Corn Dry-Milling: Cold-Tempering and Degermination of Corn of Various Initial Moisture Contents[1]

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ABSTRACT

Shelled corn initially containing 21, 17, and 13% moisture was cold-tempered (i.e., without heat) and degerminated on a pilot-plant scale to determine the variation in dry-milling response. Corn for the two lower moisture levels had been dried on the ear under extremely mild conditions typically used for seed corn. For the tempering step, low, moderate, and high addition levels were used for the first-temper water; temper times were 0.5 to 4 hr. Upon degermination of tempered corn from each of the three lots, 21%-moisture corn gave products whose yields and oil contents were excellent. Over-all, this lot had the highest yield of flaking grits with lowest oil content, along with more recoverable oil, and was the most consistent in its milling response. The 17%-moisture corn gave slightly poorer results and the 13%-moisture corn, appreciably poorer. Blending corn of various moisture contents aggravates the dry-miller's problems.

Temper time and temper moisture level have considerable effect on the degerminator response of 13%-moisture corn (1). Exploratory tests on corn of 18 to 20% moisture content indicated that its response to degermination after tempering differed appreciably from that of 13% corn. Consequently, tests were made to learn what effect initial moisture content has upon dry-milling characteristics of corn and to determine what residence time and level of moisture addition might be most suitable for cold-tempering corn as its moisture content changes.

MATERIALS AND METHODS

Corn

The yellow dent hybrid corn used was a double cross, Funk's G-83, hybrid, grown in 1965 on a farm in the Peoria area with moderate-to-heavy usage of fertilizer. Three lots of shelled corn contained initial moisture contents of about 21, 17 and 13%. Ear corn picked and shelled in the field produced the 21% moisture lot. The 17%-moisture lot was dried as ear corn from 21 to 15% in a seed-corn dryer for 23 hr. with 95°F. air—conditions that gave minimum stress-crack formation and high viability; then cooled and shelled. About 2 weeks before milling, this lot was pretempered to 17% moisture by addition of tap water in increments of approximately 1 percentage point at 1-day intervals. The 13% lot was dried for 49 hr., cooled, and shelled. Each lot was put through a grain cleaner fitted with 25/64- and 17½/64-in. round-hole-perforated (r.h.p.) sieves to remove oversized and undersized kernels and then blended before use.

The 21% lot was milled 3 to 5 months after harvest, and the 17% lot, 5 to 9 months. Both were stored under refrigeration or outdoors during cold weather until used. The 13% lot was milled 9 to 15 months after harvest. Except for moisture

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content, all lots were U.S. Grade No. 1. The corn contained (% d.b.): oil, 4.6; crude fiber, 2.3; ash (600°C.), 1.3; and protein, 9.7. The 13% lot tested 92% germination, 60.0 lb. per bu., graded as "medium" according to the floaters test (2), and had 1, 35, 50, 71, and 97% (weight) of kernels retained on 24-, 21-, 20-, 19-, and 17/64-in. r.h.p. sieves.

Experimental Equipment, Conditions, and Procedures

Corn held in cold storage was allowed to equilibrate with room temperature before tempering. A 30-bu. working-capacity, twin-shell blender equipped with spray nozzles was used for the first-temper step. Three first-temper moisture levels were used for each lot of corn. The desired moisture levels are tabulated below (temper times 0.5, 1, 2, 3 hr.):

Initial Moisture Content of Corn %	*First Temper*	
	Moisture Level %	
21	26, 24, 22	
17	25, 22, 19	0.5, 1, 2, 3, 4 hr.
13	24, 20.5, 17	

Because the first-temper moisture levels vary with initial moisture content of the corn, the three levels used have been designated arbitrarily as high, moderate, and low.

A second or dehulling temper, when used, consisted of spraying additional cold tap water (1.5 to 3.0%) onto the grain during transfer through two screw conveyors; this was followed by a 10- to 20-min. holding time. Degerminator tests were also made on untempered corn from the 17 and 13% lots.

Tempered corn was milled in a No. 0 Beall degerminator. Degerminator conditions were: three screens (0.135-in. thick, openings 18/64 in. in diameter), two grinding plates, "blunt" studded rotor, corrugated retarder ring, 850-r.p.m. rotor speed, rotor in 50% closed position, V-notch slide gate in upper half of degerminator end plate (3); 15-h.p. motor loaded to draw approximately 13.2 kw. (17.7 h.p.); and a 5% recycle level when corn was given only a first temper, or 2% for first and dehulling tempers.

Degerminator product streams were combined, sampled, air-dried, sized through standard sieves, aspirated for hull removal, and floated for separation of germ. Further details about the equipment, experimental procedure, and fractionation and analysis of the degerminator products have been published previously (1,4,5). Two changes were made, however: The Butt extraction procedure employing petroleum ether was used to determine oil content of germ and degerminator fines fractions and whole corn, but it was replaced by a gas-liquid chromatographic method for analyzing grit and hull fractions (6). For moisture content of whole corn samples, 200 g. or more was dried for 72 hr. in a forced-draft oven held at 103°C.

Stress cracks in whole corn were counted by a candling procedure (7). Kernels (approximately 50-g. samples) were inspected, germ side down, for visible stress cracks, three-power magnification being used for better detection. The percentage of kernels without stress cracks was calculated on a weight basis.

To determine the extent of hull or bran removal, a count of attached hulls was made on approximately 50-g. samples (range 10 to 60 g.) of the −4+6 grits. The grits were immersed for a few minutes in a 1% solution of sodium hydroxide to darken the hull, rinsed in water, air-dried overnight, and, if necessary, examined under three-power magnification and artificial light. The percentage (on a weight basis) of grits having any fragments of attached hull was taken as the attached hull count.

No attempt was made to determine the percentage of grits having attached germ fragments, because in previous work oil content of the grits proved a much better guide to the degree of degermination.

Graphical plots of the data proved a convenient means for examining the results. The data were also treated statistically by analysis of variance to calculate standard deviations, relative variations, degree of significance, and interactions.

RESULTS AND DISCUSSION

Results from tests made with the first temper are discussed fully; data from tests that included a dehulling temper are limited to hull removal only. During some test periods, made with a dehulling temper, a delayed and noticeable decrease in the percentage of recycle stock or tail stock occurred after steady-state conditions were believed to have been reached. This change in recycle level normally occurred when a dehulling temper was used in conjunction with the highest addition level for the first temper. Because the supply of corn was limited, no attempt was made to repeat any of the dehulling temper tests under reproducible, steady-state conditions.

Average recycle level for the single-temper tests was 6% (Table I). The average dropped from 8, down to 6, and then to 4% as initial moisture content of the corn decreased progressively from 21 to 17 to 13%. The reason for this decrease is not fully known, but it is believed to be partly due to the formation of stress cracks (see discussion under next section).

The percentage of through stock averaged 77%, varied between 61 and 93%, and was significantly higher for the 13%-moisture corn than for the 17 and 21% lots. A high percentage of stress cracks in tempered corn from the 13% lot is considered conducive to more through stock and to less recycle stock.

Initial moisture content, temper moisture level, and temper time had an important effect (statistically significant at the 90% level or better) on practically every one of the properties investigated; e.g., degerminator throughput, yield, and oil content of the various products (Table II). Two-factor interactions were significant for approximately 75% of the properties studied. For about 40% of the properties, a three-way interaction was significant. Examination of the figures in this paper is a convenient means of interpreting these interactions. Most of the results listed in Table II had a relative variation between 5 and 10%.

Data for the more important components are presented graphically. Each point in the figures represents the value from a single test.

Degerminator Throughput

For a 0.5-hr. temper the throughput was nearly 30 bu. per hr., irrespective of the corn's initial moisture content or of the temper level used (Fig. 1). With 21%-moisture corn, temper time and temper level had comparatively little effect on

TABLE I

Yields and Oil Contents of Various Dry-Milled Corn Fractions

Conditions and Fraction	Initial Moisture Content of Corn	Addition Level for Single-Temper Moisture: None	Low					Moderate					High					Std. Dev.[a]	Relative Variation
	%																	%	%
Temper time (hr.)		0	0.5	1	2	3	4	0.5	1	2	3	4	0.5	1	2	3	4		
Recycle, % g.p.[b]																			
	21	...	8	7	9	9	10	5	7	8	12	6	9	7	7	7	9		
	17	8	7	7	9	7	5	6	5	7	6	8	5	7	5	4	8		
	13	4	3	5	4	3	3	3	2	6	6	6	2	4	2	4	9		
Yields, % n.p.[c]																			
-3½+4 Grits	21	...	12	14	15	15	15	12	13	12	13	13	12	11	10	10	11	1.01	11.2
	17	9	7	10	13	13	12	7	7	8	11	10	6	7	8	5	7		
	13	8	6	9	7	7	8	7	6	5	4	5	6	8	5	2	3		
-6+8 Grits	21	...	3	3	3	4	4	3	4	4	4	4	3	3	4	4	5	0.55	7.8
	17	6	5	5	6	5	5	4	5	6	6	6	4	5	6	7	8		
	13	9	6	7	10	11	10	5	10	16	16	15	5	9	16	21	19		
-8+16 Grits	21	...	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	0.30	11.8
	17	3	2	2	2	3	2	1	2	2	3	2	1	1	2	3	3		
	13	3	2	2	4	4	4	1	3	5	5	6	1	2	4	7	7		
-16+25 Fines	21	...	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	0.23	5.1
	17	4	5	4	4	4	4	5	5	5	4	4	6	6	5	5	5		
	13	5	5	4	4	4	4	5	5	5	5	4	6	5	5	6	5		
-25+Pan fines	21	...	11	10	10	9	10	11	10	10	10	10	11	12	10	11	11	0.64	6.1
	17	12	13	11	10	9	9	14	13	10	10	9	14	14	10	11	10		
	13	16	15	11	9	9	9	15	12	9	8	8	14	11	9	9	8		
Oil contents, % d.b.																			

-3½+4 Grits	21	...	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.6	0.5	0.5		
	17	0.9	0.7	0.7	0.7	0.7	0.7	0.9	0.9	0.8	0.7	0.7	0.7	0.8	0.7	0.7	0.7	0.06	7.8
	13	1.3	0.9	1.1	1.2	1.2	1.1	0.8	1.1	1.3	1.1	1.1	0.8	1.1	1.2	1.6	1.4		
-6+8 Grits	21	...	0.7	0.7	0.8	0.8	0.7	0.7	0.8	0.8	0.7	0.6	0.7	0.7	0.7	0.6	0.6		
	17	0.9	0.7	0.8	0.7	0.9	0.6	0.8	0.8	0.8	0.7	0.6	0.7	0.8	0.7	0.7	0.7	0.06	7.9
	13	1.0	0.8	1.0	1.0	1.0	0.9	0.8	0.9	0.8	0.8	0.8	0.9	1.0	1.0	0.9	0.9		
-8+16 Grits	21	...	1.3	1.4	1.1	1.5	1.3	1.1	1.1	1.3	1.1	1.1	1.2	1.2	1.2	1.1	1.2		
	17	1.2	1.5	1.2	1.1	1.3	1.1	1.6	1.5	1.0	1.1	1.4	1.6	1.2	1.1	1.1	1.2	0.11	9.0
	13	1.4	1.4	1.3	1.1	1.3	1.2	1.6	1.2	0.9	1.0	1.0	1.5	1.1	0.9	1.0	0.9		
-16+25 Fines	21	...	7.9	8.2	8.3	8.4	8.4	8.0	8.9	8.0	8.6	8.1	7.6	7.9	8.2	7.6	8.3		
	17	9.9	9.9	9.5	9.6	9.7	9.6	10.6	10.6	9.4	9.1	9.0	10.4	10.1	8.8	9.0	8.8	0.30	3.4
	13	9.6	11.0	9.7	8.9	9.2	9.1	10.7	9.5	7.6	7.4	8.2	10.9	9.2	7.3	6.6	6.9		
-25+Pan fines (without flotation fines)	21	...	7.0	7.0	6.9	7.0	6.5	7.2	6.8	6.4	7.0	7.3	6.6	6.8	6.4	6.7	6.2		
	17	7.9	8.6	8.8	8.1	7.9	7.8	9.4	8.7	7.3	6.7	7.0	9.4	8.9	6.8	7.2	6.6	0.34	4.6
	13	10.4	10.7	8.5	7.7	7.8	7.7	10.7	7.8	5.9	5.4	5.8	10.5	8.4	6.0	4.8	4.7		

[a]Smallest significant difference (95% level) between two observations is approximately three times the standard deviation.

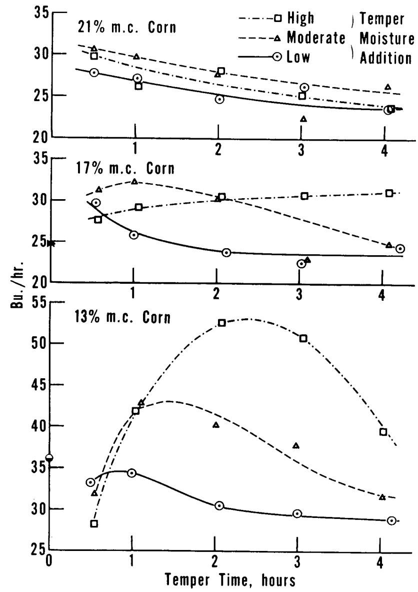
[b]Percent of gross product.

[c]Percent of net product; i.e., gross product less +3½-mesh recycle fraction.

TABLE II. RESULTS OF STATISTICAL TESTS OF SIGNIFICANCE BY MEASUREMENT BASED ON ANALYSES OF VARIANCE[a]

Component	Source of Variation							Standard Deviation	Relative Variation %
	A Initial Moisture of Corn	B Temper Moisture Level	C Temper Time	Interactions					
				AB	AC	BC	ABC		
Throughput, bu./hr.	**	**	**	**	**	**	**	1.978	6.5
Kernels with stress cracks, %	**	**	**	**	**		**		
Yields, % n.p.:									
−3½+16 Grits		**		*	**	**	0	0.776	1.2
−16 Fines	*	**	**		**			0.956	5.6
Germ fraction	*		**	*	**			0.996	7.4
Hull fraction, % g.p.	**	**	**		*	**	*	0.376	8.7
−3½+4 Grits	**	**			**	**		1.008	11.2
4+6 Grits	**	**	**	**	**	**	**	1.123	10.5
−6+8 Grits	**	**	**	**	**	**	**	0.552	7.8
−8+16 Grits	**	**	**	**	**	**	*	0.300	11.8
−16+25 Fines	**	**	**		0	*		0.234	5.1
−25+ Pan fines	**	*	**	*	**			0.643	6.1
Recoverable oil, lb./net cwt.	**	*	**		**			0.089	3.6
−4+6 Grits with attached hulls, % (wt.)		**	**		*	**		8.502	18.1
Oil Contents, % d.b.:									
−3½+16 Grits	**	*	**	0	**			0.034	4.8
−16 Fines	**	**	**	**	**	**		0.317	4.4
+8 Germ fraction	**	*	**	*				1.279	5.1
Hull fraction	**	**			**	**		0.363	10.1
−3½+4 Grits	**		**	**	**		0	0.063	7.8
−4+6 Grits	**	0	**	0	**		*	0.036	5.4
−6+8 Grits	**	0	*	*		0		0.061	7.9
−8+16 Grits	*	*	**	0	**			0.109	9.0
−16+25 Fines	**	**	**	**	**	**		0.302	3.4
−25+Pan fines	**	**	**	**	**	**	0	0.340	4.6

[a]0, Significant at the 90% level; *, significant at the 95% level; **, significant at the 99% level.



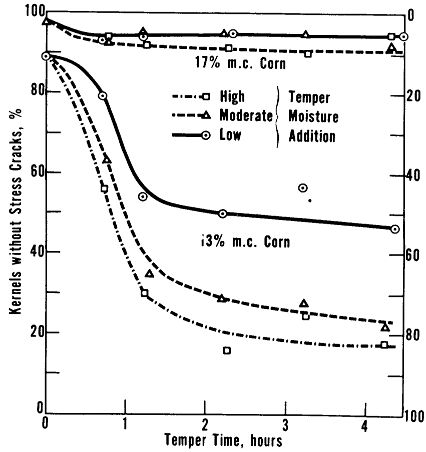


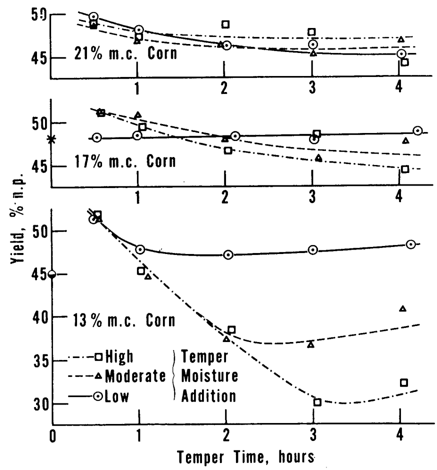
Fig. 1 (left). Effect of initial moisture content of corn, temper moisture level, and temper time on degerminator throughput. Throughput has been corrected to 15% moisture basis, 5% recycle level, and 13.2 kw. input. Standard deviation = 2.0 bu. per hr.; relative variation - 6.5%. (In this figure and in succeeding ones, m.c. = moisture content, and values at 0-hr. temper time are for corn milled without any temper. Other legends include: d.b. = dry basis.)

Fig. 2 (right). Percentage of kernels with stress cracks after tempering depended largely upon initial moisture content of the corn.

throughput. With 17%-moisture corn, tempering conditions had a greater influence than with the 21% lot. Effect of temper time varied with temper level used. Both temper time and temper level had a pronounced effect on the milling of 13%-moisture corn, and results are similar to those reported previously for another lot of 13%-moisture corn (1).

The changes in throughput are related in part to formation of endosperm stress cracks as the corn is being tempered. With 21%-moisture corn a small increase of 0 to 5 points in the percentage of kernels with stress cracks occurred during tempering. With 17%-moisture corn the increase was 3 to 8 points (Fig. 2). Temper time and temper level did not have a significant effect on the extent of stress-crack formation for these two lots. However, when the 13% lot was given a low temper, 50% of the kernels had stress cracks after 2 hr. of tempering, at the moderate temper level, 70%, and with the high temper, almost 80%. As reported earlier (8), a high percentage of stress cracks increases degerminator throughput, decreases yield of −4+6 grits, and increases their oil content.

Wen and Mohsenin (9) ascertained that the complex modulus of elasticity for horny endosperm underwent a large change in value as moisture content passed through the 14 to 15% range. Brekke (10) demonstrated that pretempering corn of 13 to 14% moisture to the 15 to 17% level improves its dry-milling characteristics, yield of −4+6 grits being increased considerably and their oil content being lowered. Hot-tempering can also be helpful (11).



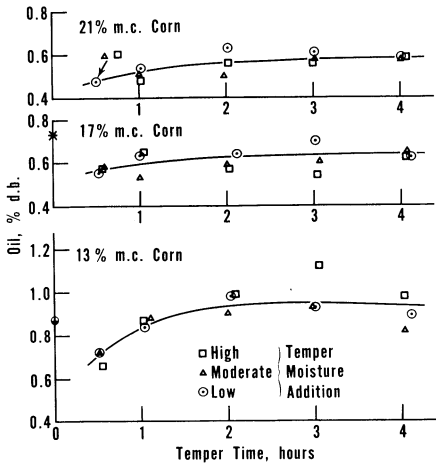


Fig. 3. (left). Effect of corn moisture and tempering conditions upon yield of −4+6 grits. Standard deviation, 1.1%; relative variation, 10.5%.

Fig. 4 (right). Oil content of −4+6 grits increased with increases in initial moisture content of corn and in temper time. Standard deviation, 0.04%; relative variation, 5.4%.

Yield and Oil Content of −4+6 Grits

Yield of −4+6 grits responded to changes in tempering conditions in much the same degree as did degerminator throughput (Fig. 3).

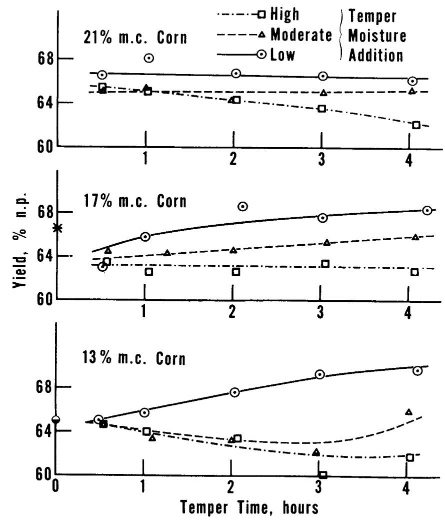
Best degermination occurred with milling of the 21%-moisture corn. Grits containing 0.5% oil were produced with 0.5-hr. temper and their oil content rose slightly to about 0.6 for the 3- and 4-hr. tempers (Fig. 4). For 17%-moisture corn, the general level was slightly higher, 0.55 to 0.65% oil, with a 0.5-hr. temper producing the 0.55 value. Degermination was considerably poorer with the 13%-moisture corn for all tempering conditions. Our data were not sufficiently precise to demonstrate any effect that temper moisture level may have had upon oil content of grits from any of the three lots.

The method of gas-liquid chromatography (GLC) used to determine oil content of the grits and hull fractions gives higher values than does the Butt extraction procedure. Black et al. (6) reported that by GLC a sample analyzed 20% more oil than by the Butt method (2.4 vs. 2.0%). Three samples of grits from the current series of experiments that contained 0.56, 0.58, and 0.70% oil (d.b.) by the Butt method analyzed 0.68, 0.71, and 0.82% oil (d.b.), respectively, by GLC for an average increase of 19%.

Yield and Oil Content of −3½+16 Grits

Yield of the −3½+16 grits held close to 64% except when the low temper level was used (Fig. 5). Temper time had little effect. For all three lots of corn, with temper times of 1 hr. or more, the yield usually decreased as temper level increased. This decrease generally was due to higher recovery of hulls.

Oil content of these grits followed the pattern exhibited by −4+6 grits and almost duplicated specific values for the −4+6 grits (Fig. 6). The −4+6 grits



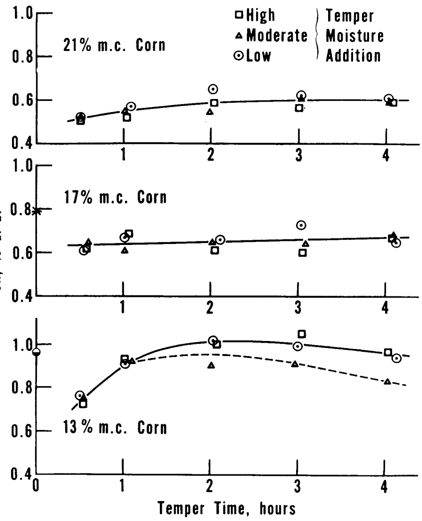


Fig. 5 (left). Small changes occurred in yield of −3½+16 grits. Standard deviation, 0.8%; relative variation, 1.2%.

Fig. 6 (right). Oil content of −3½+16 grits; pattern is quite similar to that for the −4+6 grits. Standard deviation, 0.03%; relative variation, 4.8%.

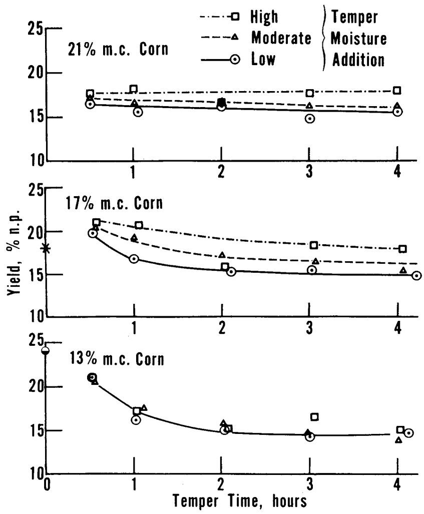
accounted for half to three-fourths of the −3½+16 grits fraction. Maximum spread in oil content between the −3½+4, −4+6, and −6+8 grits fractions usually was 0.3 to 0.4 percentage point (see Table I and Fig. 4). The −8+16 grits averaged about 1.2% in oil content (Table I), but with their low yield the net effect was minimal on oil content of the −3½+16 grits fraction. Temper moisture level had an indeterminate effect on oil content of the −3½+16 grits.

Yield and Oil Content of Degerminator Fines

Yield and oil content of −16-mesh degerminator fines varied with initial moisture content, temper moisture level, and temper time (Figs. 7 and 8). Tempering conditions had minimal effect with 21% corn, moderate with the 17% corn, and greatest with 13% corn. Yield usually decreased with temper time and increased with temper level. However, with 13% corn, the three temper levels produced no differences, and no explanation is apparent at this time. With a 0.5-hr. temper, oil content of the fines increased appreciably as initial moisture content decreased (Fig. 8). The fines generally decreased in oil content with temper time and increased at a low temper level.

Yield and Oil Content of Germ Fraction and Yield of Recoverable Oil

Yield of the germ fraction was affected by initial moisture content and tempering conditions (Fig. 9). A short temper on the 13% corn gave the poorest yield. The yield always increased with temper time, whereas temper level had little effect. Comparable yields of germ fraction did not necessarily give comparable yields of recoverable oil, however, because of contamination by endosperm material. The −3½+8-mesh germ fraction usually had an oil content of 23 to 28%, highest values being obtained with the 21 and 17% lots, short temper times, and



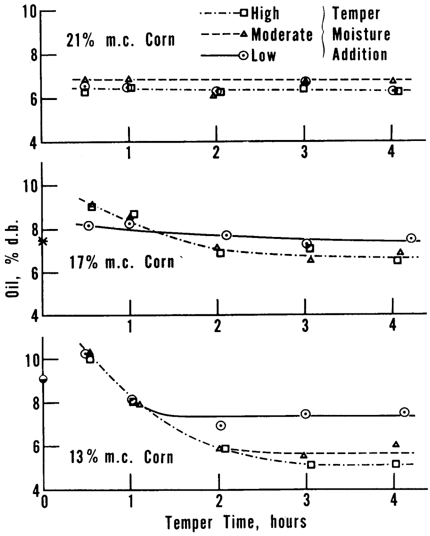


Fig. 7 (left). Effect of corn moisture and tempering conditions on yield of −16-mesh degerminator fines. Standard deviation, 1.0%; relative variation, 5.6%.

Fig. 8 (right). Variation in oil content of −16-mesh degerminator fines with corn moisture and tempering conditions. Standard deviation, 0.3%; relative variation, 4.4%.

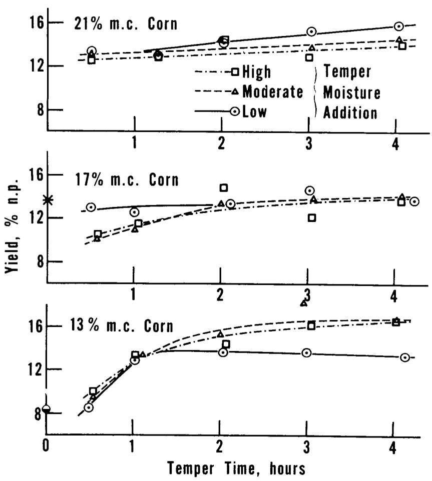
highest moisture levels. The −8+16 germ fraction from the 21 and 17% lots contained 19 to 22% oil and that from 13% corn had a lower oil content, 16 to 18%. An average of 84% of the recoverable oil came from the −3½+8 fraction. Increasing amounts were recovered from this fraction as initial moisture content increased or temper level decreased.

Yield of recoverable oil varied considerably among the three lots of corn (Fig. 10). For 21%-moisture corn, the calculated recovery was 2.8 lb. of oil per 100 lb. of net products, and tempering conditions had no effect. With a 0.5-hr. temper, the 17% corn yielded 2.2 lb. of oil and the 13% corn, 1.7 lb. With temper times of 2 hr. or more, both of these lots gave oil yields of 2.5 lb. Degermination of dry corn from the 17% lot gave an equally good oil yield, as did the 0.5-hr. temper. For the 13% lot, oil recovery was appreciably less than for the 0.5-hr. temper. The calculated yield of recoverable oil is based on weight, oil content, and moisture content of the germ fraction and a germ cake containing 5% oil, d.b.

Temper times used in commercial operation seldom exceed 2 hr. and often range from 0.25 to 1 hr. Consequently, the miller obtains highest oil recovery when corn of high moisture content, such as 21%, is milled.

Yield and Oil Content of Hull Fraction

Over the range of tempering conditions investigated, both yield and oil content of the hull fraction varied between approximately 2 and 6% (Figs. 11 and 12). For the 0.5- and 1-hr. tempers, yield of the hull fraction was 4 to 5.5% for all three lots of corn irrespective of temper moisture level used. One exception occurred: When only 1% moisture was added to the 21%-moisture corn for the low temper level, the resultant surface moisture was insufficient for reasonably adequate hull removal.



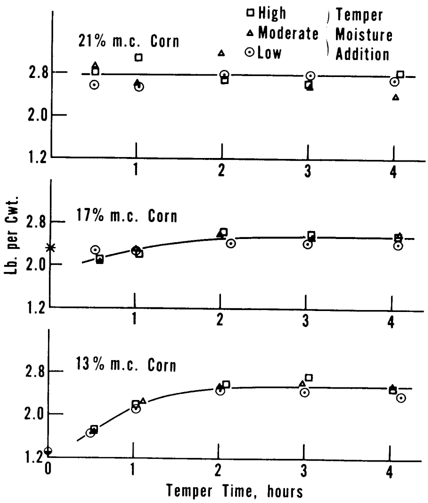
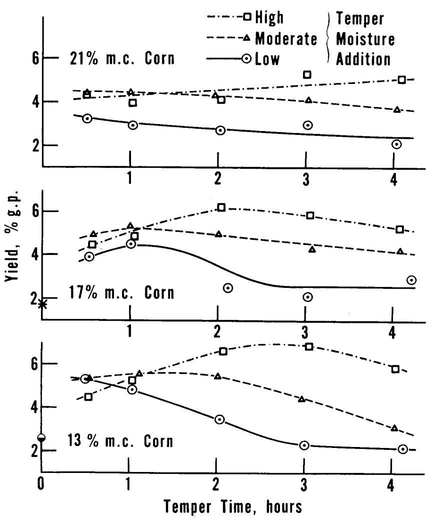


Fig. 9 (left). Effect of corn moisture and tempering conditions on yield of the germ fraction. Standard deviation, 1.0%; relative variation, 7.4%.

Fig. 10 (right). Yield of recoverable oil varied with initial moisture content of corn and with temper time. Standard deviation, 0.1 lb. per cwt. net products; relative variation, 3.6%.



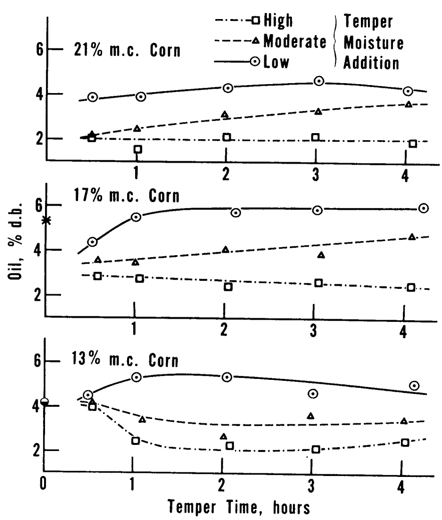


Fig. 11 (left). Variation in yield of hull fraction with corn moisture and tempering conditions. Standard deviation, 0.4%; relative variation, 8.7%.

Fig. 12 (right). Appreciable changes occurred in oil content of hull fraction. Standard deviation, 0.36%; relative variation, 10.1%.

The high temper level always produced a hull fraction of lowest oil content and, for temper times of 2 hr. or more, also produced the highest yield. Temper time usually had a smaller effect than did temper level and, in a few instances, practically no effect. If oil content is taken as a convenient index of purity of the hull fraction[3], tempering conditions that produced highest yields of the hull fraction almost always produced the best purity. The converse was also true.

Count of Attached Hulls

The percentage of –4+6 grits with attached hull fragments varied over the widest possible range. The count of the attached hulls always rose with increasing temper time and dropped with increases in the temper addition level. When percentage of grits with attached hull was plotted against temper time, three families of curves developed that represent the low, moderate, and high temper addition levels (Fig. 13). At the moderate temper level the curves exhibit a pattern of a relatively moderate increase initially, followed by a rapid rise, and finally by a more moderate increase for temper times beyond about 3 hr. The low-temper group shows general agreement with the last portion of this pattern; for temper times studied, the high-temper group conforms mainly with the first section of the pattern.

Addition of a dehulling temper did not prove as helpful as had been expected. For all tests made with a 3-hr. temper, the attached hull count ran well over 5%. Results from the 2-hr. temper are tabulated below (first-temper addition level: H = high; M = moderate; L = low):

Initial Moisture Content of Corn	*Moisture Added for Dehulling Temper*			*–4+6 Grits With Attached Hulls*		
	H	*M*	*L*	*H*	*M*	*L*
%	*%*	*%*	*%*	*%(wt.)*	*%(wt.)*	*%(wt.)*
21	1.5	1.7	2.0	4	7	18
17	2.1	2.3	2.5	1+	4+	13
13	1.5	2.4	2.7	3-	9	20

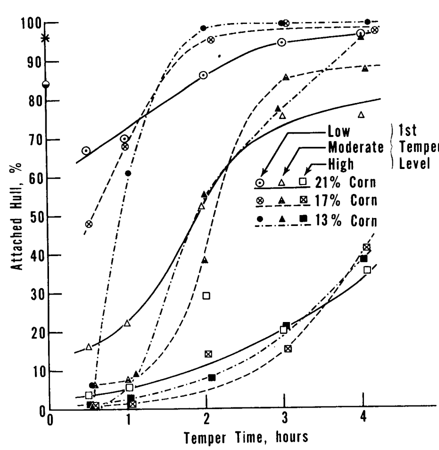


Fig. 13. Percentage of –4+6 grits having attached hulls varied considerably with initial moisture content of corn, temper time, and temper moisture level. Standard deviation, 9.5%; relative variation, 18.1%.

[3]Hull obtained by hand-dissection has an oil content of about 1%. (Earle, F. R., Curtis, J. J., and Hubbard, J. E. Composition of the component parts of the corn kernel. Cereal Chem. 23: 504; 1946).

At the high temper level, attached-hull count was always 4% or below, and at the low temper level, always above 10%. For the moderate temper level the count approached 4% only for the 17%-moisture corn.

The 21%-moisture corn proved more difficult to dehull than was anticipated. For this corn, use of a shorter temper time would have been desirable. Also, selection of degerminator screens having smaller perforations would have made a definite improvement in the polish for all three lots of corn. In subsequent work on newly harvested corn from the 1967 crop, attached-hull counts of 2% and under were reached when corn with an initial moisture content of 23% was tempered to 25 to 26% for 15 to 30 min. and milled in the degerminator fitted with screens having perforations 15/64 in. in diameter.

Other Fractions

Data are given in Table I for yield and oil content of several fractions that were produced in comparatively small proportions and for various subfractions such as the −16+25 fines and −25+pan fines.

GENERAL DISCUSSION AND CONCLUSIONS

In this study, conditions in a fairly broad range have been used covering initial moisture content of corn (carefully dried when necessary), temper moisture level, and temper time. Except for the minimum temper time for 21%-moisture corn, the range of tempering conditions studied encompasses those that would be used commercially for most cold-tempering operations.

The results demonstrate that, over-all, 21%-moisture corn required least tempering, degerminated the easiest, and produced products whose yields and oil contents were excellent. For this particular lot of corn we believe the miller need strive only for good hull removal. Therefore, he should use a short temper, about 15 min., and only sufficient temper moisture for adequate hull release or polish. Such a temper would, in essence, be a dehulling temper. Degerminator screens with smaller perforations than the 18/64-in. diameter appear necessary for proper polish; i.e., an attached hull count of 2% or less for the −4+6 grits.

Corn having a moisture content of 17% was almost as easy to degerminate as 21% corn. A moderate temper level was needed for good polish, and a miller probably would use about a 0.5-hr. temper unless he wanted to increase his oil recovery. If so, a 2-hr. rather than a 0.5-hr. temper increased the oil recovery from approximately 2.2 to 2.5 lb. per cwt. of net products, or about 14% with comparatively small changes in yields and oil contents of the various grits fractions. A dehulling temper would be needed for lower attached-hull count, and in commercial operation the return from increased oil recovery would be partially offset by the cost of the additional drying load.

Corn containing 13% moisture produced the least satisfactory results. While tempering conditions had the greatest effect on this lot, none of the conditions tried made this corn comparable to the 21% lot or even to the 17% lot in its degerminator response.

Although our results are based on corn obtained from one field, we believe, on the basis of other experiments, that similar results can be expected from most shipments of naturally dried corn varying in moisture content.

These results emphasize the objection to blending lots of corn differing in moisture content, a practice decried by dry-millers. Suppose, for example, 13% corn is mixed with 21%-moisture corn to give a blend testing 17% moisture, the unequilibrated blend being immediately tempered to 22%. Upon degermination we could expect the 21% corn to respond like that given a low temper, whereas the 13% corn might respond like that given a high temper. With a 0.5-hr. temper, −4+6 grits and −3½+16 grits from the 13% corn could contain approximately 0.7% oil and those from the 21% corn about 0.5%. Appreciable differences could occur in the amount of recoverable oil, yield and oil content of the degerminator fines, and oil content of the hull fraction. If the temper time is extended to 2 hr., large differences might occur in the attached-hull count, oil content of −4+6 and −3½+16 grits, and yield and oil content of the hull fraction.

If the blend should be a mixture of the 13, 17, and 21% lots with the blend again tempered to 22%, we could expect the degerminator response to include that for 17% corn given a moderate temper. A mitigating factor is the moisture equilibration that naturally occurs when a mixture having two or more moisture contents is held for several days at room temperature. However, hysteresis prevents the various portions from attaining the same final moisture content.

When a miller is operating rather closely to the limits set for product specifications such as attached hull count or oil content, he is in a much better position to attain desired results through adjustment of his tempering conditions if the incoming corn is uniform in moisture content.

Acknowledgments

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