# Milling, Baking, and Physical-Chemical Properties of Selected Soft White Winter and Spring Wheats[1]

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**ABSTRACT**

Samples of soft white winter and spring wheats from eastern and western Canada, respectively, were studied for their milling, baking, and physical-chemical characteristics. When the samples were evaluated according to milling or baking characteristics, the main criteria for wheat quality, six of the first 10 samples were spring and four were winter wheats. Results show that good quality soft white wheat can be produced in western Canada.

Improvements in living standards over the past 10–15 years, both at home and abroad, have increased the demand for pastries and other soft wheat products (Washington Wheat Commission 1986). Increased prosperity changes peoples' consumption patterns. Bread is the staple in many of our daily diets, but other wheat products like cookies, cakes, doughnuts, wafers, and crackers are appealing. The main source of these pastry products is soft wheat. In addition to pastry products, there is increased demand for noodles in the Far East and flat breads in the Near East, both made from soft white wheat.

Greater prosperity has increased the demand not only for quantity but also for quality in the final product. Also, the constant improvements in automation of the bakery industry have placed higher demands on soft white wheat. The industry requires flours with ever-narrowing specifications and, above all, uniformity from one shipment to the next.

The adverse effects of high protein content or starch damage from field sprouting are well known (Nagao 1981). Bakers and millers also observed that soft wheat flours from eastern or western Canada or the United States may have similar protein contents and no sprout damage but cause quality differences in the final products. Millers further asserted that cake flour yields vary between wheats grown in the East or the West.

The purpose of this work was to study, using objective measurements, the performances of soft white winter and spring wheat flours grown in eastern and western Canada.

## MATERIALS AND METHODS

Traditionally, soft white winter wheats are grown in eastern Canada (about 550,000 acres), and soft white spring wheats are grown in western Canada (about 450,000 acres). Winter and spring soft white wheats from these areas were obtained for this study. Five winter and 15 spring wheats were collected from a wide range of growing environments. Of the five winter wheat samples, three represent Fredrick cultivars grown in 1982 (sample 3), 1983 (4), and 1984 (5), and the two other samples (1 and 2) were obtained from a milling company's winter wheat supply of mixed (commercial) cultivars (about 85% Fredrick), all from nonirrigated lands of eastern Canada. Of the 15 spring wheat samples, 12 represent Fielder (10, 11, 13, 14, 15, 16, 17, and 20), Owens (18), and Dirkwin (19) cultivars grown on irrigated or dry land (9 and 12) in 1984 in western Canada. However, two of these samples, 14 and 15, came from the same location in 1983 and 1984. The remaining three samples (6, 7, and 8) represent mixed (commercial) spring wheat cultivars (Fielder, Owens, and Dirkwin) of 1984 from a milling company and a country elevator all in western Canada. All samples were hand selected for sound kernels before milling to ensure that all were of the same grade. There were no visible signs of sprouting in any of the samples. All the wheat samples were experimentally milled on a Buhler pneumatic laboratory mill at the USDA, Western Wheat Quality Laboratory (WWQL), Pullman, WA.

Break flour, total flour yield (both expressed as percent of grain), and a milling score were obtained from the milling process. Milling score was calculated from a weighted formula using flour yield, flour ash, milling time (rate), percent of long patent flour, and tempering moisture to provide an economic value of the wheat to the milling trade (Rubenthaler et al 1985). Flour protein and ash were determined as described in AACC approved methods 46-12 and 08-01 (1983).

### Cookie Baking

Cookies were baked using the procedure of Finney et al (1950). Two cookies were baked at the WWQL and the average diameter of the two was taken. Cookies with greater spread indicate better flour quality.

### Cake Baking

Sponge cakes were baked using the procedure established by the Japanese milling trade in their specifications for grain purchasing (Nagao et al 1976). For comparison and reference, cakes were also baked from a standard Japanese commercial cake flour. The cakes were evaluated on the basis of volume, crumb grain, and texture. Cakes with greater volume, finer crumb grain structure, and softer and more tender texture are considered superior. Volume, expressed in cubic centimeters, was determined by using the rapeseed displacement method. Crumb grain for internal structure and for lightness was visually evaluated. A grade of 24 was assigned for superior quality and equaled the standard flour. Texture was measured by the Fudoh rheometer (NRM-2002J) and was expressed as grams of pressure required to penetrate the cake 1 cm with a 1-cm diameter disk. Lower values indicate softer and better cake quality.

### Alkaline Water Retention Capacity (AWRC)

AWRC of flours was measured by the methods of Yamazaki (1953) and Kitterman and Rubenthaler (1971b). The flour (14% moisture basis) was slurried with 0.1*N* sodium bicarbonate solution and centrifuged; the precipitate was weighed and the gain in weight expressed as percent of water retention. The lower the gain the better the flour quality for pastry needs.

### Viscosity

Viscosity was determined by the RVT Brookfield Synchro-

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Lectric viscometer, using a no. 2 spindle at a motor speed of 50 rpm (Kitterman and Rubenthaler 1971a). Flour was suspended in water and 1 $N$ lactic acid with vigorous shaking. The viscometer reading was registered after 20 sec of spindle turns and multiplied by 7.5 to obtain the apparent viscosity values in Brookfield degrees. The lower the reading, the smaller the resistance, and generally the better the flour quality.

### Mixograph Absorption

Mixograph absorption reflects the optimum amount of water required to produce a dough of optimum consistency for handling and baking performance as described by Finney and Shogren (1972). Lower absorption indicates better quality for pastry flour.

### Falling Number Values

Falling number indicates sprout damage. The enzyme $\alpha$-amylase, synthesized in the grain, has the ability to liquefy the starch. The falling number apparatus measures the time in seconds required for a plunger to fall through the flour slurry after stirring for 60 sec in a boiling water bath (method 56-81B; AACC 1983). The higher the value, the lower the enzyme activity, and the better the flour quality. At higher enzyme activity a greater portion of the starch is liquefied and the plunger falls faster.

### $\alpha$-Amylase Test

The Cibacron dye method (method 22-06; AACC 1983) measures the $\alpha$-amylase activity in cereals and expresses it in dextrinizing units per gram (DU/g). In this test a higher value means higher enzyme activity and poorer flour quality.

Data were subjected to statistical analyses by the SAS linear regression and $t$-test procedures (SAS Institute 1985).

## RESULTS AND DISCUSSION

Milling, baking, and analytical data and their averages for the winter and spring soft white wheats are summarized in Table I. Correlation coefficients among milling, baking, and analytical data for the wheat samples are presented in Table II. Correlation coefficients were determined for winter and spring wheats separately and tested for homogeneity. Because the correlations did not differ significantly, the pooled correlation coefficients are presented.

### Break Flour

The amount of break flour yield was significantly higher ($P \leqslant 0.01$) for the winter than for the spring wheat cultivars (Table I). The higher break flour yields for the winter wheats, a 20.3% gain, verifies the milling industry's claim of better recovery of a high quality cake flour fraction. When ranked for milling quality, however, among the 10 best samples six were spring wheat and four were winter wheat flour (Table III). The correlations were significant between break flour and cookie diameter, both observed and corrected for protein ($P \leqslant 0.01$), cake volume, and the external cake factors ($P \leqslant 0.05$) (Table II). These correlations confirm that the factors controlling break flour yield similarly contribute to greater cookie spread and cake volume (Yamazaki and Donelson 1972). Alkaline water retention capacity was inversely correlated with break flour yield at $P \leqslant 0.05$.

### Flour Yield

Total flour yield, representing a composite of the six flour streams of the Buhler laboratory mill, was significantly higher ($P \leqslant 0.05$) for the winter cultivar samples than for the spring wheat samples (Table I). There was a significant correlation between flour yield and milling score ($P \leqslant 0.01$) and an inverse correlation between flour yield and AWRC at $P \leqslant 0.01$ (Table II).

### Flour Ash

The ash content of the spring wheat flour was lower than that of the winter wheat flour, an indicator of higher flour quality (Table I). The difference, however, was not significant. There were

**TABLE I**
**Milling, Baking, and Analytical Data for Five Soft White Winter and 15 Soft White Spring Flours[a]**

| Sample No. | BFLR (%) | FYELD (%) | FASH[b] (%) | MSCOR (1–100) | FPROT[b] (%) | AWRC (%) | VISC (°Brookfield) | MABSC[c] (%) | CODI (cm) | CODIC[d] (cm) | CAVOL (ml) | EXFAC (1–32) | CCRGR (1–24) | Texture (1–100) | SCSOR (1–100) | FN[b] (sec) | AA (DU/g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Winter wheat | | | | | | | | | | | | | | | | | |
| 1 | 22.8 | 73.6 | 0.44 | 84.2 | 7.7 | 55.8 | 46.9 | 54.7 | 9.15 | 9.01 | 1,275 | 31.0 | 23.0 | 37 | 77.0 | 416 | 0.050 |
| 2 | 25.6 | 70.5 | 0.43 | 80.6 | 8.0 | 55.7 | 49.9 | 55.5 | 9.41 | 9.30 | 1,325 | 33.0 | 23.0 | 39 | 79.0 | 425 | 0.051 |
| 3 | 20.0 | 73.1 | 0.41 | 84.9 | 9.0 | 54.7 | 42.8 | 55.1 | 9.05 | 9.05 | 1,245 | 30.0 | 20.0 | 56 | 70.0 | 451 | 0.047 |
| 4 | 23.7 | 72.1 | 0.40 | 84.8 | 7.2 | 54.1 | 41.3 | 56.1 | 9.25 | 9.05 | 1,290 | 32.0 | 20.0 | 41 | 75.0 | 380 | 0.051 |
| 5 | 21.4 | 73.1 | 0.42 | 84.2 | 8.4 | 53.5 | 54.8 | 55.4 | 9.19 | 9.12 | 1,295 | 32.0 | 23.0 | 36 | 79.0 | 347 | 0.050 |
| $\bar{x}$ | 22.6**[f] | 72.5* | 0.42 | 8.37 | 8.1 | 54.8** | 47.1* | 55.4 | 9.21** | 9.11** | 1,286** | 31.6** | 21.8 | 42 | 76.0 | 404 | 0.050 |
| SD | 2.4 | 1.2 | 0.02 | 1.8 | 0.7 | 1.0 | 5.5 | 0.5 | 0.13 | 0.12 | 29 | 1.1 | 1.6 | 8 | 3.7 | 41 | 0.002 |
| Spring wheat | | | | | | | | | | | | | | | | | |
| 6 | 18.0 | 70.5 | 0.38 | 81.9 | 8.3 | 61.0 | 65.3 | 53.8 | 8.92 | 8.85 | 1,260 | 31.0 | 22.0 | 35 | 77.0 | 408 | 0.058 |
| 7 | 20.0 | 72.4 | 0.41 | 83.9 | 9.2 | 61.0 | 88.9 | 52.0 | 9.11 | 9.13 | 1,235 | 30.0 | 21.0 | 50 | 73.0 | 417 | 0.063 |
| 8 | 16.7 | 70.8 | 0.39 | 81.8 | 10.1 | 61.1 | 128.3 | 55.6 | 8.51 | 8.63 | 1,175 | 27.0 | 19.0 | 51 | 68.0 | 471 | 0.049 |
| 9 | 21.5 | 70.4 | 0.31 | 84.8 | 8.6 | 61.2 | 65.3 | 50.1 | 9.25 | 9.21 | 1,135 | 26.0 | 10.0 | 54 | 57.0 | 110 | 2.0+ |
| 10 | 21.8 | 68.5 | 0.40 | 76.9 | 9.1 | 63.7 | 97.1 | 51.9 | 8.90 | 8.91 | 1,205 | 29.0 | 16.0 | 50 | 67.0 | 227 | 0.576 |
| 11 | 17.0 | 71.8 | 0.39 | 83.2 | 9.4 | 58.5 | 120.8 | 55.4 | 8.62 | 8.67 | 1,250 | 30.0 | 22.0 | 32 | 76.0 | 479 | 0.067 |
| 12 | 17.6 | 70.9 | 0.36 | 84.7 | 8.5 | 60.1 | 73.9 | 56.5 | 8.89 | 8.83 | 1,250 | 30.0 | 23.0 | 36 | 77.0 | 327 | 0.056 |
| 13 | 16.0 | 65.1 | 0.36 | 74.4 | 7.5 | 60.7 | 56.3 | 57.9 | 9.06 | 8.90 | 1,270 | 31.0 | 23.0 | 35 | 78.0 | 400 | 0.058 |
| 14 | 17.0 | 69.1 | 0.38 | 80.6 | 9.3 | 60.4 | 101.6 | 57.0 | 8.81 | 8.85 | 1,180 | 28.0 | 19.0 | 65 | 67.0 | 473 | 0.053 |
| 15 | 17.7 | 69.4 | 0.40 | 78.9 | 9.3 | 59.4 | 99.4 | 56.2 | 8.79 | 8.82 | 1,165 | 27.0 | 18.0 | 64 | 65.0 | 467 | 0.049 |
| 16 | 17.8 | 70.1 | 0.41 | 79.6 | 8.9 | 60.0 | 61.1 | 54.7 | 8.97 | 8.96 | 1,250 | 30.0 | 23.0 | 24 | 76.0 | 442 | 0.054 |
| 17 | 16.4 | 69.8 | 0.41 | 80.5 | 7.7 | 60.5 | 49.5 | 54.3 | 9.06 | 8.92 | 1,225 | 29.0 | 22.0 | 38 | 73.0 | 434 | 0.053 |
| 18 | 21.1 | 71.7 | 0.40 | 82.3 | 7.5 | 58.5 | 47.3 | 55.0 | 9.04 | 8.87 | 1,260 | 31.0 | 22.0 | 25 | 78.0 | 373 | 0.061 |
| 19 | 17.1 | 71.3 | 0.43 | 80.3 | 8.3 | 56.7 | 46.5 | 51.6 | 8.89 | 8.81 | 1,205 | 29.0 | 19.0 | 40 | 71.0 | 390 | 0.064 |
| 20 | 16.5 | 61.2 | 0.43 | 7.28 | 9.4 | 61.6 | 82.5 | 54.4 | 8.76 | 8.81 | 1,160 | 27.0 | 18.0 | 58 | 65.0 | 440 | 0.055 |
| $\bar{x}$ | 18.2**[f] | 69.5* | 0.39 | 80.4 | 8.7 | 60.3** | 78.9* | 54.4 | 8.91** | 18.88** | 1,215** | 29.0** | 19.8 | 44 | 71.2 | 391 | 0.057[e] |
| SD | 1.9 | 2.3 | 0.03 | 3.5 | 0.8 | 1.6 | 26.3 | 2.2 | 0.19 | 0.15 | 43 | 1.6 | 3.5 | 13 | 6.2 | 102 | 0.006[e] |

[a] Abbreviations: BFLR = break flour; FYELD = flour yield; FASH = flour ash; MSCOR = milling score; FPROT = flour protein; AWRC = alkaline water retention capacity; VISC = MacMichael viscosity via Brookfield; MABSC = optimum mixograph water absorption corrected; CODI = cookie diameter; CODIC = corrected cookie diameter; CAVOL = sponge cake (SC) volume; EXFAC = external factor SC; CCRGR = SC crumb grain score; Texture = SC texture; SCSOR = SC score; FN = falling number; AA = $\alpha$-amylase activity units.

[b] Results on a 14% moisture basis.

[c] Corrected to 14% moisture and 9% protein.

[d] Corrected to 9% protein.

[e] Values for no. 9 and 10 excluded (outliers).

[f] Significantly different at * $P \leqslant 0.05$; ** $P \leqslant 0.01$.

TABLE II

Correlation Coefficients Among Milling, Baking, and Analytical Data for Five Soft White Winter and 15 Spring Wheat Flours

| Parameter | Break Flour | Flour Yield | Flour Ash | Milling Score | Flour Protein | AWRC[a] | Vis-cosity | Mix. Abs. | Cookie Diam. | Cookie Diam. Corr.[b] | Cake Volume | Extern. Factor | Crumb Grain | Texture | Sponge Cake Score | Falling Number | α-Amylase |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Break flour, % | ··· | | | | | | | | | | | | | | | | |
| Flour yield, % | 0.40 | ··· | | | | | | | | | | | | | | | |
| Flour ash, % | 0.20 | 0.10 | ··· | | | | | | | | | | | | | | |
| Milling score, 1–100 | 0.37 | 0.90** | 0.15 | ··· | | | | | | | | | | | | | |
| Flour protein, % | −0.37 | −0.17 | −0.05 | −0.14 | ··· | | | | | | | | | | | | |
| AWRC, % | −0.49*[c] | −0.57** | −0.44 | −0.51* | 0.43 | ··· | | | | | | | | | | | |
| Viscosity, ° Brookfield | −0.39 | −0.21 | −0.22 | −0.18 | 0.83** | 0.56** | ··· | | | | | | | | | | |
| Mixograph abs., % | −0.16 | −0.13 | 0.07 | −0.13 | −0.12 | −0.26 | 0.06 | ··· | | | | | | | | | |
| Cookie diam., cm | 0.72** | 0.29 | 0.05 | 0.30 | −0.71** | −0.48* | −0.78** | −0.16 | ··· | | | | | | | | |
| Cookie diam. corrected, cm | 0.74** | −0.27 | 0.03 | 0.31 | −0.40 | −0.40 | −0.58** | −0.27 | 0.93** | ··· | | | | | | | |
| Cake volume, ml | 0.48* | 0.41 | 0.36 | 0.28 | −0.62** | −0.61** | −0.53* | −0.38 | 0.54* | 0.38 | ··· | | | | | | |
| External factor, 1–32 | 0.51* | 0.40 | 0.36 | 0.26 | −0.64** | −0.60** | −0.55* | 0.32 | 0.56** | 0.40 | 0.99** | ··· | | | | | |
| Crumb grain, 1–24 | −0.05 | 0.22 | 0.48* | 0.06 | −0.35 | −0.37 | −0.26 | 0.60** | 0.08 | −0.08 | 0.79** | 0.75** | ··· | | | | |
| Texture, 1–100 | −0.09 | −0.28 | −0.12 | −0.17 | 0.56** | 0.23 | 0.42** | −0.10 | −0.24 | −0.01 | −0.69** | −0.66** | −0.64** | ··· | | | |
| Sponge cake score, 1–100 | 0.17 | 0.33 | 0.37 | 0.18 | −0.53* | −0.45* | −0.39 | 0.46* | 0.27 | 0.08 | 0.92** | 0.90** | 0.93** | −0.80** | ··· | | |
| Falling number, sec | −0.36 | −0.03 | 0.55* | −0.16 | 0.20 | 0.20 | 0.19 | 0.60** | −0.40 | −0.41 | 0.20 | 0.16 | 0.61** | 0.00 | 0.36 | ··· | |
| α-Amylase, DU/g[d] | −0.31 | −0.06 | −0.18 | −0.08 | −0.03 | 0.33 | 0.16 | −0.42 | −0.22 | −0.31 | 0.00 | 0.06 | 0.14 | −0.39 | 0.23 | −0.12 | ··· |

[a] AWRC = Alkaline water retention capacity.
[b] Cookie diameter corrected.
[c] Significantly different at * $P \leqslant 0.05$, ** $P \leqslant 0.01$.
[d] Values for samples 9 and 10 excluded (outliers).

TABLE III

Ranking of Samples in Order of Milling and Baking Quality for Five Soft Winter (W) and 15 Soft Spring (S) Wheat Flours[a]

| | Sample No. | Milling Quality[b] | Baking Quality[c] |
|---|---|---|---|
| Commercial, W | 1 | 5 | 4 |
| | 2 | 11 | 1 |
| Fredrick, W | 3 | 3 | 13 |
| | 4 | 1 | 9 |
| | 5 | 5 | 2 |
| Commercial, S | 6 | 9 | 7 |
| | 7 | 7 | 11 |
| | 8 | 12 | 17 |
| Fielder, S | 9 | 2 | 18 |
| | 10 | 13 | 16 |
| | 11 | 9 | 10 |
| | 12 | 4 | 8 |
| | 13 | 18 | 3 |
| | 14 | 13 | 14 |
| | 15 | 15 | 19 |
| | 16 | 15 | 5 |
| | 17 | 18 | 12 |
| Owens, S | 18 | 7 | 6 |
| Dirkwin, S | 19 | 17 | 15 |
| Fielder, S | 20 | 20 | 20 |

[a] A score of 1 was given for best and 20 for least desirable. Same numbers indicate identical data in actual results. In such case ranking is done as: 1, 1, 3, 4, 4, 6, 7 ..., etc.
[b] Milling quality = break flour, flour yield, flour ash, and milling score.
[c] Baking quality = corrected cookie diameter, sponge cake volume, external sponge cake factors, sponge cake crumb grain score, sponge cake texture, and sponge cake score.

significant correlations between the ash content and cake crumb grain ($P \leqslant 0.05$) and falling number at $P \leqslant 0.05$ (Table II).

## Milling Score

Winter wheats had higher milling scores than spring wheats, an indicator of higher economic value for the milling trade; however, the difference (3.3) was not significant (Table I). There was a significant correlation between milling score and flour yield ($P \leqslant 0.01$). The inverse correlation between milling score and AWRC was significant at $P \leqslant 0.05$ (Table II).

## Flour Protein

Protein contents of the winter wheat flours were lower than those of the spring wheat flours, but the differences were not significant (Table I). The correlations between protein content and viscosity and protein content and cake texture were significant at $P \leqslant 0.01$ (Table II). A higher protein content resulted in greater viscosity and smaller cookie spread, and firmer, tougher cake textures were more likely. Correspondingly, the inverse correlations were significant between protein content and cookie diameter ($P \leqslant 0.01$), cake volume ($P \leqslant 0.01$), external cake factors ($P \leqslant 0.01$), and sponge cake score at $P \leqslant 0.05$ (Table II). Viscosity is known to increase with increasing protein content, but earlier studies found that cookie diameter is affected only slightly or not at all by protein content (Finney and Yamazaki 1953, Minor 1966, Abboud et al 1985). In this study, however, increasing protein content decreased the size of cookies (Fig. 1 and Table I). The data also demonstrated that cookies at the same protein content could differ in size when one was baked from spring and the other from winter cultivars (Fig. 2). The spring wheats yielded somewhat smaller cookies, which indicates that protein quantity is not necessarily the only cause of smaller cookie size, increased viscosity, lesser cake volume, or heavier cake crumb structure.

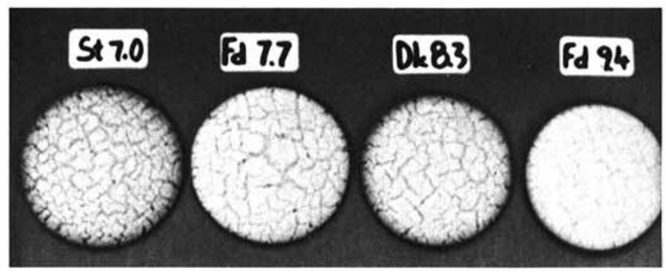


**Fig. 1.** The influence of flour protein on cookie diameter of three soft white spring wheats and the laboratory cookie standard flour. Left to right are cookie standard, Fielder, Dirkwin, and Fielder at 7.0 (9.29), 7.7 (9.06), 8.3 (8.89), and 9.4% (8.76 cm) protein and cookie diameter in parentheses, respectively.

## AWRC

The AWRC test is actually a standardized method of measuring the water retention ability of a flour against centrifugal force. It is recognized that the lower the percent of water retained, the better the pastry quality. In this study, winter wheat had a significantly lower AWRC ($P \leqslant 0.01$) than the set of spring wheats (Table I). The correlation between AWRC and viscosity was significant at $P \leqslant 0.01$ (Table II). Correspondingly, the inverse correlations were significant between AWRC and break flour ($P \leqslant 0.05$), flour yield

($P \leqslant 0.01$), milling score ($P \leqslant 0.05$), cookie diameter ($P \leqslant 0.05$), cake volume ($P \leqslant 0.01$), external cake factors ($P \leqslant 0.01$), and sponge cake score ($P \leqslant 0.05$).

### Viscosity

Flours from winter wheats had significantly ($P \leqslant 0.05$) lower viscosities than those from spring wheats (Table I). The difference in protein content between the two sets was not significant; therefore, other factor(s) contributing to viscosity are believed to be present. The correlations between viscosity and flour protein and water retention capacity were both significant at $P \leqslant 0.01$ (Table II). The inverse correlations between viscosity and observed or corrected cookie diameter ($P \leqslant 0.01$), cake volume ($P \leqslant 0.05$), and external cake factors ($P \leqslant 0.05$) were all significant.

### Mixograph Absorption

There was no significant difference in absorption values between winter and spring wheat flours (Table I). Significant correlation existed between mixograph absorption and sponge cake crumb grain ($P \leqslant 0.01$), cake score ($P \leqslant 0.05$), and the falling number at $P \leqslant 0.01$ (Table II). Spring wheats consistently showed an undesirably stronger mixing character (mixing peak heights and curve area) than the winter wheats.

### Cookie Diameter

The cookie baking test is an important test in soft wheat flour evaluation. The principal criterion of quality is the diameter increase during the baking process, which is also referred to as spread factor. Flour that produces cookies of large diameter is considered superior for most soft wheat products. For comparative purposes, Figure 3 shows the baked cookies. Cookies numbered 1 to 5 are those from the winter wheat set and are generally larger than the remainder, which are from soft white spring flours. The first and last are cookies baked from a laboratory-prepared cookie standard reference flour. The slightly larger cookie 9 represents flour with incipient sprout damage. The cookie diameters were significantly higher ($P \leqslant 0.01$) for the winter wheat flours than for the spring wheat flours (Table I). The correlation was significant between cookie diameter and break flour yield ($P \leqslant 0.01$), cake volume ($P \leqslant 0.05$), and external cake factors at $P \leqslant 0.01$ (Table II). Cookie diameter related inversely to flour protein ($P \leqslant 0.01$), AWRC ($P \leqslant 0.05$), and viscosity at $P \leqslant 0.01$ (Table II).

### Cookie Diameter Corrected

To examine cookie spread free of the influence of protein content, values for cookie diameter are corrected to a constant protein of 9% (Table I) by a long-term average correction factor of 0.12 cm/% of protein (Rubenthaler et al 1985). The corrected cookie diameter was significantly higher ($P \leqslant 0.01$) for winter wheat flours than for the spring wheat flours (Table I). Table II shows that even after excluding the protein influence, break flour has a positive relationship to cookie diameter. Similarly, corrected cookie diameters maintained the same significant correlations with other measurments as the observed cookie diameters, except with flour protein and AWRC where the relationships are not significant.

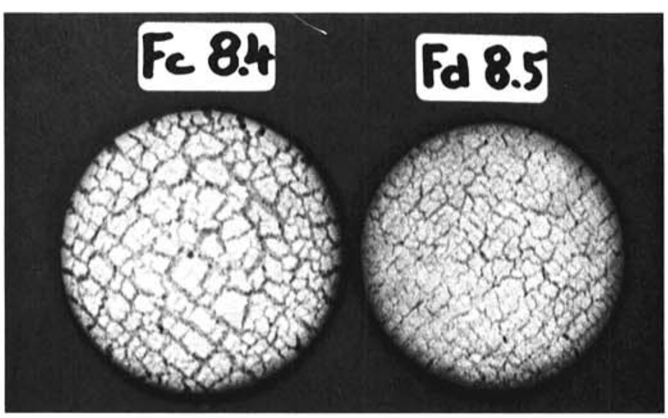


**Fig. 2.** Observed differences in cookie diameter and top grain characteristics between **left**, soft white winter (Fredrick, sample 5) and **right**, soft white spring wheats (Fielder, sample 12) at a similar protein (8.4–8.5%) level. Cookie diameters are 9.19 and 8.83 cm for samples 5 and 12, respectively.

### Cake Volume

The cake baking test is also an important test in the evaluation of soft wheat flour. The main criteria for good cake quality are high cake volume and a fine uniform crumb structure that is tender and moist. Flour with high protein content or strong gluten, or both, produces a coarse and heavy crumb structure and a small compact volume. Cake is made with a batter system instead of a dough system as in cookie or bread production. In the batter system, the aqueous phase forms the continuous phase in which the other ingredients are dispersed (Pomeranz 1978). With whipping, air is

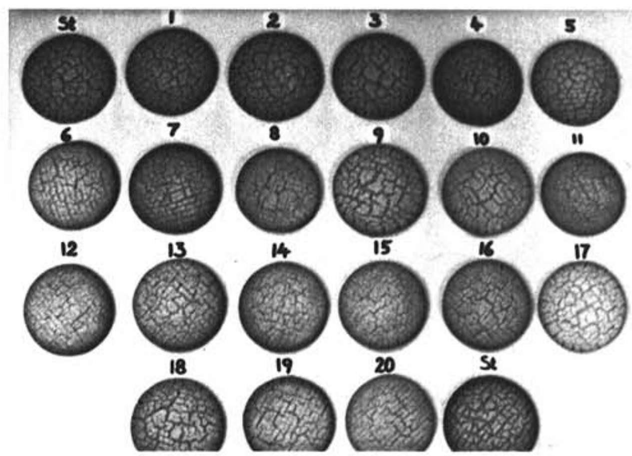

**Fig. 3.** Cookies baked from five soft white winter wheats (1–5) and 15 soft white spring wheats (6–20). **St** = Standard.

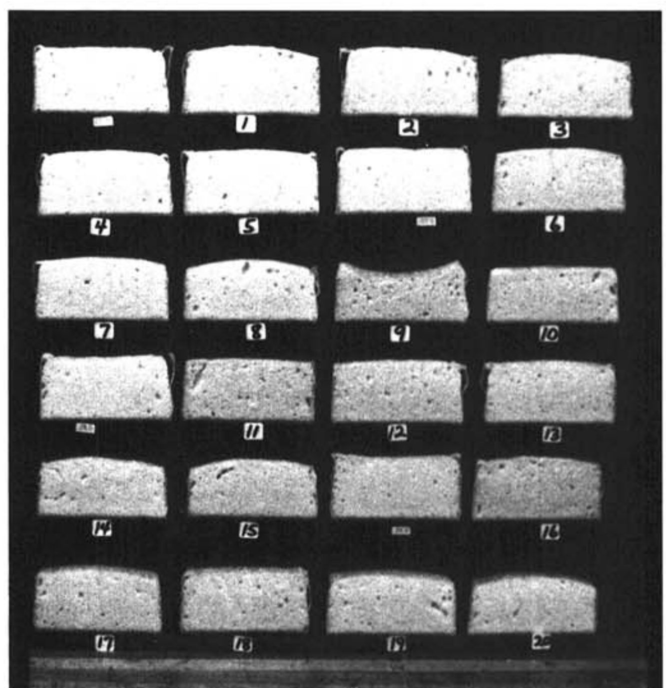

**Fig. 4.** Cross-sections of sponge cakes baked from the five soft white winter wheat flours (1–5), 15 soft white spring wheat flours (6–20), and four replicates of a standard reference Japanese commercial cake flour (Std).

incorporated into the batter and a foam structure develops from the egg and sugar. Flour protein with strong gluten matrix formation disrupts the foam structure in the batter system. $\alpha$-Amylase from sprouted grain is also known to disrupt the batter system.

The cake volume of the winter wheat flour set was significantly greater ($P \leqslant 0.01$) than that of the spring wheat flour (Table I). The correlation was significant between cake volume and break flour ($P \leqslant 0.05$), cookie diameter ($P \leqslant 0.05$), external factors for cake ($P \leqslant 0.01$), crumb grain ($P \leqslant 0.01$), and sponge cake score at $P \leqslant 0.01$ (Table II). Inverse correlations were significant between cake volume and flour protein ($P \leqslant 0.01$), AWRC ($P \leqslant 0.01$), viscosity ($P \leqslant 0.05$), and texture ($P \leqslant 0.01$). Figure 4 shows the sponge cakes baked from the 20 samples and four from a standard cake flour. Cakes 1–5 are from winter wheats and 6–20 from the spring wheat samples. Cakes 9 and 10 represent flours with sprout damage. Cake 9, with the depressed top, had the highest $\alpha$-amylase activity among the group. Cake 10, a less affected sample, shows no shape deformation other than smaller size.

**External Factors**

These values are derived from the shape, crust color, appearance, and volume of the cake and make up 40% of the cake score. These external factors were significantly higher for cakes made from the winter wheat flours ($P \leqslant 0.01$) than those from the spring wheat flours (Table I). The correlation was significant between external factors and break flour yield ($P \leqslant 0.05$), cookie diameter ($P \leqslant 0.01$), cake volume ($P \leqslant 0.01$), crumb grain ($P \leqslant 0.01$), and sponge cake score ($P \leqslant 0.01$) (Table II). A significant inverse correlation was found between external factors and flour protein ($P \leqslant 0.01$), AWRC ($P \leqslant 0.01$), viscosity ($P \leqslant 0.05$), and texture ($P \leqslant 0.01$).

**Crumb Grain**

Crumb grain scores reflect the cell uniformity, size, and wall thickness, and represent 30% of the cake score. There was no significant difference between crumb grain of cakes made from winter and spring wheats (Table I). The average score for the winter wheat cakes was slightly higher than that from spring wheats. The spring wheat values were lowered mainly by the two samples showing sprout damage. There were significant correlations between crumb grain scores and flour ash ($P \leqslant 0.05$), mixograph absorption ($P \leqslant 0.01$), cake volume ($P \leqslant 0.01$), external factors ($P \leqslant 0.01$), sponge cake score ($P \leqslant 0.01$), and falling number at $P \leqslant 0.01$ (Table II). The inverse relationship was significant between crumb grain score and texture ($P \leqslant 0.01$).

**Texture**

This portion of the sponge cake score (30%) gives a measurement for softness and tenderness. There were no significant differences between cakes made from winter or spring wheat flours (Table I). The range of texture measurements, however, was twice as much for the spring set (24–65) as for the winter set (36–56). There was a significant correlation between texture and flour protein ($P \leqslant 0.01$), indicating that increasing flour protein increased firmness of the cake structure (Table II). A significant inverse correlation was found between cake texture and cake volume ($P \leqslant 0.01$), external factors ($P \leqslant 0.01$), crumb grain ($P \leqslant 0.01$), and sponge cake score at $P \leqslant 0.01$ (Table II). Texture, however, did not correlate with the tests measuring sprout damage.

**Sponge Cake Score**

The sponge cake scoring system (Nagao et al 1976) is a summary of measured factors that characterize overall cake quality. Therefore, correlations between this score and the individual factors for cake quality were expected. Excluding those correlations, however, there was a significant inverse correlation between cake score and flour protein ($P \leqslant 0.05$), AWRC ($P \leqslant 0.05$), and mixograph absorption ($P \leqslant 0.05$) (Table II). There was no significant difference between the scores assigned to cakes made from winter and spring wheat flours (Table I).

**Falling Number Values**

Wheats with falling numbers below 300 (sec) are suspected of having some sprout damage. No significant difference between the winter or spring wheats was found. Two spring wheat flours, 9 and 10, had values below 300 (Table I). The cake from sample 9, described earlier, showed these effects by its fallen center (Fig. 4), lowest cake volume, and lowest crumb grain score (Table I). The cake from sample 10, with less enzyme activity, showed no deformed structure but received the second lowest score for crumb grain. Cookie diameter was not affected by the variation in falling number. There was significant correlation between falling number and flour ash ($P \leqslant 0.05$), mixograph absorption ($P \leqslant 0.01$), and crumb grain at $P \leqslant 0.01$ (Table II).

**$\alpha$-Amylase**

An average dextrinizing unit (DU/g) of 0.068 is considered normal for sound wheat samples (Mathewson et al 1981). Values above this may indicate some sprout damage. Two spring wheat flours, 9 and 10, had values at considerably higher levels. Correspondingly, cake 9 showed a fallen center and the lowest cake volume and crumb grain score among all samples. Cake 10, with less enzyme activity, showed no deformed shape but was low in crumb grain score.

$\alpha$-Amylase values for samples 9 and 10 were omitted (outliers) when the mean, standard deviation (Table I), and correlation coefficients (Table II) were calculated. There were no significant correlations ($P \leqslant 0.05$) between $\alpha$-amylase and other quality variables.

## CONCLUSIONS

Samples of soft white winter and spring wheats were collected from eastern and western Canada, respectively, and studied for milling, baking, and physical-chemical characteristics. Two samples had incipient sprout damage. One of them (sample 9), with the lowest falling number and highest $\alpha$-amylase activity, produced a cake with a fallen center and low crumb grain score, and the other (sample 10), with a moderately low falling number and higher $\alpha$-amylase activity, produced a cake that did not fall but was low in crumb grain score. In cookie baking, however, sample 9 produced a larger cookie caused by the liquefaction of starch cells by enzyme action.

Based on quality parameters, samples were ranked in decreasing order from one to 20 for milling and baking quality (Table III). When ranked for milling or baking quality, among the 10 best samples were six spring and four winter wheat flours (Table III). Both milling and baking quality, which subsequently determines wheat quality, show that some spring wheats compete well with winter wheat.

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