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CORN DRY-MILLING: A COMPARATIVE EVALUATION OF COMMERCIAL DEGERMINATOR SAMPLES[1]

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ABSTRACT

Samples of degerminator product streams from four processors using cone mills, granulators, or disk mills as degerminators were fractionated in the laboratory to give data on yields and oil content of grits of several sizes, fines, germ, and hull. Disregarding variations resulting from differences in the corn processed and the tempering conditions used, the cone mill gave the best degermination, but the disk mill produced the most recoverable oil, and the granulator, an intermediate amount of oil. From the data presented, which should be useful to those working for improved degermination, the possibility of a shorter milling flow is suggested.

Degermination is one of the more important steps in corn dry-milling. Various types of degerminators are currently used, although the Beall[2] is commonly chosen. According to one estimate (1), 85–90% of the mills degerminating corn use Beall degerminators, reportedly introduced in 1906 (2). Some mills have installed other types in an effort to decrease the cost of the degermination step. Corn dry-millers have expressed a need for degerminators with the following features: high yield of grits in the degerminator product stream(s) (particularly flaking grits), minimum "fines" production, good degermination and dehulling (i.e., good release of germ and hull from the endosperm), minimum grinding of the released germ and hull, minimum operator attention, minimum maintenance, high capacity, and low power requirement.

In conjunction with current studies on tempering and degerminating corn, samples were obtained of the degerminator product streams from four commercial mills. Two of the mills used cone degerminators (Beall); one, granulator-degerminators; and the fourth, disk mills.

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[2]Mention of firm names or trade products does not imply that they are endorsed or recommended by the Department of Agriculture over other firms or similar products not mentioned.

All three types of degerminators can be classified as attrition mills. The Beall consists of a cast-iron, cone-shaped roll, rotating on a horizontal shaft in a conical cage. Part of the cage is fitted with perforated screens and the remainder with plates having conical protrusions on their inner surface. The cone has similar protrusions over most of its surface. Also, the small or feed end of the cone has spiral corrugations to move the corn forward; the large end is corrugated in an opposing direction to retard the flow. The product leaves in two streams. One stream, discharged through the perforated screens, contains a major portion of the released germ and hull, fines, and some of the large grits. The second stream, which normally contains a major portion of the large grits, escapes through an opening in an end plate facing the large end of the cone. A hinged gate with an adjustable weight restricts flow of this latter stream.

The granulator has a cylinder composed of eight knives or blades rotating on a horizontal shaft. A perforated screen surrounds about three-fourths of the cylinder's surface, and all the corn must pass through this screen. Some millers operate with knife edges on the rotor leading and some prefer to have them trailing. In the latter case, more of an extrusion effect is obtained. The granulator may also be fitted with two stationary knives.

The disk mill uses no screens and its principle is well known. Our sample was obtained from a mill fitted with 36-in.-diameter plates having a series of concentric interrupted corrugations or ridges.

Materials, Process Conditions, and Methods

All mills used yellow dent corn of good quality, presumably from their current crop year; i.e., 1959 for the two Bealls, 1960 for the granulator, and 1961 for the disk mill. In the four mills the tempering and degerminating conditions naturally varied (Table I). For the Beall operation in mill B, sufficient heat was added during the tempering step to heat the corn from 70° to 115°F. (approximate temperatures). For the disk-mill operation in mill D, a small amount of steam was added in the tempering step to heat the corn slightly to about 75°F. The disk mill was set to merely crack the corn and, consequently, the motor load was very small.

Samples of 5- to 10-lb. size, and as representative as practicable, were obtained from the degerminator discharge streams by mill personnel. These were air-dried before shipment to our laboratory. Upon receipt, a representative portion of each sample was subjected to screening, aspiration, and flotation for particle sizing, hull removal, and germ separation according to the procedure outlined by Brekke *et al.*

(3). Oil contents of whole corn, grits, fines, germ, and hull fractions are on dry basis (DB).

TABLE I
TEMPERING AND DEGERMINATING CONDITIONS

	Type of Degerminator, and Processor			
	Beall No. 2 A	Beall No. 2 B	Granulator C	Disk Mill D
Corn moistures (%)				
Initial	14.4	14.8	14.5	14.0
First temper	21.3	21.1	19.0	19.5
Second temper	3.2	1.7	1.5	none
Increase	10.1	8.0	6.0	5.5
Temper time				
First, hr.	3.1	2.5	2.0	2.1
Second, min.	5	1	45	none
Warm tempering?	No	Yes	?	No
Equipment manufacturer's rating, bu./hr.	40–80	40–80	100–200	220
Gross throughput, bu./hr.	100	120	?	170
Net throughput, bu./hr.[a]	98	119	?	152
Motor size, h.p.	50	75	?	40
Kw.-hr./net bu.	0.39	0.47	?	<0.2[b]
Rotor speed, r.p.m.	870	850	460[c]	865
Screen perforation diameter, in.	19/64	16/64	?	none

[a] Gross throughput less recycle fraction.
[b] Motor was not fully loaded; therefore power usage was less than 0.2 kw.-hr./bu.
[c] Assumed value based on equipment manufacturer's literature.

Results and Discussion

From yield data given in Table II for the four samples, a number of differences are apparent. The Bealls were set to produce a minimum amount of recycle stock (i.e., material, largely whole corn, retained on a 3½-mesh sieve[3]); the disk mill, a fairly high amount; and the granulator, an intermediate percentage. As the recycle stream increased in size for the three types of degerminators, its oil content also increased, as shown in Fig. 1. For Beall-A and Beall-B the respective fractions contained 1.6 and 1.8% oil; that from the granulator, 4.5%; and from the disk mill, 4.8%. These last two values are essentially the oil content of whole corn.

The Beall degerminators released a larger hull or bran fraction from the corn kernels than did either the granulator or the disk mill. Considerable variation also occurred in the oil content of this fraction. If oil content is used as an index of purity, the Beall product was least pure, the granulator intermediate, and the small quanitity of hulls freed by the disk mill was a comparatively pure fraction because

[3] All sieves used in the laboratory fractionation were U.S. Standard series.

TABLE II
COMPARATIVE YIELDS

	Type of Degerminator, and Processor			
	Beall No. 2	Beall No. 2	Granulator	Disk Mill
	A	B	C	D
Recycle, % GFS[a]	2	1	5	10
Hull fraction, % GFS	7	9	3	1
Hull fraction, % oil, d.b.[b]	5−	3+	3−	1+
−4+6 Grits with attached hulls, %	4	9	92	100
Germ fraction, % NFS[c]	7	7	13	12
Germ fraction, % oil, d.b.	26.0[d]	27.4	20.5	23.4
Recoverable oil, lb./net bu.[e]	0.8	0.8	1.0	1.2
−3½+4 Grits, % NFS	7	6	10	9
−4+6 Grits, % NFS	55	45	39	30
−6+8 Grits, % NFS	9	8	21	23
−8+16 Grits, % NFS	3	7	5	7
−16-Mesh fines, % NFS	12	18	8	17

[a] Gross feedstock.
[b] Dry basis.
[c] Net feedstock, i.e., gross less than +3½-mesh recycle stock.
[d] Estimated value, based on typical oil content.
[e] Based on weight of germ fraction recovered by flotation and its moisture and oil content; and assuming oil cake contains 5% residual oil on a dry basis.

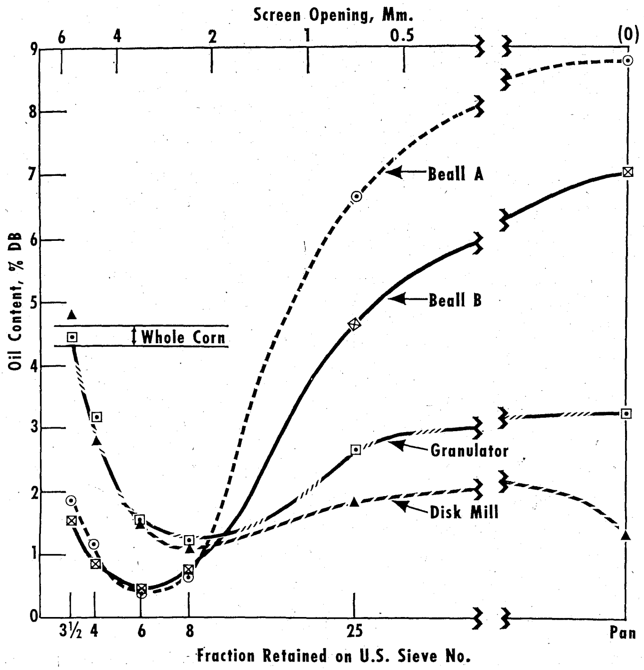

Fig. 1. Oil content of endosperm fractions from commercial degerminators.

it contained only slightly more than 1% oil, a level comparable to that obtained by hand dissection (4).

While the proportion of −4+6 grits with attached hulls varied considerably, much of this difference is attributed to the fact that mill D did not use a second temper and that in mill C the 45-min. residence time for the second temper reduced its effectiveness.

Large differences were also noted in amount of germ freed by the three types of degerminators. The quantity recovered from the granulator and from the disk mill was almost double that from either Beall A or B but lower in oil content. This value is reflected in the amount of recoverable oil, which increased from 0.8 lb. per net bu. for the Bealls to 1.0 lb. for the granulator and 1.2 lb. for the disk mill.

There was no unusual variation in yield of −3½+4-mesh grits, but the Beall degerminators produced a fraction much lower in oil content (Fig. 1). The Bealls also produced more −4+6 grits and their oil content was at a very acceptable level, 0.35% for mill A and 0.42% for mill B. The respective −4+6 grits from the granulator and from the disk mill contained 1.53 and 1.47% oil and were far above the 0.7 to 1.0% maximum usually stipulated. Consequently, in the subsequent milling process, further degermination on roller mills was needed to decrease the oil content of these grits, which naturally reduced their particle size and the yield of large grits.

In general, a large yield of −4+6 grits lowers the yield of −6+8 grits, and this decrease was reflected in the current series of samples. When higher yields of the −4+6 grits were obtained as with the Bealls, the yield of −6+8 grits was less; the converse was true for both the granulator and the disk mill. Again, the better degermination obtained in the Beall was apparent in the −6+8 grits. From mill A, these contained 0.68% oil; from mill B, 0.80% (value estimated from curve in Fig. 1), as compared with 1.28% for the granulator and 1.10% for the disk mill.

No significant variation was noted in yield of −8+16 grits or in quantity of −16-mesh fines. While an 8% yield of −16-mesh fines for the granulator is desirably low, this value is based upon a single sample and may be in error. Less attrition is expected in a disk mill because it was set to merely crack the corn; however, its product contained 17% fines. As a check, two more samples from the disk mill, operating at "loose" and "tight" settings, also contained 16 and 17% fines. On this basis, the 8% figure for the granulator appears low.

Oil content of fractions finer than 16-mesh reflects the severity of attrition to which the germ is subjected within each degerminator. The −8+25-mesh fraction and −25-mesh fines from the disk mill were lowest in oil content, granulator fractions intermediate, and the Beall fractions climbed to very high levels (Fig. 1). Action within the disk mill must have been particularly mild because the −25-mesh fines from each of the three samples analyzed lower in oil content than did the −8+25 fraction.

Yield of −3½+16 grits for all degerminators fell in the 66–76% range (Table III). Oil content of this fraction and the −16-mesh fines

TABLE III

ENDOSPERM PRODUCTS

	Type of Degerminator, and Processor			
	Beall No. 2	Beall No. 2	Granulator	Disk Mill
	A	B	C	D
−3½+16 Grits				
Yield, % NFS[a]	74	66	76	69
Oil content, % d.b.	0.68	(1.07)[b]	1.73	1.51
−16-Mesh fines				
Yield, % NFS	12	18	8	17
Oil content, % d.b.	(7.6)[b]	(6.5)[b]	3.4	1.4
Hominy feed				
Yield, % NFS[c]	24	33	23	28
Oil content, % d.b.[d]	6.5	5.4	4.1	2.7

[a] Net feedstock.
[b] The −8+16- and −16+25-mesh fractions were combined for the chemical analyses. Values given in parentheses are calculated from available data.
[c] Calculated yield based on quantity of −16-mesh fines, hull fraction, and germ cake.
[d] Calculated value based on oil contents given here and in Table II for −16-mesh fines, and germ and hull fractions; and assuming 5% oil (d.b.) in oilcake.

varied considerably and again reflected differences in degree of degermination. The −3½+16 grit mixture from mill A was considerably below the 1.0% maximum oil content usually specified. This means that no further degermination was needed and suggests that subsequent milling steps could be limited to separation of germ and hull fractions from these grits. Thus, it should be possible to use a shorter milling flow, an objective sought by mill management. The grit mixture from mill B almost met this limiting oil maximum, and it is apparent from Fig. 1 that if the mixture contained only −3½+8 grits, its oil content would be well below 1%. Further degermination on rolls was needed for the granulator and disk mill to produce grits of less than 1% oil content.

The high oil content of the Beall fines fraction indicates probable presence of finely ground germ particles. Pfeifer, Stringfellow, and Griffin (5,6) demonstrated that air-classification can produce a fraction from rice, sorghum, and corn flours of slightly lower oil content through removal of the smaller particles. Their work suggests that the fines fraction be processed by air-classification or other appropriate means to reduce its oil content to the approximate level of the disk mill fines. A starting material of oil content, such as the Beall degerminator fines, may show an appreciable "oil shift" if the flour can be satisfactorily handled mechanically. Fines from the disk operation are sufficiently low in oil content to permit their direct usage for some industrial applications.

Yield of hominy feed varied more between the two Beall degerminators than between various types of degerminators; also oil content of the hominy feed varied widely, the disk mill product being the lowest.

Conclusions

While variations in tempering and degerminating and among the several lots of corn undoubtedly contributed somewhat to the observed differences, the data point to several conclusions. Appreciable differences were noted in degree of degermination obtained and in yield of large grits, the Beall degerminator samples appearing best. In the disk mill the cracking and mild abrasion of the corn produced some degermination; however, more extensive rubbing or scouring such as occurs in the Beall was needed to produce −4+6-mesh grits of 0.5% or less oil content. With proper tempering and degerminating, and with corn that responds adequately to treatment, sufficient degermination was obtained within the Beall degerminator for practically all grits in the −3½+16-mesh range so that the need for further degermination on roller mills is eliminated. Thus, the subsequent milling flow could be shortened, because the problem is then limited to separation of germ and hull fractions from grits and to reduction of endosperm material to grits of desired sizes.

All three types of degerminators produced essentially comparable quantities of −3½+16-mesh grits.

The more severe rubbing action attained with the Beall degerminator ground some germ into fine particles. As a result, oil recovery was lowered considerably and oil content of the fines fraction was almost twice that of the whole corn. This same action also produced a larger hull fraction but decreased its purity and produced −4+6-mesh grits with fewer attached hull fragments.

Compared to the Bealls, the disk mill used less power per bu. of corn processed. The disk mill also gave the best oil recovery, whereas the granulator was intermediate. Both of these machines presumably can degerminate corn at a lower temper (moisture) level than the Beall and thus reduce the drying load, which is one of the more costly processing steps and one that often limits plant capacity.

Information gained from this study should be of use to those working for improved degermination. Also, the possibility of using a shorter milling flow becomes evident.

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