CORN DRY-MILLING: INFLUENCE OF FEED RATE AND TAIL-GATE LOADING UPON BEALL DEGERMINATOR PERFORMANCE[1]

O. L. BREKKE, L. A. WEINECKE, AND E. L. GRIFFIN, JR.

ABSTRACT

In degerminating corn with a No. 0 Beall degerminator in a series of short experimental tests, the germ recovery was excellent at the lowest feed rate. As the net throughput (gross less +3½ mesh recycle stock) was increased from 8.4 to 17.9 bu. per hour (degerminator is rated by the manufacturer at 10 to 20 bushels hourly capacity), the germ recovery fell off sharply, then more slowly, and finally leveled off. The potential oil yield varied accordingly from 1.56 to 0.92 lb. per bu. Oil content of the −4+6 and −6+8 grit fractions increased steadily to levels more than double the initial values of 0.44 and 0.83%, respectively. The finer fractions were not analyzed for oil content. The yield of −4+6 grits rose steadily, and the −6+8 grits reached a maximum at 12 bu. per hour (i.e., about 80% of the normal feed rate) while yields of the recycle and −3½+4 mesh stocks increased in an exponential manner. The best recovery of hull and minimum amount of −4+6 grits with attached hulls were obtained at 11-12 bu. per hour. Power requirement decreased from 0.8 to 0.6 kw.-hr. per bu. with increasing feed rate.

These results were obtained with fixed degerminator settings on corn of 13% initial moisture content tempered for 3 to 4 hours to 23% moisture. While the net hourly throughput decreased 20% with the degerminator tail-gate loading almost doubled, a smaller yield of −4+6 grits and a better yield of −6+8 grits, germ, and hull were obtained. Reductions were noted simultaneously in attached hulls and in oil content of the −4+6 and −6+8 grits. However, the germ recovery and oil content of the coarser grits were not equal to those obtained at the lowest feed rate.

Improved germ and oil recovery and grits of lower oil content are obtainable by operating Beall degerminators at much less than usual throughput rates (i.e., ca. 0.8 of manufacturer's minimum rating or 0.3 of present commercial rates) and with a minimum to moderate tail-gate loading.

Economic aspects and production demands force corn dry millers to operate their degerminators at the highest throughput consistent with product quality. However, no information is available in the literature on the effect of throughput rate on degerminator performance.

In the current study, data from our experimental procedures were used to determine the influence of feed rate and tail-gate loading (TGL) upon the amount of recoverable germ and oil; the yield, oil

[1]Manuscript received September 15, 1961. Contribution from the Northern Regional Research Laboratory, Peoria, Illinois. This is a laboratory of the Northern Utilization Research and Development Division, Agricultural Research Service, U.S. Department of Agriculture. Presented at the 46th Annual Meeting of the American Association of Cereal Chemists, Dallas, Texas, April 9-13, 1961.

Mention of trade products is for identification only and does not imply endorsement by the Department.

content, and other quality factors of the large grits produced; amount of hull or bran removed; yields of the finer fractions; and power requirements for a No. 0 Beall degerminator and corn dehuller.

Materials, Equipment, and Methods

Yellow dent hybrid corn, grade No. 2, a mixture of Doubet varieties D25 and D41 from the 1959 crop was milled 11 months after harvest. It had been grown at Elmwood, Illinois, on a silt loam soil with 175 lb. per acre of 12-12-12 fertilizer applied at the time of planting. The corn analyzed 4.70% oil, 2.04% crude fiber, 1.37% ash (600° C.), and 9.44% protein on a m.f.b. Test weight was 58.3 lb. per bu. with 70 and 95% (wt.) of the kernels retained on U. S. No. 3 and 3½ sieves, respectively. According to the "floaters test," the corn was "average" in hardness (2).

The Beall degerminator was driven by a 10-hp. electric motor and is rated at 10-20 bu. per hour capacity by the manufacturer. Details of the pilot-plant installation, the laboratory procedure used for fractionating the degerminator product streams, and the analytical methods used have been described previously (1).

Experimental Operation. The corn contained 13.2% moisture initially and was tempered to 22.7% at room temperature (about 85° F.) for 3.0 to 3.8 hours by the addition of tap water. The degerminator shell was fitted with 4 screens having 14/64-in. round-hole perforations, and the rotor, which had "blunt" studs, was operated at 785 r.p.m. in a 50% closed position.

A series of 4-minute tests was made as the *net* throughput was varied between 8.4 and 17.9 bu. per hour (14% moisture basis). *Net* throughput is *gross* throughput less the recycle fraction, i.e., particles which were retained on a 3½-mesh U. S. sieve. The feed rate was controlled to load the motor to 25.4, 27.5, 30.8, and 34.0 amp. For the first test, made at 15.2 bu. per hour net, the tail-gate loading was adjusted to give satisfactory polish, i.e., hull removal from the large grits in the tailings stream as judged by a visual inspection. At this feed rate and TGL the motor was essentially fully loaded (30.8 amp.). This same TGL was used for the remainder of this series. In a second series, two tests were made using the two highest motor loads but with heavier TGL's (Table I).

Results and Discussion

At the lowest feed rate the degerminator product streams contained no recycle fraction. Small but increasing amounts of recycle stock were produced as the feed rate was increased up to the normal level,

TABLE I

MOTOR LOADS AND TAIL-GATE LOADINGS USED AND THEIR EFFECTS ON THROUGHPUT, AMOUNT OF RECYCLE STOCK, THROUGHS STOCK, AND TAILS-TO-THROUGHS RATIO

Motor Load	Throughput [a]		+3½ Recycle	Tail-Gate Loading	Throughs Collected	Tails-to-Throughs Ratio
	Gross	Net				
Amp.	*Bu./hr.*	*Bu./hr.*	*% F.S.* [b]	*In.-g.*	*Lb.*	
	Effect of Feed Rate					
25.4	8.4	8.4	0	165	27.8	0.24
27.5	10.0	9.9	1.0	165	30.8	.33
30.8 [c]	15.9 [d]	15.2	3.9	165	38.3	.69
34.0	25.8	17.9	29.4	165	34.5	2.06
	Effect of Tail-Gate Loading					
33.9	14.7	14.2	2.6	295	39.8	0.51
31.1	9.6	9.6	0.2	215	33.3	0.17

[a] Adjusted to 14% moisture basis.
[b] Percent of gross feedstock.
[c] Approximately 100% motor load.
[d] Tail-gate loading set for this rate.

i.e., 15.2 bu. per hour in these experiments. At the highest rate, 17.9 bu. per hour, almost 30% of the corn fed to the degerminator appeared in the recycle fraction and, consequently, the net throughput was considerably less than the gross throughput (Table I).

With this same maximum motor load and the TGL increased almost twofold from 165 to 295 in.-g. to give good polish, the recycle fraction decreased to a satisfactory level, i.e., 2.6% of the gross feedstock, but the net throughput fell to 14.2 bu. per hour, which was somewhat lower than for the normal motor load. Therefore, the heavier TGL decreased the net throughput about 20%. With an intermediate TGL (215 in.-g.) at the normal or full motor load (31.1 amp.), the feed rate was about two-thirds of that for normal TGL.

In these tests the perforated screens functioned to some extent as an orifice as the throughput varied. For four of the tests, where both feed rate and TGL were at comparatively high levels, the quantity of through stock held between 33 and 40 lb. while the tails-to-throughs ratio varied from 0.17 to 2.06 (Table I).

One of the most significant effects of varying the feed rate was the pronounced influence on the amount of germ released from the corn. At the lowest rate, 8.4 bu. per hour, the quantity of germ released and recovered was exceptionally good (11.9% of the net feedstock), then fell off, sharply at first and more gradually later, as the throughput was increased (Fig. 1). At the highest rate the germ recovery was only 7.3% of the net feedstock, a value comparable to that obtained from commercial degerminator samples. Increasing the TGL almost two-

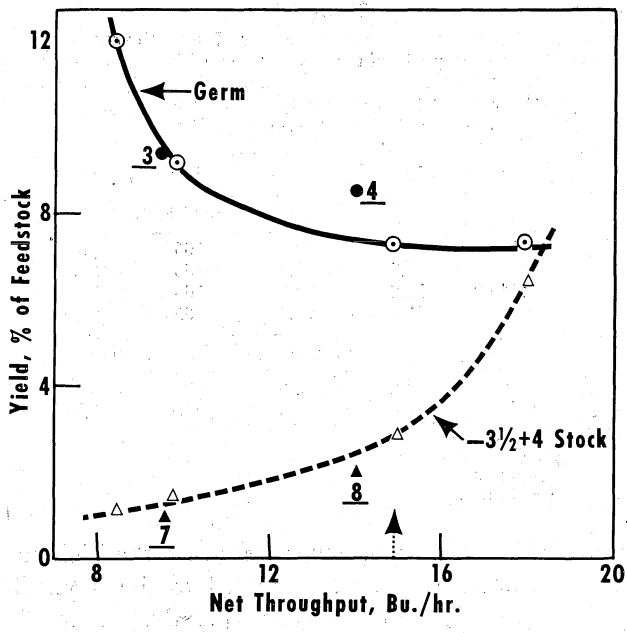

Fig. 1. Effect of net throughput and tail-gate loading on quantity of germ and of $-3\frac{1}{2}+4$ mesh stock recovered from Beall degerminator product streams.

LEGEND AND NOTES: (a) All yields are based on the net feedstock (adjusted to 14% moisture). (b) Tail-gate loading = 165 in.-g. for all points except 3 and 7 = 215, 4 and 8 = 295. (c) Points *3* and *4* with the solid circles represent data obtained at the same motor load as the third and fourth open circles counting from left to right, but with heavier tail-gate loadings as indicated (see Table I). A similar analogy applies to points *7* and *8* with the solid triangles. (d) The vertical dotted arrow at 15.2 bu. per hour on the abscissa indicates the normal feed rate for 100% motor load and a tail-gate loading of 165 in.-g.

fold and using the highest motor load increased the germ recovery from 7.3 to 9.4% (point 4 on Fig. 1) for 14.2 bu. per hour net throughput. However, for the normal motor load no improvement was obtained when TGL was increased moderately.

The amount of recoverable oil is directly dependent upon the amount of germ recovered and its oil content. For the first series, the predicted oil recovery ranged from 1.56 lb. per bu. of corn (14% moisture basis) at the lowest rate to 0.94 lb. per bu. at the highest rate (Table II). (The increase from 0.92 to 0.94 lb. per bu. may be due either to experimental error or to partial degermination of the recycle fraction.) Total oil content of the corn was 2.25 lbs. per bu. [(56)(1.00-.14)(.047)]. With the comparatively large TGL and the maximum motor load, the oil recovery was increased by about one-sixth (from 0.92 to 1.10 lb./bu.). For the normal motor load and a moderate

TABLE II

EFFECT OF THROUGHPUT ON OIL RECOVERY IN CORN DRY MILLING

Net Throughput	Tail-Gate Loading	Dry Germ Recovered	Oil Content Germ [a]	Oil in Germ		
				Available	In Cake [b]	Recoverable
Bu./hr.	*In.-g.*	*Lb./bu.*	*% M.f.b.*	*Lb./bu.*	*Lb./bu.*	*Lb./bu.*
	Effect of Feed Rate					
8.4	165	5.74	30.9	1.77	0.21	1.56
9.9	165	4.41	29.1	1.28	.16	1.12
15.2	165	3.51	30.0	1.05	.13	0.92
17.9	165	3.54	30.2	1.07	0.13	0.94
	Effect of Tail-Gate Loading					
14.2	295	4.06	30.7	1.25	0.15	1.10
9.6	215	4.44	29.4	1.31	0.17	1.14

[a] Correction of 1.9% added for estimated loss of oil in solvent decantation step.
[b] Assuming cake contains 5% oil on a moisture-free basis.

increase in TGL the oil recovery increased but 0.02 lbs., a variation entirely within the limits of experimental error. In neither case did the recovery reach the high level obtained with the low feed rate. Throughout both series the oil content of the germ fraction remained essentially constant.

Feed rate and TGL also influenced the oil content of the larger grits. The lowest oil levels for the −4+6 and −6+8 grits were obtained at the lowest rate (Table III) and as the rate increased, the oil con-

TABLE III

OIL CONTENT OF CORN GRIT FRACTIONS

Net Throughput	Tail-Gate Loading	Oil in Grits, %, m.f.b.				
		+3½ [a]	−3½+4	−4+6	−6+8	Mixture −4+6 and −6+8
Bu./hr.	*In.-g.*					
	Effect of Feed Rate					
8.4	165	...	1.11	0.44	0.84	0.63
9.9	165	4.15	1.03	.56	1.14	.84
15.2	165	5.20	1.93	.67	1.31	.98
17.9	165	4.73	3.76	0.96	1.74	1.29
	Effect of Tail-Gate Loading					
14.2	295	4.93	1.30	0.57	1.11	0.84
9.6	215	...	0.90	0.47	0.96	0.72

[a] Essentially whole corn.

tents of these grits also increased progressively. The over-all increase was approximately twofold. At the three lowest rates, a mixture of the −4+6 and −6+8 grit fractions contained less than 1.0% oil, but at

the highest rate only the −4+6 grits met this specification and, consequently, the yield of grits containing 1.0% or less oil decreased from 65 to 33%.

The oil content of all fractions between 3½- and 8-mesh was reduced one-eighth or more by using a heavier TGL (e.g., 0.96 *vs.* 1.14% for −6+8 grits).

Hull recovery and the percentage of −4+6 grits having attached hulls were also influenced by feed rate and TGL. The best hull release and the lowest percentage of attached hulls were obtained at a net throughput of about 11 bu. per hour (Fig. 2). Poorer results were ob-

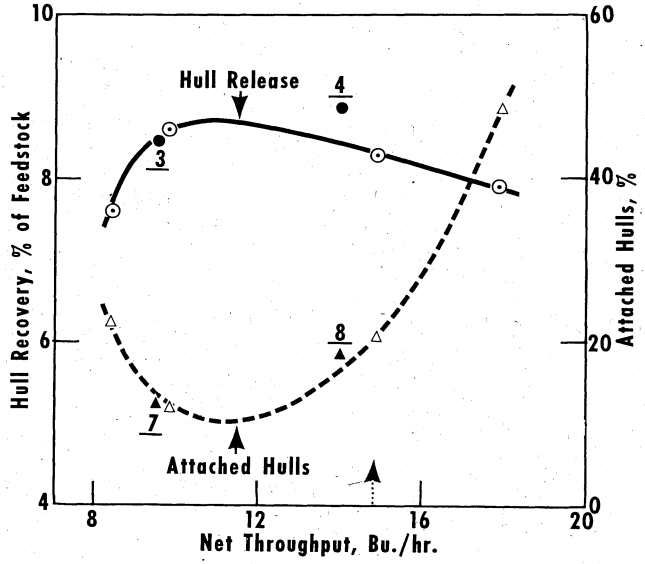

Fig. 2. Effect of net throughput and tail-gate loading on hull release and percentage of −4+6 grits having attached hulls. (Legend for symbols same as Fig. 1.)

tained at rates both below and above this value. As the rate increased above 11 bu. per hour, the hull recovery fell off slowly and the proportion of −4+6 grits with attached hulls increased rapidly. Doubling TGL again brought about desirable improvements, though not exceptional, in both hull release and attached hull count.

The yield of −3½+4 stock increased moderately with an increasing feed rate as long as TGL was adequate (Fig. 1). The −4+6 grit yield increased slowly but gave indications of leveling off; the −6+8 grit yield passed through a maximum about 12 bu. per hour (Fig. 3), and the finer fractions decreased steadily in quantity (Fig. 4). A heavier

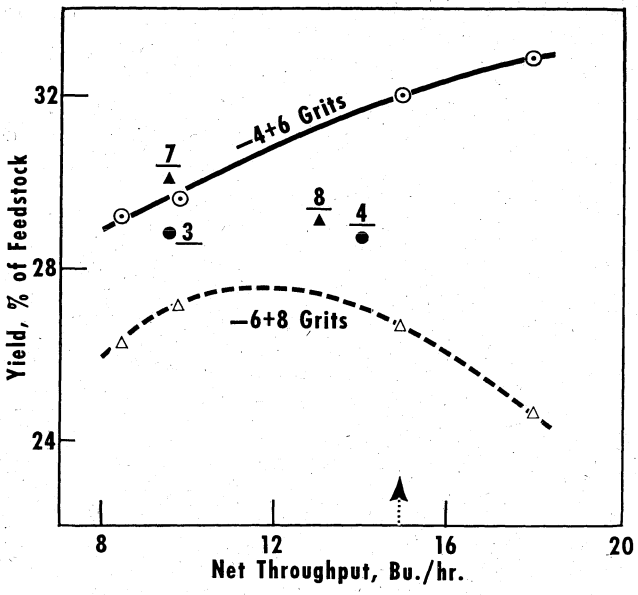

Fig. 3. Effect of net throughput and tail-gate loading on yield of −4+6 and −6+8 grits. (Legend for symbols same as Fig. 1.)

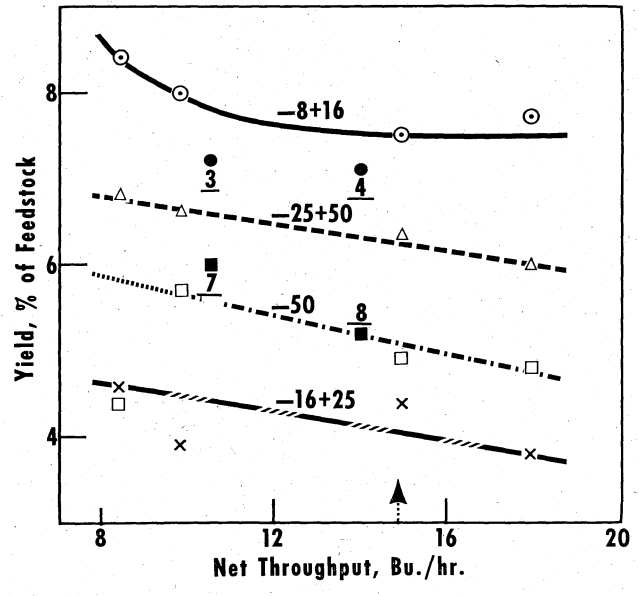

Fig. 4. Effect of net throughput and tail-gate loading on yield of stocks finer than 8 mesh. (Legend for symbols same as Fig. 1.)

TGL decreased the $-3\frac{1}{2}+4$ stock yield, decreased $-8+16$ grits slightly and $-4+6$ grits moderately, and simultaneously increased the yield of $-6+8$ grits and of particles smaller than 16-mesh.

The power required to operate the degerminator is important. Data given in Table IV indicate that both throughput rate and TGL

TABLE IV
POWER REQUIRED

NET THROUGHPUT	POWER USED	TAIL-GATE LOADING
Bu./hr.	*Kw.-hr./bu.*	*In.-g.*
	Effect of Feed Rate	
8.4	0.80	165
9.9	.78	165
15.2	.59	165
17.9	0.57	165
	Effect of Tail-Gate Loading	
14.2	0.71	295
9.6	0.94	215

have considerable bearing on the power used. For most economical use of power, TGL should be no more than necessary to give appropriate polish and degermination for a particular feed rate.

Acknowledgment

The authors express their appreciation to Richard S. Diem and Raymond J. Wagner for assistance in the experimental work and to Dean Uhl and Francis Alaksiewicz for analytical determinations.

Literature Cited

1. BREKKE, O. L., WEINECKE, L. A., WOHLRABE, F. C., and GRIFFIN, E. L., JR. Tempering and degermination for corn dry milling: a research project for industry. American Miller and Processor **89** (9): 14–17 (1961).
2. WICHSER, W. R. The world of corn processing. American Miller and Processor **89** (4): 29–31 (1961).