The Effect on Residual Flour Quality of Removing Farina During Common Wheat Milling[1,2]

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ABSTRACT

Representative samples of Canada Western Red Spring, Canada Western Red Winter, Canada Utility, and Canada Prairie Spring wheat classes were milled to 75, 79, and 83% extraction, and up to 24% (wheat basis) high-quality middlings (farina) was removed at each extraction rate. As extraction rate increased, straight-run flour (no farina removed) color darkened; ash content increased; farinograph, extensigraph, and alveograph curves weakened; and bread quality deteriorated. However, at each extraction rate the removal of up to 24% farina had only marginal effects on the rheological and baking properties of the residual flour, although flour color and bread crumb color became noticeably darker.

The baking performance of bread wheat flour is related to wheat strength and milling conditions (Ziegler and Greer 1971). Strength, a complex concept that defines loaf volume potential and mixing requirements, is related to protein content and protein quality (Finney and Barmore 1948, Tipples et al 1982). The variable properties of flour mill streams are well documented (Ziegler and Greer 1971). Tail-end flour streams are the darkest, weakest streams with the poorest baking quality (Holas and Tipples 1978). As flour extraction rate increases, the inclusion of greater amounts of tail-end streams results in progressively darker straight-run flour with diminished loaf volume potential (Dexter et al 1984, Orth and Mander 1975).

In recent years, South America has become an increasingly important market for Canadian wheat. Extraction rates vary widely among South American countries, but it is common practice for all when milling bread wheat to remove some high-quality flour and/or farina for specialty baked products and pasta. The baking performance of the residual flour should depend on milling extraction rate, the proportion of high-quality product removed, and the inherent baking quality of the wheat. An understanding of the wheat quality requirements of South America requires that the relative importance of each factor be established. Accordingly, this study was instigated to investigate the effect on residual flour quality of removing various amounts of high-quality middlings (farina) at three extraction rates for four Canadian bread wheat classes with inherently different gluten properties.

MATERIALS AND METHODS

Wheats

Representative samples of the four classes of bread wheat grown in western Canada were drawn from terminal elevators in Vancouver and Thunder Bay following the 1987 harvest (Table I). Canada Western Red Spring (CWRS) wheat is the predominant bread wheat class grown in Canada and comprises strong hard red spring wheat varieties of excellent milling quality. Canada Utility (CU) wheat is a hard red spring wheat class with exceptionally strong gluten properties. Canada Western Red Winter (CWRW) is a hard red winter wheat class of medium protein content and good strength noted for its exceptional milling quality. Canada Prairie Spring (CPS) wheat is a moderately strong, medium hard, medium protein content red spring wheat class.

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Milling

Samples were milled using the Grain Research Laboratory (GRL) research roll stands (Black et al 1980a) in conjunction with a Bühler laboratory bran finisher (Bühler-Miag, Don Mills, Ontario) and GRL sifter units (Black et al 1980b). All grinding rolls are 10 in. (254 mm) in diameter and have an effective grinding length of 5 in. (127 mm). All corrugated rolls have Allis sharp corrugations with a spiral of 0.5 in./ft (41.7 mm/m) of roll length and are set dull to dull at 2:1 differential (fast roll speed 500 rpm). Smooth rolls have a frosted finish and are run at 1.5:1 differential (fast roll 450 rpm). Feed rate for each grinding pass is 0.15 kg/cm roll length per minute.

Mill flows were developed to give approximate flour yields of 75, 79, and 83% on a clean wheat basis corrected to constant moisture content (Table I). The 83% extraction mill flow is shown in Figure 1. Break releases, measured as the proportion of stock passing through a 24-wire sieve (678-μm aperture), were set at 20, 65, and 35% for first break (B1), B2, and B3, respectively, using the No. 2 CWRS wheat. Roll gaps for the remaining breaks, sizings, and reduction passages were set by adjusting the rolls so they barely touched when running empty, then backing off slightly (about 0.03 mm).

The 75 and 79% extraction mill flows were identical to the 83% extraction mill flow except that the break system was shortened. For the 79% extraction procedure, the B5 passage was eliminated, and the first bran finisher pass followed B3. For the 75% extraction procedure, B4, B5, and the second bran finisher passes were eliminated.

The proportion of farina and/or fancy flour removed by South American mills during common wheat milling varies widely. The amount removed depends on customer requirements and in some countries is limited by government regulations.

The fine middling fraction (i.e., fine farina) from the S1 sifter (through a 68 grit gauze [247-μm aperture] and held on a 10XX

TABLE I
Wheat Properties

Property	No. 2 CWRS[a]	No. 1 CWRW[b]	No. 1 CPS[c]	No. 1 CU[d]
Test weight, kg/hl	82.6	84.9	82.3	79.6
Protein content,[e] %	12.7	11.1	11.3	12.7
Ash content,[e] %	1.65	1.34	1.60	1.68
Falling number,[e] sec	295	459	445	415
Flour yield,[f] %				
Procedure 1	76.0	75.2	73.3	75.3
Procedure 2	79.2	78.0	77.9	78.8
Procedure 3	83.2	82.7	82.9	82.3

[a]Canada Western Red Spring.
[b]Canada Western Red Winter.
[c]Canada Prairie Spring.
[d]Canada Utility.
[e]Expressed on a 13.5% moisture basis.
[f]Proportion of clean wheat on constant moisture basis.

[136-μm aperture] sieve was ideal to simulate the effects of farina and/or fancy flour removal (Fig. 1). The stream is low in ash content and bright (Table II). Bran specks are virtually absent, making purification unnecessary. The properties of the stream are independent of extraction rate, and yield exceeds 30% (wheat basis) for each wheat. At each extraction rate, 0, 12, and 24% of fine middlings (wheat basis), hereafter referred to as farina, was removed. A representative portion of farina from each wheat was subsequently reduced into flour (through a 10XX sieve) to allow meaningful baking quality evaluation.

Wheats were prepared for milling and test weights were determined as described by Dexter and Tipples (1987). Wheats were milled in triplicate 3-kg lots at each level of farina removal (0, 12, and 24% wheat basis) at each extraction rate in completely randomized design. Temper moisture was adjusted to predetermined optimum levels for each wheat—16.5% for CWRS and CU, 15.5% for CWRW, and 15% for CPS. Mill room conditions were controlled at 21°C and 60% rh. Flours from each treatment were bulked prior to quality assessment.

Wheat and Flour Properties

Wheat and flour tests were performed in duplicate and results

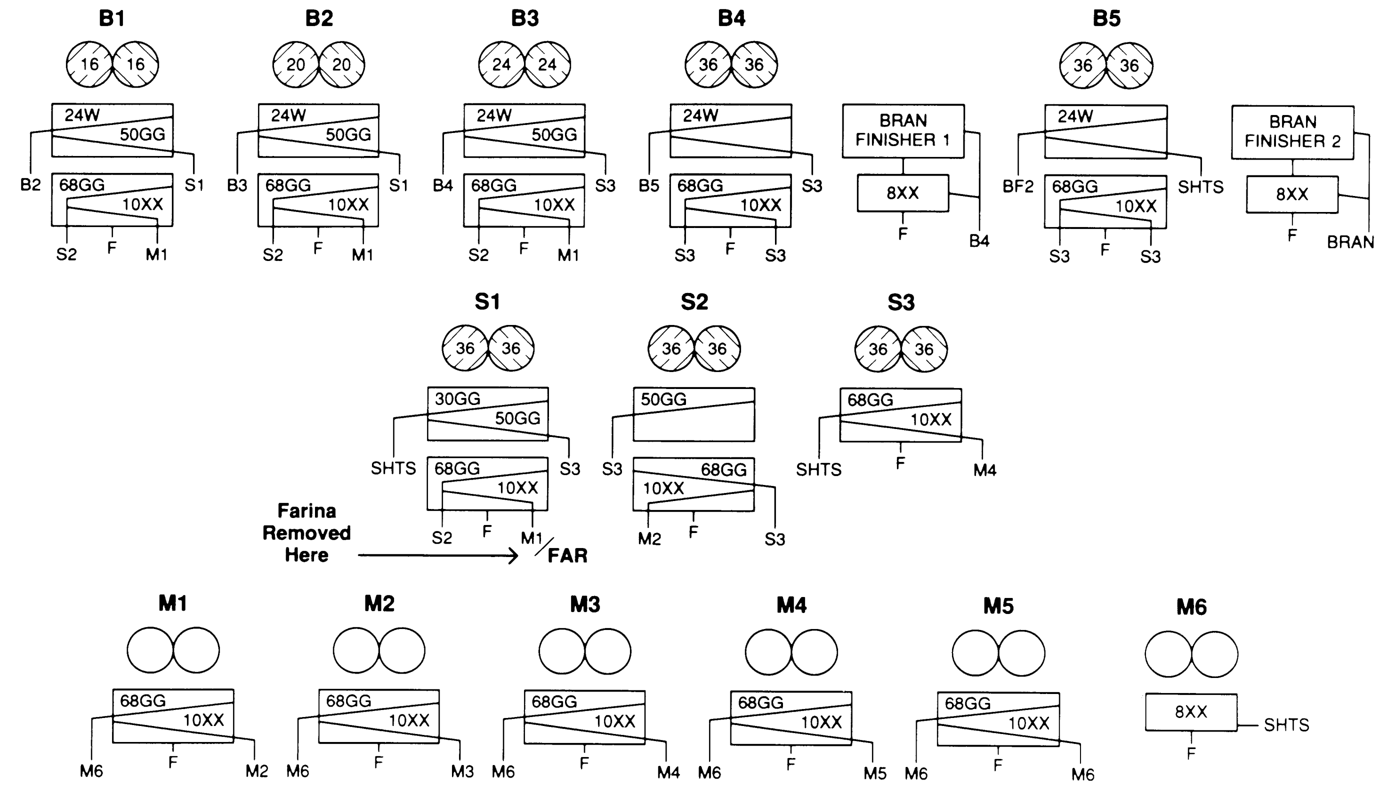

Fig. 1. Grain Research Laboratory research mill flow for production of 83% extraction flour. Numbers for corrugated rolls indicate corrugations per inch.

TABLE II
Properties of Flour Prepared by Reducing Farina

Property	No. 2 CWRS[a]	No. 1 CWRW[b]	No. 1 CPS[c]	No. 1 CU[d]
Flour				
Protein content,[e] %	11.1	9.9	9.2	11.3
Ash content,[e] %	0.38	0.35	0.38	0.42
Kent-Jones color, units	−2.4	−2.5	−2.9	−2.5
Starch damage,[e] Farrand units	36	25	17	30
Amylograph viscosity,[e] Brabender units	445	960	995	740
Dough				
Farinograph absorption,[e] %	65.1	54.2	56.6	59.0[f]
Farinograph development time, min	2.25	11.0	2.25	8.75[f]
Farinograph stability, min	9.0	29.5	4.5	9.0[f]
Extensigraph area, cm^2	120	190	130	270
Alveograph, W $\times$ 10^3 ergs	390	250	215	370
Bread				
Baking absorption,[e] %	61	56	57	60
Remix time, min	4.1	4.6	1.9	5.2
Loaf volume, cm^3	700	650	615	865
Baking strength index, %	97	102	105	118

[a]Canada Western Red Spring.
[b]Canada Western Red Winter.
[c]Canada Prairie Spring.
[d]Canada Utility.
[e]Expressed on 14% moisture basis.
[f]Mixed at 90 rpm.

were adjusted to 13.5 and 14% moisture basis, respectively. Wheat falling number was performed by the standard ICC (1980) procedure. Protein content (% N × 5.7) was determined by the Kjeldahl procedure as modified by Williams (1973), and ash content was determined by the AACC (1983) procedure. The Simon Color Grader Series IV (Henry Simon, Stockport, England) was used for flour color as outlined in the instruction manual. The enzymatic method of Farrand (1964) was used to determine flour starch damage. Amylographs were performed using 65 g of flour in 450 ml of distilled water, and maximum viscosity was measured as described in the AACC (1983) procedure.

Dough Properties

Farinograph and extensigraph properties were determined by AACC (1983) procedures with slight modifications (Preston et al 1982). Values for extensigraph curves after 135 min of relaxation are reported. Alveograph properties were obtained using the standard ICC (1980) procedure.

Baking

Flours were baked in duplicate using ingredients and procedures identical to the remix procedure (Irvine and McMullan 1960, Kilborn and Tipples 1981) except that mixing requirements at the remix stage were optimized by remixing doughs to peak consistency (Preston et al 1984). Baking strength index values, which are used to compare remix loaf volumes of Canadian wheats independently of protein, were determined as described by Tipples and Kilborn (1974).

Statistical Analysis

The significance of the effects of wheat type, amount of farina removed, and flour extraction rate were determined by completely randomized factorial analysis of variance in an IBM-compatible personal computer (Mind Computer Products, Winnipeg, Manitoba) using the Stat-Pac Gold Statistical Analysis Package (Walonick Associates, Minneapolis, MN).

RESULTS AND DISCUSSION

Wheat and Farina Properties

All the wheats used in the study were plump and sound, as shown by satisfactory falling number and high test weight (Table I). The differences in falling number between the wheats reflect environmental effects rather than intrinsic differences between wheat classes. For a given milling procedure, the wheats exhibited comparable flour yield. The CWRW wheat exhibited the low ash content typical of its class (Dexter et al 1984, 1987).

Farina drawn off during the milling of each wheat was reduced into fancy flour and evaluated for quality (Table II). Flour amylograph peak viscosity differences were consistent with variations observed in wheat falling number. Other differences among the flours were consistent with previously reported intrinsic differences between the Canadian bread wheat classes (Dexter et al 1984, 1987). The flours were comparable in brightness, but differences in flour ash content among the wheats were apparent. The CWRW exhibited the lowest flour ash content, whereas the CU exhibited the highest flour ash content. Differences in wheat hardness were apparent from flour starch damage levels, the CWRS and CU being the hardest and the CPS being the softest.

The flours exhibited a range of physical dough properties. The relatively low protein content and low starch damage of the CPS and CWRW flours were reflected by low farinograph absorption. The extraordinarily strong gluten of the CU was evident from the large extensigraph area and the requirement to increase the farinograph speed to 90 rpm to achieve dough development. Differences in alveograph *W* among the flours were related to differences in protein content, gluten strength, and flour starch damage (Chen and D'Appolonia 1985, Farrand 1964, Preston et al 1987).

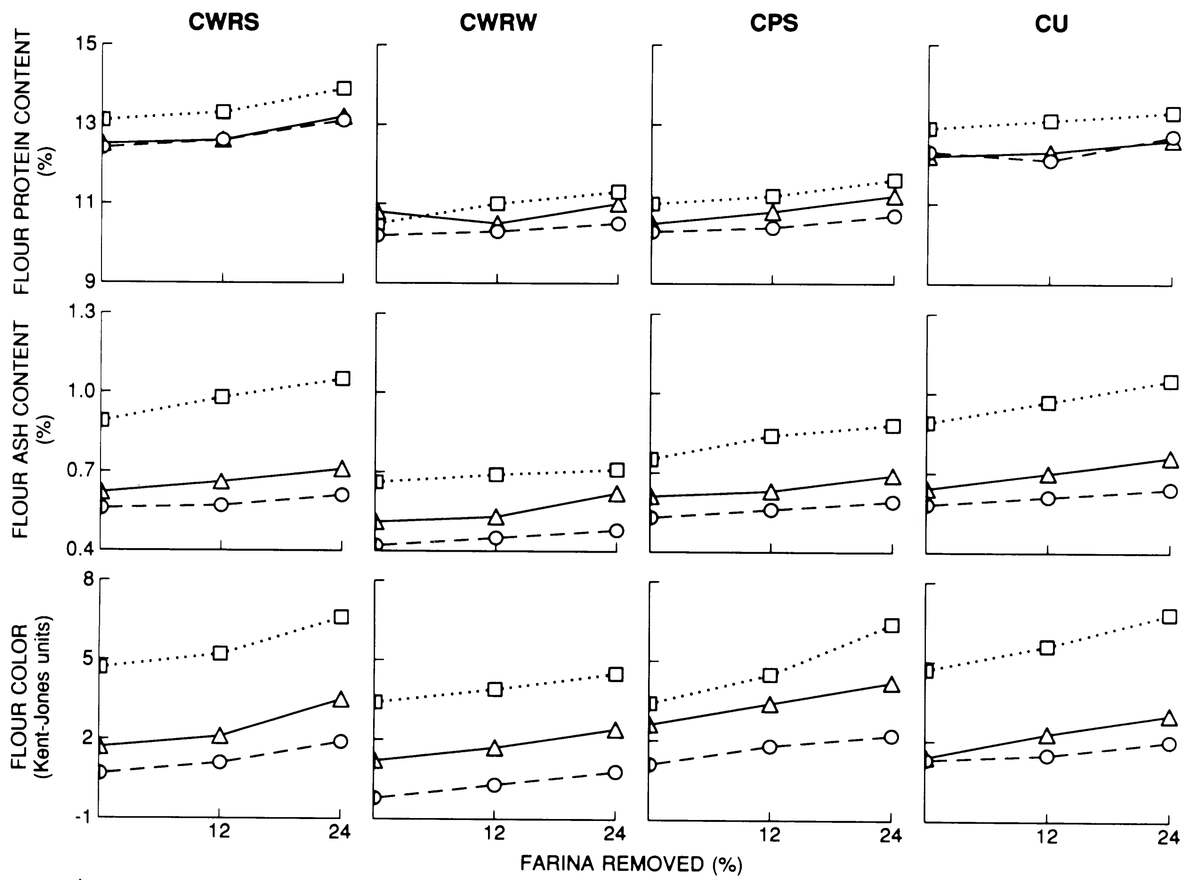

Fig. 2. Flour protein content, ash content, and color for four Canadian wheat classes milled to 75% (○), 79% (△), and 83% (□) extraction with up to 24% (wheat basis) farina removed.

All the flours produced high-quality bread. The higher protein content and higher starch damage of the CWRS and CU patent flours imparted higher baking absorption than the CPS and CWRW patent flours. The strength of the CU patent flour was reflected by a long remix mixing time and exceptional loaf volume for its protein content (high baking strength index).

Straight-Run and Residual Flour Analytical Properties

Significant ($P < 0.01$) differences among wheat classes were observed for straight-run flour and residual flour protein content, ash content, color, starch damage, and amylograph peak viscosity. For a given wheat, flour starch damage was not significantly ($P > 0.05$) influenced by either extraction rate or the amount of farina removed (results not shown). Flour α-amylase levels are highest in lower quality tail-end streams (Kruger 1981). As a result, the 75% extraction, straight-run flours for each wheat were about 150 Brabender units lower in amylograph peak viscosity than the corresponding patent flour, and there was a slight (about 20 Brabender units) but significant ($P < 0.01$) drop in amylograph peak viscosity as extraction rate was increased to 83% (results not shown). However, amylograph peak viscosity was not significantly ($P > 0.05$) influenced by the amount of farina removed during milling (results not shown).

Flour protein content, and ash content significantly ($P < 0.01$) increased and flour became significantly ($P < 0.01$) darker as extraction rate and the amount of farina removed were increased (Fig. 2). These results reflect the lower protein content and lower ash content of wheat endosperm compared with subaleurone and bran (Hinton 1959, Morris et al 1946). All the wheats exhibited the same general trends, but significant ($P < 0.05$) interactions between wheat and extraction rate for all three flour properties reflected differences in the magnitude of the effect of extraction rate on flour ash content, color, and protein content among wheats. Significant ($P < 0.05$) extraction rate to amount of removed farina interactions for flour ash content and flour color reflected a greater effect of farina removal as extraction rate increased.

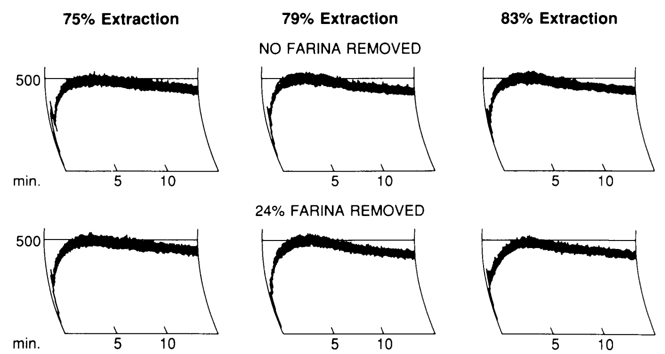

Fig. 3. Canada Western Red Spring farinograph curves for straight-run flours and residual flours remaining after removal of 24% (wheat basis) farina at three extraction rates.

Straight-Run and Residual Flour Physical Dough Properties

Farinograph properties of straight-run and residual flours were significantly ($P < 0.01$) different among wheats. For a given wheat, extraction rate also influenced farinograph properties, but the amount of farina removed at a given extraction rate had minimal effects. CWRS farinograph curves for straight-run flours and residual flours remaining after removal of 24% farina at each extraction rate are shown as examples (Fig. 3).

The effect of extraction rate on farinograph absorption, although significant ($P < 0.01$), was so slight (less than 1% range within flours for a given wheat) to be of no practical importance (results not shown). The effects ($P < 0.01$) of extraction rate on farinograph development time (results not shown) and farinograph stability (Fig. 4) were complex, as evidenced from significant ($P < 0.01$) interaction terms between wheat and extraction rate. The effects of extraction rate on farinograph development time and farinograph stability were mainly attributable

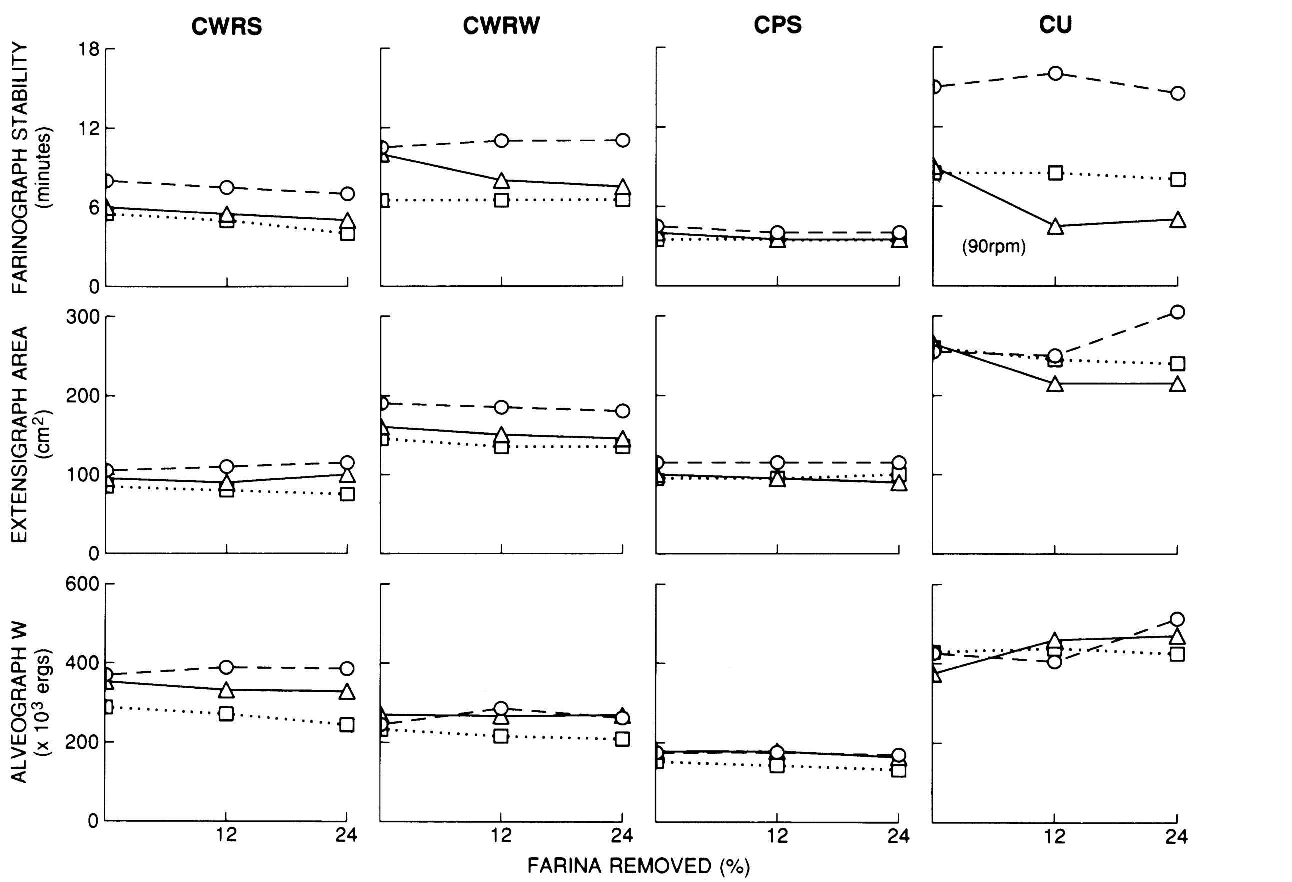

Fig. 4. Farinograph stability, extensigraph area, and alveograph W for four Canadian wheat classes milled to 75% (○), 79% (△), and 83% (□) extraction with up to 24% (wheat basis) farina removed.

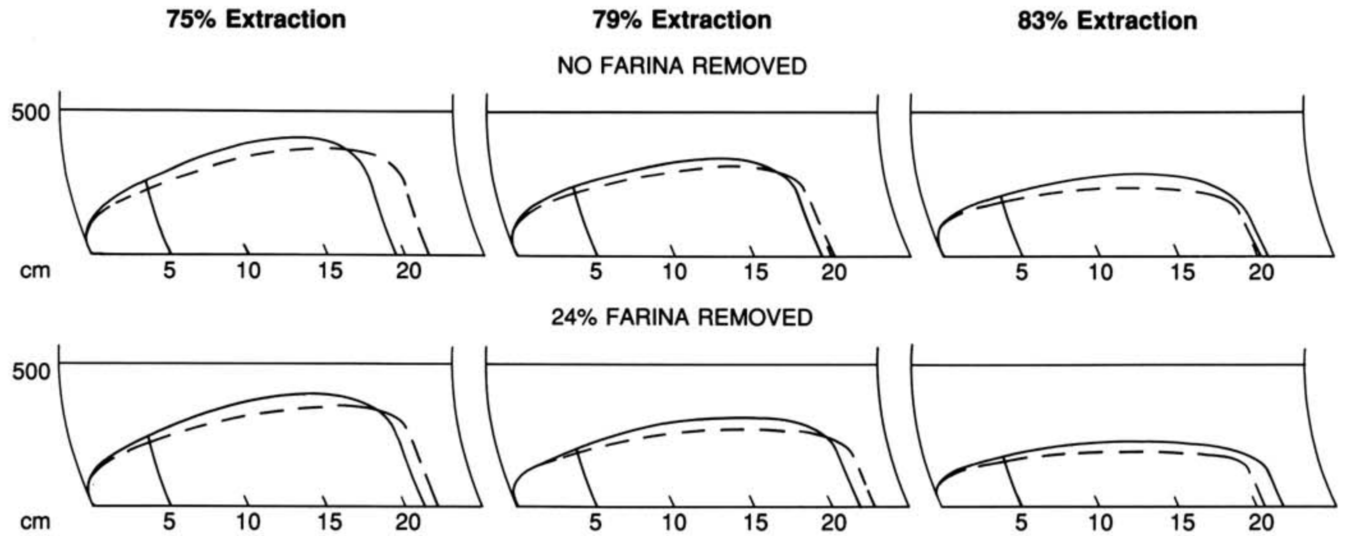

Fig. 5. Canada Western Red Spring extensigraph curves for straight-run flours and residual flours remaining after removal of 24% (wheat basis) farina at three extraction rates.

to weakening of CU flours at 79 and 83% extraction, as seen by the farinograph stability results shown in Figure 4. All the CU flours were extraordinarily strong regardless of extraction rate; the farinograph had to be run at 90 rpm to achieve dough development for all CU flours. Removal of up to 24% farina had no significant effect ($P > 0.05$) on either farinograph absorption or farinograph development time (results not shown). There was a significant ($P < 0.05$) trend to reduced farinograph stability as amount of farina removed increased, but for all wheats the observed effect was subtle.

Variations in protein content and gluten properties among the wheat classes imparted significant ($P < 0.01$) effects on extensigraph properties. For all wheats, as extraction rate increased, extensigraph properties weakened, as evidenced by increased length ($P < 0.05$), decreased maximum height ($P < 0.01$), and reduced area ($P < 0.01$). CWRS extensigraph curves for straight-run flours and residual flours remaining following removal of 24% farina at each extraction rate are shown as examples (Fig. 5).

Removal of farina during milling imparted slight weakening indications in the extensigraph curves. As the amount of farina removed was increased, extensigraph length increased ($P < 0.05$), and maximum height decreased ($P < 0.05$) slightly. However, as seen in Figure 4, extensigraph area, a widely accepted dough strength indicator, was not significantly ($P > 0.05$) affected by removal of up to 24% (wheat basis) high-quality farina.

Alveograph properties differed significantly ($P < 0.01$) among wheat classes but were not strongly influenced by extraction rate or the removal of farina. Alveograms of CWRS straight-run flours and residual flours remaining following 24% farina removal at each extraction rate are shown as examples (Fig. 6).

Alveograph properties are strongly influenced by flour starch damage (Farrand 1964, Preston et al 1987), but as discussed previously, neither extraction rate nor removal of farina significantly ($P > 0.05$) affected flour starch damage (results not shown). Therefore, within each wheat, effects of extraction rate and farina removal on alveograph properties can be attributed to differences in protein content and protein properties.

Alveograph length was not significantly ($P > 0.05$) influenced by extraction rate (results not shown). Alveograph height decreased ($P < 0.01$) with increasing extraction rate, but the maximum range for flours from a given wheat was less than 15 mm (results not shown). Alveograph W was significantly ($P < 0.01$) influenced by extraction rate, but a significant ($P < 0.05$) interaction between wheat and extraction rate arose because CWRS was the only wheat class to show a strong tendency for alveograph W to decrease with increasing extraction rate (Fig. 4).

Removal of up to 24% farina had a highly significant ($P < 0.01$) tendency to reduce alveograph height and increase alveograph length, but the magnitude of the effects was small (results not shown). Alveograph W, an accepted index of flour strength, was not significantly ($P > 0.05$) influenced by farina removal (Fig. 4).

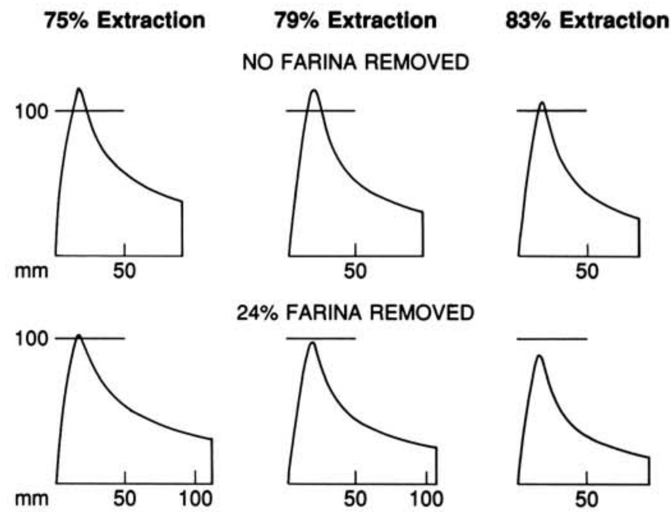

Fig. 6. Canada Western Red Spring alveograph curves for straight-run flours and residual flours remaining after removal of 24% (wheat basis) farina at three extraction rates.

Baking Performance of Straight-Run and Residual Flours

Dough weakening induced by increasing extraction rate and removal of high-quality farina should be amplified by the 165-min initial fermentation of the remix baking process prior to the remix stage. Increasing extraction rate significantly ($P < 0.01$) reduced remix mixing requirements (Fig. 7). A significant ($P < 0.01$) interaction between wheat and extraction rate was present because CPS exhibited less tendency to reduced remix requirement at high extraction than the other wheat classes. Removal of farina induced a significant ($P < 0.01$) reduction in remix requirement but the effect was slight for all wheats (Fig. 7).

Baking absorption differed over a wide range ($P < 0.01$) among wheats because of inherent differences in wheat hardness, protein content, and strength (results not shown). However, neither extraction rate nor removal of up to 24% (wheat basis) farina influenced ($P > 0.05$) baking absorption.

Bread properties were strongly influenced by extraction rate but influenced only slightly by farina removal. Breads baked from CWRS straight-run flours and residual flours remaining after

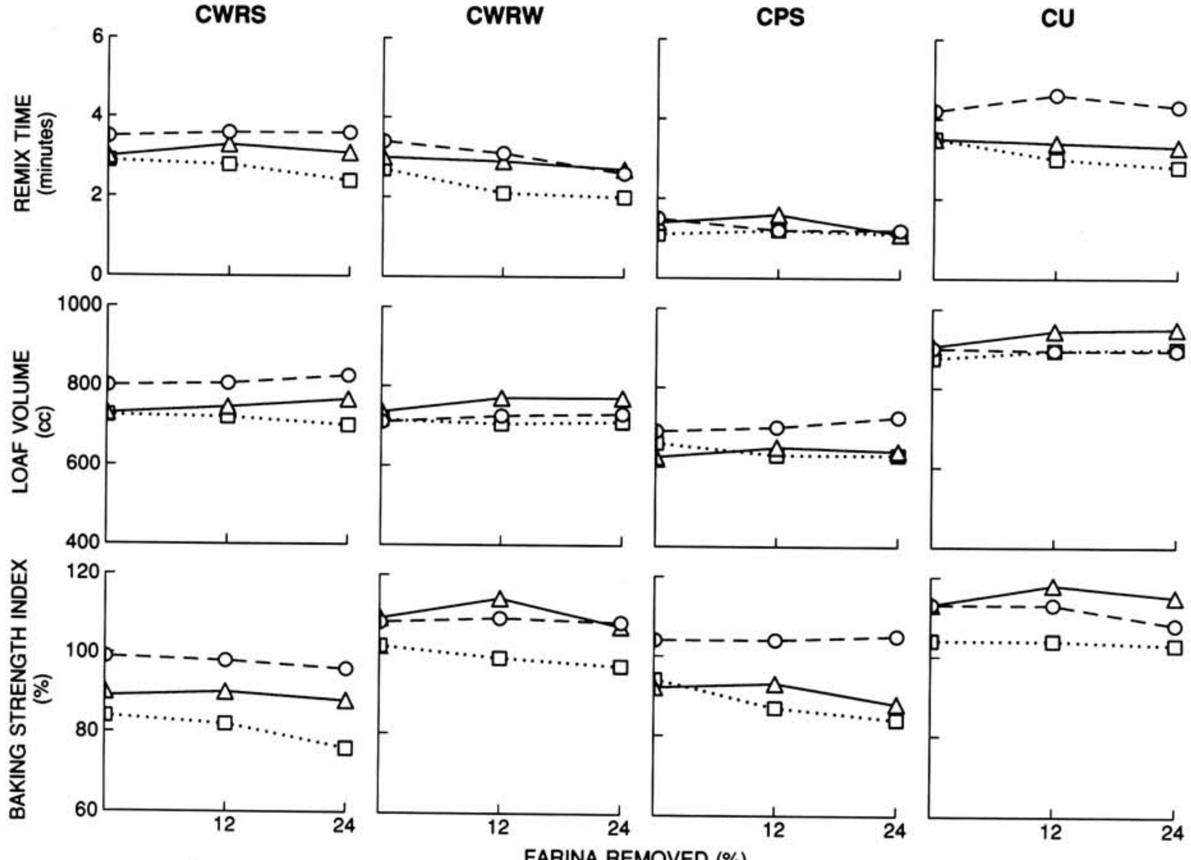

Fig. 7. Remix mixing time, loaf volume, and baking strength index for four Canadian wheat classes milled to 75% (○), 79% (△), and 83% (□) extraction with up to 24% (wheat basis) farina removed.

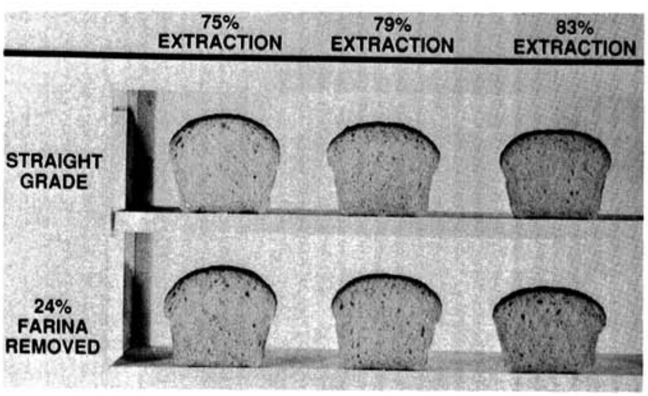

Fig. 8. Bread baked from Canada Western Red Spring straight-run flours and residual flours remaining after removal of 24% (wheat basis) farina at three extraction rates.

removal of 24% farina at each extraction rate are shown as examples (Fig. 8).

Bread loaf volumes were significantly ($P < 0.01$) influenced by extraction rate, but a significant ($P < 0.01$) interaction between wheat and extraction rate reflected inconsistencies in the patterns between wheat classes (Fig. 7). Similarly, when flour baking strength indexes, which measure the loaf volume achieved by a flour independently of protein content, were considered, extraction rate exerted a significant ($P < 0.01$) effect, but there were differences in response ($P < 0.01$) among wheat classes (Fig. 7). These inconsistencies among the wheats reflect differences in gluten strength. It is well known (Ziegler and Greer 1971) that strong wheats show less tendency to reduced loaf volume at high extraction rate than weak wheats.

Removal of up to 24% farina exerted a slight but significant ($P < 0.01$) trend towards increased loaf volume (Fig. 7). The increase in residual flour protein content induced by removing relatively low protein content farina (Fig. 2) apparently was sufficient to overcome the slight weakening of physical dough properties (Figs. 3–6). The slight weakening in dough properties induced by removal of farina was reflected by a very slight but significant ($P < 0.01$) drop in baking strength index (Fig. 7).

Bread crumb structure became coarser and more open ($P < 0.01$) as extraction rate increased (Figs. 8 and 9). The effect was more noticeable ($P < 0.01$) for CWRS and CPS than for CU and CWRW, presumably reflecting the stronger gluten properties of the latter two wheat classes. Removal of farina had a marginal but significant ($P < 0.05$) deleterious effect on crumb structure.

Bread crumb color became progressively duller ($P < 0.01$) as extraction increased (Fig. 9), a direct reflection of the darker color of the higher extraction flours (Fig. 2). Bread crumb color was affected adversely by farina removal ($P < 0.01$), but the effect was slight.

CONCLUSIONS

Flour becomes increasingly darker and weaker as extraction rate increases because of the inclusion of progressively darker and weaker tail-end millstreams. As a result, bread crumb color becomes duller and loaf volume decreases as extraction rate increases. Strong gluten wheats such as the Canada Utility wheat class show less tendency to reduced loaf volume at high extraction rate than less strong wheats.

Removing farina or high quality flour also results in the enrichment of the residual flour with lower grade tail-end millstreams. As expected, the residual flour becomes darker and higher in ash content, and bread crumb color becomes darker. However, removal of up to 24% farina (wheat basis) does not weaken residual flour appreciably. Changes in physical dough properties are barely perceptible for all Canadian bread wheat classes. Bread volume, appearance, and crumb structure are not diminished.

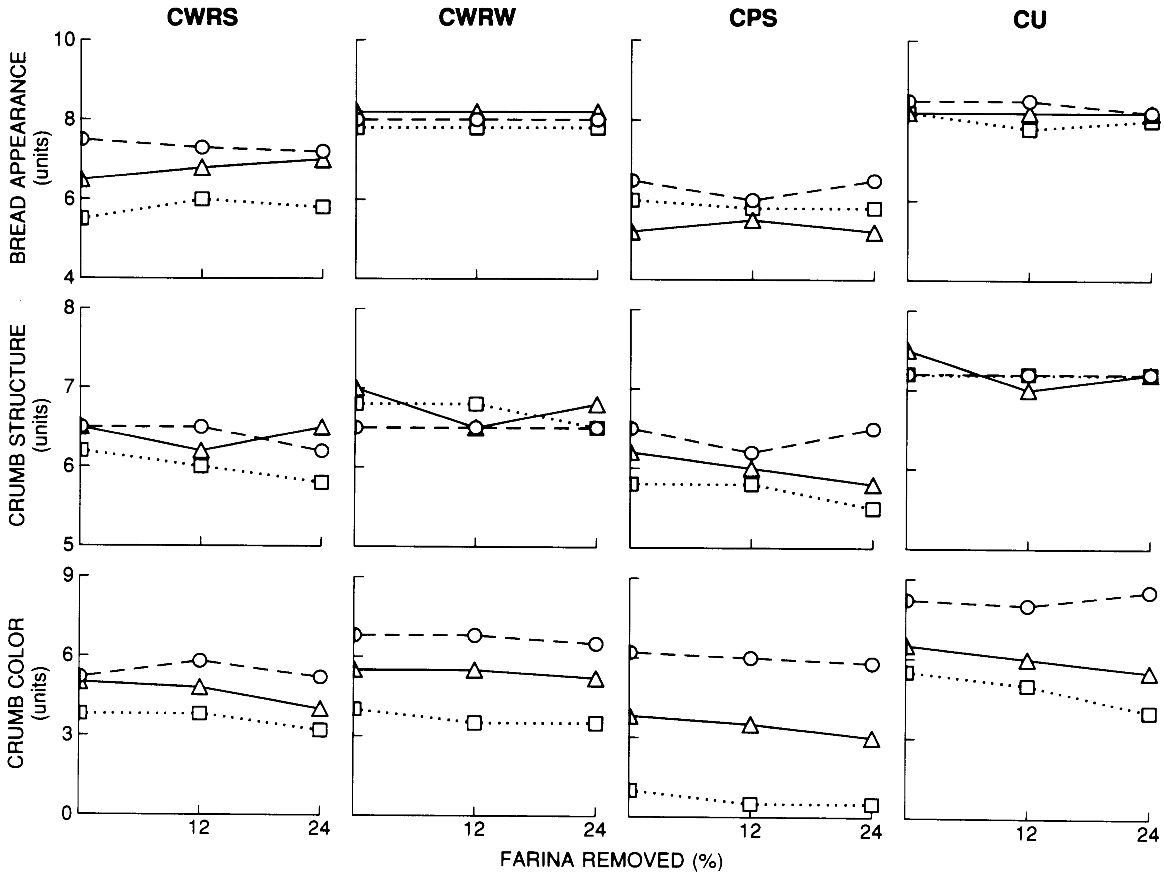

Fig. 9. Bread crumb structure and color for four Canadian wheat classes milled to 75% (○), 79% (△), and 83% (□) extraction with up to 24% (wheat basis) farina removed.

The discovery that removal of up to 24% farina does not affect flour physical dough and baking properties has important implications for all markets where divide milling is prevalent. Apparently, the slight weakening effects induced by a greater proportion of tail-end streams as high-quality millstreams are removed is compensated for by increased flour protein content and a greater proportion of strong break flours.

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 08-01, revised October 1976; Method 22-10, approved May 1960; Methods 54-10 and 54-21, approved April 1961. The Association: St. Paul, MN.

BLACK, H. C., HSIEH, F.-H., MARTIN, D. G., and TIPPLES, K. H. 1980a. Two Grain Research Laboratory research mills and a comparison with the Allis-Chalmers mill. Cereal Chem. 57:402.

BLACK, H. C., HSIEH, F.-H., TIPPLES, K. H., and IRVINE, G. N. 1980b. The GRL sifter for laboratory flour milling. Cereal Foods World 12:757.

CHEN, J., and D'APPOLONIA, B. L. 1985. Alveograph studies on hard red spring wheat flour. Cereal Foods World 30:862.

DEXTER, J. E., and TIPPLES, K. H. 1987. Wheat milling at the Grain Research Laboratory. Part 2. Equipment and procedures. Milling 180(7):16.

DEXTER, J. E., PRESTON, K. R., MATSUO, R. R., and TIPPLES, K. H. 1984. Development of a high extraction flow for the GRL pilot mill to evaluate Canadian wheat potential for the Chinese market. Can. Inst. Food Sci. Technol. J. 17:253.

DEXTER, J. E., PRESTON, K. R., and KILBORN, R. H. 1987. Milling and baking qualities of some Canadian wheat classes alone and in blends with Brazilian wheat under Brazilian processing conditions. Can. Inst. Food Sci. Technol. J. 20:42.

FARRAND, E. A. 1964. Flour properties in relation to the modern bread process in the United Kingdom, with special reference to alpha-amylase and starch damage. Cereal Chem. 41:98-111.

FINNEY, K. F., and BARMORE, M. A. 1948. Loaf volume and protein content of hard winter and spring wheats. Cereal Chem. 25:291.

HINTON, J. J. 1959. The distribution of ash in the wheat kernel. Cereal Chem. 36:19.

HOLAS, J., and TIPPLES, K. H. 1978. Factors affecting farinograph and baking absorption I. Quality characteristics of flour streams. Cereal Chem. 55:637.

INTERNATIONAL ASSOCIATION FOR CEREAL SCIENCE AND TECHNOLOGY (ICC). 1980. Standard 107, Determination of 'falling number' (according to Hagberg-Perten) as a measure of alpha-amylase in grain and flour; Standard 121, Method for using the Chopin-Alveograph. The Association: Vienna, Austria.

IRVINE, G. N., and McMULLAN, M. E. 1960. The 'remix' baking test. Cereal Chem. 37:603.

KILBORN, R. H., and TIPPLES, K. H. 1981. Canadian test baking procedures I. GRL remix method and variations. Cereal Foods World 26:624.

KRUGER, J. E. 1981. Severity of sprouting as a factor influencing the distribution of amylase levels in pilot mill streams of Canadian wheats. Can. J. Plant Sci. 61:817.

MORRIS, V. H., ALEXANDER, T. L., and PASCOE, E. D. 1946. Studies of the composition of the wheat kernel III. Distribution of ash and protein in central and peripheral zones of whole kernels. Cereal Chem. 23:540.

ORTH, R. A., and MANDER, K. C. 1975. Effect of milling yield on flour composition and breadmaking quality. Cereal Chem. 52:305.

PRESTON, K. R., KILBORN, R. H., and BLACK, H. C. 1982. The GRL pilot mill II. Physical dough and baking properties of flour streams milled from Canadian red spring wheats. Can. Inst. Food Sci. Technol. J. 15:29.

PRESTON, K. R., MYDLO, E., and KILBORN, R. H. 1984. Remix and remix-to-peak baking methods: Effects of fermentation time and salt on baking properties of a Canadian bread wheat. Can. Inst. Food Sci. Technol. J. 17:260.

PRESTON, K. R., KILBORN, R. H., and DEXTER, J. E. 1987. Effects of starch damage and water absorption on the alveograph properties

of Canadian hard red spring wheats. Can. Inst. Food Sci. Technol. J. 20:75.
TIPPLES, K. H., and KILBORN, R. H. 1974. 'Baking strength index' and the relation of protein content to loaf volume. Can. J. Plant Sci. 54:231.
TIPPLES, K. H., and PRESTON, K. R., and KILBORN, R. H. 1982. Implications of the term 'strength' as related to wheat and flour quality. Baker's Dig. 57(6):16.
WILLIAMS, P. C. 1973. The use of titanium dioxide as catalyst for large-scale Kjeldahl determination of the total nitrogen contents of cereal grains. J. Sci. Food Agric. 24:343.
ZIEGLER, E., and GREER, E. N. 1971. Principles of milling. Page 115 in: Wheat Chemistry and Technology. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

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