FACTORS AFFECTING FARINOGRAPH AND BAKING ABSORPTION
I. QUALITY CHARACTERISTICS OF FLOUR STREAMS[1]

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ABSTRACT

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Analytic, physical dough, and baking tests were performed on a series of flours and flour streams milled from Canadian red spring wheat. The samples ranged widely in protein content (11.5–19.2%) and damaged starch level (15–89 Farrand units). Relative to the middlings and straight-grade flours, the break flours were characterized by high protein content, low damaged starch, strong dough characteristics, large loaf volume, and high baking absorption. By contrast, the tail-end streams had a high damaged starch and pentosan content, weak dough characteristics, poor baking quality, high farinograph absorption, and low baking absorption.

Water absorption is an important quality factor to the baker, because it is related directly to the amount of bread he can produce from a given weight of flour. Optimum baking absorption, which is normally judged by the handling properties of the dough at panning, is the maximum amount of water that may be used consistent with a high yield of bread per unit weight of flour, satisfactory dough handling properties at panning (that is, no stickiness problems at the divider, rounder, and molder), and satisfactory bread quality. Baking absorption is not necessarily closely related to farinograph absorption, which is the amount of water that may be added to flour to produce a dough of a fixed consistency. Only initial mixing is considered, and no account is taken of any softening that may occur during subsequent resting.

The contribution of damaged starch to farinograph water absorption is well established (1), and Farrand (2) has developed mathematical models for absorption based on analytic values for protein and damaged starch of a series of British bakers' flours. Other workers (3,4) also have shown the dependence of water absorption on protein content and the degree of starch granule damage. Kulp (5) estimated the contribution of pentosans to farinograph absorption to be ten times their own weight, and suggested that the pentosan fraction of flour absorbs about one-third of the total water in a dough.

Baking absorption and factors influencing it have received less attention. Working with pin-milled flours, Tipples and Kilborn (6) illustrated how the particular baking method used and the presence or absence of malt in the formula were of prime importance in affecting the extent to which baking absorption changed with differences in flour-damaged starch level. An earlier study (7) described the effect of malt and sprouted wheat on baking quality and baking absorption. Working with flours commercially milled at three controlled levels of starch damage from the same wheat grist, Farrand (8) showed how starch damage can affect both absorption and the meaning of conventional rheologic parameters in relation to loaf quality.

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Noguchi et al (9) studied seven flour streams and measured quality parameters, including dough consistency and stickiness, using a texturometer. Hayashi et al (10) prepared air-classified fractions from pin-milled flour streams derived from four hard red spring wheat varieties; the fractions were subjected to analytic, farinograph, bread, cake, and cookie-baking tests. Most recently, Dick et al (11) worked with air-classified fractions to prepare blends with the object of manipulating water absorption and rheologic properties of dough in flours from different wheats.

We have made a study of the interrelationships between damaged starch, protein, wet gluten, soluble and insoluble pentosans, and α-amylase activity with farinograph absorption and baking absorption in both long and short fermentation processes. To obtain a series of samples exhibiting a wide range in these various characteristics, we worked with individual flour streams from an average sample of Canada Western red spring wheat. The flour streams were subjected to a wide range of analytic, rheologic, and baking tests so that conclusions relating to absorption could be viewed within the full context of flour, dough, and bread quality. Differences in analytic properties between flour streams have been documented in detail (12,13), although the literature contains less information on differences in physical dough properties and baking quality.

For convenience, the report of this study is divided into two parts. This article is a detailed qualitative evaluation of the series of flour streams. The second article is a consideration of the absorption prediction from analytic data on flour using multiple regression analysis.

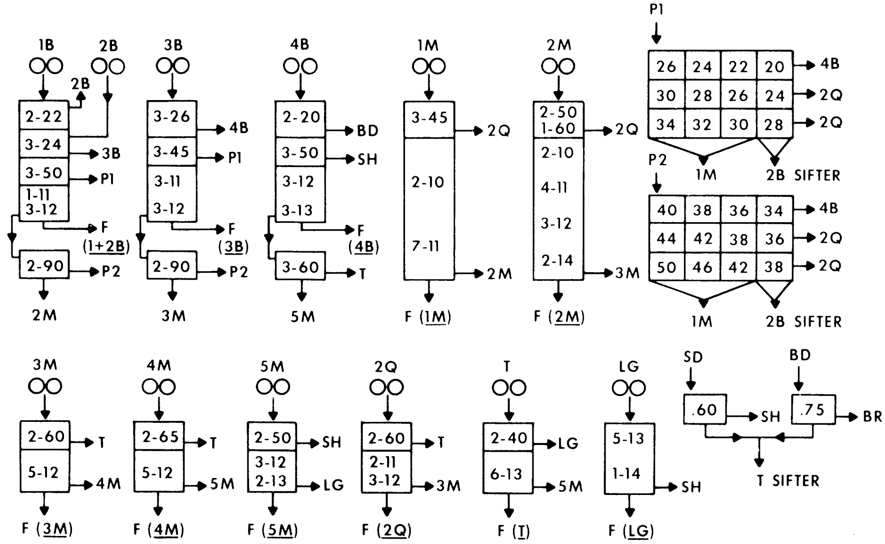

Fig. 1. Milling flow sheet. Flour streams (underlined) were taken at stages shown (see Table I for code). In this diagram, P = purifier, SD = shorts duster, BD = bran duster, SH = shorts, BR = bran. For Plansifters, first number indicates number of sieve trays having an aperture, in microns, shown by second number. All sieves are wire except flour sieves (10–14 inclusive), which are XX equivalent. All purifier clothing is monofilament nylon grit gauze equivalent.

MATERIALS AND METHODS

Wheat

A 1-MT sample of No. 1 Canada Western red spring wheat was used for this study. This wheat weighed 81.7 kg/hl and contained 13.6% protein (13.5% mb) and 1.63% ash.

Milling

The cleaned wheat was tempered to 16.5% moisture for 16 hr and milled on a small commercial-scale Buhler Mill located at the Canadian International Grains Institute. This mill has a capacity of 6.4 MT/24 hr and requires a minimum charge of approximately 800 kg/3 hr. Spring wheat milling consisted of four breaks, eight reductions, and two purifications as shown in the flow sheet (Fig. 1).

Individual mill stream flours were collected at the points shown, and in addition, a straight-grade flour was made up from all 11 individual streams in proportion to their yield. The code letters are listed in Table I.

In an attempt to achieve an even wider range of starch damage, three additional flour streams and three additional straight-grade flours were obtained as follows: During part of the milling run, the first middlings rolls were set closer together and the first middlings flour (Cl-1M) and straight-grade flour (C1-S) were collected. No attempt was made to compensate for any change in the mill balance nor were changes in yield of individual streams recorded. Similarly, during a further part of the milling run, the second middlings rolls were set closer,

TABLE I
Flours and Flour Streams

Code	Description	Yield (%)
1 + 2B	First + second break flours	9.5
3B	Third break flour	4.2
4B	Fourth break flour	3.2
1M	First middlings flour	11.5
2M	Second middlings flour	16.5
3M	Third middlings flour	14.0
4M	Fourth middlings flour	4.4
5M	Fifth middlings flour	3.3
T	Tailings	3.8
2Q	Second-quality flour	4.0
LG	Low-grade flour	1.7
S	Straight-grade flour, total of above	76.1
C1-1M	First midds - first midds rolls set closer	
C1-S	Straight-grade flour - first midds rolls set closer	
C2-2M	Second midds - second midds rolls set closer	
C2-S	Straight-grade flour - second midds rolls set closer	
C1,2-2M	Second midds - first and second midds rolls closer	
C1,2-S	Straight-grade flour - first and second midds rolls closer	
F	Laboratory-milled straight-grade flour	75.1
G	Cold steep treatment before laboratory milling - straight-grade flour	75.5

and flours and straight-grade flours were collected with the first middlings rolls set in both the regular and close positions. Thus, two additional second middlings flour streams (C2-2M and C1,2-2M), plus two more straight-grade flours (C2-S and C1,2-S), were obtained.

Two further samples were laboratory milled from the same wheat and included in this series. One was the straight-grade flour (F) obtained by the standard laboratory milling process using the Allis-Chalmers Mill. The other was milled from a portion of the wheat that was steeped in ice-cold water for 48 hr and rapidly air dried before tempering in the usual way. Flour milled from this wheat (G) showed only a slight increase in α-amylase activity, but was lower in starch damage as was found in a previous study using this technique (6).

Table I lists the various flours and flour streams used together with yield (14% mb) based on the amount of clean wheat at 13.5% mb.

Flour Analysis

Standard AACC methods (14) were used for protein, wet gluten, ash, diastatic activity, and gassing power. All data are on 14% mb.

Flour Color

A color index was obtained with the Kent-Jones and Martin Flour Color Grader, which gives the relative reflectance (with filter No. 58) of a flour-water slurry. Results are reported as arbitrary scale units; the lower the number, the brighter the flour.

Starch Damage

Starch damage was determined by Farrand's (15) method.

Yellow Pigment

Yellow pigment was determined on an 8-g sample of flour extracted for 30 min with 40 ml of water-saturated *n*-butyl alcohol. The extract was filtered and light transmission determined at 435.8 nm. Concentration was calculated on the basis of beta carotene.

Amylograph Viscosity

Amylograph viscosity was determined on 65 g of flour and 450 ml of distilled water using the Brabender Amylograph with the pin stirrer. Other conditions were as described in AACC methods (14).

Farinograph Test

The Farinograph test was performed with the small Brabender Farinograph bowl and the constant flour weight procedure. Absorption values are based on dough consistency at the 500-BU line.

Extensigram

Doughs were made from 300 g of flour (14% mb), 6 g of salt, and distilled water equal to the farinograph absorption less 2.0 percentage units to compensate for both the salt and the substitution of the large stainless steel Brabender Farinograph bowl. Doughs were mixed for 1 min and rested for 5 min, and mixing was continued until the curve was centered about the 500-BU line. Curves were drawn for duplicate doughs at 45 and 135 min, though doughs also were rounded and shaped at 90 min. Average curves for 45 and 135 min are reproduced, but measurements (length in centimeters, height in Brabender units, and area in square centimeters) are reported only for the 135-min curve. The extensigraph was set so that 100 BU equaled a 100-g load.

Alveogram

The alveogram was operated according to the manufacturer's instructions using an absorption of 50%. Dough temperature from the mixer was 29° C, and subsequent processing was done at 24° C.

Total Flour Pentosans

The method that Cerning and Guilbot (16) described was used, with slight modifications. The flour sample was weighed into a gelatin capsule (product No. 00, Eli Lilly and Co., Indianapolis), which was inserted into part "a" of the Duffau distillation apparatus. The gelatin capsule does not affect the results of the pentosan determination and has several advantages. Absorbance readings of the developed colors were made after 60 min (instead of the 45 min suggested in the original method) using a Coleman Model 55 UV-VIS digital spectrophotometer.

Water-Soluble Pentosans

Demineralized water (15 ml) was added to a 1-g sample of flour in a plastic screw-top centrifuge tube. To dissolve the soluble pentosans, the tube was shaken for 2 hr on a wrist-action shaker. The suspension was centrifuged and the supernatant decanted. An aliquot of this supernatant was pipetted into the distillation apparatus and 36% HCl was added to adjust the concentration to 4.15*N* HCl. Then 4.15*N* HCl was added to bring the total volume of liquid in the distillation apparatus to 30 ml. The distillation and subsequent spectrophotometric determination of furfural was done in the same way as for total pentosans.

Baking

Two baking methods were used: the Remix method (17) with 15 ppm of potassium bromate, which involves a bulk fermentation period of 2-3/4 hr, and the short GRL-Chorleywood method (18) with 75 ppm of ascorbic acid and 45 ppm of potassium bromate. Malt syrup (250° Lintner) was used at levels of 0, 0.1, and 0.3% (normal) in the Remix method and 0 and 0.1% (normal) in the GRL-Chorleywood method. All baking data shown are means from at least two separate tests.

RESULTS AND DISCUSSION

Analytic Data for Flour

Table II shows analytic data for the 14 flours studied. Protein content varied for the streams from 11.5% for the 4M flour to 19.2% for 4B.

The ratio of wet gluten to flour protein was generally around 3:1 except for the break flours, where it was slightly higher, and for the tail-end flours, particularly 5M and LG, where it was around 2.5:1. The lower the ratio, the higher is the

TABLE II
Analytic Data[a] for Flours and Flour Streams

Flour Code	Protein (%)	Wet Gluten (%)	Wet Gluten/ Protein	Ash (%)	Color (Kent-Jones Units)	Yellow Pigment (ppm)	Starch Damage (Farrand Units)	Diastatic Activity (mg)	Gassing Power (mm)	Amylograph Peak Viscosity (BU)	Pentosans Total (%)	Pentosans Soluble (%)
1 + 2B	15.2	47.8	3.14	0.56	3.4	3.14	17	128	225	770	1.45	0.52
3B	16.1	50.6	3.14	0.55	3.1	3.36	16	120	240	810	1.54	0.45
4B	19.2	62.7	3.27	0.71	5.7	3.98	15	118	255	700	1.57	0.43
1M	12.5	37.0	2.96	0.41	−0.4	2.76	29	205	325	860	1.41	0.53
2M	12.1	35.4	2.93	0.38	−0.5	2.76	22	160	270	930	1.53	0.55
3M	11.6	33.8	2.91	0.38	−0.8	2.74	40	247	380	840	1.59	0.56
4M	11.5	33.6	2.92	0.42	0.3	2.94	63	370	515	730	1.62	0.64
5M	13.4	33.8	2.52	0.94	7.4	4.04	89	578	740	410	1.97	0.65
T	14.0	37.9	2.71	0.98	7.9	3.80	50	329	565	510	1.99	0.62
2Q	12.3	34.0	2.76	0.70	4.0	3.25	56	349	575	540	1.91	0.53
LG	13.5	33.3	2.47	0.95	6.1	4.02	54	387	620	470	1.95	0.64
S	13.0	37.9	2.92	0.51	2.0	3.07	33	217	385	750	1.73	0.59
C1-1M	12.2	36.3	2.98	0.38	−1.2	2.87	37	253	375	860	1.49	0.53
C1-S	13.3	39.2	2.95	0.56	2.7	3.28	42	271	445	690	1.71	0.53
C2-2M	11.9	34.8	2.92	0.36	−0.6	2.77	43	289	400	820	1.58	0.54
C2-S	13.6	39.3	2.89	0.56	3.1	3.24	45	312	480	650	1.81	0.53
C1,2-2M	11.6	33.8	2.91	0.41	0.5	2.90	78	459	575	710	1.61	0.64
C1,2-S	13.4	38.1	2.84	0.56	3.1	3.12	52	339	505	650	1.78	0.59
F	12.9	38.3	2.97	0.48	0.7	3.07	26	172	325	790	1.61	0.60
G	12.9	38.9	3.02	0.42	0.2	2.91	18	137	280	760	1.42	0.62

[a] 14% mb.

proportion of nongluten protein (nitrogen), although higher figures also may indicate a higher water-binding capacity in the gluten.

Ash and color values varied as expected, being lowest for the 1M, 2M, and 3M flours and highest for the 5M and T fractions. The laboratory-milled flours had significantly lower ash and color values than did the straight-grade flours from the pilot mill. The cold-steeping treatment caused a further reduction in ash and color values for laboratory-milled flour. Yellow pigment content was lowest for the middlings flours and highest for the 4B, 5M, T, and LG streams.

Damaged Starch and α-Amylase Activity

Starch damage varied widely, from a low of 15–17 Farrand units for the three break flours to a high of 89 units for the 5M flour. The variation in amylograph viscosity may be partly accounted for by differences in starch damage, since peak viscosity values tended to decrease with increasing starch damage. This is illustrated by the drop in peak viscosity for the straight-grade flours F, S, C1-S, and C2-S. The damaged starch values for these flours were 26, 33, 42, and 45 Farrand units, respectively, and the corresponding peak viscosity values were 790, 750, 690, and 650 BU, respectively.

When starch damage was plotted against amylograph viscosity (Fig. 2), the points could be divided conveniently into three groups. Within each group, the α-amylase activity appeared to be approximately the same and differences in peak viscosity seemed to be due mainly to differences in damaged starch. The first

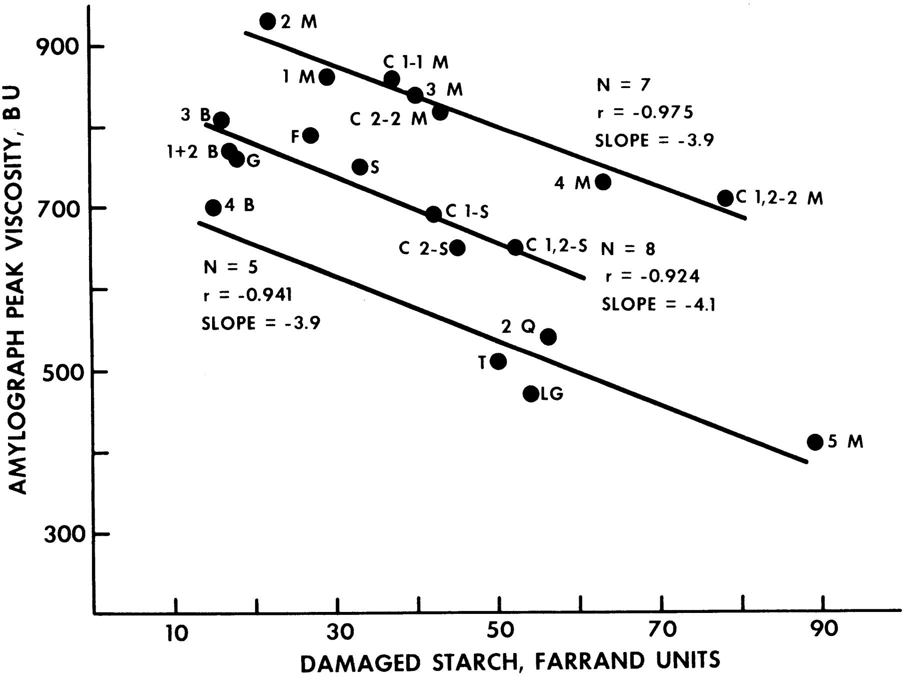

Fig. 2. Starch damage versus amylograph peak viscosity for flours and flour streams.

TABLE III
Farinogram, Extensigram, and Alveogram Data for Flours and Flour Streams

Flour Code	Farinogram		Extensigram (135 min)				Alveogram		
	Absorption (%)	Peak Development Time (min)	Length (cm)	Height at 5 cm (BU)	Maximum Height (BU)	Area (cm^2)	Length (mm)	Height (mm)	Work ($\times 10^3$ ergs)
1 + 2B	61.9	6.00	27.0	270	560	205	174	66	279
3B	63.2	7.75	*[a]	230	520	...	180	72	308
4B	66.4	6.50	*	...	...	...	228	68	311
1M	62.6	5.00	22.5	280	580	145	115	115	362
2M	60.5	4.75	23.1	280	460	155	111	102	325
3M	64.6	5.75	17.6	380	630	150	79	172	406
4M	69.9	4.00	17.7	300	440	110	**[b]	...	...
5M	79.2	5.00	16.0	140	140	35	**	...	...
T	68.6	4.50	25.6	150	180	70	58	94	149
2Q	69.1	4.50	19.5	210	260	80	57	144	249
LG	69.5	4.50	21.5	100	100	35	37	98	118
S	64.0	5.50	25.6	250	410	135	108	111	313
C1-1M	64.5	6.50	20.5	330	600	165	86	175	453
C1-S	66.8	5.50	23.4	220	350	115	105	127	333
C2-2M	65.6	8.00	19.7	340	600	160	85	179	456
C2-S	68.0	5.75	22.4	250	390	125	103	129	342
C1,2-2M	73.8	3.00	18.5	320	490	130	85	*	*
C1,2-S	69.5	5.00	21.7	240	380	120	83	163	374
F	62.9	4.25	23.1	270	460	155	120	106	343
G	61.3	4.50	24.0	270	430	145	133	86	287

[a] * Outside range of instrument.

[b] **Dough too stiff for test.

TABLE IV
Loaf Volume[a] of Flours and Flour Streams

Flour Code	Loaf Volume (cm^3) Remix Method With Malt Syrup (250° Lintner) (0)	Remix Method With Malt Syrup (250° Lintner) (0.1%)	Remix Method With Malt Syrup (250° Lintner) (0.3%)	GRL-Chorleywood Method With Malt Syrup (250° Lintner) (0)	GRL-Chorleywood Method With Malt Syrup (250° Lintner) (0.1%)
1 + 2B	600	815	940	1005	1055
3B	480	850	1030	1060	1075
4B	475	820	890	1045	1015
1M	725	735	800	895	935
2M	580	780	785	880	910
3M	670	665	720	795	825
4M	580	635	625	720	645
5M	345	430	430	405	410
T	590	595	635	690	665
2Q	600	640	650	725	650
LG	395	440	470	550	550
S	785	820	830	905	915
C1-1M	690	675	735	880	920
C1-S	785	800	830	860	905
C2-2M	690	640	685	825	775
C2-S	800	800	825	910	885
C1,2-2M	580	575	560	700	625
C1,2-S	775	790	815	870	895
F	685	805	830	920	940
G	600	850	840	965	970

[a] Mean of at least two separate bakes.

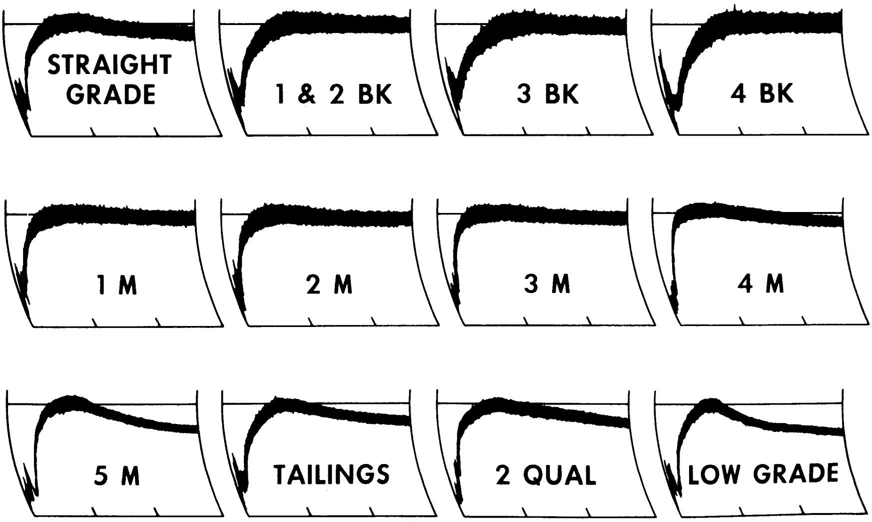

Fig. 3. Farinograms for flour streams.

group, having the lowest α-amylase activity (highest viscosity) at a given starch damage level, contained the first four middlings flours. The second group contained the straight-grade and early break flours, and the third group, with the highest activity, contained the lowest quality tailings streams.

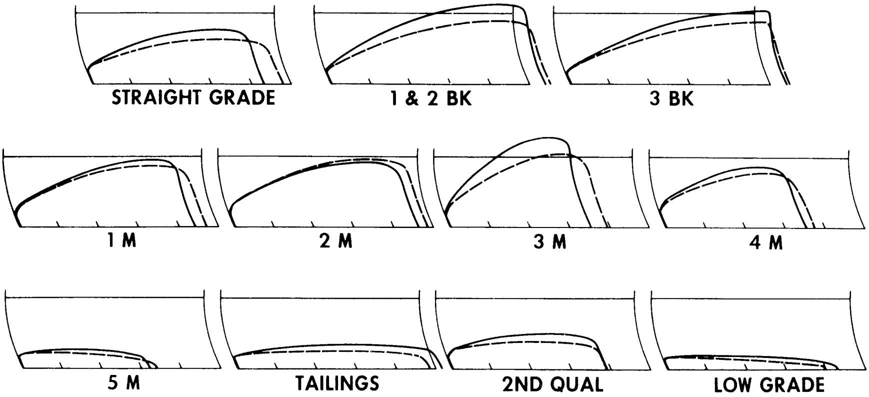

Fig. 4. Extensigrams for flour streams. Solid line is 135-min curve, broken line is 45-min curve.

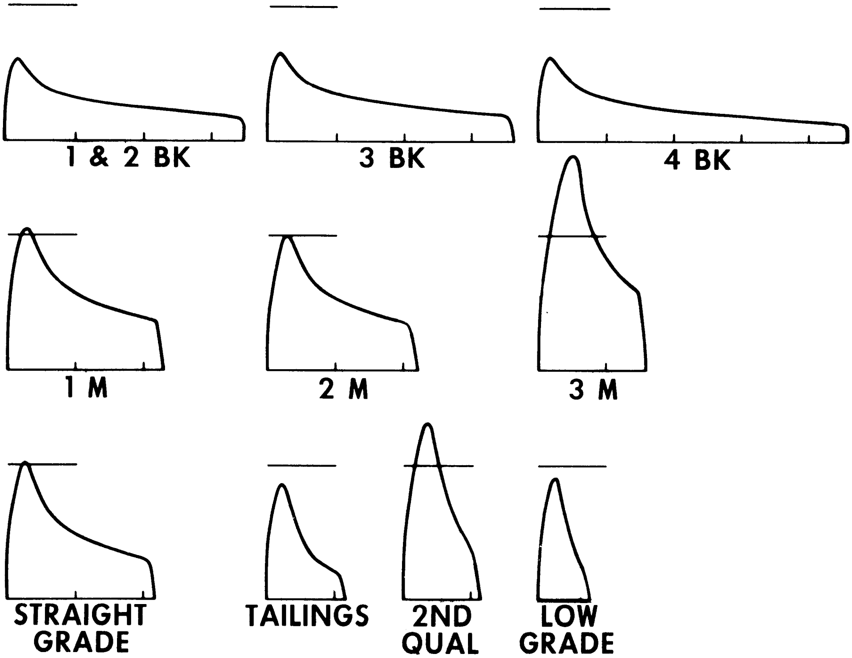

Fig. 5. Alveograms for flour streams.

The slopes of the three regression lines were almost identical, and every 10-unit increase in starch damage was associated with a reduction of about 40 BU in peak viscosity. When the amylograph peak viscosity for each of the three groups was expressed on a constant damaged starch basis of 30 Farrand units, the values were 880, 740, and 615 BU, respectively.

Diastatic activity and gassing power values reflect the combined effects of damaged starch and α-amylase activity. In both tests, increasing values were closely related to increasing starch damage and decreasing amylograph peak viscosity.

Pentosans

Total pentosan content increased with decreasing flour quality from a low of 1.41% for 1M to a high of 1.99% for fraction T. Soluble pentosan ranged from 0.43% for 4B to 0.65% for 5M.

Physical Dough Properties

Data for farinograph, extensigraph, and alveograph tests are listed in Table III. Figures 3–5 show the curves obtained. In terms of development time and

TABLE V
Baking Strength Index and Loaf Characteristics for Flours and Flour Streams in Remix and GRL-Chorleywood Baking Methods

	Remix 0.3% Malt				GRL-Chorleywood 0.1% Malt			
		Loaf Scores[b]				Loaf Scores[b]		
Flour Code	BSI[a]	External Appearance	Crumb Texture	Crumb Color	BSI[c]	External Appearance	Crumb Texture	Crumb Color
1 + 2B	93	9.0	6.5	5.0gy	96	8.5	6.8-o	8.0
3B	96	8.5	6.0-o	5.0gy	94	8.5	6.0-o	8.5
4B	69	7.5	6.5-o	3.0gy	76	7.5	6.0-o	6.5g
1M	98	8.0	7.0-o	7.0	100	7.8	6.0-o	8.0
2M	99	8.0	6.8-o	7.0	100	7.8	6.5-o	7.8
3M	95	7.5 old	5.8-o	7.0	94	7.0	6.2-o	7.5
4M	83	6.5 old	5.8-o	5.5dy	74	6.2 old	7.0	6.5dy
5M	54	3.5	2.5c-o	brown	42	4.0 old	1.0c	1.0g
T	69	6.0	5.0c-o	2.5g	67	5.5	6.0	4.0g
2Q	80	6.5	6.5-o	5.0d	70	6.5 old	6.8-o	5.0dy
LG	53	4.5	2.0c-o	brown	54	5.0	4.0c-o	3.0gy
S	97	8.0	6.2-o	6.5dy	95	7.5	6.5-o	8.2
C1-1M	92	7.2	7.0	6.8	100	7.8	6.0-o	8.0
C1-S	94	8.0	6.0-o	6.2d	92	7.8	6.2-o	8.5
C2-2M	88	6.8	7.0	6.8dy	86	6.2	6.5-o	7.0
C2-S	92	7.8	6.5-o	5.8d	89	7.5	6.5-o	7.5
C1,2-2M	74	6.2 old	5.8	5.2d	71	5.5 old	6.0	6.5dy
C1,2-S	92	7.8	6.8-o	6.0d	91	7.8	6.8-o	7.5
F	100	8.0	7.0	6.5dy	98	8.2	6.5-o	8.5
G	105	8.5	6.5-o	6.8dy	101	8.2	6.0-o	8.2

[a] Remix baking strength index = $\frac{\text{loaf volume} \times 100}{(\text{flour protein} \times 70) - 55}$.

[b] o = open, c = coarse, g = grey, d = dull, y = yellow.

[c] GRL-Chorleywood baking strength index = $\frac{\text{loaf volume} \times 100}{(\text{flour protein} \times 59.5) + 190}$.

stability, farinograms (Fig. 3) were strongest for the break flours and became progressively weaker as flour quality decreased, with the weakest characteristics being shown by the 5M and LG samples. Farinograph absorption ranged from 60.5% for the 2M flour to 79.2% for 5M.

Extensigraphic characteristics of doughs from 3B and 4B were such that the extensibility (length) was greater than the maximum recorded by the apparatus.

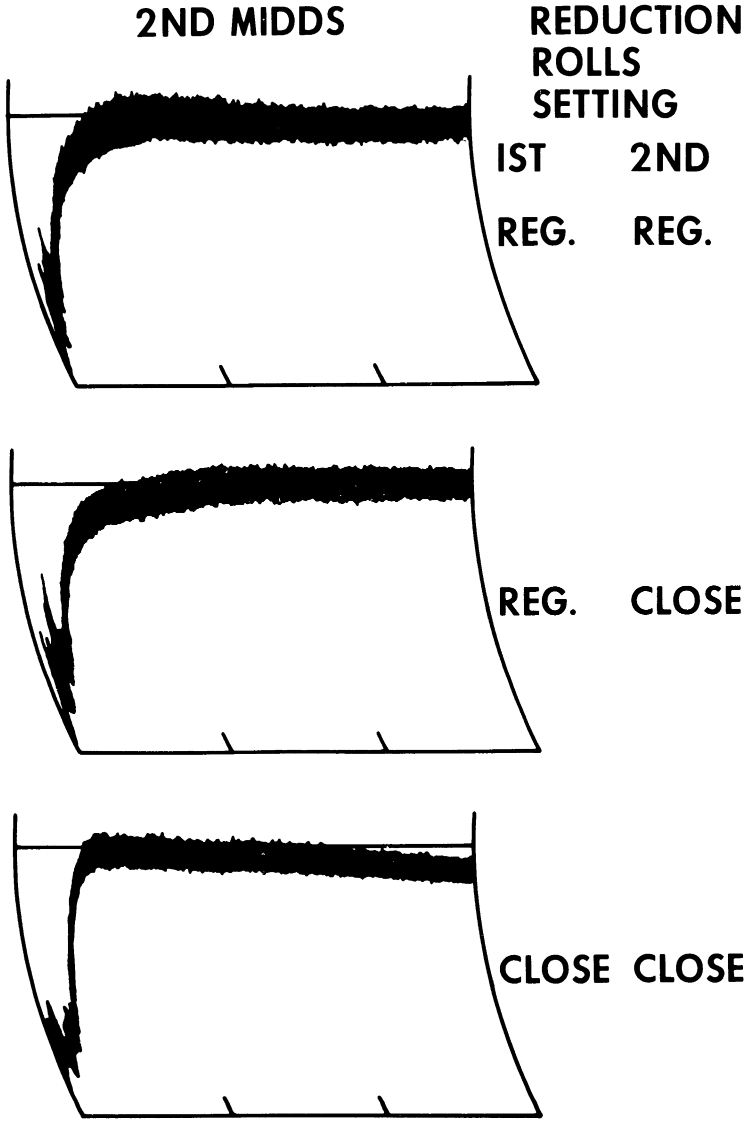

Fig. 6. Farinograms for second middlings flours produced with first and second reduction rolls at either regular or close setting. Top, 2M; middle, C2-2M; bottom, C1,2-2M.

Break flour extensigrams were characterized by high values for area and length. Curves for 1M and 2M flours were well balanced, with good extensibility and resistance to extension. The 3M and 4M flours showed a reduced extensibility, while the 3M extensigram had an increased resistance to extension. Small extensigrams were obtained for the four tail-end flours, particularly 5M and LG.

Because the alveograph test is performed at a fixed absorption, differences in starch damage, and hence absorption, tend to have a marked effect on the alveogram shape. Doughs from 4M and 5M flours, which were high in starch damage, were too stiff for testing. As with the extensigrams, the curve length increased for the break flours, going from 1 and 2B to 4B. Well-balanced curves were obtained for 1M and 2M flours and a marked increase in height and decrease in length was again noted for the 3M flour. Because of the high starch damage of the tail-end flours, the alveograms did not show the reduced height/length ratio shown in the extensigrams, although curve areas were markedly reduced.

Baking Quality

Table IV lists loaf volumes obtained in Remix and GRL-Chorleywood baking tests using various levels of malt syrup (250° Lintner). In the Remix method, maximum loaf volume was generally only obtained with the normal malt level of 0.3%. The greatest loaf volume response to malt was shown by the break flours.

TABLE VI
Baking Absorption of Flours and Flour Streams

Flour Code	Baking Absorption (%) Remix Method With Malt Syrup (250° Lintner) (0)	(0.1%)	(0.3%)	GRL-Chorleywood Method With Malt Syrup (250 ° Lintner) (0)	(0.1%)
1 + 2B	69	67	64	71	69
3B	70	67	64	72	69
4B	75	71	68	77	73
1M	64	61	60	66	63
2M	65	63	62	67	65
3M	64	61	60	66	63
4M	68	61	60	70	63
5M	62	58	56	64	60
T	63	61	60	65	63
2Q	64	60	59	67	62
LG	59	57	56	61	59
S	65	62	61	67	64
C1-1M	68	62	60	70	64
C1-S	66	62	61	69	63
C2-2M	67	61	60	69	63
C2-S	67	61	60	69	63
C1,2-2M	69	61	60	69	63
C1,2-S	67	62	61	70	64
F	65	62	62	68	66
G	66	63	63	69	65

In the short GRL-Chorleywood method, almost enough gas was produced without malt to achieve maximum loaf volume; for some flours, particularly some of the tail-end streams, a reduction in loaf volume occurred when 0.1% malt was used. The high damaged starch level of these samples resulted in an adequate gassing power without addition of malt and too high a level with addition of malt.

Additional baking quality data for the individual streams are presented in Table V, which shows baking strength index (BSI) (19) values and external and internal bread characteristic scores for the standard Remix method with 0.3% malt syrup added and for the GRL-Chorleywood method with 0.1% malt added.

Bread quality was poorest for the 5M and LG flours. BSI values for these samples indicated that loaf volumes in both baking methods were only about one-half of what is normally expected for high-quality Canadian wheat flour of the same protein content; external loaf appearance, crumb structure, and crumb color were poor. Best overall baking quality (considering the protein level) was exhibited by the 1M and 2M flours, although samples S, 1 + 2B, and 3B gave satisfactory results. Baking quality was markedly poorer for the 4M, 4B, and 2Q flours; poorer still for fraction T; and extremely poor for 5M and LG.

The closer setting of the reduction rolls caused a marked deterioration in baking quality of the second middlings flour. Loaf volume in the Remix method with 0.3% malt decreased from a maximum of 785 cc for 2M, to 685 cc for C2-2M, to 560 cc for C1,2-2M. A similar decrease in loaf volume occurred in the GRL-Chorleywood method. From the change in shape of the farinograph curves for these three flours (Fig. 6), we suspect that heat damage was the major factor in this deterioration. From our own (unpublished) observations on the effect of heat damage due to improper drying of wheat, we concluded that the increase in development time for sample C2-2M was consistent with a moderate heat damage effect whereby the flour became "stronger." This was consistent with the increased values for extensigram and alveogram height. More pronounced heat damage coupled with a high starch damage level caused the farinograph curve for flour C1,2-2M to appear weaker, with a shorter development time. The deterioration in baking quality was not considered to have a significant effect on the baking absorption results for these flours.

Baking Absorption

Baking absorptions used are listed in Table VI. These values indicate the maximum amount of water that may be added consistent with satisfactory handling properties at the time of panning. When the farinograph absorption is used as a guide for preliminary baking tests, the baker may adjust, quite considerably, the amount of water ultimately used. For the full series of baking tests with different malt levels, the lowest baking absorption was 56% for the 5M and LG flours in the Remix method with 0.3% malt. Farinograph absorptions for these two flours were 79.2 and 69.5%, respectively. The highest baking absorption was for the 4B flour. Its baking absorption varied from 68% in the Remix method with 0.3% malt to 77% in the GRL-Chorleywood method without malt (compared with a farinograph absorption of 66.4%). Farinograph absorption and baking absorption were, therefore, not closely related for this population of flour streams. The difference between Remix baking absorption (with 0.3% malt addition) and farinograph absorption ranged from +2.1

percentage units for 1 + 2B to −23.2% for 5M.

In conclusion, the large differences in analytic, rheologic, and baking properties between individual mill fractions serve to underline the potential control a miller can exert over the final properties of his blended end products by judicious proportioning of individual streams.

We do not suggest that all flour mills would produce flour streams from a given wheat in the same proportions and with the same analytic values. Specific values for mill fractions from different mills depend on many factors, including roll settings, flow, and sieve clothing. Our primary intention is to illustrate the extent to which individual mill fractions can vary in characteristics of quality.

In the second part of this study, we will examine further the relation of protein content, damaged starch level, and other flour components with water absorption.

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