MILLING PROPERTIES OF WHEAT IN RELATION TO PEARLING, SCOURING, AND IMPACTION[1]

G. M. GROSH, J. A. SHELLENBERGER, AND E. P. FARRELL

ABSTRACT

Pearled hard red winter wheat when experimentally milled gave a higher-ash flour than unpearled wheat. It was possible to effect relatively clean removal of the outer pericarp from the wheat kernel by scouring, but this peeling adversely affected subsequent milling results. Samples of Ponca wheat were tempered to 14 or 16.5% or untempered, allowed to stand for 0, 4, 12, or 24 hours, and impacted on a 27-in. Entoleter at 1,600, 2,000, or 2,400 r.p.m. It was possible with both Ponca seed and a commercial hard winter wheat to effect a 0.028% decrease (7 to 9% of the flour ash) in ash content of 60% extraction flour by prebreak impaction of tempered wheat just prior to milling, using a 27-in.-diameter impact machine at 2,400 r.p.m. Prebreak impaction studies with soft wheat indicated no significant improvement in experimental milling results.

While numerous articles have appeared in the trade journals on the use of abrasive or peeling techniques to remove the bran and germ prior to milling (3,4,5,12,13,14,18), few data were offered verifying any benefit to milling results. During the 1920's, some milling companies in this country adopted peeling systems only to abandon them later. In Europe a few mills are said to use peeling or severe scouring prior to milling.

[1] Manuscript received August 3, 1959. Contribution No. 321, Department of Flour and Feed Milling Industries, Kansas Agricultural Experiment Station, Kansas State University, Manhattan. A report of work done under contract with USDA and authorized by the Research and Marketing Act of 1946. The contract was supervised by the Northern Utilization Research and Development Division of Agricultural Research Service, Peoria, Illinois.

Impact machines are used widely in the milling industry to kill and remove insects before the wheat is milled. Anderson (2) reported in a study of premilling impaction at lower impact velocities that this had no effect on milling behavior of wheat. Since the nature of impact grinding (10) is different from that of grinding by rolls, it is conceivable that a moderate reduction by prebreak impaction might improve the milling behavior of wheat by lowering the ash content of the flour at a given extraction.

These studies were undertaken to determine if various physical treatments of wheat prior to milling might benefit the milling properties of hard and soft wheats.

Materials and Methods

A hard red winter wheat, variety Ponca, with 12.6% protein and 1.64% ash (14% moisture basis) was used in the majority of the studies reported. A commercial hard winter wheat mix with 11.5% protein and 1.77% ash and a soft red winter wheat, variety Brevor, with 10.7% protein and 1.78% ash were also used.

Pearling. A Strong-Scott laboratory barley pearler driven by a 1/6 h.p., 1,725 r.p.m. motor was used to observe the value of abrasive action as a prebreak treatment. Wheat was tempered to 16% moisture 24 hours before pearling and experimental milling. To 2 kg. tempered wheat, 0, 2, or 5% water was added and the material was mixed for 10 minutes. Samples were pearled 0, 20, 40, or 60 seconds. The wheat sample (100 g.) was placed in the hopper of the pearler, with the outlet blocked, and abraded from 0 to 60 seconds. Polishings removed were determined by sifting the stock on a 14-mesh screen in a Ro-Tap sifter for 2 minutes.

Scouring. A Forster Model 10 wheat scourer driven by a ½ h.p., 1,725 r.p.m. motor was modified by installing paddles the length of the scouring chamber and closing the outlets to permit more vigorous scouring action for varying times up to 1 minute. To observe the effect of scouring on milling behavior, samples of Ponca wheat were tempered to 14.5, 15.5, and 16.5% moisture, allowed to stand 24 hours, wetted with an additional 0, 3, or 5% water, mixed for 5 minutes, scoured 0, ½, or 1 minute, and then milled.

Impaction. An Entoleter with 27-in.-diameter rotor with pin rotor and smooth stator liner was used in the studies reported in this paper. Wheat was impacted at 1,600, 2,000, or 2,400 r.p.m. under seven representative tempering conditions as indicated in Figs. 3 and 4. Time between initial wetting and milling was always 24 hours; moisture content at time of milling was always 16.5%, adjusting to that moisture level by an additional wetting after impaction. Each experiment was replicated a minimum of four times. The four prebreak impaction treatments which showed most improvement of milling behavior (reduction of ash content at constant flour yield) as indicated in Table II, when compared to the unimpacted control sample, were repeated in experimental milling trials ten times. Mean values of the product of ash and percentage of product of each flour stream from each treatment were calculated (corrected to 14% moisture basis), and cumulative ash-extraction curves were plotted.

Sectioning and Hardness Test. Plane kernel slices were prepared with a freezing microtome sectioning technique employed in this laboratory (9). Hardness tests on 15 kernels at each treatment were determined by means of the MIAG hardness tester (16).

Analyses. Ash, protein, and moisture determinations were performed by using procedures 9.1a, 67.1, and 48.3a as outlined in *Cereal Laboratory Methods* (1).

Experimental Milling. There is no agreement on a standard experimental milling procedure. Because of the many factors which can affect results (8,19), it is difficult to reproduce such millings with accuracy, even under carefully controlled conditions. Geddes and West (7) were able to minimize variations in yield to 1% of the total product, but careful roll adjustment, temperature, and humidity control were essential. By using the Allis-Chalmers experimental milling equipment, it was possible to minimize variations in results within each day, but variations from day to day were more difficult to control. For this reason, the randomized block experimental design was used, in which each treatment was compared with a control sample milled on the same day, permitting allowance for possible day-to-day variations when results were analyzed.

The experimental milling flowsheet (Fig. 1) was used in most of the studies reported. Earlier studies concerned with pearling, scouring, and prebreak impaction used a flow similar to that illustrated but with minor alterations of sieve sizes and break corrugations. Break roll corrugations were as follows: first and second breaks, 7 in. by 7 in., 14 corrugations per inch, ½-in. spiral, 2:1 differential dull to dull; third and fourth breaks, 24 corrugations per in., ½-in. spiral, 2:1 differential dull to dull. Roll spacings were: first break, 0.025 in.; second break, 0.016 in.; third break, 0.006 in.; fourth break, 0.004 in.; first sizings, 0.003 in.; second sizings, 0.002 in. Smooth rolls were adjusted to remove 30% of the control stock to the rolls to pass through 11xx silk screen. Sifting times were standardized as follows:

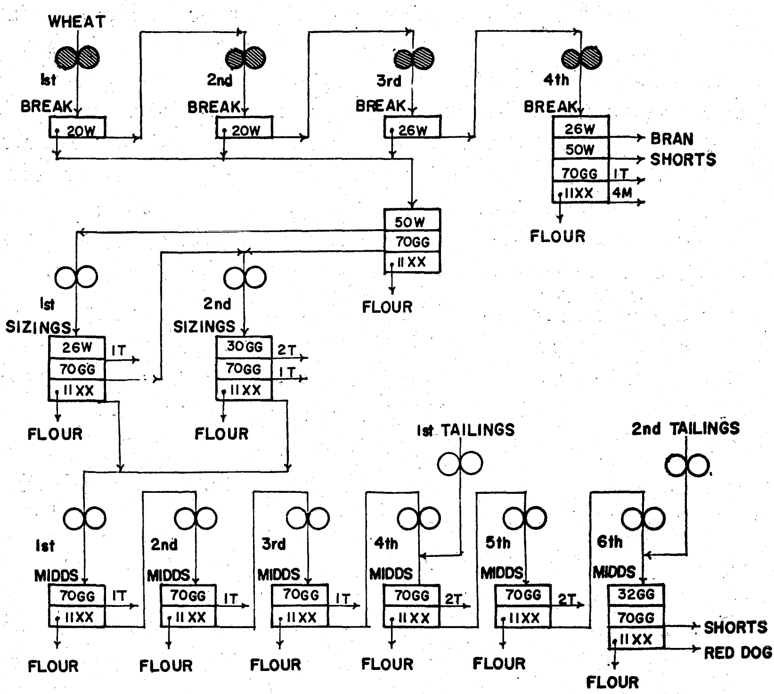

Fig. 1. Experimental milling flowsheet.

breaks, 1 minute; sizings and low-grade middlings, 1.5 minutes; first to third middlings, 2 minutes.

Seeborg (15) proposed an experimental milling score recognizing five interdependent factors contributing to milling quality: milling rate, optimum milling moisture, total flour yield, patent flour yield, and ash of patent and straight-grade flour. Flechsig (6) also developed a standard milling technique which comprises power consumption, flour ash at constant yield, and optimum moisture level. For the purpose of these studies where moisture and wheat sample were constant throughout the experiment, it was desirable to have a single quantitative index of milling quality, and with flour ash content and yield interdependent, the cumulative ash curve was plotted for each sample milled. The flour produced from each sample was removed as five composite streams (a, break; b, sizings; c, first and second middlings; d, third to fifth middlings; e, sixth middlings and tailings), weighed, sampled, and analyzed for ash and moisture content. After correction of weight and ash value to a 14% moisture basis, curves which showed a change in ash content with increasing extraction were plotted. From each curve it was possible to obtain a single ash value at constant yield as a criterion of milling quality.

Baking Test. The straight dough procedure as outlined in *Cereal Laboratory Methods* (1) using the following bread formula was followed: flour, 700 g.; sugar, 35 g.; salt, 14 g.; shortening, 21 g.; Arkady, 3.5 g.; malt, 3.5 g.; nonfat dry milk, 21 g.; yeast, 14 g.; water, based on farinograph absorption.

Results and Discussion

Pearling Studies. A typical set of analytical results is presented in Table I. Ash content of the wheat decreased and protein content of the polishings increased as the quantity of polishings removed

TABLE I

EFFECT OF VARIOUS PEARLING TREATMENTS PRIOR TO MILLING ON POLISHINGS REMOVED AND EXPERIMENTAL MILLING BEHAVIOR

MOISTURE ADDED	PEARLING TIME	POLISHINGS			WHEAT		FLOUR YIELD [a]	ASH CONTENT AT 70% EXTRACTION
		Yield [a]	Ash	Protein	Ash	Protein		
	seconds	%	%	%	%	%	%	%
Control	. .	0	. .	. . .	1.7	12.7	76.1	0.46
2	40	6.7	4.7	14.4	1.5	12.8	70.4	0.53
5	40	5.5	4.4	12.8	1.6	13.2	74.4	0.50
5	60	10.9	4.4	15.8	1.3	12.5	73.6	0.52

[a] Expressed as percent of total product including polishings.

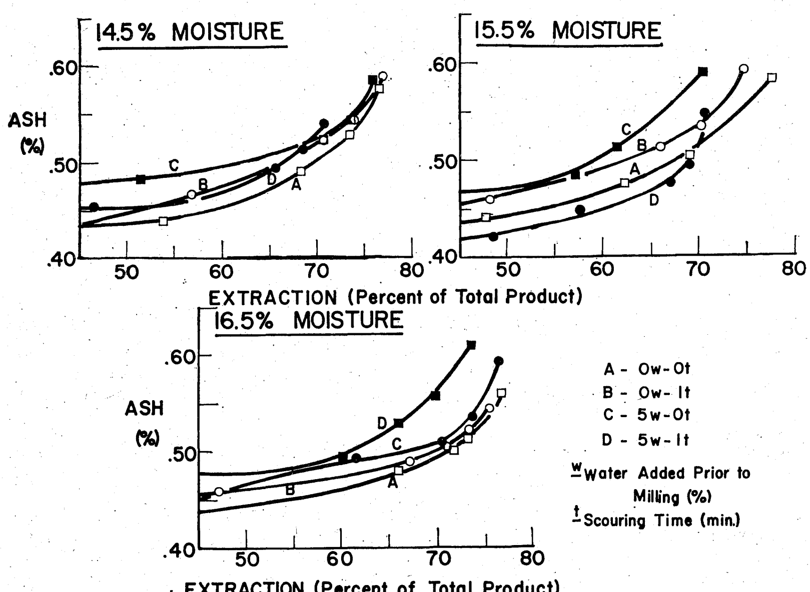

Fig. 2. Effect of wetting and scouring of wheat tempered to 14.5, 15.5, or 16.5% moisture on cumulative ash-extraction curves.

increased with longer pearling time. This may be due to removal with the polishings of the aleurone layer, which is high in both ash (11) and protein content. In no instance, on repetition of these studies, did pearling improve milling behavior as evidenced by flour yield or 70% extraction ash content.

Scouring Studies. Preliminary trials indicated that it was possible to obtain a visibly clean separation of the outer pericarp from the seed coat when 5% water was added 5 minutes before scouring. Temperature (from 20° to 100°C.) of the water did not affect the percentage of scourings removed. Use of more than 5% water before scouring did not appreciably increase the percentage of outer pericarp (wing) removed.

Cumulative ash-extraction curves (Fig. 2) showed that in most cases observed, scouring, with or without the addition of moisture, increased the ash content of the flour at the same yield as flour from unscoured wheat. It is possible that scouring damages the bran surface and this increases bran contamination and, hence, ash content of the flour produced.

Prebreak Impaction Studies. Preliminary experiments using a 10.5-

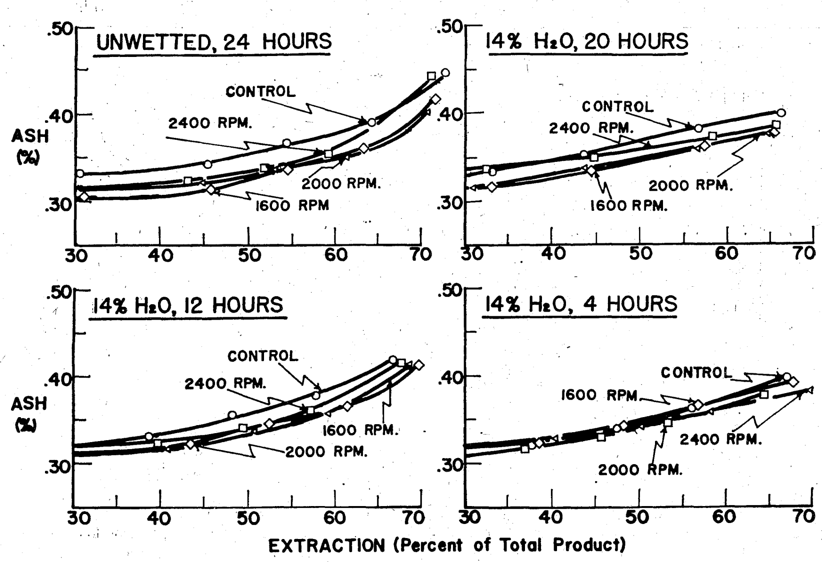

Fig. 3. Effect of various impaction treatments of unwetted or 14% moisture Ponca Seed wheat at 1,600, 2,000, and 2,400 r.p.m. with 27-in.-diameter Entoleter on cumulative ash-extraction curves. Upper left: Impaction of unwetted wheat 24 hours prior to milling. Upper right: Impaction at 14% moisture, 4 hours after initial wetting and 20 hours prior to milling. Lower left: Impaction at 14% moisture, 12 hours after initial wetting and 12 hours prior to milling. Lower right: Impaction at 14% moisture, 20 hours after initial wetting and 4 hours prior to milling.

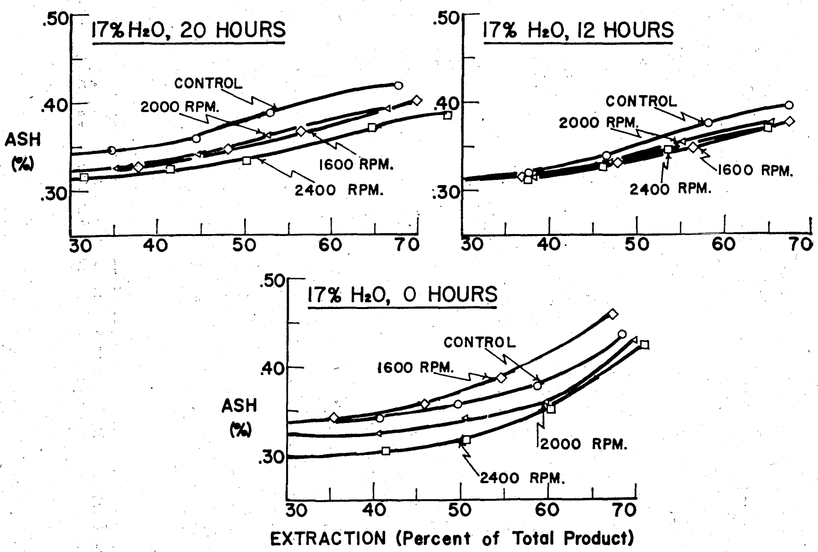

Fig. 4. Effect of various impaction treatments at 16.5% moisture of Ponca Seed wheat at 1,600, 2,000, and 2,400 r.p.m. with 27-in.-diameter Entoleter on cumulative ash-extraction curves. Upper left: Impaction 4 hours after initial wetting and 20 hours prior to milling. Upper right: Impaction 12 hours after initial wetting and 12 hours prior to milling. Bottom: Impaction 24 hours after initial wetting, immediately before milling.

in.-diameter Entoleter showed that a decrease in ash content as much as 0.09% at the same extraction (i.e., decrease from 0.51 to 0.42%) could result from prebreak impaction. When plane sections of impacted and unimpacted wheat kernels were prepared prior to milling, it was noted that as impaction speed increased and moisture content decreased, the regular radial and transverse cracking pattern, which can be noted in hard wheats as a result of tempering (9), was altered, with irregular cracking originating from the germ end of the wheat berry. Comparison of hardness values of unimpacted control samples (8.1) and impacted samples (8.2–9.7) which showed an improvement in milling indicated that the endosperm was softer as a result of impaction at time of milling.

Experimental milling experiments to verify these findings (Figs. 3 and 4) revealed that impaction at 17% moisture produced most improvement in flour ash at higher impaction speeds (2,400 r.p.m. using a 27-in.-diameter rotor). Most improvement in ash level was noted when 20–40% of kernels were broken by impaction (determined by weighing percentage of total stock passing through a No. 10 Tyler standard sieve after impaction). This extent of breakage was achieved with lower speeds (1,600–2,000 r.p.m.) when wheat was impacted

TABLE II

EFFECT OF VARIOUS PREBREAK TREATMENTS ON EXPERIMENTAL MILLING AND BAKING BEHAVIOR OF HARD AND SOFT WINTER WHEATS
(Average and product mean values of all replicates)

Prebreak Treatment			Cracked Kernels	Flour Yield[c]	Flour Ash Extraction		Significance			Bread Score[g]
Impaction Moisture[a]	Temper Time[b]	Entol. Speed			60%	70%	t[d]	Sig.[e]	Improvement[f]	
%	*hours*	*rpm*	%	%	%	%			%	
Ponca Seed Wheat										
16.5	24	0[h]	. . .	69.8	0.40	0.43	. . .	. . .	. .	88
16.5	24	0[i]	27.1	70.1	.38	.41	1.6	x	. .	96
16.5	4	2400	34.7	66.6	.37	.40	3.2	√√	9.0	90
16.5	24	2400	40.1	65.5	.36	.39	4.9	√√	6.5	95
12.0	0	1600	33.7	67.7	.37	.40	3.5	√√	4.6	91
14.0	12	0[h]	. . .	70.4	.39	.43	. . .	. . .	. .	93
14.0	12	1800	21.0	68.2	.37	.40	2.4	√	4.1	90
Hard Winter Wheat Mix										
16.5	24	0[h]	. . .	70.1	.39	.43	. . .	. . .	. .	88
16.5	24	0[i]	23.6	67.6	.38	.42	0.0	x	. .	92
16.5	4	2400	25.7	67.3	.38	.42	1.6	x	. .	92
16.5	24	2400	22.6	66.1	.36	.39	5.7	√√	7.2	90
12.0	0	1600	29.7	66.5	.37	.39	1.3	x	. .	89
14.0	12	0[h]	. . .	69.8	.40	.43	. . .	. . .	. .	. .
14.0	12	1800	18.8	68.2	.37	.40	13.0	√√	8.2	82
Soft Winter Wheat										
15	24	0[h]	. . .	68.1	.32	.36	. . .	. . .	. .	. .
15	24	0[i]	28.3	67.3	.34	.38	1.7	x	. .	. .
15	4	2000	20.3	66.4	.32	.36	0.4	x	. .	. .
15	24	2000	27.9	64.0	.33	.37	0.4	x	. .	. .
11	0	1600	40.5	64.3	.32	.37	1.1	x	. .	. .
13	12	0[h]	. . .	68.7	.34	.37	. . .	. . .	. .	. .
13	12	1800	34.5	64.3	0.32	0.35	0.2	x	. .	. .

[a] Moisture content of first temper and impaction. Following prebreak treatment, all moistures were adjusted to 16.5% (hard wheat) or 15% (soft wheat).
[b] Period between first tempering and impaction or between first and second temper (in the case of controls). The period between prebreak treatment and milling will be 24 hours less the value shown.
[c] Expressed as percent total product.
[d] Value computed from analysis of variance.
[e] √√ — Significant at 99% confidence level; √ — significant at 95% confidence level; x — insignificant at 90% confidence level.
[f] Difference below control ash at 60% extraction expressed as percent of flour ash. Improvements are indicated only in cases of statistical significance.
[g] Maximum possible bread score = 100.
[h] Control sample (not impacted).
[i] Control sample with prebreak treatment on corrugated rolls.

unwetted or at 14% moisture. Time of impaction was unimportant for samples impacted at 16.5% moisture content; less than 12 hours between initial temper and impaction were needed for improvement in ash level at moisture contents less than 14%. Other studies showed that Entoleter speeds above 2,400 r.p.m. did not improve the separation of bran from endosperm in milling, as indicated by the ash extraction values.

The four optimum impaction treatments were compared in further milling experiments to determine which treatment was most practical and desirable.

To compare roll and impaction prebreak treatments, a sample, which received a prebreak treatment on first-break rolls (speed differential 2:1), producing 20 to 30% cracked kernels, was also milled. A hard winter wheat commercial mill mix and a soft wheat were also milled in similar comparison experiments. (Speeds of 1,600, 1,800, and 2,000 r.p.m. were used for soft wheats, since this produced breakage similar to that of the treatment at the higher speeds for hard wheats.) Average values of product yield, kernel breakage, and 60–70% extraction flour ash, based on results of all milling determinations, are presented in Table II. The 60% extraction flour ash values were compared with the unimpacted control samples, using the t test for significance (17) for randomized block experiments with two treatments. The four chosen prebreak impaction treatments of hard wheats produced improvements which were significant at the 95% confidence level. Impaction at 2,400 r.p.m. immediately before milling at 16.5% moisture improved the ash value of 60% extraction flour an average of 0.028% (7% of the total flour ash at this extraction).

Impaction of soft wheat showed no significant improvement in ash extraction value at the 90% confidence level.

When the flours obtained from these various prebreak treatments on hard wheat were compared with unimpacted control flours by the baking test, all loaves were of very acceptable quality (Table II).

These studies show that prebreak impaction of tempered hard red winter wheat will improve the separation of bran from endosperm during milling. Prebreaking with rolls to the same percent breakage did not improve the ash value even at the 90% confidence level. Since the roll prebreak grinding involves considerably more shear and less compression forces than impact prebreak grinding, it is possible that it is the nature of the grindings and not the extent of kernel breakage or an additional break reduction which resulted in the better separation of bran from endosperm in subsequent milling. While the reason for this improvement is uncertain, it is possible that prebreak impaction cracks the wheat endosperm into agglomerates the size of coarse sizings. This cracking, induced by tempering and impaction, relieves internal endosperm stresses and thus produces a coarser breakup of the endosperm to middlings than would be obtained by reduction with break rolls alone.

When Ponca wheat is tempered to 17% moisture, it should be impacted just before milling at a rotor speed of 2,400 r.p.m., using an Entoleter with smooth stator lining (equivalent to impact velocity of 17,000 ft. per minute).

Literature Cited

1. AMERICAN ASSOCIATION OF CEREAL CHEMISTS. Cereal laboratory methods (6th ed.). The Association: St. Paul, Minn. (1957).
2. ANDERSON, J. E. Some tests with the Entoleter. Assoc. Operative Millers, Tech. Bull. No. 2, pp. 393–400. Sosland Press, Inc.: Kansas City, Mo. (1943).
3. BORTH, K. Bas Schälproblem in der Getreidemullerei. Die Mühle **80** (10): 130–131 (1943).
4. EISGRUBER, G. Die Nasschälung-Getreideanthäutung. Mühlen-Zeitung 3 (11): 216 (1949).
5. ESCHAUS, K. H. Weizenschälen oder-bürsten. Die Müllerei **6** (9): 121–122 (1953).
6. FLECHSIG, J. Die Berechnung der Nehlausbeute aus den Ergebnissen des Mahlversuches und aus analytischen Daten. Getreide u. Mehl 4 (8): 60–62 (1954).
7. GEDDES, W. F., and WEST, H. E. A statistical study of the reliability of the experimental milling test. Sci. Agr. **10:** 333–343 (1930).
8. GEDDES, W. F., and AITKEN, T. R. The comparative quality of flours from corresponding wheats milled on an Allis-Chalmers experimental mill and a Brabender automatic laboratory mill. Cereal Chem. **14:** 511–524 (1937).
9. GROSH, G. M., and MILNER, M. Water penetration and internal cracking in tempered wheat grains. Cereal Chem. **36:** 260–273 (1959).
10. HIBBS, A. N., SHELLENBERGER, J. A., and PENCE, R. O. The theory of impact grinding with centrifugal machines. Trans. Am. Assoc. Cereal Chemists **6:** 26–31 (1948).
11. HINTON, J. J. C. The distribution of ash in the wheat kernel. Cereal Chem. **36:** 19–31 (1959).
12. HOPF, L. Die halbfeuchte Schälung. Die Müllerei **3:** 861–863 (1950).
13. MELGES, B. W. Schälmaschine mit Schälrotoren. Die Mühle **90:** 367 (1953).
14. SCHULZ, A. Beeinflussung des keimgehalfes von Weizen durch Wäsche und Schälung. Getreide u. Mehl **2:** 62–64 (1952).
15. SEEBORG, E. F. Evaluation of wheat milling characteristics by laboratory methods. Trans. Am. Assoc. Cereal Chemists **11** (1): 1–5 (1953).
16. SMEETS, H. S., and CLEVE, H. Determination of conditioning by measuring softness. Milling Production **21** (4): 5, 12, 13, 16 (April 1956).
17. SNEDECOR, G. W. Statistical methods (4th ed.), pp. 263–265. Iowa State College Press: Ames, Iowa (1946).
18. UHLMANN, W. Ein neues Schälverfahren. Die Mühle **90:** 144 (1953).
19. ZIEGLER, E. The effect on diastatic activity of surface pressure, differential, and temperature of the reduction rolls in milling. Cereal Chem. **17:** 668–679 (1940).