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Corn Dry-Milling: Stress Crack Formation in Tempering of Low-Moisture Corn, and Effect on Degerminator Performance[1]

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ABSTRACT

Corn of 15% moisture or less often fails to give the desired improvement when tempered under typical conditions used in the dry-milling process. Such corn develops stress cracks during tempering at room temperature. Corn kernels having stress cracks break readily and do not respond properly to degermination. In laboratory studies, stress crack formation varied with initial moisture content of the corn (yellow dent hybrid) and with moisture level, time, and temperature during tempering. In a 2-hr. temper with 8% moisture added, kernels having stress cracks increased from between 0 and 5% to more than 60% as the initial moisture content decreased from 20 to 13.5%. For periods beyond 1 hr. for tempering corn at 13.5% moisture, formation of stress cracks increased progressively as the moisture level of tempered corn increased from 15 to 24%. Stress crack formation was temperature-sensitive and was essentially eliminated when the corn was preheated and tempered at 125°F. In pilot-plant tests, yields were improved by preheating and then tempering the corn at 110°–125°F. before milling. Use of a steam-water mixture to simultaneously heat and temper the corn was almost as satisfactory as preheating and tempering the corn in separate steps.

The usual moisture level in the new crop of corn, when it is first marketed in the fall and obtained for processing by corn dry-millers, is about 22%. As the year progresses the moisture content decreases, and by the following September the level often is 13%. In some regions moisture content will be down to 11% or less. Corn from previous crop years usually has less than 14% moisture. Millers generally prefer not to process low-moisture corn because of its poor tempering response, which results in an imbalance in the mill streams, poorer degermination, and lower yields of large grits and oil. In our research on corn dry-milling, we have noted appreciable differences between the degerminator response of low-moisture corn and of corn containing 18% or more moisture.

In a previous report (1) in which tempering of 13%-moisture corn to levels of 18, 21, and 24% was described, variations in degerminator through-

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put were noted for which there was no complete explanation at the time. In that study, 3% increments in the temper level produced unequal increases in throughput (Fig. 1). Also, the yield of larger-sized grits (–4+6 mesh)

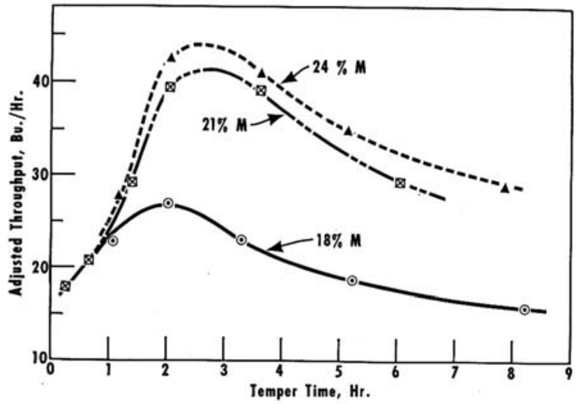


Fig. 1. Effect of temper time and temper moisture level on degerminator throughput in tempering low-moisture (13%) corn. Corn was tempered to moisture levels of 18, 21, and 24%. (M = moisture level in this figure and in succeeding ones.)

fell off with increasing temper time, and the ultimate yield decreased as the temper moisture level increased. Work reported herein on formation of stress cracks (i.e., endosperm fissures with the hull not broken) during tempering of low-moisture corn helps provide an explanation for these variations.

Reports have appeared in the literature on the development of stress cracks (variously referred to as endosperm cracks, fractures, crazed kernels, checking, and checked grain) during drying of corn (2) and rice (3), tempering of wheat (4), and removal or addition of moisture in popcorn (5). Millers are well aware of the possible presence of these cracks in incoming grain and of their effect on product yields.

MATERIALS AND METHODS

Materials

Much of the work was done with one lot of corn, a mixture of three varieties, grown on a farm in the Peoria area in 1963. This lot (No. 35) was field- and crib-dried as ear corn and shelled at a moisture content of about 13%. Because further drying during storage had reduced its moisture to 11.5 or 12%, it was sprayed with sufficient water to bring the moisture level up to 13.5% and held for several days before laboratory tests were begun. At the time stress crack tests were made, this corn was about 2 years old.

A second lot of corn (No. 38), a single variety from the 1965 crop, also locally grown, was processed to give three sublots varying in moisture content. One sublot represented 20%-moisture corn as received directly from a picker-sheller. For another sublot, freshly picked ear corn was dried in a seed-corn dryer with 95°F. air to 15% moisture level and then shelled.

The third sublot was further dried as ear corn, also with 95°F. air, to 13.4% before shelling. These drying steps required about 1 and 2 days, respectively. Some of the shelled, 13.4%-moisture corn was air-dried on a laboratory bench to 10%, and some of the 15% corn was conditioned at room temperature to levels of 16.5 and 17.4% by addition of tap water in daily increments of about 1%. Most of the stress crack tests on lot 38 were made 1 to 3 months after this corn had been harvested.

A third lot of corn (ENH) grown at Lafayette, Ind., in 1964, was dried as ear corn in a simple drying frame or box to approximately 15%. Ambient outdoor air was blown through the corn for a 6-week period during October-November 1964, except when drying conditions were unsatisfactory. When used in the stress crack tests, this corn was about 1 year old and contained 13.6% moisture.

All of the above lots of corn were cleaned in a grain cleaner to remove foreign material, cob pieces, broken kernels, and very small or very large kernels.

Tests were also made on a white popcorn and on a flour corn. The popcorn was purchased in a local grocery store and probably was about 1 year old. The flour corn (white Cuzco variety) had been grown in Peru, South America, during the 1941-42 season and stored at 40°F., 50% r.h. since then. Data on characteristics of the various lots are given in Table I.

TABLE I
CORN CHARACTERISTICS

Corn Identity	Crop Year	Variety	Oil	Protein	Ash (600°C.)	Crude Fiber	Weight/ 1,000 Kernels	Sieve Analysis[a] On 25/64 in.	On 21/64 in.	Thru 18/64 in.
			% d.b.	% d.b.	% d.b.	% d.b.	g.	%	%	%
Lot 35[b]	1963	DeKalb 633 Funk 671 Pioneer 354	4.1	9.2	1.1	2.0	326	3	58	6
Lot 38[b]	1965	Funk G-83	4.6	9.7			301	0	35	11
Lot ENH[b]	1964	Pfister SX-29	4.7	8.5	1.2	2.7	337	0	29	12
Popcorn	1965	?	4.2	13.6	1.4	2.8	113	0	0	100
Flour corn	1941–42	Cuzco (white)	4.8	7.9	1.3	2.1	1,180	100	0	0

[a] Sieves with round-hole perforations.
[b] Yellow dent hybrid, U.S. Grade No. 1.

Laboratory Tests

Stress crack formation was studied on a laboratory scale by tempering samples of corn and examining subsamples at specified time intervals for appearance of stress cracks. Dry corn was adjusted to the specified temperature for several hours by use of a constant-temperature bath before tempering was started. For tests made at 75°F., corn stored at room temperature was generally used without any further conditioning. Temper time started with the mixing of the calculated volume of water, adjusted to the desired temperature, with 300- to 400-g. quantities of corn in a 1-qt. bottle.

For some tests, 125 g. of corn and a smaller bottle were used. The bottle was immersed in a constant-temperature bath and periodically removed and shaken to get good distribution of the temper water. For some tests, the bottle was slowly rotated (19 r.p.m.) by a mechanical drive while immersed in the bath. For this test, a liner made of galvanized window-screen wire or of hardware cloth (¼-in. mesh) promoted mixing and prevented dampened kernels from clinging to the wetted glass surface.

Stress crack counts were made periodically on roughly 50-g. samples by the candling technique described by Thompson and Foster (2). Each kernel was inspected for stress cracks by a visual examination from one or more directions while the kernel rested, germ side down, on transparent plastic placed over a 1-in. hole in a $10 \times 10 \times 10$-in. box housing a 150-w. incandescent bulb. Approximately three-power magnification was used for better detection of the stress cracks. The percentage kernels free of stress cracks was calculated on a weight basis. Stress crack counts were made 0.5, 1, 2, 3, 4, and 6 hr. after tempering started, and a final count was made after about 24 hr., although occasionally this last count varied between 12 and 72 hr. afterward. It took from 15 to 25 min. to count the stress cracks in a 50-g. sample.

Milner and Shellenberger (6), using a radiographic technique on weathered wheat, were able to detect fissures greater than approximately 2% of the kernel diameter. They suggested that fissures smaller than any detectable by radiography presumably occur, even under very mild conditions of wetting or drying. However, Thompson and Foster (2), using X-rays, found no stress cracks in artificially dried corn not detected by candling. In the corn being tempered, stress cracks not only varied in number and length, but also undoubtedly varied in width. Some variability in the stress crack count is to be expected, as some cracks were readily seen by candling but others were detected only after close scrutiny. A preliminary examination showed that successive maximums in stress crack formation could occur as tempering proceeded. The first maximum was for the number of kernels with single fissures; this was followed by kernels with two or more. Finally, an increasing number of kernels had intersecting fissures, causing what might be called "crazed" kernels.

The effect of the initial moisture content of corn was investigated over a range of 10–20%. For these tests, each sample was tempered by the addition of 11 cc. of tap water per 100 g. corn, d.b. This amount is equivalent to an 8–9% moisture addition.

To show the effect of temper moisture level, corn with an initial moisture content of 13.5% was tempered at 75°F. to levels of 15, 16, 18, 21, and 24%. Tests were made to learn the effect of temperature over the range of 35°–125°F. for corn with 13–14% moisture, tempered to a level of 21–22%.

Extent of stress crack formation was also noted in white popcorn and in flour corn, a sample of each being tempered at 75°F. from 13 or 13.5% to 21% moisture. These two types differ widely in proportion of horny endosperm in the kernel. Most of the endosperm in popcorn is horny, whereas that of Cuzco flour corn is not but its kernels are very large.

Pilot-Plant Equipment and Tests

Degerminator tests were made with a No. 0 Beall degerminator rated by the manufacturer at 10–20 bu./hr. when driven by a 10-hp. motor at 750 r.p.m. In commercial practice a larger motor is often used to obtain increased throughput; in our case we used a 15-hp. motor. The degerminator had a "blunt" studded rotor which was driven at 840 r.p.m. in the 50% closed position. The cage of the degerminator was fitted with three screens having 14/64-in. round-hole perforations and two plates in the upper right-hand quadrant as viewed from the tailings end.

The cold-tempering was done in a 16-bu., double-cone grain blender. For preheating the corn and for the dry-hot tempering test, this blender was fitted with electric strip heaters and a manually operated on-off timer for temperature control. The transfer elevator and conveyors were steam-traced and insulated to minimize cooling of the corn. In the wet-hot temper the grain blender was preheated sufficiently with the strip heaters to minimize heat losses before steam, followed by hot water, was mixed with the corn.

Degerminator response was determined for 13% moisture corn tempered to a 21% level in three ways: 1) corn and water mixed at room temperature, 2) corn and water preheated separately to approximately 122°F. (dry-hot temper), and 3) corn mixed first with open steam and then with hot water to heat and temper simultaneously at about 110°F. (wet-hot temper). For some of the hot-tempering tests, about 2% additional moisture (as cold tap water) was added as a second temper about 20 min. before degermination to provide the necessary surface moisture for good hull release.

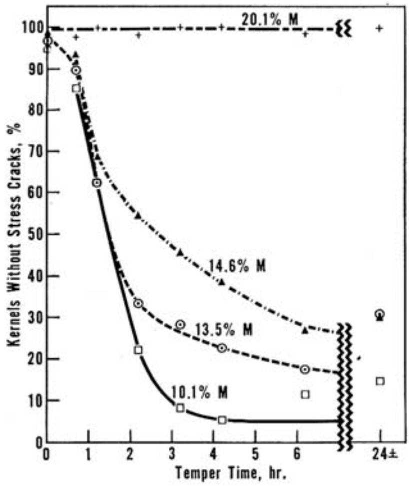
The degerminator products were sampled, air-dried, and then fractionated in the laboratory by a procedure employing screening for particle size separation, aspiration for removal of hull fragments, and flotation for removal of germ fragments to give data on yield and oil content of the various fractions. Other details about the equipment and procedure for the tempering and degerminating steps and for fractionation and analysis of the products have been described previously (1,7).

RESULTS

Influence of Initial Moisture Content

For this series, stress crack counts were made on samples of corn, ranging from 10 to 20% in moisture content, that had been tempered at 75°F. by addition of sufficient tap water to raise the moisture level by 8–9%. Tempering the 20.1% corn produced essentially no stress cracks in a 6-hr. temper. For 14.6% corn, almost 50% of the kernels developed stress cracks in 2 hr. The extent and also, to some degree, the rate of stress crack formation showed further increases as initial moisture of the corn was lowered to 13.5 and again to 10.1% (Fig. 2).

Extensive development of stress cracks in the 14.6% corn was largely eliminated after it had been reconditioned to 16.5% moisture level (Fig. 3). Reconditioning or pretempering the corn to 17.4% resulted in still fewer stress cracks developing. This finding is at least a partial explanation why pretempering 13% corn even to a 15.5% level reduced degerminator throughput and increased the yield of large grits, as reported previously (8).



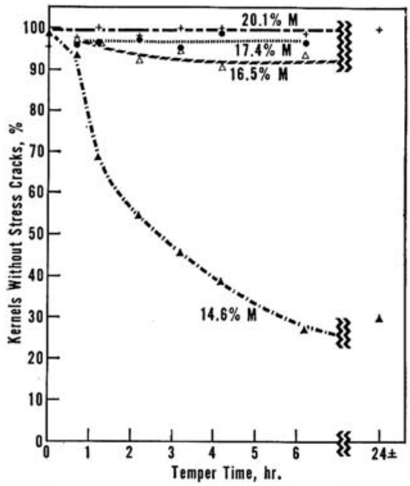


Fig. 2 (left). Effect of initial moisture content of corn on formation of stress cracks during tempering. Corn (lot 38) was tempered at 75°F. by addition of 11 cc. water/100 g. dry matter.

Fig. 3 (right). Pretempering 14.6% corn to higher moisture levels reduces formation of stress cracks. Corn (lot 38) was tempered at 75°F. by addition of 11 cc. water/100 g. dry matter.

In a repetition of certain tests several months after the first set, the curve for corn of 13.5% initial moisture content was essentially like that obtained previously. With the pretempered samples, the same general pattern was again produced, but the values were lower. For corn pretempered to 16.4% in 1% increments from 13.5% initially rather than 14.4% as in the first set, the curve for percentage of tempered kernels without stress cracks leveled off at approximately 83% as compared with 92% earlier. For corn pretempered to 17.1%, the curve leveled off at about 88% rather than 97%. These differences indicate that such factors as extent of drying and age of corn also influence the development of stress cracks.

Increasing Temper Levels for 13% Corn

The effect on stress crack formation of tempering 13.4% corn at 75°F. to moisture levels of 15, 16, 18, 21, and 24% is shown in Fig. 4. Essentially, no stress cracks developed with the 15% temper, but they gradually increased as temper levels were progressively raised up to 21%. With the 21% temper, approximately 60% of the kernels had stress cracks after a 2-hr. temper. The 24% level showed a further increase in stress crack formation, but only for temper times beyond 2.5 hr.

These data help explain the differences in degerminator throughput that occurred in earlier work when 13% corn was tempered to moisture levels of 18, 21, and 24% (Fig. 1). The maximums in throughput at these levels exhibited differences that, in general, agree with maximums observed in stress crack formation.

Effect of Temperature

Temperature had a varying effect upon development of endosperm

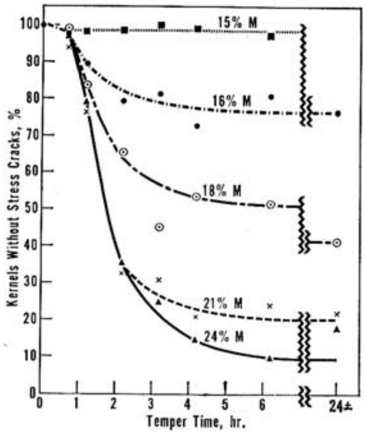
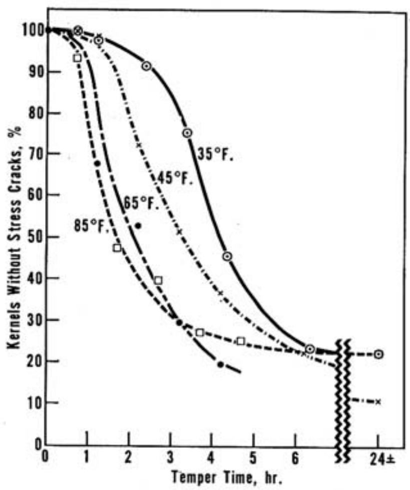


Fig. 4. Effect of temper moisture level on formation of stress cracks in tempering of 13.4% moisture corn. Corn (lot 35) was tempered at 75°F.

fissures. At 35°F., stress cracks developed more slowly, but eventually to about the maximum extent for any temperature used. The initial rate increased to a maximum at about 85°F., and at this temperature a limitation on the ultimate extent of stress crack formation first appeared. Fewer stress cracks developed as the temperature rose above 85°F., and at 125°F. no endosperm fissures were detected. At this higher temperature the kernel apparently could adjust sufficiently rapidly to internal stresses, so that fissures were prevented from developing (Figs. 5, 6).



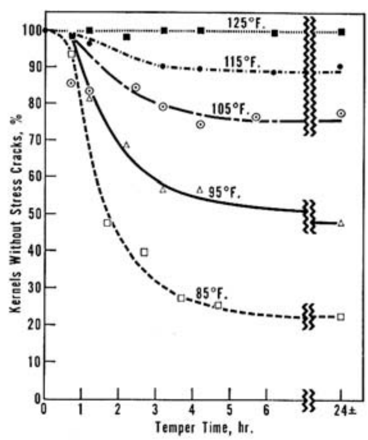
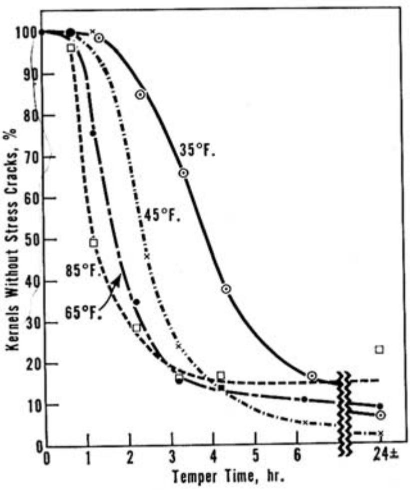


Fig. 5 (left). Initial rate of formation of stress cracks increased between 35° and 85°F. in tempering corn. Corn (lot 35) was tempered from 13 to 21% moisture level.

Fig. 6 (right). Both rate and extent of formation of stress cracks decreased as temper temperature was raised from 85° to 125°F. Corn (lot 35) was tempered from 13 to 21%.

Lot ENH corn exhibited a similar pattern. At 35°F., curves for the two lots are comparable. Appreciable differences between comparable curves for the two lots are noted as the temperature was increased, but again at 125°F. no stress cracks were detected (Figs. 7, 8). Differences at the inter-



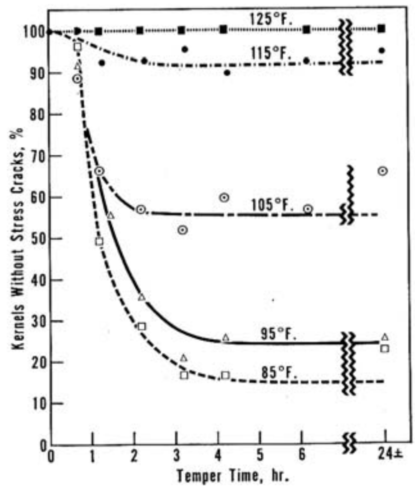


Fig. 7 (left). Effect of temperature in range of 35° to 85°F. on development of stress cracks in tempering corn. Corn (lot ENH) was tempered from 14 to 22%.

Fig. 8 (right). Formation of stress cracks decreased as temperature for tempering corn increased from 85° to 125°F. Corn (lot ENH) was tempered from 14 to 22% moisture.

mediate temperatures possibly were due to the different varieties, a slightly higher initial moisture content, and various historical factors such as age, agronomic conditions, and drying conditions.

A sample of corn first freed of hull by hand-peeling after brief wetting (about 2 min.) and then equilibrated to 13.3% moisture content over a saturated sodium chromate solution was tempered to 20+% at 75°F. After a 6-hr. temper, more than 95% of the kernels exhibited stress cracks. Without the hull and with all the endosperm exposed, temper water was absorbed faster; more of the kernels had stress cracks. Consequently, any differential in expansion rate between hull and endosperm during tempering in the range of 35° to 100+°F. does not appear to be the main cause of stress cracks.

Popcorn and Flour Corn

No endosperm fissures were detected from tempering the flour corn. When the popcorn was tempered, fissures developed that were comparable to, but not in excess of, those for dent corn.

Pilot-Plant Tests

Reduction in stress crack formation by heating low-moisture corn during tempering was verified in pilot-plant tests. When both corn and temper water were preheated to about 122°F. before they were mixed for the tempering step, formation of stress cracks was negligible. When steam followed by hot water was used to heat (to about 110°F.) and temper the corn simultaneously, about 90% of the kernels were free of stress cracks. When the corn was tempered at 75°F., only 52% of the kernels showed no stress cracks. Degerminator throughput increased and yield of –4+6 grits decreased as the percentage of kernels with stress cracks increased (Table II).

TABLE II

EFFECT OF HOT-TEMPERING LOW-MOISTURE CORN ON DEGERMINATOR PERFORMANCE

TYPE OF TEMPER	COLD CONVENTIONAL	PREHEATED (DRY HOT)	STEAM/HOT WATER (WET HOT)
Tempered corn moisture (%): 1st temper	21	21	21
2nd temper[a]	....	23	23
Temper times (hr.): 1st temper	1.2	0.7[b]	0.8
2nd temper	....	0.3	0.3
Corn temperatures (°F.): max. in tempering	76	123	111[c]
to degerminator	74	104	106
Tempered kernels without stress cracks (%)[d]	52	96	90
Degerminator throughput (bu./hr.)[e]	41	16	21
Recycle yield (% of gross product)	2	1	1
Yields (% of net product):[f] –3½ + 25 grits	62	61	61
–3½ + 4 grits	4	4	5
–4 + 6 grits	34	41	39
–6 + 8 grits	18	11	12
–25 + pan fines	15	17	16
germ	16	13	15
hull	7	8	8
Oil contents (% d.b.): –3½ + 25 grits	0.7	0.5	0.6
–3½ + 4 grits	0.9	0.4	0.4
–4 + 6 grits	0.7	0.4	0.5
–6 + 8 grits	0.7	0.6	0.6
–8 + 16 grits	0.9	1.0	0.9
–16 + 25 grits	1.7	1.8	2.0
–25 + pan fines	6.1	5.4	5.8
germ	19.3	20.0	18.4
hull	2.5	3.0	2.8
Recoverable oil (lb./bu.)[g]	1.1	1.1	1.1
–4 + 6 Grits with attached hulls (%)	1	1	1

[a] Second temper was used with hot-tempering only to provide sufficient surface moisture at time of degermination for good hull removal. Cold water was used for 2nd temper.

[b] Corn preheated from 54° to 122°F. in about 1 hr.

[c] Initial corn temperature was 62°F. Corn reached 111°F. about 15 min. after hot-tempering started.

[d] Untempered corn had 99% of kernels free of stress cracks.

[e] Corrected to 15% moisture content and recycle level of 2% for tests with a 2nd temper; 5% for test with 1st temper only.

[f] Gross product less +3½ mesh recycle.

[g] Calculated yield based on weight of germ fraction recovered by flotation and its moisture and oil contents; and assuming oil cake contains 5% residual oil on dry basis.

With hot-tempering, better degermination resulted for grits in the –3½+8-mesh range. Other differences in yield and product characteristics were not significant, on the basis of single tests. Although these data are from single tests only, the reduction in throughput and the increase in yield of large grits as a result of hot-tempering agree with results noted previously.

Data for a series of tests made with temper times of 0.5 to 6 hr. on corn given either a cold or a hot temper are plotted in Fig. 9 and recorded in Table III. For hot-tempering, a steam-water mixture (wet hot) was used,

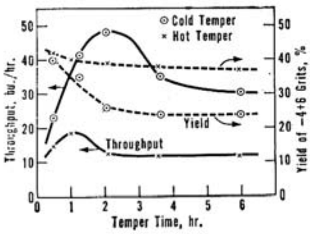


Fig. 9. Effect of hot- and cold-tempering of low-moisture corn on degerminator throughput and on yield of –4+6 grits in pilot-plant tests.

TABLE III

HOT VS. COLD TEMPERING FOR EXTENDED TEMPER TIMES

TYPE OF TEMPER[a]	COLD					HOT				
Temper time (hr.)	0.5	1.2	2.0	3.6	6.0	0.5	1.0	2.1	3.6	6.0
Tempered kernels without stress cracks (%)	70	52	48	56	52	99	99	100	100	99
Throughput (bu./hr.)	23	41	47	35	30	15	19	13	12	12
Recycle yield (% g.p.)	2	2	8	3	5	3	3	2	3	2
Yields (% n.p.):										
–3½ + 16 Grits	59	61	59	58	60	61	61	60	61	60
–3½ + 4 Grits	5	4	3	1	2	6	7	5	5	5
–4 + 6 Grits	40	35	26	24	24	43	40	39	39	37
–6 + 8 Grits	11	17	23	24	25	9	10	11	13	14
–8 + 16 Grits	3	5	7	9	9	3	4	5	4	4
–16 + Pan fines	21	17	17	18	18	19	19	21	20	22
Germ fraction	13	16	18	17	16	13	13	15	14	13
Yield of hull fraction (% g.p.)	7	7	6	7	6	7	7	4	5	5
Oil contents (% d.b.):										
–3½ + 16 Grits	0.5	0.7	0.8	0.7	0.7	0.5	0.6	0.6	0.7	0.7
–3½ + 4 Grits	0.5	0.9	1.5	0.9	1.1	0.4	0.5	0.6	0.6	0.6
–4 + 6 Grits	0.4	0.7	0.7	0.6	0.6	0.5	0.6	0.5	0.6	0.7
–6 + 8 Grits	0.6	0.7	0.7	0.7	0.7	0.6	0.7	0.6	0.8	0.8
–8 + 16 Grits	1.0	0.9	0.8	0.6	0.9	1.2	1.2	1.1	1.0	1.3
–16 + Pan fines	6.9	5.6	3.6	4.2	4.3	5.9	5.7	4.3	4.1	3.8
Germ fraction	18.3	19.3	15.7	17.8	17.5	20.6	19.7	20.5	19.8	20.9
Hull fraction	3.9	2.5	2.1	2.7	3.2	3.9	....	....	4.4	3.6
Recoverable oil (lb./net bu.)	1.0	1.1	1.1	1.1	1.1	1.1	1.0	1.1	1.2	1.2
–4 + 6 Grits with attached hulls (%)	1	1	23	55	83	5	33	95	98	99

[a]Lot 35 corn used; 12–13% initial moisture content.

since this combination is more practical than preheating dry corn (dry hot). Again with hot-tempering, fewer stress cracks, a lower degerminator throughput, and a higher yield of –3½ +4 and –4+6 grits resulted for temper times of 1 hr. and more. Since the yield of –3½ +16 grits remained essentially constant, the yield of –6+8 and –8+16 grits decreased. While hot-tempering produced a smaller germ fraction of higher oil content, the amount of recoverable oil remained the same.[2] There was some indication of increased fines production in hot-tempering. This effect is consistent with the cleaner germ fraction (8). Although the oil analyses showed more variability than usual, degermination of the larger grits was better during the first 2 hr. of hot-tempering. The attached hull count for the –4+6 grits was higher with hot-tempering than with cold-tempering. This is probably due to the presence of less surface moisture on the hot-tempered corn during degermination.

DISCUSSION

The apparent lack of stress cracks in the flour corn after tempering suggests that stress cracks tend to originate in the horny endosperm. According to one theory expressed by Duvick (10), cells in the horny endosperm are sufficiently compressed so that air is largely eliminated from intercellular interstices, and this makes the horny endosperm translucent. In contrast, floury endosperm is opaque because of the refraction at interfaces surrounding the minute air spaces. Voids created by these air spaces possibly serve as expansion zones which largely relieve strains developing within the floury endosperm as the temper water is being absorbed. This hypothesis could explain why stress cracks did not develop in the flour corn. In a typical hybrid dent corn, the horny endosperm forms an incomplete shell, with floury endosperm and germ filling the core. More horny than floury endosperm comes in contact with the hull; thus, a greater portion of the temper moisture first contacts the horny rather than the floury endosperm. This factor could also create more stress in the horny endosperm.

From his research on the viscoelastic properties of corn kernels, White (11) reported that during sorption of added moisture in 13% corn, swelling stresses in the endosperm developed forces estimated at several thousand lb. per sq. in. These forces diminish rapidly as initial moisture content increases.

No positive explanation is known as to why formation of stress cracks should be largely prevented when heat, applied in the proper manner, is added in the tempering step. Apparently, the kernel becomes sufficiently plastic at about 125°F. to relieve the stresses without crack formation. However, this temperature appears low for development of plasticity in the usual sense. Bemis and Huelsen (5) reported that rehydration of overdried popcorn by means of blanching in live steam produced less fracturing than by storage under controlled air humidities or by direct addition of water. The popcorn was blanched for periods of about 1 to 6 min. by steam at 208°F.

With the conventional temper, the degerminator throughput exceeded the manufacturer's rating by at least one-third after an adjustment for use

[2] Yield and oil content of the recovered germ fraction (11 to 18% yield and 16 to 21% oil content in Tables II and III) differ from values reported in the literature (9) for hand-dissected fractions (10 to 13% yield and 31 to 39% oil content) because of accompanying endosperm fragments. Specific gravity of the flotation solution used for separation of germ from grits has been deliberately set to give a reasonably pure grits fraction (with removal of a number of grits having attached germ), at some expense to purity of the germ fraction. Recoverable oil values fall considerably below a theoretically obtainable value of 1.8 lb./bu. based on hand-dissected fractions (9). [(56 lb./bu.) (0.85, assuming 15% moisture in corn) (0.048, oil content of corn, d.b.) (0.837, proportion of total oil in kernel found in germ) minus (56) (0.85) (0.119, weight fraction of kernel represented by germ) (0.345, oil content of germ, d.b.) (0.05/0.95, correction for oil left in press cake) equals 1.9 minus 0.1 or 1.8 lb./bu.] The attainable oil yield is lowered because of degerminator attrition, which abrades the germ particles to such an extent that many are not retained on a 16-mesh sieve and thus appear in the degerminator fines fraction. The interrelationship between the germ and degerminator fines fractions has been discussed previously (8).

of an oversized motor. Because approximately half the kernels in the tempered corn had visible stress cracks, less energy was needed to break open the kernels. Consequently, a higher feed rate was required to maintain a fixed motor load. The yield of –4+6 grits was lower because of the detrimental effect of these stress cracks. Also, the large grits were not subjected to sufficient abrasion within the degerminator to remove, to a normal degree, the adhering germ fragments and possibly some of the aleurone layer. As a result, the oil content was higher for the –3½+8 grits, particularly those of the –3½+4 and –4+6 size.

Corn dry-millers have been using hot-tempering for a number of years, so this approach is not new. While some millers use it on occasion, others use it all the time. These data should help the miller to understand better when hot-tempering should be included and what advantages and disadvantages he might expect. Various means are being employed to heat and temper the corn in mill operations. It should be emphasized that in order to minimize stress crack formation by use of heat, the corn must be heated during or before the tempering step so that temperature of the corn is sufficiently high to alleviate the developing stresses before they can produce fissures in the endosperm.

CONCLUSIONS

Factors that control the formation of stress cracks in corn during the tempering step include initial moisture content of the corn, temper moisture level, temper time, and temperature of the corn. Conditions used to dry the corn, and possibly other factors such as variety and cultural practices, have some influence. The critical level for initial moisture content of the corn was in the approximate range of 15–16%. At moisture contents below this percentage, stress cracks developed during tempering at room temperature, and extent of stress crack formation increased as the initial moisture content fell off and as the temper moisture level was raised. The highest rate of stress crack formation usually occurred between 0.5 and 2 hr. of tempering and at 65°–85°F. At lower temperatures the rate was slower, but stress cracks developed to the maximum. At higher temperatures both the rate and extent of stress crack formation fell off, and essentially no stress cracks were formed at 125°F. In comparison with cold-tempering, hot-tempering of low-moisture corn increases the yield of large grits, reduces their oil content, and lowers degerminator throughput.

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