25	15.1	86	14	...	8	
	15.5	100	44	...	2	
Stored 1 year						
12	14.4	48	6	3	45	
	15.2	100	3	4	36	
20	14.5	100	6	1	46	
	15.4	100	9	63	1	
25	15.2	100	41	41	0	
	15.9	100	88	12	0	
Stored 1½ years						
12	14.6	50	4	0	20	
	15.2	90	5	4	1	
20	14.5	100	0	0	21	
	15.2	100	13	40	0	
25	14.9	100	28	40	0	
	15.9	96	100	100	0	
Stored 2 years						
12	14.7	46	10	3	15	44.4
	15.3	96	11	19	0	55.5
20	14.5	100	10	12	0	48.3
	15.5	98	60	100	0	71.7
25	14.9	94	95	100	0	75.7
	16.0	96	100	100	0	95.5

(damaged) embryos did not increase in 1.5 years, but may have increased slightly in 2 years. No clumps of sporophores were visible on any of the kernels after 2 years, although a few clumps were visible in the germ cavities of the sectioned kernels. Germination percentage of the seeds decreased slowly, and after 2 years the FAV was only slightly above the range reported in No. 2 corn (6). Except for the more rapid decrease in germination percentage, changes in the characteristics tested also were minor in the samples stored at 12°C. and 15.2% m.c. in the first 1.5 years, and the grain at that time appeared sound and bright. After 2 years, however, 19% of the kernels had clumps of *A. glaucus* in the cavities of the embryos, and most of these kernels

had a narrow streak of sporophores of the same fungus on the outside of the pericarp covering the embryo, as shown in Fig. 1.

Samples Stored at 20°C. The difference between the samples stored at 14.5 and 15.2% m.c. was very marked after 1, 1.5, and 2 years, especially

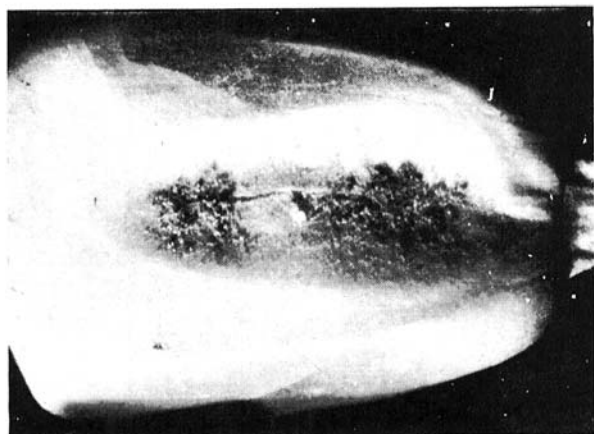


Fig. 1. Kernel of corn from sample stored 2 years at 12°C., with 15.2% moisture content. *Aspergillus* (probably *A. restrictus*) sporulating on the outside of pericarps covering the embryo.

in percentage of discolored embryos, in the percentage of embryos with clumps of sporophores in their cavities, and in brightness of the grain. The samples stored with 15.2% m.c. had, after 1.5 years, heavy clumps of sporophores of *A. glaucus* on the outside of and within many kernels, and had a musty odor, whereas those at 14.5% m.c. appeared bright and clean after 2 years, although the embryos of a few kernels were decayed. FAV's also were appreciably higher in the grain stored at 15.2% than in that at 14.5% m.c. At 20°C., a difference of less than 1% in moisture content made a great difference in the degree of invasion of the grain by fungi and in accompanying spoilage.

Samples Stored at 25°C. In the stored grain at both moisture contents many kernels were rather heavily overgrown by *A. glaucus* within 6 months, the germination percentage decreased rapidly, and percentage of discolored embryos increased rapidly. After 2 years nearly 100% of the kernels had dark and decayed embryos, and the cavities of nearly all embryos were filled with mycelium and sporophores. FAV's of these samples after storage for 2 years ranged from 76 to 95.

Effect of Different Temperatures. Great differences were apparent in the final condition of the samples stored at the same original moisture contents but at different temperatures. After 1.5 years at 12°C., for example, the percentage of brown and obviously fungus-invaded embryos was low in the

samples at 14.5 and 15.2% m.c., but at 25°C. 40% of those with 14.5% m.c. and 100% of those with 15.2% m.c. had been heavily invaded and damaged by fungi. The effect of low temperature in retarding the rate of spoilage of stored grains by fungi is, of course, well known (7), but the data presented here add weight to the contention that quality of No. 2 corn, even if the grain has a moisture content of 14.5–15.0%, may remain essentially unchanged for at least 1.5 years if the grain is kept constantly at 12°C. Even in the samples stored at 20°C. for 1.5 years there was no detectable change in the grain with a moisture content of 14.5%, and relatively little change in that with 15.2%. It has been maintained by some that spoilage occurs in grain during ship transport because the grain, when loaded into the ship, had some inherent (but unexplained) tendency to spoil, even if it is No. 2 grade and has between 14.5 and 15.0% m.c.; and that such spoilage is not a result of conditions to which the grain may have been exposed during transit or after arrival. While it is possible that some lots of No. 2 corn could be so heavily invaded by a storage fungi that they might be prone to spoil during an ocean voyage of a few weeks, even if maintained at 20°C. and 14.5–15.0% m.c., no specific case of this sort is known to me. Results from storage of a single lot of No. 2 corn, as reported here, can not be applied to all lots of No. 2 corn, but they do indicate that corn of this grade and with 14.5 to 15.0% moisture will not "go out of condition" or undergo visible or otherwise detectable spoilage within a year or more if kept at 12°C., and that even at 20°C. the deterioration processes are slow. Studies now are under way on many more samples of No. 2 corn taken as they were being loaded into ships at various U.S. ports for transport abroad.

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