TESTS OF CORN STORED FOUR YEARS IN A COMMERCIAL BIN[1]

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ABSTRACT

In September 1957, approximately 100,000 bushels of Grade No. 2 yellow corn were loaded into a flat-type bin at Mankato, Minnesota. When stored the corn was high in germination percentage, low in storage fungi, with zero germ damage and a moisture content from just below to just above 14%. Periodic aeration maintained a temperature between 40° and 50°F. throughout most of the bulk. Samples were taken every 6 months at depths of 3, 9, and 12 ft. in each of seven locations in the bin, and tested for moisture content, germination, number and kinds of fungi, and germ damage. Temperature fluctuated somewhat in the grain at a depth of 3 ft., with seasonal changes in temperature of the outside air, but remained constant at depths of 9 and 12 ft. Moisture content of the grain decreased slightly at a depth of 3 ft., remained constant at a depth of 9 ft., and increased slightly at a depth of 12 ft. Invasion by storage fungi increased considerably in the corn at a depth of 3 ft., and slightly at depths of 9 and 12 ft., and this was accompanied by reduction in germination percentage of the seed. Other than this the grain remained in essentially its original condition throughout the more than 4 years of storage. The laboratory tests served to indicate condition of the grain when samples were taken and to predict storability.

Evidence from work with small samples in the laboratory indicates that corn stored under conditions that permit little or no development of storage fungi may remain in good condition for years (5). Aeration systems have been developed that make it possible to maintain a fairly uniform temperature throughout a bin of grain (2,3,4,6) and so to minimize the transfer of moisture that often occurs in grain not so aerated (1,4). With our present knowledge of the relation of moisture content, temperature, and time to the growth of storage fungi, and with the aeration facilities available, it presumably should be possible to keep grain in good condition for years in commercial bins. The present study was undertaken to determine what changes might occur, in characters which we were able to measure, in originally sound corn stored for several years at moisture contents from just below to just above the lower limit required by storage fungi. It was also hoped that the tests might serve to indicate not only the condition of the corn when samples were taken, but also would predict storability, or danger of going out of condition, for 3 to 6 months in the future.

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Materials and Methods

The Bin from which samples were taken was located in Mankato, Minnesota. It was of so-called flat type, 160 ft. long, 50 ft. wide, and 14 ft. high at the eaves, with concrete floor, steel sides, and gable roof. Several thermocouple cables extended down through the grain, and temperatures were measured and recorded every week in summer and fall and every 2 weeks during winter and spring. Four exhaust fans, to draw air down through the grain, were spaced at equal distances at the bottom of one of the side walls; these were operated at intervals in fall and winter to provide a temperature of approximately 45°F. throughout the grain.

The Grain. The bin was loaded with 100,000 bu. of No. 2 yellow corn in the fall of 1957. According to the Handbook of Official Grain Standards of the U.S. (7), this means that it had no more than 15.5% moisture, no more than 3% cracked grain and foreign material or more than 5% total damage, and weighed at least 54 lb. per bu. Actually the corn when stored probably was close to No. 1 Grade, since when samples first were taken and tested in July, 1958, very few had more than 14% moisture, none had more than 14.5% moisture, there was zero germ damage, very few kernels had been invaded by storage fungi, and the germination of 21 samples averaged 93%.

Sampling. Samples were taken in June or July and again in December, January, or February, with a bucket probe of 250-g. capacity, at depths of 3, 9, and 12 ft. (during the last 2 years of storage, samples were taken also from a depth of 6 ft.) at each of seven locations in the bin, as indicated in Fig. 1. Each sample was placed immediately in a moisture-proof bag, taken to the laboratory the same day, and tested within a few days at most.

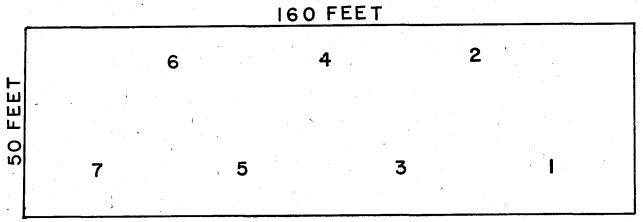

Fig. 1. Sample locations.

Moisture contents were determined by the 2-stage air-oven method, and are given on a wet-weight basis.

Germination. One hundred kernels were shaken 1 min. in 1% sodium hypochlorite, placed on moist paper towels, wrapped in waxed paper, and incubated at room temperature; the germinated kernels

were counted at intervals up to 7 days. If either a coleoptile or root developed, the seed was considered to have germinated.

Number of Kernels Invaded by Storage Fungi. Fifty to 100 kernels were shaken 1 min. in 1% sodium hypochlorite to kill surface contaminants, rinsed in sterile water, placed on malt agar containing 10% sodium chloride, and incubated 5 to 10 days at room temperature; the fungi that grew from them were identified and recorded.

Germ Color. Fifty to 100 kernels were cut lengthwise through the middle of the embryo and examined with the naked eye and with a stereoscopic microscope using ×10 magnification. The color was recorded as normal, ocher, or brown.

Results

The results of tests on samples taken at depths of 3, 9, and 12 ft. in seven locations in the bin after the corn had been stored for 10, 15, and 33 months are summarized in Table I.

TABLE I

CHARACTERISTICS OF CORN STORED 31 MONTHS IN A COMMERCIAL BIN
(Each figure is an average of seven samples)

TIME STORED	DEPTH	MOISTURE CONTENT		TEMPERATURE		GERMINATION		OCHER GERMS	SURFACE-DISINFECTED KERNELS YIELDING STORAGE FUNGI	
		Av.	Range	Av.	Range	Av.	Range		Av.	Range
mo.	*ft.*	%	%	°F.	°F.	%	%	%	%	%
10	3	14.2	13.9–14.7	62	59–67	94	77–98	2	8	0–20
	9	13.4	12.1–14.2	47	45–53	92	76–98	1	9	2–16
	12	13.2	12.0–14.2	45	42–49	92	85–98	1	5	0–12
15	3	13.3	13.1–13.8	43	41–45	80	48–94	2	47	6–58
	9	13.5	13.0–13.9	45	41–50	90	81–95	1	14	2–46
	12	13.4	13.0–14.1	47	44–52	91	79–99	1	17	1–32
33	3	13.4	13.1–13.8	63	57–73	62	17–72	1	90	78–100
	9	13.6	13.2–14.1	46	43–48	81	61–95	0	19	0–100[a]
	12	13.6	12.4–14.1	50	47–60	79	49–95	1	33	0–100

[a] One sample with 14.1% moisture content yielded storage fungi from 100% of the surface-disinfected kernels; four samples with moisture contents ranging from 13.2 to 13.5% yielded storage fungi from an average of 4% of the surface-disinfected kernels.

The moisture content of the grain 3 ft. deep decreased gradually with increasing time of storage, from an average of 14.2% at 10 months to 13.4% after 33 months. The average moisture content of the grain 9 ft. deep did not change, although the range in moisture content among samples taken from the seven locations decreased, owing to an increase of 1.2% in those portions of the grain that originally were of lowest moisture content. The average moisture content of the grain 12 ft. deep increased slightly, again because of an increase in moisture

content of those portions that originally were of lowest moisture content. After 10 months the moisture content among all samples ranged from 12.0 to 14.7%, and after 33 months from 12.4 to 14.1%. Had the grain not been aerated, it seems likely that the range in moisture content would have increased with time rather than decreased (4), and that the figure of average moisture content of the whole bulk might have given a poor indication of deterioration risk.

The temperature of the grain at a depth of 3 ft. increased in the summer and decreased in the winter, but the fluctuations were by no means as great as in the outside air. The temperatures at depths of 9 and 12 ft. remained relatively constant, mostly in the range of 40°–50°F.; indeed the temperatures in most sampling sites at depths of 9 and 12 ft. remained almost constant throughout the 33 months; the aeration system evidently fulfilled its function very well.

Germination percentage of the corn was high and uniform after storage for 10 months, while after 33 months it decreased to an average of 62% in the grain 3 ft. deep and to 81 and 79% in the grain 9 and 12 ft. deep. The decrease in germination percentage of the corn was preceded by, and presumably was at least partly a product of, invasion of the grain by storage fungi.

Surfaced-disinfected kernels yielding storage fungi increased from an average of 8% after 10 months, in the grain 3 ft. deep, to 90% after 33 months, whereas in the grain 9 and 12 ft. deep the increase was much less. Evidently a moisture content in corn between 13.0 and 14.1% was sufficient to permit gradual invasion by storage fungi, especially by *Aspergillus restrictus*. This invasion was more rapid where the temperature was periodically above 60°F., in the grain 3 ft. deep, than where the temperature was lower, as it was in the grain 9 and 12 ft. deep, but invasion did increase slowly where the temperature did not exceed 50°F. and the moisture content did not exceed 14.1%. Table II shows the association between increasing invasion by storage fungi, especially *A. restrictus*, and decreasing germination percentage of the seeds with increasing time of storage; the data in Table II are from one sampling site only, but the same relationship prevailed at several other sampling sites also.

A number of samples were taken at different times with a nine-compartment probe which obtained samples a few inches apart down to a depth of about 5 ft. Tests of these samples indicated that the grain from just beneath the surface down to a depth of 3 ft. was in about the same condition as that at a depth of 3 ft.; a few samples from at or near the surface had been invaded fairly extensively by storage fungi,

TABLE II

INFLUENCE OF INCREASING TIME OF STORAGE UPON INCREASING INFECTION BY STORAGE FUNGI AND DECREASING GERMINATION PERCENTAGE OF CORN FROM A DEPTH OF 3 FEET AT ONE SAMPLING SITE IN A COMMERCIAL BIN

Time Stored	Moisture Content	Temperature	Germination	Surface-Disinfected Kernels	
				Yielding *Aspergillus restrictus*	Yielding *Aspergillus repens*
mo.	%	°F.	%	%	%
10	13.9	63	98	0	0
15	13.2	44	92	30	28
31	13.2	45	84	82	22
33	13.1	73	72	68	0
39	13.6	35	67	66	24
52	13.3	37	64	78	22

and the embryos of a few of these kernels were medium to dark brown and probably would have been rated "damaged" by an inspector, but these involved only a very small amount of grain. Table III indicates the condition of the corn at a depth of 6 ft. after 33 to 52 months.

TABLE III

CHARACTERISTICS OF CORN TAKEN FROM A DEPTH OF 6 FEET IN A COMMERCIAL BIN AFTER STORAGE FOR 33 TO 52 MONTHS
(Each figure is an average of seven samples)

Time Stored	Moisture Content		Temperature		Germination		Ocher Germs	Surface-Disinfected Kernels Yielding Storage Fungi	
	Av.	Range	Av.	Range	Av.	Range		Av.	Range
mo.	%	%	°F.	°F.	%	%	%	%	%
33	13.8	13.4–14.5	50	47–54	81	52–91	0	10	0–28
39	13.6	13.4–13.9	41	40–43	78	48–90	2	14	0–62
52	13.5	13.1–13.8	43	.....	90	80–97	2	22	8–78

In general, this corn was in very good condition when stored, and remained in very good condition throughout the more than 4 years of observation. The moisture content ranged from just above to just below the minimum that would permit slow invasion by *A. restrictus*, and in the bulk of the grain both temperature and moisture content remained very uniform; there was no pronounced migration of moisture, with consequent accumulation in certain places, such as often occurs in bins of grain not subjected to artificial aeration. There was a considerable increase in the number of kernels invaded by *A. restrictus*, especially in the grain at a depth of 3 ft., and this was accompanied or followed by a decrease in germination percentage of the seed, but this invasion had not progressed to the point of germ damage or other changes that would result in reduction of grade. If grain were to be stored for considerably longer periods without invasion by stor-

age fungi and the accompanying deleterious changes, it probably would be desirable to have the moisture content below 13.0% or temperature below 40°F., although other considerations may make undesirable a temperature much below 40°–45°F.

There were no unexpected or sudden changes in condition of the grain, no "mysterious" development of germ damage such as some practical grain men still believe may occur in corn stored at moisture contents of 12.5–13.0%, and certainly none of this corn ever displayed the slightest "urge to heat and germinate in the spring." The periodic sampling appeared to give a reliable measure of the condition of the corn throughout the bin at the time when samples were taken, and also permitted an accurate evaluation of storability of the corn up to the next sampling period. All of the evidence indicates that if corn is sound and free of storage fungi when stored, of uniform moisture content no higher than 14.0–14.5%, and is cooled and kept at a uniform temperature of about 45°F., it will remain in excellent condition for at least 4 years, and probably longer.

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