Dry-Milling of Opaque-2 (High Lysine) Corn[1]

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ABSTRACT

Because *opaque-2* (o_2) corn is deficient in horny endosperm, studies were undertaken to learn what modifications of the dry-milling process might be necessary to produce prime products (grits, meal, and flour) of acceptable quality and yield. A range of tempering conditions and two types of degermers were investigated with corn from several sources. If degermer fines are included, prime products in good yield and acceptable fat content were obtained when the corn was tempered to 23% or higher moisture levels. Degerming was adequate in either a Beall degermer or an experimental machine. Grits yield was low and flour yield high because of the soft kernel. No flaking grits were recovered. The degermer fines contained only 0.5 to 1.5% fat. Prime products had a lower protein content than those from a dent corn. Because of insufficient density differences between germ and endosperm particles, gravity table separators cannot be used. Except for this aspect, o_2 can be dry-milled with conventional equipment. A greater variation was noted between different varieties of o_2 corn than for corn from different crop years.

Because of its high-quality protein for nutritional use, high-lysine corn (maize) has been accorded worldwide interest. At the High Lysine Corn Conference held at Purdue University in 1966, Wichser (1) described a method for milling *opaque-2* (o_2) corn into grits, meal, and flour, with impact mills being used for the dehulling-degerming steps. His was essentially a dry degerming system because the corn was not tempered except for bringing the moisture content to 14% before milling. Studies were undertaken at the Northern Regional Research Laboratory (NRRL) to adapt to o_2 corn the more conventional tempering-degerming system employed in the U.S. for dry-milling normal dent corn. The o_2 kernel has a soft, floury structure, and will withstand to a lesser degree the rubbing and impacting action often used in dehulling and degerming normal dent corn. A second objective was to determine product yields and characteristics, particularly for the type of corn available from more recent plant breeding studies.

Tests were made: a) to study cold (spray or dip) and hot (steam and dip) tempering of corn to levels ranging from 18 to 29% moisture, b) to compare results with a Beall degermer with those obtained with an experimental "horizontal drum" degermer developed at NRRL, and c) to compare milling response of different lots of corn.

MATERIALS AND METHODS

Corn

Of five lots of o_2 corn milled, most of the experimental tests were made on the following two: Lot B (variety $W64o_2 \times B37o_2$, 1967 crop, grown by Agriculture

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Alumni Seed Improvement Association for Purdue University) and lot D (1969 crop, grown on a farm near Paris, Ill.). Data on various characteristics of the whole kernel and hand-dissected endosperm for the o_2 lots (all officially graded as yellow corn) and a typical normal yellow dent hybrid corn of above-average protein content are given in Table I. Moisture content of the lots varied between 10 and 13%. All lots were of good quality, grading U.S. No. 1 except for test weight.

Equipment and Procedures

For Beall degermer tests, the corn was given a pretemper, a first temper, or both, in a 16-bu. working capacity, double-cone blender equipped with spray nozzles. A cold water spray (CWS) added in two screw conveyors while the grain was being transferred to the degermer supply hopper served as a cold dehulling temper. A 5 percentage-point increase in moisture content usually was about the maximum obtainable. As an alternate procedure for some tests, immersion of the corn in tap water for 2 min. provided the dehulling temper (CWD).

The corn was dehulled and degermed in a No. 0 Beall degerminator fitted with a "blunt" studded rotor operated in 50% closed position at 840 r.p.m. with a 18-h.p. motor load. The degermer cage consisted of three screens (approximately 0.13 in. thick, 15/64-in. round-hole perforations) and two grinding plates. Tail gate was normally adjusted to give an approximate 2:1 ratio of through stock to tail stock. Recycle fraction usually ranged between 9 and 14%.

For the horizontal drum degermer tests, corn was tempered in a 5-gal. can fitted with a tight cover and mixing flights, while rotating on a drum roller. For addition of a hot dehulling temper (designated as S-HWD), a screw-conveyor-type feeder fitted with an inlet for open steam served to heat the corn to about 125°F. (retention time approximately 7 sec.). The heated corn was immersed for 2 min. in water approximately 125°F. and drained for 3 min. before start of the degermer test. The S-HWD would usually increase the corn's moisture content by about 8 percentage points.

TABLE I. CORN CHARACTERISTICS

Lot No.	A	B	D	E	F	ED47[a]
Crop year	1967	1967	1969	1969	1969	1967
State grown	Ill.	Ind.	Ill.	Ill.	Minn.	Ill.
U.S. Grade No.	4	3	4	4	4	2
Test wt., lb./bu.	49.5	53.5	51.0	49.5	50.0	55.0
Germination, %	15	75	73	25	90	5
Whole grain analysis:						
Fat, % d.b.	6.7	5.9	5.4	5.5	5.9	4.2
Protein, % d.b.	11.0	10.6	9.9	10.5	9.7	10.2
Ash (600°C.), % d.b.	2.2	1.6	1.4	1.6	1.6	1.3
Crude fiber, % d.b.	2.1	2.0	2.2	2.7	2.6	1.9
Fat acidity, mg. KOH/100 g. dry corn	39	23	36	40	36	14
Lysine, g./16 g. nitrogen	4.0	4.3	4.1	3.7	4.5	2.4
Hand-dissected endosperm:						
Fat, % d.b.	0.80	0.59	0.57	0.59	0.73	0.68
Protein, % d.b.	9.1	8.4'	8.2	8.6	7.0	9.1
Lysine, g./16 g. nitrogen	3.1	3.1	3.1	2.9	3.6	1.5

[a]A normal dent corn. All others are opaque-2 corn.

Total time for first and dehulling tempers was 2 hr. and for the pretemper 16 to 18 hr. unless otherwise stated. Dehulling temper time was 5 min. for the horizontal drum degermer tests and about 15 min. for the Beall degermer tests.

The horizontal drum degermer was operated at 1,650 r.p.m. and driven by a 3/4-h.p. motor for a net motor load of about 0.4 h.p. This degermer consisted of a 5-7/16-in. diameter by 9-in. long rotor mounted on a horizontal shaft turning in a 7-in. inside diameter shell. On the drum or rotor surface were mounted two 0.25- X 0.5-in. impact bars parallel to the axis, while a short third bar of the same size mounted at approximately 30° to the rotor axis helped move material away from the feed inlet. The rotor, supported at each end by ball bearings, was driven through a variable speed drive. A steel screen, 0.032 in. thick with 20/64-in. round-hole perforations, was held in place inside the shell by three pieces of 1/8- X 1-in. strap iron set about 6° off from the rotor axis, and by some screws. About 70% of the shell area covered by the screen was cut out to leave three supporting ribs about 2 in. wide X 8 in. long. Clearance between the screen and face of the rotor impact bars was 0.6 in. A 2- X 2.5-in. opening (2-in. dimension parallel to rotor axis) just beyond top center of the shell served as a feed inlet. All material had to pass through the perforations and was discharged through the tapered bottom outlet of a sheet-metal housing surrounding the shell. This unit is a modification of a brush degermer (2).

Beall degermer throughputs were corrected to 15% moisture basis, 13.2 kw. motor load, and 5% recycle level unless stated otherwise. Throughputs for the horizontal drum degermer were corrected to a 15% moisture basis with a deduction made for the recycle content.

Degermer stock was either dried to 17.0±1.0% moisture content in a forced-circulation tray dryer operated at 180°F. air temperature or tempered to 16.5% by addition of water and held for 1 hr.; and then the material was fractionated by a rolls-and-grading system.

Density differences between the endosperm and germ particles were insufficient for a separation to be made by flotation in a sodium nitrate solution, 1.30 specific gravity, as has been done for dent-corn degermer stock (3). Attempts to make the separation on a gravity table also were unsuccessful.

Flowsheet for the roller-milling and grading operation used for Beall degermer stock is given in Fig. 1. Three pairs of corrugated rolls, 6 X 6 in.; a Bates laboratory aspirator; and a box sifter, holding three 12- X 12-in. sieves, were used. Woven-wire fabric meeting specifications for the U.S. Standard Sieve Series clothed all sieves. The rolls had modified Dawson corrugations and operated dull-to-dull. Other details for the roller mills and their usage are given below:

Mill	A	B	C
Corrugations per in.	10	16	24
Spiral, in. per ft.	0.25	0.5	0
Differential	1.5:1	1.5:1	2.0:1
Usage	1st Break 2nd Break 1st Germ	3rd Break 2nd Germ	3rd Germ Tailings

For o_2 corn, use of a smaller roll gap at the third break rolls (0.004 in. less than used for normal dent corn) proved necessary to obtain grits under 1% fat content, based on initial tests made with the solid-rotor degermer. The first germ rolls were

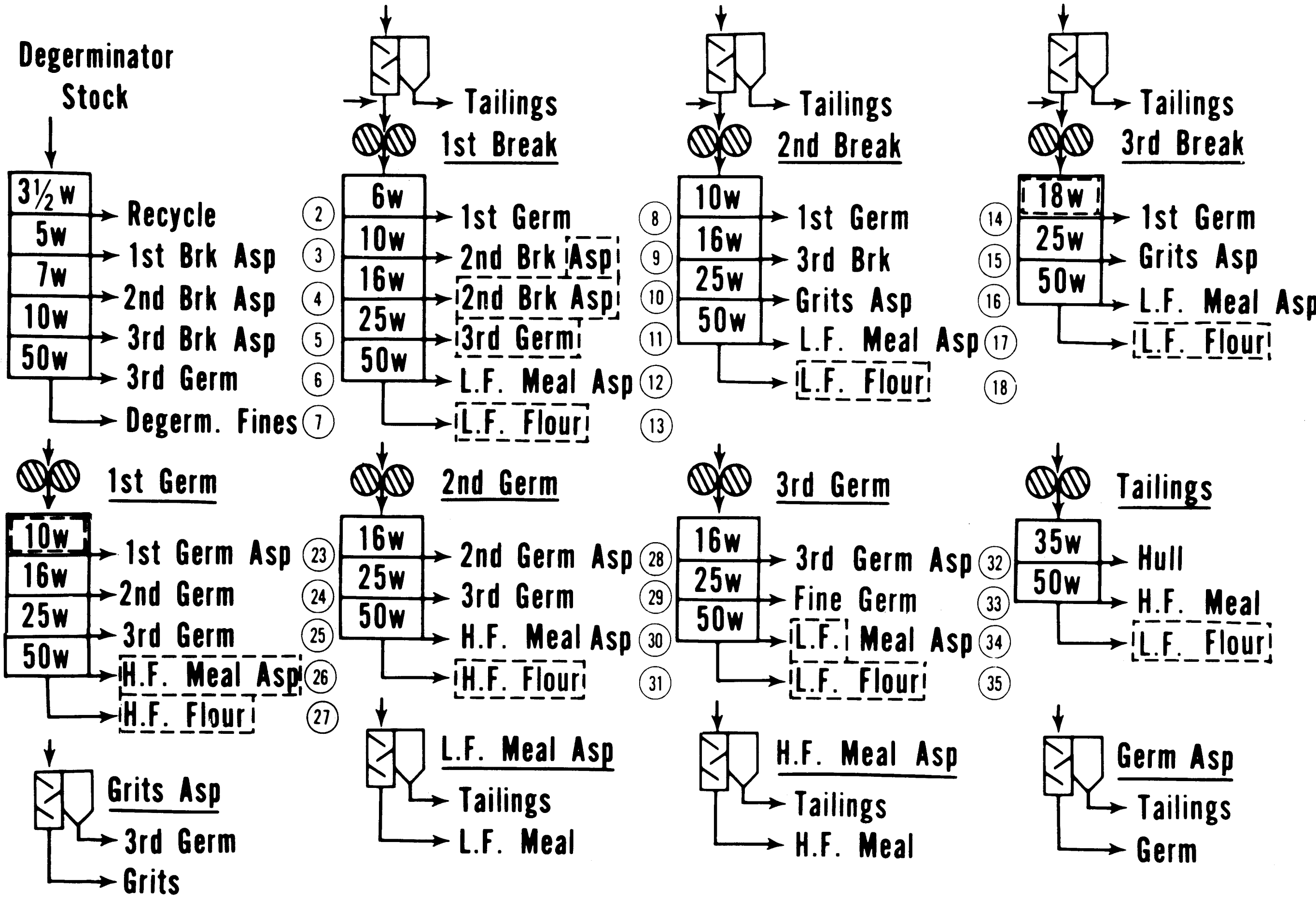

Fig. 1. Rolls-and-grading flowsheet for laboratory milling of Beall degermer stock from o_2 corn. Legend for Figs. 1 and 2: Brk = break; Asp = aspirator; L.F. Meal = low-fat meal; H.F. Meal = high-fat meal; W = wire mesh; e.g., number of wire meshes per lineal inch of sieve surface. Encircled numbers indicate mill stream.

also set 0.004 in. closer to obtain a first germ fraction (+10 mesh) reasonably free of hull fragments after aspiration. Because of the smaller roll gap, the 14-mesh sieve used in third break sifter for dent corn was replaced with an 18-mesh sieve, and a 10-mesh for the 8-mesh sieve in the first germ sifter.

Samples weighing roughly 3 lb. each were roller-milled and the products air-dried 1 or 2 days before they were weighed for yield calculations. The following products were recovered:

Product	Mill Streams Used[a]	Particle-Size Range
Grits, 2nd break	16	−16 + 25 Mesh
Grits, 3rd break	20	−18 + 25 Mesh
Low-fat meal	12,17,21	−25 + 50 Mesh
Low-fat meal from 3rd germ	34	−25 + 50 Mesh
Low-fat flour	13,18,22,35,38	−50 Mesh + pan
Degermer fines	7	−50 Mesh + pan
Prime product mix is a blend of above products.		
Tailings meal	37	−35 + 50 Mesh
High-fat meal and flour	26,27,30,31	−25 Mesh + pan
Germ fraction I	23,28,32	+16 Mesh
Germ fraction II	33	−16 + 25 Mesh
Hull fraction	36	+35 Mesh
Recycle stock	2	+3½ Mesh

[a]See Fig. 1.

Two further modifications in the flow were made when horizontal drum degermer stock was roller milled. Practically no kernels were found in +3½ mesh fraction in the initial sifting step. However, a heavy aspiration of this fraction followed by a light reaspiration of the liftings proved desirable. Heaviest material went to first germ rolls, intermediate material to first break rolls, and lightest material to tailings rolls (Fig. 2). For the second modification, material collected on the 18-mesh sieve of the third break sifter was aspirated to remove free hull fragments before the remainder of the stock was sent to the first germ rolls.

Moisture in corn samples was based on loss of weight after heating approximately 200-g. samples for 72 hr. in a forced-draft oven operating at 103°C. Fat contents of germ fractions and whole grain were determined by the Butt extraction procedure for which the solvent was a pentane-hexane mixture. Other fractions were analyzed for their fat content by a gas-liquid chromatographic method (4) which gives values some 15 to 20% higher than those of the Butt method on fractions containing about 2% or less fat.

AOAC procedures were used for protein, ash, and crude fiber analyses (5). Lysine was determined by the method of Benson and Patterson (6).

Other details of the equipment, procedures, and analytical methods have been described previously (3,7,8). Unless otherwise indicated, data are for a single test.

RESULTS

Comparison of Degermers

Opaque-2 corn used in these tests had a comparatively soft, low-density endosperm, and adjustment of the Beall degermer tail gate (a V-notched slide located above the rotor axis) to give a 2:1 ratio of through stock to tail stock (i.e., about 67% through stock) proved better than a higher ratio. Increasing the through stock from 66 to 87% (based on wet degermer stock) decreased the recycle level

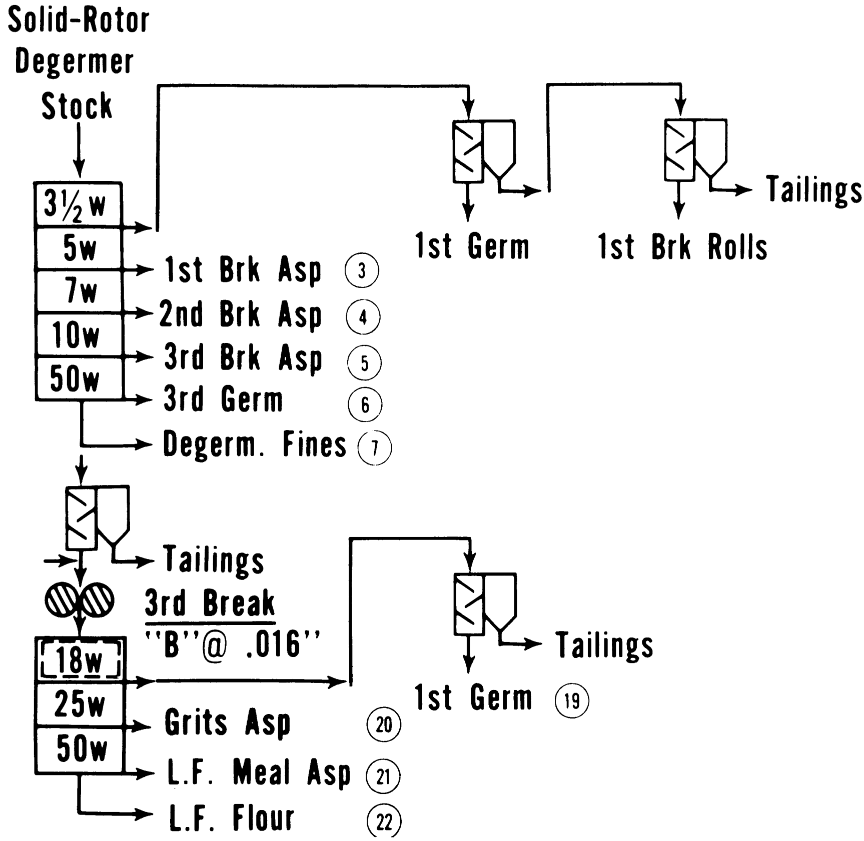

Fig. 2. Modification of Fig. 1 flowsheet when NU horizontal drum degermer was used instead of Beall.

from 14 to 2% but increased the fat content of the prime product mix from 1.0 to 1.2% (d.b.). These milling percentages represent results with lot D corn that had been given a 21% first temper plus 5% CWS. Net degermer throughput and yield of grits, meal, flour, prime product mix, and recoverable oil[2] were not affected. Since a prime product mix with 1.0% or less fat was desired, most Beall tests were made with about 67% through stock.

The horizontal drum degermer gave a lower yield of prime product mix and almost always better degerming than did the Beall (Table II). Lower yield was due to fewer degermer fines; better degerming was due to these fines and the low-fat meal from third germ having appreciably lower fat contents. The horizontal drum degermer also gave from 0.0 to 0.8 lb. more recoverable oil per cwt. corn, depending upon the corn and tempering conditions employed, and 0 to 4 percentage points more hull fraction of slightly higher fat content. Yields and fat contents of other products generally showed only small variations.

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[2]Calculated yield of recoverable oil was based on yield of germ fraction I and its fat and moisture contents, with residual germ cake assumed to contain 5% fat, d.b.

TABLE II. AVERAGE PERFORMANCE OF HORIZONTAL DRUM AND BEALL DEGERMERS BASED ON FOUR TESTS

Product	Horizontal Drum Degermer	Beall Degermer
Prime product mix		
Yield, % n.p.[a]	65	70
Fat, % d.b.	0.7	0.9
Low-fat meal from 3rd germ		
Yield, % n.p.	12	12
Fat, % d.b.	1.2	1.7
Degermer fines		
Yield, % n.p.	9	13
Fat, % d.b.	0.5	0.9

[a]Net product (n.p.), i.e., gross products less +3½ mesh recycle fraction.

TABLE III. COMPARATIVE EFFECT OF TWO DEHULLING TEMPERS

Specific Results	Yield, % n.p.[a]		Fat, % d.b.		Crude fiber, % d.b.	
	S-HWD[b]	5% CWS[c]	S-HWD	5% CWS	S-HWD	5%CWS
Product						
Grits, 2nd break	7	8	0.5	0.5		
Grits, 3rd break	4	3	1.3	1.6		
Low-fat meal	12	14	0.5	0.6		
Low-fat meal from 3rd germ	13	13	0.7	2.2	0.8	1.1
Low-fat flour	17	18	1.5	0.6		
Degermer fines	15	16	1.0	1.1	0.6	0.7
Prime product mix	68	72	0.9	1.0		
Tailings meal	1	<1	1.7	3		
High-fat meal and flour	<1	<1	6	7		
Total endosperm product	70	73	1.0	1.1		
Hull fraction	8	8	1.5	0.9		
Germ fraction I	17	15	25	26		
Germ fraction II	5	4	6	8	3.6	4.3
Recoverable oil, lb./cwt. corn	3.2	3.0				
Tempered corn moisture, %	29	26				
Degermer throughput, bu./hr.	19	31				

[a]Percent net product; i.e., gross product less +3½ mesh recycle fraction.
[b]Steaming treatment plus hot-water dip (S-HWD).
[c]5% Moisture added as a cold water spray (CWS).

Comparison of Two Dehulling Tempers

The two dehulling tempers—S-HWD and 5% CWS—gave reasonably similar results (Table III). The tests were made on lot D corn which had been given a first temper to 21%, the desired dehulling temper, and milled in the Beall degermer. The more conventional dehulling temper, i.e., the 5% CWS, gave highest yield of prime product mix, slightly poorer germ removal from the endosperm, lower yield of

TABLE IV. EFFECT OF TEMPER TREATMENT AND TEMPER MOISTURE LEVEL WITH LOT B CORN AND HORIZONTAL DRUM DEGERMER

Treatment	Tempered Corn Moisture %	Degermer Throughput bu./hr.	Prime Product Mix Yield % n.p.	Prime Product Mix Fat % d.b.	Streams with <1% Fat % n.p.	Recoverable Oil lb./cwt.	Degermer Fines Yield % n.p.	Degermer Fines Fat % d.b.	Degermer Fines Crude Fiber % d.b.
None	11	8.4	59	1.1	40	3.4	6	2.3	0.9
CWD[a]	18	4.8	67	1.0	48	3.4	7	1.4	0.8
16% Pretemper + CWD	24	3.9	65	0.7	54	3.5	7	0.7	0.6
19% Pretemper + CWD	26	3.4	64	0.6	64	3.9	7	0.6	0.5
22% Pretemper + CWD	29	3.4	62	0.6	62	4.0	7	0.6	0.5
18% 1st Temper + 5% CWS	23	3.9	67	0.9	49	3.7	8	0.5	0.5
18% 1st Temper + S-HWD	26	3.1	63	0.7	50	4.0	7	0.5	0.3

[a]CWD = cold water dip.

TABLE V. EFFECT OF TEMPER TREATMENT AND TEMPER MOISTURE LEVEL—LOT D CORN

Treatment	Tempered Corn Moisture %	Degermer Throughput bu./hr.	Prime Product Mix Yield % n.p.	Prime Product Mix Fat % d.b.	Streams with <1% Fat % n.p.	Recoverable Oil lb./cwt.	Degermer Fines Yield % n.p.	Degermer Fines Fat % d.b.	Degermer Fines Crude Fiber % d.b.
6% CWS	19	43[a]	74	1.7	22	2.4	14	2.4	0.8
S-HWD	24	3.2[b]	67	0.9	50	2.8	9	0.7	0.4
16% 1st Temper + S-HWD	25	3.2[b]	68	1.1	32	3.0	10	0.6	0.4
18% 1st Temper + S-HWD	26	3.1[b]	65	0.7	49	3.5	10	0.5	0.4
22% Pretemper + S-HWD	29	2.6[b]	64	0.6	64	4.0	10	0.5	0.4

[a]Beall degermer test. Throughput corrected to 15% moisture content, 13.2 kw. motor input, and 2% recycle level.

[b]Horizontal drum degermer tests.

TABLE VI. VARIATION IN MILLING RESPONSE OF CORN LOTS B AND D

Specific Results	18% 1st Temper + S-HWD[a]		18% 1st Temper + 5% CWS[b]		22% Pretemper + CWD[a]	
	B	D[c]	B	D	B	D
Product	Yield, % n.p.					
Grits, 2nd break	8	8	7	8	9	8
Grits, 3rd break	8	5	4	3	8	6
Low-fat meal	11	11	15	15	12	12
Low-fat flour	15	20	17	18	15	21
Blend No. 1	42	44	43	44	44	47
Degermer fines	8	10	13	15	7	9
Blend No. 2	50	54	56	59	51	56
Low-fat meal from 3rd germ	13	11	13	13	11	11
Blend No. 3 (Prime product mix)	63	65	69	72	62	67
	Fat, % d.b.					
Grits, 2nd break	0.6	0.6	0.7	0.5	0.5	0.6
Grits, 3rd break	0.7	1.2	1.3	1.6	0.6	1.2
Low-fat meal	0.5	0.6	0.6	0.6	0.4	0.6
Low-fat flour	0.5	0.6	0.6	0.6	0.4	0.6
Blend No. 1	0.6	0.7	0.7	0.7	0.5	0.7
Degermer fines	0.5	0.6	0.8	1.1	0.6	0.6
Blend No. 2	0.6	0.7	0.7	0.8	0.5	0.7
Low-fat meal from 3rd germ	1.0	1.0	2.0	2.2	0.9	1.2
Blend No. 3 (Prime product mix)	0.7	0.7	0.9	1.0	0.6	0.8
Recoverable oil, lb./cwt. corn	4.0	3.5	3.7	3.0	4.0	3.5
Tempered corn moisture, %	26	26	23	26	29	28
Degermer throughput, bu./hr.	3.1	3.2	19	31	3.5	3.0

[a]Tests made with horizontal drum degermer.

[b]Tests made with Beall degermer.

[c]Lot D was given a 1st temper to 21% instead of 18%.

recoverable oil, and a slightly higher crude fiber content for the products analyzed. Products making up the prime product mix were quite similar in fat content with two exceptions: The cold temper produced flour of lower fat content but meal of higher fat content; the hot temper toughened the grain, as indicated by the lower degermer throughput.

Effect of Varying the Tempering Procedure and Temper Moisture Level

Results of experiments made with various tempering procedures and temper moisture levels are given in Tables IV and V. For tests made with the horizontal drum degermer on lot B corn (Table IV), degree of germ removal, based on fat content of the prime product mix, improved as temper moisture content of the corn was raised. For moisture contents of 23% and above, the mix's fat content dropped to 0.9% or less. Two of the tempering conditions (16 or 19% pretemper plus CWD) produced a mix the fat content of which was the same as the hand-dissected endosperm; namely, 0.6% d.b. Higher temper moisture levels increased the yield of recoverable oil but lowered the yield of prime product mix and degermer throughput. While tempering conditions had little influence on yield of degermer fines, their fat and crude fiber contents fell off at higher temper moisture levels. Overall, a first temper to 18% plus a 5% CWS gave very good results when this lot of corn was milled in the horizontal drum degermer.

Results very similar to those in Table IV were obtained for lot A corn (a mixture from plant breeding test plots) given similar tempers.

The response of lot D corn (Table V) to variations in tempering conditions and moisture levels was much like that of lot B. Use of only a S-HWD gave good results except for a low oil yield. The test with only a 6% CWS added to the corn was made with the Beall degermer set for a low recycle level, a condition which raised the fat content of every prime product fraction by about a 0.2 percentage point; but this temper obviously proved to be unsatisfactory because of the high fat level (1.7%) of the prime product mix.

Milling Response of Different Lots of Corn

Lot D corn usually gave fewer grits but sufficiently higher amounts of flour and degermer fines to thus increase yield of both prime product mix and product blend No. 1 above that obtained from lot B corn (Table VI). For lot D, the third break grits definitely ran high in fat content, and only under the best tempering condition (22% pretemper + S-HWD) and with use of the horizontal drum degermer did their fat content fall under 1.0% (unreported data). By contrast, for lot B corn these grits analyzed under 1.0% fat for eight out of nine tests made under varying temper conditions (all with horizontal drum degermer). The one test in which their fat content exceeded 1% was where lot B corn was given an 18% first temper plus 5% CWS (see Table VI). In our judgment, lot D was a little more difficult to degerm than lot B and gave a higher yield of grits, product blend No. 1, degermer fines, and prime product mix, but a lower yield of recoverable oil.

TABLE VII. VARIATION IN MILLING RESPONSE OF CORN LOTS D, E, AND F WITH BEALL DEGERMER

Specific Results	21% 1st Temper + 5% CWS: D	21% 1st Temper + 5% CWS: E	18% 1st Temper + 5% CWS: F
Product		Yield, % n.p.	
Grits, 2nd break	8	6	5
Grits, 3rd break	3	5	2
Low-fat meal	15	11	9
Low-fat flour	18	17	16
Blend No. 1	44	39	32
Degermer fines	15	15	24
Blend No. 2	59	54	56
Low-fat meal, 3rd germ	13	13	13
Blend No. 3 (Prime product mix)	72	67	69
		Fat, % d.b.	
Grits, 2nd break	0.5	0.6	1.3
Grits, 3rd break	1.6	1.4	2.6
Low-fat meal	0.6	0.6	0.8
Low-fat flour	0.6	0.7	0.8
Blend No. 1	0.7	0.7	1.0
Degermer fines	1.1	0.9	0.9
Blend No. 2	0.8	0.8	1.0
Low-fat meal, 3rd germ	2.2	1.7	2.0
Blend No. 3 (Prime product mix)	1.1	1.0	1.2
Recoverable oil, lb./cwt.	3.0	3.4	3.3
Degermer throughput, bu./hr.	31	31	34

TABLE VIII. PROPORTION OF HORNY AND FLOURY ENDOSPERM AND THEIR FAT CONTENTS FOR OPAQUE-2 AND NORMAL DENT CORN

Fraction	Proportion of Endosperm, %		Fat, % d.b.	
	O_2	Dent	O_2	Dent
Horny endosperm	26	54	0.90	0.65
Floury endosperm	74	46	0.56	1.14
Fat content of total endosperm				
Calculated			0.65	0.87
By direct analysis			0.65	0.90

Variations also existed in milling response among the three lots from 1969 crop (Table VII). Of these, lot D gave highest yield of both product blend No. 1 and prime product mix but lowest yield of recoverable oil. Lot F apparently had a softer kernel than either lots D or E because it produced fewer grits and more degermer fines. Fat content of F's products reflects the higher fat content of its endosperm, although use of a higher moisture level in the first temper step or of a S-HWD for the dehulling temper presumably would have helped lower the product's fat contents. Lot E gave lowest yield of prime product mix.

Product Spectrum and Characteristics

The yields in Table III show a typical product distribution. Compared with the distribution obtained from a normal dent corn, such as was used in a previous study (8), the product spectrum was shifted to production of fewer grits, more meal, a large quantity of flour and degermer fines, and more oil. Although grits of flaking size could be found in the degermer stock, they were easily crushed and therefore would not be suitable for flaking purposes.

The quantity of recoverable oil amounted to about 60% of total fat content of the grain, a recovery very similar to that obtained for one set of milling conditions and one lot of dent corn (8). However, because o_2 corn has a higher fat content, calculated yield of recoverable oil was about one-third greater than that from the normal dent corn.

Data obtained on hand-dissected endosperm help explain why appreciably more flour and degermer fines were produced and why they were low in fat content. Hand-dissected endosperm from lot E and from a locally grown normal dent corn (1968 crop, artificially dried) was subjected to selective grinding and sieving[3] to produce a +50 mesh fraction considered as horny endosperm and a −50 mesh fraction that was largely floury endosperm. The o_2 corn contained a high proportion of floury endosperm and its fat content was less than that of the horny endosperm, in direct contrast to results for the dent corn (Table VIII). (Note: The hand-dissected endosperm from lot E was not the same sample analyzed in Table I.) Because of the relatively soft nature of the o_2 kernel, it was degermed with less mechanical action than the dent corn. Fewer abraded germ particles appeared, therefore, in the flour and fines fractions to raise their fat content above their native level.

Most of the dry-milled products from o_2 corn were lower in protein content

[3]Baecker, Heinz. Personal communication regarding method developed by parent company of Miag North America, Inc.

TABLE IX. PROTEIN CONTENTS OF DRY-MILLED PRODUCTS FROM OPAQUE-2 AND NORMAL DENT CORN

Products	Yield, % n.p.		Protein, % d.b.	
	Dent[a]	O_2[b]	Dent[a]	O_2[b]
Grits, 1st break	12	None	9.6	...
Grits, 2nd break	32		9.2	
Grits, 3rd break		5		10.4
Low-fat meal	13	13	8.2	7.1
Low-fat flour	8	19	7.4	6.2
Degermer fines	...	14	...	7.2
Low-fat meal, 3rd germ	...	12	...	10.4
Prime product mix	65	71	8.9	7.7
Hand-dissected endosperm			9.2	8.2, 8.6
Whole-kernel corn			10.2	9.9, 10.5
No. of tests averaged	1	7	1	7

[a]Data from Brekke (8).

[b]From lots D and E milled in Beall degermer.

than their counterparts from a normal dent (Table IX), contrary to Wichser's results (1). Comparative nutritional value of o_2 fractions of lower protein content than corresponding dent fractions remains to be determined. *Opaque-2* has more protein than an average dent, but the increase is found in the germ portion of the kernel.

Opaque-2 corn differs from a normal dent in color and general appearance of the prime products. Grits were a pale rather than a bright yellow color, and interspersed with more white. By visual inspection, the flour was whiter than that from yellow dent; degermer fines were about as light in color as the flour, although they had a grayish cast; and the meal fractions were intermediate in color between the grits and flour.

In only a few instances were any abnormal odors noted in milling o_2 corn, and generally the odors were considered to be agreeable. For five samples of degermer stock, descriptions of the odor by several individuals ranged from that of normal corn to freshly husked sweet corn, freshly cut grass, sweet, carbide gas, or slightly musty. After standing for 2 days at room temperature, degermer stock from a sixth run for which the corn (Lot D) was given a hot dehulling temper developed a fairly strong "fruity" smell similar to that of ethyl acetate.

SUMMARY

Opaque-2 corn of the type used in these studies was processed into products of acceptable fat content with conventional dry-milling equipment. Either a Beall degermer or a type less severe in its abrading action proved satisfactory. Gravity table separators cannot be used to separate and recover the germ fraction because of insufficient difference in density between germ and grit particles. Several changes made in the flow of the rolls-and-grading system to produce prime products of acceptable fat content were of a minor rather than major nature, but required additional aspiration steps. Best degerming results were obtained at temper moisture levels of 23% and above.

The prime product spectrum was shifted considerably in comparison with

products from normal dent corn. No flaking grits were produced, while a considerably reduced percentage of regular grits and more meal and more flour were obtained. If degermer fines can be included, the yield of prime product mix was greater from o_2 corn than from dent corn. If not, the yield would be appreciably less. About one-third more oil was recovered because the grain contains more oil. Protein content of the prime products varied between 6.2 and 10.4% (d.b.) and the prime product mix contained less protein than mix prepared from a dent corn of above-average protein content. A greater variation was noted between different varieties of o_2 corn than for corn from different crop years.

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Literature Cited

1. WICHSER, W. R. Comparison of the dry milling properties of *opaque-2* and normal dent corns. In: Proceedings of the high lysine corn conference, p. 104. Corn Refiners Association, Inc.: Washington, D.C. (1966). Opaque-2 can be dry milled commercially. Amer. Miller Process. 94(8): 11 (1966).
2. WEINECKE, L. A., and MONTGOMERY, R. R. Experimental unit now suitable for scale-up to mill production size. Amer. Miller Process. 93(9): 8 (1965).
3. BREKKE, O. L. Corn dry-milling: Effect of temper time and moisture level on degerminator performance (for low-moisture corn). Cereal Chem. 42: 288 (1965).
4. BLACK, L. T., SPYRES, G. G., and BREKKE, O. L. Determination of oil contents of dry-milled corn fractions by gas-liquid chromatography. Cereal Chem. 44: 152 (1967).
5. ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS. Official methods of analysis (9th ed.), p. 169. The Association: Washington, D.C. (1960).
6. BENSON, J. V., Jr., and PATTERSON, J. A. Accelerated automatic chromatographic analysis of amino acids on a spherical resin. Anal. Chem. 37: 1108 (1965).
7. BREKKE, O. L., WIENECKE, L. A., WOHLRABE, F. C., and GRIFFIN, E. L., Jr. Tempering and degermination for corn dry-milling: A research project for industry. Amer. Miller 89(9): 14; (10): 19 (1961).
8. BREKKE, O. L. Dry-milling artificially dried corn: Roller-milling of degerminator stock at various moistures. Cereal Sci. Today 15: 37 (1970).

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