Quality Changes of Hard Red Winter Wheat Stored in Concrete Silos

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Abstract

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Freshly harvested Hard Red Winter wheat (15,000-30,000 bushel lots) was stored with and without aeration in 20 concrete silos to determine changes in quality during storage after harvest. Differences in storability were related to initial moisture and temperature conditions. Aerated wheat cooled more rapidly and reached a lower temperature and a lower moisture content than wheat that was not aerated.

Tough wheat should be aerated within 3 days of harvest. Early aeration prevents development of fungi, heating of the grain, and reduces loss in germination and development of fat acidity. Odor and appearance are better for aerated wheat than for wheat stored without aeration.

Keywords: Wheat quality, concrete silos, aeration of wheat, turning of grain, wheat storage, deterioration of wheat

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Introduction

Warm, dry air is desirable to ripen wheat in the field and to establish a moisture content favorable for harvesting and storage. In the Central Plains, wheat is harvested when temperatures are 90° to 100° F. Unfortunately, these temperatures also are ideal, provided sufficient moisture exists, to develop microorganisms and to continue respiration of grain, which cause grain to heat during storage. In addition to temperature, the main factors that determine the condition of stored wheat are moisture content of the grain, storage time, extent of mold and insect contamination, and facilities to maintain the grain.

Weather is usually unfavorable somewhere in the harvest area every year, which causes elevator managers to experience grain deterioration losses. In 1962, some wheat-belt elevators received new wheat high in moisture. Much unpublished work was done to determine changes in quality of that crop—as well as the 1963 crop—stored with and without aeration in concrete silos. As there was no shortage of fuel then, grain too wet for storage could be dried with natural gas or propane heat. Now, there is a fuel shortage; much of the grain is stored in elevators where aeration or turning, or both, can be carried out. A summary of work done on the aeration of grain has been written by Burrell.[3]

This report discusses changes in quality of wheat stored with and without aeration in concrete silos. It also discusses continuing surpluses and the necessity to conserve energy, including that used to dry grain.

Storage and Aeration Facilities

Twenty concrete silos (bins) ranging in capacity from 15,000 to 30,000 bushels were used at country elevators in Kansas and Oklahoma. Bins 1A, 2A, 5A, 6A, 7A, and 8A were equipped with individual aeration

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[3] Burrell, N. J. Aeration. *In* Storage of cereal grains and their products. Ch. 12, p. 454. C. M. Christensen, ed. American Association of Cereal Chemists. St. Paul, Minn. 1974.

systems, each with a set of automatic fan controls and time recorder. The aeration systems provided an airflow of 1/20 ft^3/min of air per bushel. Efficient operation and control of these systems were established in an earlier study.[4]

Bins 3A, 4A, and 9A to 13A were aerated with a manifold type system powered by a 20-hp electric motor. Representative airflow rates for the manifold system ranged from 1/35 ft^3/min per bushel for the bin farthest from the fan to 1/30 ft^3/min per bushel for the bin closest to the fan. Each bin contained approximately 30,000 bushels of wheat.

Although elevator facilities and equipment varied, facilities were generally the same. Transfer and handling procedures differed depending on the superintendent and conditions of the wheat.

Sampling

Bins were normally filled at the rate of 4,000 to 6,000 bushels per hour. Samples were obtained from the grain stream on the gallery conveyor belt at 5-minute intervals by drawing an aluminum mixing bowl across the stream to obtain approximately 3 quarts of wheat. Care was taken to obtain a complete cross section of the flow. The sample was poured through a Boerner divider[5] three times, and seven-eighths of the original sample was returned to storage. This sampling procedure was continued until the bin was filled or turned. A composite sample was made of the one-eighth portions of the samples and submitted for official grading and analysis.

Testing Methods

Fat acidity

Fat acidity is an accepted index of changes occurring in stored grain, although it does not provide accurate information on the extent of damage.[6] It is expressed as the number of milligrams of potassium hydroxide (KOH) required to neutralize the free fatty acid extracted from 100 grams of wheat (dry basis). Fat acidity increases during storage because of one or more of the following factors: high moisture, long storage, high temperature during storage, and invasion by fungi. Fat acidity was determined by personnel of the Department of Grain Science, Kansas State University, Manhattan, using AACC method 02-01.[7]

[4] Kline, G. L., and Converse, H. H. Operating grain aeration systems in the hard winter wheat area. U.S. Department of Agriculture, Marketing Research Report No. 480, 22 pp. 1961.

[5] Trade names are used to provide specific information. Mention of a trade name does not constitute a warranty of the product by the U.S. Department of Agriculture nor an endorsement over other products not mentioned.

[6] Pomeranz, Y. Biochemical, functional, and nutritive changes during storage. *In* Storage of cereal grains and their products. Ch. 2, p. 56. C. M. Christensen, ed. American Association of Cereal Chemists, St. Paul, Minn. 1974.

Germination test

Seed viability is perhaps the best index of grain soundness.[6] Germination tests were made by the Kansas State Board of Agriculture Seed Laboratory in Topeka.

Moisture

Electronic moisture testers were used to measure moisture.

Temperature

The grain temperature was measured by thermocouples. Readings were made at 6-foot intervals through the depth of the grain.

Results

Grain storage in aerated bins

Six bins (lots 1A to 6A) were filled with harvested wheat from the 1962 crop and seven bins (lots 7A to 13A) with harvested wheat from the 1963 crop for aeration in storage. Storage data (grain temperature and moisture) and quality data (fat acidity and germination) are shown at the time of initial storage and at each transfer (table 1).

Probed samples at 1-, 2½-, and 4-foot depths below the grain surface revealed a 1 percent drying effect by cool air pulled through warm grain during summer and fall operations. Nearly uniform temperatures and moisture values were attained throughout the bin during the winter when the surface temperature of the grain was near or lower than that of the air drawn into the bin.

Test lots 3A, 4A, 12A and 13A were aerated many hours more than necessary and produced grain temperatures below 42° F. The additional operating cost to remove the heat and to accomplish an additional 10° of cooling was unnecessary because no advantage was shown by storing grain at temperatures below 42°. Lot 12A had an initial average temperature of 102°, which was reduced to 82° during the first 30 days by aeration.

The wheat in lot 5A received no aeration during the first month of storage. Later aeration reduced the average grain temperature to 75° F. Additional cooling completed during fall and winter reduced the average grain temperature to 42°. During the first year, the grain was given two double turns (to place it back in the same bin). The wheat was held in storage without aeration during the summer of 1963. Temperature readings showed strong evidence of heating, and composite sampling confirmed germ damage and quality deterioration. Grade was reduced and fat acidity increased to 35 mg KOH. This lot should have been

[7] American Association of Cereal Chemists. Approved Methods of the AACC. The Association, St. Paul, Minn. 1962.

TABLE 1.—*Storage and analytical data for commercial lots of wheat in aerated storage*

Year, lot number	Storage data				Quality data	
	Storage time	Operation	Grain temp.	Moisture	Fat acidity	Germination
	Months		*°F*	*Percent*	*Mg KOH*	*Percent*
1962:						
1A	0	Filled	86	12.4	11.4	96
	12	Turned	53	11.8	18.2	93
	15	Turned	70	11.6	25.0	95
2A	0	Filled	91	12.8	9.4	96
	12	Turned	54	11.8	21.8	95
	22	Turned	55	—	30.0	—
3A	0	Filled	88	13.3	13.5	95
	18	Turned	41	12.5	21.1	94
4A	0	Filled	88	12.8	16.2	94
	18	Turned	41	12.0	23.9	89
5A	0	Filled	94	14.6	15.8	93
	1	Turned twice	87	14.5	—	91
	5	Turned twice	42	14.1	21.9	42
	11	Turned	39	13.9	27.9	42
	16	Turned	70	13.9	35.2	32
6A	0	Filled	101	13.8	10.9	95
	1	Turned twice	80	13.1	—	96
	5	Turned	67	13.3	15.0	91
	10	Turned	42	13.0	17.5	92
	22	Turned	47	12.7	33.2	94
1963:						
7A	0	Filled	88	12.4	13.0	93
	10	Turned	44	11.4	26.3	86
8A	0	Filled	85	12.3	11.0	92
	10	Turned	37	11.3	24.8	84
9A	0	Filled	90	12.0	9.4	95
	10	Turned	44	11.3	20.6	87
10A	0	Filled	95	12.3	10.1	94
	10	Turned	45	11.6	22.4	90
11A	0	Filled	86	12.8	10.6	96
	10	Turned	44	11.9	23.6	91
12A	0	Filled	102	12.5	11.3	95
	9	Turned	35	11.6	23.5	80
13A	0	Filled	87	12.8	12.2	93
	9	Turned	35	12.0	24.5	82
Average at start of test			90.9	12.8	11.9	94.4
Average at end of test			46.8	12.0	25.7	85.5
Difference			—44.1	—0.8	+13.8	—8.9

aerated during the first month of storage to accomplish early temperature reduction and moisture equalization.

Lots 9A, 10A, and 11A represent approximately 1 day's harvest receipts. The bin containing lot 9A was the last to be filled and was the driest. The bin containing lot 11A was the first to be filled and was highest in moisture content. Summer and winter cooling reduced the grain temperature to about 45° F. During 10 months of storage, grain moisture content was reduced 0.9 percent; the grain was in good physical condition.

The grain in lot 6A contained 13.8 percent moisture, which was too high for safe storage at harvest temperatures of 100° F. During the first month of storage, the average grain temperature was reduced from 101° F to 80° F during 182 hours of fan operation. Aeration reduced the temperature to 67° F in November and to 34° F by January. Grain grading factors confirmed the physical appearance of the wheat, that it was in good condition 10 months after harvest, and that no great change in grain quality was found after an additional year's storage. Much of the favorable storage results from this test can be attributed to early reduction in grain temperature by aeration.

The average reduction in moisture content of 0.86 percent for wheat aerated in storage was slightly more than necessary. It is equivalent to the loss of 1 bushel of wheat for each 100 bushels in storage.

Grain storage in nonaerated bins

For wheat stored without aeration, the primary method of conditioning was repeated turning from bin to bin as a means of maintaining quality. Five bins (lots 1N to 5N) were filled with harvested wheat from the 1962 crop, and two bins (lots 6N to 7N) were filled with harvested wheat from the 1963 crop. Storage data (temperature and moisture) and quality data (fat acidity and germination) are shown at the times of initial storage and each transfer (table 2).

Six lots of wheat stored without aeration from harvest until the next spring resulted in only slight changes in fat acidity and germination. An exception was lot 3N, which had an initial moisture content too high (14.2 percent) for safe storage. Although the wheat was scheduled to remain in storage until loaded out in the spring of 1963, the temperature of the grain began to rise soon after harvest, so it was artificially dried. After 10 months' storage, fat acidity increased to 30 mg KOH and germination dropped to 19 percent. However, flour milled from this wheat after 11 months' storage still made a good loaf of bread.

Disregarding lot 3N, the average initial moisture content of the wheat in nonaerated storage was 12.67 percent. The final average moisture content was 12.47 percent or a loss of only 0.2 percent.

Comparison of qualities of grain stored with and without aeration

The average moisture contents at harvest for all aerated and non-

TABLE 2.—*Storage and analytical data for commercial lots of wheat stored without aeration*

Year, lot number	Storage data				Quality data	
	Storage time	Operation	Grain temp.	Moisture	Fat acidity	Germination
	Months		*°F*	*Percent*	*Mg KOH*	*Percent*
1962:						
1N	0	Filled	89	12.7	8.8	92
	⅔	Turned	—	12.7	14.2	96
	2	Turned, fumigated	—	12.6	—	—
	4	Turned, fumigated	—	12.4	—	—
	5	Turned	73	12.9	17.5	86
	7½	Turned	42	12.7	18.9	84
2N	0	Filled	88	12.5	11.8	92
	2½	Turned, fumigated	—	12.6	—	—
	8	Turned, fumigated	48	12.6	20.2	83
3N	0	Filled	91	[1]14.2	13.6	96
	2½	Mixed	—	14.4	—	—
	4½	Dried	72	—	22.2	13
	10½	Turned	70	[1]12.4	30.0	19
4N	0	Filled	90	12.9	14.8	92
	1⅔	Turned, fumigated	—	12.9	—	—
	5	Turned, fumigated	59	12.8	15.6	92
	9	Turned	—	12.9	—	—
	16	Turned	50	13.0	27.1	86
	20	Turned	49	12.8	32.0	78
5N	0	Filled	84	12.4	12.0	94
	3	Turned	—	11.3	—	—
	6	Turned	—	11.6	—	—
	9	Turned	55	11.6	13.4	93
	14	Turned	70	11.5	26.2	96
1963:						
6N	0	Filled	98	12.8	13.0	96
	1	Turned twice	93	12.8	—	—
	2⅓	Turned twice	94	12.6	22.1	97
	7	Turned twice	54	12.4	27.4	63
7N	0	Filled	89	12.7	14.2	94
	3	Turned	83	13.3	24.0	82
	8	Turned	60	13.1	28.7	59
	10	Turned	55	12.8	33.1	63
Average at start of test			89.9	12.7	12.6	93.7
Average at end of test			55.4	12.5	26.8	69.4
Difference			−34.5	−0.2	+14.2	−24.3

[1] Not used in average moisture because the wheat was artificially dried.

aerated samples were 12.8 and 12.7 percent. At the end of the tests, the average moisture content for the wheat in aerated storage was 12.0 percent, while that stored without aeration averaged 12.5 percent. Thus, aeration reduced the moisture content 0.6 percent more than storage without aeration.

Wheat from aerated lots had a better physical appearance and a more desirable aroma than wheat from nonaerated lots. Less fumigant was used on wheat stored with aeration, thus, partly offsetting loss from moisture evaporation.

The rate and amount of fat acidity increases varied with each test lot and with storage time. The acidity of aerated samples increased an average of 13.8 mg KOH. The acidity of samples stored without aeration increased an average of 14.2 but in less time than aerated samples.

Average reduction in grain germination was 8.9 percent for wheat in aerated storage and 24 percent for wheat stored without aeration.

Conclusions

Each of the test lots of wheat was of uniform high quality at the start of the storage tests. Differences in storability resulted mainly from high initial moisture and temperature.

Moving outside atmospheric air downward through stored grain at airflow rates of 1/40 to 1/20 ft^3/min per bushel was practical for controlling and providing uniform grain temperatures. Aerated test lots were cooled more rapidly and reached lower temperatures than those not aerated. The downward flow of air counteracts the natural tendency of convection currents from warm grain to move upward to cold surfaces so cool air is moved through warm grain in the lower part of the bin where it is warmed and expelled by the fan.[8]

Newly harvested grain should be transferred to a storage bin equipped for aeration within 2 days. Aeration should be started no later than 1 week after receipt of the grain and preferably within 3 days. Fan operation may be initiated the day after a bin is full, or even when it is half full, when conditions make it difficult to fill a bin. If the harvest season is interrupted by wet weather, partially filled bins may be aerated before the harvest is completed to obtain a higher airflow rate and faster cooling. Aeration of several half-full bins can remove much harvest heat and may help obtain more uniform grain moisture at various grain depths.

Early grain aeration after receipt is an important step to prevent the development of storage fungi and accompanying heating and mustiness of grain. Aeration of the wheat reduced the moisture content 0.8 percent and significantly reduced the loss in germination and development of fat acidity. The rate and amount of fat acidity increase varied with each test lot and storage time. The acidity of aerated samples increased an average of 13.8 mg KOH compared with an increase of 14.2 mg KOH in less time for nonaerated samples.

[8] Holman, L. E. Aeration of grain in commercial storages. U.S. Department of Agriculture, Marketing Research Report No. 178, 46 pp. 1960.

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