Effects of Modifications of a Model CK2 Stein Breakage Tester on Corn Breakage Susceptibility[1]

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ABSTRACT

The effects on corn breakage susceptibility of several modifications of a model CK2 Stein breakage tester were studied. Modifications consisted of an improved impeller assembly; thicker, longer, and harder blades; and a stainless steel cup. These were incorporated into the model CK2-M Stein breakage tester currently in production. Use of the modified instrument doubled the breakage of breakage-prone corn and lessened the time required to determine the percentage of breakage.

Miller et al (1981) observed differences in the blade characteristics of five model CK2 Stein breakage testers used to measure corn breakage susceptibility but no appreciable differences in cup dimensions. Blade characteristics that affected breakage results most were clearance between the leading edge of the impeller blades and the bottom of the cup and clearance between the radial edge of the blades and the inner wall of the cup. This study was conducted to determine the effects on the breakage of corn of differences in those characteristics, of radiusing[5] the blade edges, and of using cups made from aluminum or stainless steel. A device is desired that will differentiate between the breakage susceptibilities of sound and breakage-prone corn in minimum time.

MATERIALS AND METHODS

Materials

The Andersons, Maumee, OH, provided one sound and one breakage-prone commercial corn sample, used by Miller et al (1981). The moisture contents at the time of use were 12.2 and 9.6% (wet basis), respectively.

Tester blades (compatible with the Stein breakage tester) with different lengths and thicknesses, some with and some without radiused edges, were made in our shop with DoAll oil-hardened, precision-ground tool and die steel (Fig. 1). The radial edges were shaped with a straight mill (by means of a rotary table and clamping device to hold the steel) to fit the curvature of the cup. Edges were radiused with a concave cutter (DoAll 717-021117). Some blades were hardened to a Rockwell hardness of 50, according to instructions provided by the supplier. The steel normally used to make the blades for the model CK2 Stein breakage tester was too soft to obtain a Rockwell hardness reading.

Stein breakage tester cups were made from aluminum by casting

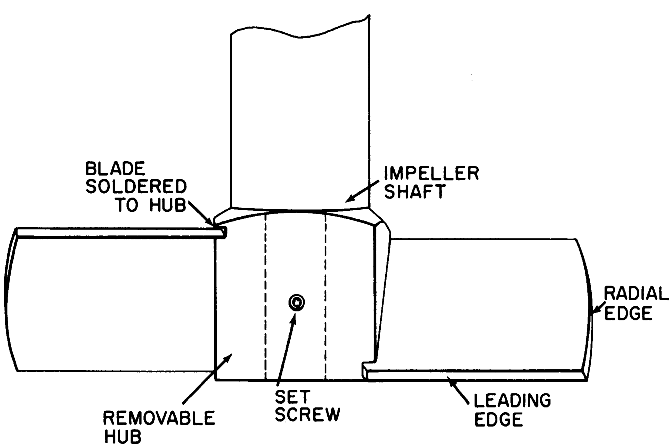

Fig. 1. Diagram of removable blade assembly attached to impeller shaft by two set screws.

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Mention of firm names or trade names does not constitute endorsement of a product by the USDA over others of a similar nature not mentioned.

[5]Rounding the edge with a concave cutter used for milling half circles (DoAll Master Catalogue No. 968-115501, 10/79).

and from a 304 stainless steel tube by turning on a lathe. The 303 stainless steel bottom of the cup was attached by tungsten, inert gas welding.

Methods

Corn samples were tested for breakage susceptibility according to the procedure outlined by Miller et al (1981) for corn. After cleaning a sample by the standard dockage procedure, we ran a 100-g portion in a Stein breakage tester for 1–4 min, and sieved it 30 sec (30 strokes) on a Gamet shaker equipped with a 4.76-mm (12/64-in.), round-holed sieve. The amount of sample passing through the screen gave the percentage of breakage. Except where otherwise indicated, all data represent the average for triplicate subsamples.

RESULTS AND DISCUSSION

Blade-to-Cup-Bottom Clearance

Miller et al (1981) reported that the effect of variations in blade-to-cup-bottom clearance was not clear but that the clearance should be maintained within close tolerance. To test the effect of blade-to-cup-bottom clearance, we cut a 6.4 × 12.7-mm window in the side of a cup, flush with its bottom, so we could measure the clearance between the bottom of the cup and the leading edge of the impeller blades. We changed the blade depth by placing shims between the upper cup support and the motor. Figure 2 shows that breakage for sound corn varied from 7.5 to 12.3% when the blade-to-cup-bottom clearance ranged from 0.5 to 4.0 mm.

A straight line can be fitted to the data (Fig. 2) to obtain the relation

$$\text{breakage, }\% = a + b \times (\text{mm clearance})$$

where $a = 7.51 \pm 0.28$ and $b = 1.18 \pm 0.12$.

Although the line fits only marginally (lack of fit P value = 0.08), the clear upward trend seems sufficient for recommending a close tolerance between the blade and the cup bottom. We believe that a clearance of 0.64 ± 0.25 mm between the blade and cup bottom is satisfactory and attainable.

Radiused Edges

A series of blades made in our shop were used in a comparative study with modified (standard) blades for determination of corn breakage susceptibility (Table I). Analysis of variance of the data showed that laboratory-made blades produced significantly ($P<0.05$) more breakage than did standard blades for both sound and breakage-prone corn. Heat treating the laboratory-made blades had no significant ($P>0.10$) effect on breakage for either type of corn, nor did radiusing the leading edge ($P>0.10$), the trailing edge (data not shown), or both trailing and leading edges (data not shown). However, radiusing the radial edge (of heat treated, laboratory-made blades) significantly ($P<0.05$) decreased breakage for both sound and breakage-prone corn.

The decreased breakage with radiused-edged blades indicated that a sharp radial edge is needed to cause maximum breakage. The greater breakage with laboratory-made blades than with standard blades probably was caused by differences in the radial edges; the standard blade was slightly radiused due to wear.

Blade Thickness

An analysis of variance of the data (Table II) showed that the thicker blades produced significantly more breakage of breakage-prone corn, regardless of whether or not the radial edge was radiused ($P<0.01$), than did blades of standard 1.59-mm thickness. This result was probably caused by the greater rigidity of the thicker blades.

Blade Length

An analysis of variance of the data (Table III) showed that blade length had no detectable effect on sound corn ($P = 0.10$) but significantly increased the amount of breakage for breakage-prone corn ($P<0.01$). Chung et al (1973) and Miller et al (1979) showed that breakage of corn was directly related to velocity of grain movement. Thus, the increase in breakage with increases in blade length was probably caused by an increase in the impact velocity at the radial edge of the blades as blade length increased.

Polishing the Blades

Blades were polished by hand to a smooth finish, first with 280-grit emery cloth, then with crocus cloth. Care was taken to avoid rounding the radial edge. Results obtained with polished

TABLE I
Effect of Blade Modifications and Heat Treatment on Corn Breakage

	Breakage (%)[b,c]	
Blade[a]	Sound Corn	Breakage-Prone Corn
Standard	3.7 a	23.1 a
Laboratory-made		
Polished	6.9 b	29.0 b
Heat-treated and polished	7.4 b	28.8 b
With leading edge radiused	7.0 b	28.1 b
With radial edge radiused	3.4 a	17.8 c

[a] All blades 1.59 mm thick; length of blade's cutting edge, 34.92 mm; clearance between radial edge of blade and inner wall of cup, 7.95 mm; blade-to-cup-bottom clearance, 0.48–0.85 mm.
[b] Average for triplicate subsamples; 4-min running time.
[c] Different letters indicate differences at 0.05 level obtained from Duncan's multiple range test and Tukey's W procedure (Steel and Torrie 1980).

TABLE II
Effect of Blade Thickness on Breakage of Breakage-Prone Corn

Laboratory-Made Blade[a]	Blade-to-Cup-Bottom Clearance (mm)	Breakage[b] (%) from Blades with Thickness (mm) of	
		1.59	3.18
Radial edge radiused	0.56	17.8	27.4
No radiused edges	0.48	28.8	37.9

[a] Length of blade's cutting edge, 34.92 mm; blade clearance between the radial edge of blade and inner wall of cup, 7.95 mm; all blades polished and made from hardened steel.
[b] Average for triplicate subsamples; 4-min running time.

TABLE III
Effect of Blade Length on Corn Breakage

Cutting Edge[a] Length (mm)	Breakage (%)[b]	
	Sound Corn	Breakage-Prone Corn
28.58	5.2	16.9
31.75	7.9	27.1
41.28[c]	5.9	46.7

[a] All blades polished, 3.18 mm thick, and made from hardened steel; blade-to-cup-bottom clearance, 0.84 mm.
[b] Average for triplicate subsamples; 4-min running time.
[c] Tip-to-tip blade length measured at blade centerline, 88.90 ± 0.050 mm.

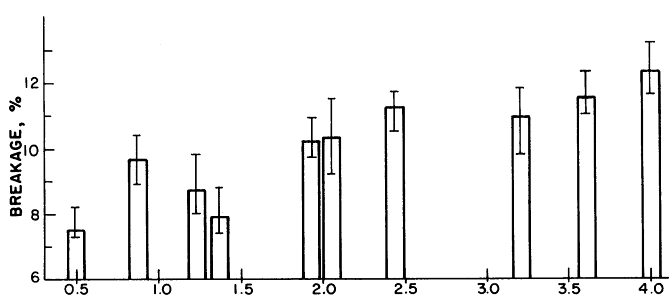

Fig. 2. Effects of blade-to-cup-bottom clearance on breakage of corn measured at 24°C with a model CK2-M Stein breakage tester with a 4-min running time. Vertical lines represent the range for triplicate values.

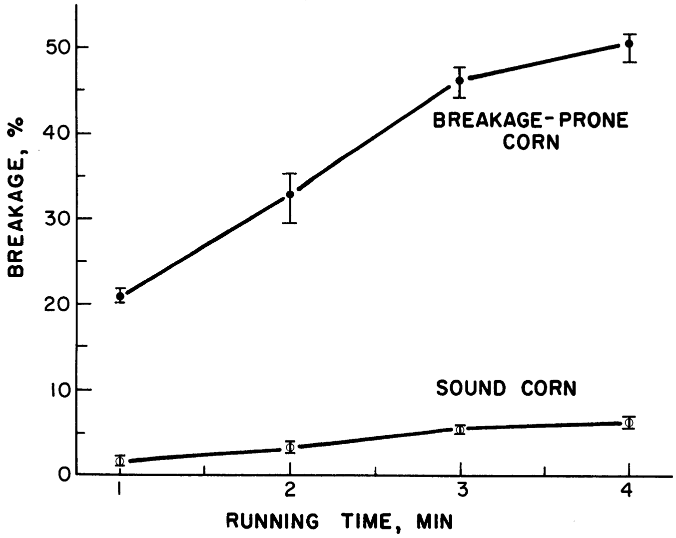

Fig. 3. Effects of Stein breakage tester (model CK2-M) running time on breakage of corn measured at 24°C. Vertical lines represent the range for quintuplicate values.

standard blades showed that, for a new set of blades, a "break in" period of 80 min (20 100-g samples) was necessary to polish the blades before constant breakage was achieved (data not shown). Modified machines with hardened blades of 3.18-mm thickness did not require "breaking in" because breakage results were reproducible. The blades were polished during their manufacture.

Aluminum vs Stainless Steel Cups

Results from testing sound and breakage-prone corn with a modified Stein breakage tester equipped with cups made from aluminum or stainless steel are summarized in Table IV. An analysis of variance of the data showed no detectable difference in breakage for breakage-prone corn for the different cups ($P = 0.21$). For sound corn, however, less breakage resulted with stainless steel cups ($P < 0.05$). The use of a stainless steel cup reduced operating noise and eliminated the potential problem of aluminum-cup wall erosion with extended use.

Effect of Running Time

The data in Fig. 3 show the effects of running time, using hardened steel blades of 3.18-mm thickness and blades with a leading (cutting) edge 41.28 mm long (a clearance of 1.60 mm between the radial edge of the blade and the inner cup wall), and a clearance of 0.84 mm between the blade and the cup bottom. A t-test of the data obtained at a 1-min running time showed a clear differentiation ($P < 0.01$) of sound and breakage-prone corn. Therefore, for rapid testing of breakage susceptibility of corn in marketing channels, a 1-min running time may be adequate.

Recommended Modifications of a Stein Breakage Tester

We recommend that the model CK2 Stein breakage tester be modified in several ways.

TABLE IV
Breakage (%) of Sound and Breakage-Prone Corn with a Modified CK2 Stein Breakage Tester and with Aluminum and Stainless Steel Cups

	Cup		
	Stainless Steel		
Corn/Subsamples	No. 1[a]	No. 2[a]	Stock Aluminum
Sound			
1	2.9	2.8	3.7
2	2.8	3.1	3.3
3	3.2	2.3	3.3
4	3.1	2.8	3.8
5	2.5	2.6	3.7
Mean	2.9	2.7	3.5
SD	0.3	0.3	0.2
Breakage-prone			
1	19.7	17.7	23.7
2	20.8	21.6	22.7
3	20.2	20.5	20.8
4	21.3	19.5	21.9
5	22.5	19.8	18.8
Mean	20.9	19.8	21.6
SD	1.1	1.4	1.9

[a]The dimensions of these cups, made in two machine shops, were within tolerances specified in the text.

1. Use tool and die steel of 3.18-mm thickness to make blades with a sharp radial edge; lengthen the blades to give a clearance of 1.60 mm between the sharp radial edge of the blade and the inner wall of the cup, and polish them as described.
2. Silver-solder the blades to a removable hub attached to the impeller shaft with two set screws (Fig. 1).
3. Replace the Teflon plate at the top of the cup assembly with a stainless steel ring to provide a hard surface on which grain will impact.
4. Use a stainless steel cup.

In addition to modifying the breakage tester as described, we recommend the following manufacturing specifications: blade-to-cup-bottom clearance, 0.64 ± 0.25 mm; cup ID, 92.08 ± 0.152 mm; cup depth, 88.90 (+0.127 to −0.025) mm; length of blade's leading (cutting) edge, 41.28 ± 0.030 mm; tip-to-tip blade length, 88.90 ± 0.050 mm. The model CK2-M Stein breakage tester is being manufactured with these specifications.

LITERATURE CITED

CHUNG, D. S., CHUNG, C. J., and CONVERSE, H. H. 1973. Damage to Corn from Pneumatic Conveying. USDA ARS-NC-5.

MILLER, B. S., HUGHES, J. W., ROUSSER, R., and POMERANZ, Y. 1979. Note on a method for measuring breakage susceptibility of shelled corn during handling. Cereal Chem. 56:213.

MILLER, B. S., HUGHES, J. W., ROUSSER, R., and POMERANZ, Y. 1981. Measuring the breakage susceptibility of shelled corn. Cereal Foods World 26:75.

STEEL, R. G. D., and TORRIE, J. H. 1980. Principles and Procedures of Statistics, 2nd ed., pp. 185-6. McGraw-Hill, Inc.: New York.

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