Rheological Properties and Baking Qualities of Selected Soft Wheats Grown in the United States

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ABSTRACT

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Seventeen soft wheat cultivars from four classes of U.S. soft wheats, eastern soft white winter (ESWW), western soft white winter (WSWW), club, and soft red winter (SRW) wheats, were selected for evaluation of their milling, physicochemical, and rheological properties and their suitability for making Japanese-type sponge cakes (JSC) and AACC sugar-snap cookies (SSC). The texture characteristics of JSC were determined with texture profile analysis (TPA). Results indicated that some SRW and ESWW wheats could be potential substitutes for WSWW and club wheats for JSC end-use. Both ESWW and SRW wheat short patent flours produced relatively larger diameter cookies than did WSWW and club wheat short patent flours. Correlation analyses indicated that decreasing flour particle size was a very important parameter related to improving quality of both JSC and SSC, while starch damage was more detrimental to SSC quality. Results from the present study also showed that the alveograph and mixograph were useful tools for evaluation of soft wheat quality for cake and cookie baking.

Soft wheat flour has been used for a wide range of commercial baked products. In the United States, the sugar-snap cookie and layer cake baking tests are usually used to evaluate soft wheat baking quality. A soft wheat flour that can produce large spread cookies and/or large volume cakes is usually considered a good quality flour for soft wheat products. However, it should be recognized that an ideal flour for one class of products may not be ideal for another (Finney 1989).

Most soft wheat milled in Japan has been imported from the United States, and is mainly U.S. western white wheat (Nagao 1989). The flour for making Japanese-type sponge cakes (JSC) is specifically milled from 100% U.S. western white wheat. Japan has not imported U.S. soft red winter (SRW) wheat for many years because of its higher price, lower availability, and the less desirable high protein content for Japanese soft wheat products.

A recent survey of U.S. soft wheat quality indicated that the protein content of U.S. soft white wheat (western soft white winter [WSWW] and eastern soft white winter [ESWW]) and club wheat had increased over the last 13 years, being higher than that of SRW wheat since 1988, while the protein content of SRW wheat has remained almost constant during the same period (U.S. Wheat Associates 1980–1992). Most Japanese milling and baking companies have been concerned about the increases in protein content of U.S. western white wheat due to the direct negative influence on the quality of Japanese cakes. For JSC, low flour protein content is usually desirable (Nagao et al 1976).

There has been little information in the past 18 years comparing the qualities of different soft wheat cultivars grown in the United States, especially as to their suitability for making JSC. The objectives of the present study were to: 1) evaluate rheological properties and baking qualities of selected U.S. soft wheats for JSC and AACC sugar-snap cookie (SSC) end-use; and 2) investigate potential tools for properly evaluating soft wheat flour properties for JSC and SSC baking qualities.

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MATERIALS AND METHODS

Wheat Samples

Seventeen soft wheat cultivars harvested in 1992 or 1993 from the states of Washington, Michigan, Ohio, and Indiana were selected for this study. These cultivars cover four classes of soft wheats produced in the United States: three ESWW wheats (Augusta, Chelsea, and Frankenmuth); five WSWW wheats (Kmor, Lewjain, Madsen, Malcolm, and Stephens); four club wheats (Crew, Hyak, Rely, and Tres); and five SRW wheats (Caldwell, Clark, Excel, Dynasty, and Freedom).

Milling Evaluation

The samples were cleaned using a Carter Dockage Tester, tempered to 15% moisture for 24 hr, and milled on a Miag-Multomat pilot flour mill to obtain short patent flours of 45% extraction.

Wheat and Flour Physicochemical Analyses

Test weight of wheat samples, wheat and flour moisture contents, and flour ash content were determined according to approved methods 55-10, 44-15A, and 08-01, respectively (AACC 1983). Total nitrogen content of flour and wheat was determined by the micro-Kjeldahl method (method 46-13, AACC 1983). Protein content was calculated by multiplying the nitrogen content by the conversion factor 5.7 and reported on a 14% moisture basis. Flour particle size was determined by a Coulter Multisizer (Coulter Electronics Limited, Bedfordshire, England) according to the Operator's Handbook (Anonymous 1986). Starch damage was determined with a Chopin SD4 apparatus (Chopin S.A., Garenne, France) (Dubois 1988). Alkaline water retention capacity and Zeleny sedimentation volume were determined according to approved methods 56-10 and 56-60, respectively (AACC 1983).

Flour Starch Pasting Properties

Flour samples were analyzed by a Brabender Viscograph-E to determine the effect of α-amylase on flour viscosity as a function of temperature according to the Amylograph Handbook (Shuey and Tipples 1982). A mixture of flour (65 g) and distilled water (450 ml) was heated in the viscograph-E from 30°C to 95°C at 1.5°C/min, held at 95°C for 15 min, and cooled to 50°C at 1.5°C/min. Viscosity was measured at a torque of 700 cm·gf (gf = gram of force) and recorded at a chart speed of 30 cm/hr. The pasting parameters obtained from a pasting curve were defined according to Dengate (1984). However, only peak viscosity, breakdown viscosity, and breakdown from each pasting curve are reported in this article.

Flour Rheological Measurements

Farinogram values (water absorption, peak time, stability time, and mixing tolerance index) were obtained from a 15-min farinograph mixing curve using 50 g of flour (14% mb) according to method 54-21 (AACC 1983). Alveogram values (tenacity *P*, extensibility *L*, stability *P/L*, swelling index *G*, and work *W*) were also determined according to method 54-30 (AACC 1983) using a Chopin Alveograph with hydrostatically controlled airflow. Dough mixing properties were measured using 35 g of flour (14% mb) with a mixograph (National Manufacturing Co., Lincoln, NE) according to method 54-40A (AACC 1983). Mixograph tolerance was defined as the width, in millimeters, of the mixograph curve two minutes past peak time (Graybosch et al 1993). Mixograph stability time was defined as the interval, in minutes, between the arrival time and departure time from the center line of the mixograph curve (Pyler 1988).

Flour Baking Quality Evaluation

JSC and SSC were baked to evaluate the flour's baking performances. All sponge cakes and cookies were made from each of the short patent flours.

Sponge Cake Testing Method

Sponge cakes were prepared by the formula and procedure described by Nagao et al (1976) with some modifications. The cake formula and ingredients for one cake are: flour (as is moisture basis) 150 g; sugar (fine-granulated sucrose) 150 g; fresh whole egg 150 g; and distilled water 60 ml. The Hobart mixer (N-50) with three speed settings (1, 2, and 3) was equipped with a 5-qt bowl and a wire whip for creaming sugar, whole egg, and water. Whole eggs (without shells) were weighed into a mixing bowl and fast beat with a hand whip for 10 sec, after which the same amount of sugar was added into eggs. The mixture was warmed to 45°C in a water bath with slow mixing by hand whip to dissolve the sugar. The mixture was then mixed in the Hobart mixer at medium speed (setting 2) for 6–7 min until the specific gravity of the egg-sugar batter reached 0.28 ± 0.01 g/cm^3, at which point the mixer speed was reduced to low (setting 1) for 1 min while 60 ml of water was added: each 30 ml of water was added slowly in the first and third 15-sec interval. The mixing bowl was then removed from the mixer, after which sifted flour was added into the cream. The cream-flour mixture was subjected to mixing for 80–100 strokes by hand at a speed of 1 stroke/sec with a wooden spoon until the cake batter specific gravity reached 0.50 ± 0.01 g/cm^3. At this stage, the cake batter temperature was between 25 and 30°C. The cake batter (320 g) was poured into a circular baking pan (15.3 cm i.d.; 5.1 cm depth) with parchment paper lining the bottom and inner side wall. The surface of the cake batter was smoothed with a plastic spatula, and the pan was placed into a rotary oven (National Manufacturing) along with a cup of water to bake for 30 min at 180°C.

The remaining cake batter was used for measuring its viscosity with a Brookfield Synchro-Lectric viscometer (RV-1, Brookfield Engineering Laboratories, Inc., Stoughton, MA), using a no. 6 spindle at a motor speed of 20 rpm. The viscometer reading was conducted after 30 sec of spindle turns. This reading was multiplied by 500 to obtain viscosity value in centipoise (cp).

After baking, the pan was removed from the oven and a shock treatment was applied to the cake for easy removal. The cake was then removed from the pan immediately and cooled for more than 1 hr at room temperature before packaging. Cake volume was determined by the rapeseed displacement method and graded according to method 10-90 (AACC 1983). Flour that can produce a larger volume cake predicts its better end-use quality.

Sugar-Snap Cookie Testing Method

SSC were baked according to the micro method of method 10-52 (AACC 1983). The diameter and thickness of the cookies were measured. Cookies with larger diameters predict better flour end-use quality.

TABLE I
Selected Wheat and Flour Physicochemical Properties of 17 Soft Wheat Cultivars

		Flour Physicochemical Properties[a]								
Wheat Cultivar	Test Wt. (lb/bu)	Ash (%)[b]	Starch Damage (UCD)[c]	Particle Size (µm)	Protein (%)[b]	AWRC (%)[b]	Sed. Vol. (ml)	Peak Viscosity (BU)	Breakdown Viscosity (BU)	Breakdown (BU)
ESWW[d]										
Augusta	56.4	0.29	12.3	41.6	7.1	55.4	17	740	615	125
Chelsea	60.0	0.35	14.3	39.1	7.2	55.0	14	715	585	130
Frankenmuth	60.0	0.35	10.5	48.6	8.2	50.2	21	1040	870	170
WSWW[d]										
Kmor	60.6	0.37	15.6	31.9	7.8	55.0	26	595	560	35
Lewjain	61.3	0.28	16.3	42.8	8.1	58.8	21	370	330	40
Madsen	62.6	0.37	18.4	63.0	8.9	57.8	19	320	265	55
Malcolm	59.4	0.33	16.9	53.8	7.7	56.3	14	610	580	30
Stephens	62.3	0.32	18.4	60.2	8.3	58.5	13	360	275	85
Club										
Crew	60.5	0.39	14.5	53.4	7.2	52.2	13	910	830	80
Hyak	61.8	0.30	18.1	57.2	6.7	60.4	24	200	110	90
Rely	59.5	0.40	14.2	47.0	8.2	53.4	17	810	755	55
Tres	60.2	0.38	16.1	60.5	8.7	60.5	10	770	695	75
SRW[d]										
Caldwell	59.8	0.36	13.3	31.9	7.6	58.1	21	860	730	130
Clark	60.8	0.36	10.1	40.3	7.3	52.5	15	1090	810	280
Dynasty	58.7	0.27	10.5	28.9	7.9	57.2	17	840	640	200
Excel	58.8	0.30	9.7	30.5	7.3	55.3	16	840	720	120
Freedom	60.3	0.28	15.4	45.2	7.8	55.4	16	655	455	200

[a] Values are means of two replicates. AWRC = alkaline water retention capacity; sed. vol. = sedimentation volume.
[b] Percentage of flour weight (14% mb).
[c] Arbitrary unit used in the Chopin/Dubois method.
[d] ESWW = eastern soft white winter; WSWW = western soft white winter; SRW = soft red winter.

Texture Profile Analysis of JSC

An Instron universal testing machine (UTM) (4202, Instron Corp., Canton, MA) was used to determine the texture characteristics of the cakes the next day after baking. The texture profile analysis (TPA) was used to obtain the force-time curves of sponge cake samples with the UTM connected to a computer with Instron Series XII software (Cyclic Test). The operation procedures were based on the methods of Szczesniak (1963) and Vovan et al (1982). A 0.635-cm diameter plunger, attached to the UTM, compressed a cake twice in sequence to a depth of 40% of cake thickness. The UTM was operated with a crosshead speed of 20 cm/min, chart speed of 20 cm/min, and a full scale load of 2 N. These operating conditions yielded the lowest variation coefficients for cake firmness, cohesiveness, adhesiveness, and elasticity (springiness) (Vovan et al 1982). Analyses of the force-time curve led to the extraction of six textural parameters: four measured (hardness, cohesiveness, adhesiveness, and elasticity), and two calculated from the measured parameters (gumminess and chewiness) (Bourne 1978).

Statistical Analyses

Data were subjected to correlation analysis on a Microsoft Excel (Cambridge, MA) program.

RESULTS AND DISCUSSION

Wheat and Flour Physicochemical Properties

Table I shows some of the quality parameters related to milling and flour physicochemical properties for the soft wheat cultivars used in this study. Test weight values ranged from 56.4 to 62.6 lb/bu, with limited variation among all samples. There were some differences in flour ash content among cultivars (0.27–0.40%). However, flour starch damage due to the milling process varied greatly from 9.7 UCD for Excel to 18.4 UCD for Madsen. As expected, in addition to the wide variations in flour particle size, flour of Madsen, which had the highest amount of damaged starch, also had the largest particle size (63.0 µm). Conversely, flour of Excel, which had the lowest amount of damaged starch, had the second smallest particle size (Table I). Flour protein content was relatively low, ranging from 6.7% for Hyak to 8.9% for Madsen (Table I) because short patent flour of a 45% extraction rate was used.

Alkaline water retention capacity (AWRC) of flour samples ranged from 50.2 to 60.5% (Table I). AWRC was originally considered an important parameter for predicting the cookie baking quality of a soft wheat flour because of its inverse relationship with SSC diameter (Yamazaki 1953). However, for today's soft wheats, AWRC values do not show the same close association with cookie diameter as they did earlier, perhaps due to changes in breeding materials and practices (Finney 1989). Zeleny sedimentation volumes of these flour samples ranged from 10 to 26 ml, all of which are indicative of weak flours.

Starch Pasting Characteristics

Flour starch pasting characteristics obtained from the viscograms are presented in Table I. The peak viscosity range was 200 BU for Hyak to 1,090 BU for Clark. The peak viscosity indicates the highest viscosity yielded by the starch during the gelatinization process under the given conditions of the test (Shuey and Tipples 1982). It is generally interpreted as an index of α-amylase activity present in the flour, the lower peak viscosity indicating higher levels of α-amylase activity (Shuey and Tipples 1982), though the peak viscosity can be influenced by the amount of damaged starch, starch granule composition, and granule size distribution of the starch (Dengate 1984). However, the amylose content did not show any significant correlation with peak or breakdown viscosity (Bhattacharya and Sowbhagya 1978). The peak viscosity has proven to be an important quality parameter for JSC baking because a low peak viscosity indicates a potential detriment to JSC by the dropping (or dipping) of the cake centers during cooling (Nagao et al 1976). Therefore, flour of Clark had the highest peak viscosity indicating the least α-amylase activity, and perhaps the least damaged starch, which was consistent with the result of starch damage measurement. In contrast, flour of Hyak had the smallest peak viscosity and the second highest starch damage.

Breakdown viscosity, which measures the degree of disintegration of the starch granules (Mazurs et al 1957) or of paste stability (Olkku and Rha 1978), varied from 110 to 870 BU (Table I). The stability of the hot paste can be practically reported as the difference between the peak viscosity and breakdown viscosity (Shuey and Tipples 1982). This difference is termed breakdown (Dengate 1984), which in the current study ranged from 30 to 280 BU (Table I).

TABLE II
Alveograph Rheological Properties[a]

Wheat Cultivar	*P* (mm)	*L* (mm)	*P/L*	*G*	*W* ($\times 10^{-4}$ J)
ESWW[b]					
Augusta	21.5	132.5	0.16	25.5	86
Chelsea	23.1	166.0	0.14	28.6	92
Frankenmuth	31.9	128.0	0.25	25.2	125
WSWW[b]					
Kmor	33.3	153.7	0.22	27.6	111
Lewjain	44.4	108.6	0.41	23.1	128
Madsen	37.7	146.1	0.26	26.8	111
Malcolm	36.7	110.0	0.33	23.3	88
Stephens	33.2	106.5	0.31	22.9	88
Club					
Crew	35.5	69.5	0.51	18.5	62
Hyak	56.7	100.7	0.56	22.2	173
Rely	37.1	133.5	0.28	25.7	97
Tres	24.2	75.2	0.32	19.2	43
SRW[b]					
Caldwell	35.4	138.8	0.26	26.2	141
Clark	29.8	110.5	0.27	23.3	90
Dynasty	21.3	188.1	0.11	30.4	98
Excel	22.0	146.0	0.15	26.8	73
Freedom	33.2	150.7	0.22	27.1	111

[a] *P* = tenacity; *L* = extensibility; *P/L* = ratio of tenacity to extensibility; *G* = swelling index; *W* = flour strength.
[b] ESWW = eastern soft white winter; WSWW = western soft white winter; SRW = soft red winter.

Patent Flour Rheological Properties

Table II lists the alveograph test parameters of the 17 short patent flour samples. The ranges for the alveograph flour properties were: 21.3–56.7 mm for tenacity (*P*), 69.5–188.1 mm for extensibility (*L*), 0.11–0.56 for stability (*P/L*), 18.5–30.4 for swelling index (*G*), and 43-173 × 10^{-4} J for strength (*W*). All samples exhibited properties typical of soft wheat flours. Of all samples, Dynasty had the smallest *P* value, the largest *L* and *G* values, and the smallest *P/L* ratio, indicating that this flour was more extensible and stretchable than any other wheat flours tested.

Farinograph and mixograph test parameters are shown in Table III. The ranges of farinograph properties were: 48.6–55.0% for water absorption, 0.7–2.0 min for dough development time (peak time), 1.0–4.3 min for stability, and 90–190 BU for mixing tolerance index. Mixograph properties of the 17 samples are: peak time 0.8–5.5 min; peak height 32–48.5 mm; stability 1.4–9.5 min; and tolerance 3.0–11.5 mm.

Variation in farinograph water absorption is generally recognized to be affected by two major factors, protein content and starch damage (Farrand 1969). This was generally supported by the present study. Flour of Madsen, which had the highest farinograph water absorption value, had the highest flour protein content and the highest level of damaged starch. In contrast, Chelsea flour, which had the lowest farinograph water absorption, also had relatively lower flour protein content and starch damage (Tables III and I). Pentosans, which were reported to have a relatively large effect on flour's water absorption (Meuser and Suckow 1986), were not determined in this study.

Mixograph peak height of a soft wheat flour can be used as an indicator of protein strength (Finney et al 1987). Accordingly, flour of Kmor with longest mixograph peak height value would be stronger in protein strength than flour of Excel with shortest peak height.

JSC and SSC Baking Results

Patent flour of 45% extraction rate has been found to be ideal for JSC baking. Flour samples in the current study produced JSC whose volumes ranged from 1,088 to 1,218 ml; batter viscosity from 7,000 to 11,000 cp; and cake score from 61 to 84 (Table IV).

The patent flour quality was also evaluated by making SSC. The cookie diameter ranged from 8.24 to 9.01 cm; cookie thickness from 5.8 to 8.4 mm, and cookie spread factor from 10.0 to 15.3 (Table IV). Greater volume sponge cakes and/or larger spread cookies predicted better flour end-use quality.

In Japan, cake flour is milled from 100% U.S. western white wheat (Nagao 1989). Earlier, club wheats were found to produce better quality sponge cakes and cookies than did soft white wheats, even though their protein contents were slightly higher than those of soft white wheats (Nagao et al 1977). However, it appeared, from the present study, that all five SRW wheat flours (Caldwell, Clark, Dynasty, Excel, and Freedom), two of three ESWW wheat flours (Augusta and Chelsea), and one of five WSWW wheat flours (Malcolm) produced larger volume cakes than did club wheat flours (Crew, Hyak, Rely, and Tres) (Table IV). The overall quality of cakes made from flours of Kmor, Crew, Rely, and Dynasty was better than that made from other flours, as indicated by their higher cake scores (Table IV). These results may suggest that some U.S. SRW and ESWW wheats may be alternative choices for Japanese milling and baking companies due to their better suitability for JSC. However, Japan has not imported U.S. SRW wheats for many years because of high price and low availability. Their reputation for having a higher protein content than any other class of soft wheat (prior to 1986) might also have prevented Japan from considering importing U.S. SRW wheats. With regard to cookie quality, both ESWW and SRW wheat short patent flours produced relatively larger diameter cookies than did WSWW and club wheat short patent flours. However, it should be mentioned that short patent flours can be quite different from straight-grade flours which are traditionally used for making SSC; therefore, cookie-baking results of these patent flours might not reflect their actual cookie-baking potential.

Sponge Cake Texture Measurements

Aside from cake volume, the textural characteristics of cakes are also important to cake quality because of their direct relationship to consumer acceptance. Table V shows the TPA results of sponge cakes. Six parameters were derived from each TPA curve and value ranges were: firmness 0.732–1.075 N; adhesiveness –0.001 to –0.003 J; cohesiveness 2.322–3.951; elasticity 59.449–

TABLE III
Farinograph and Mixograph Physicochemical and Rheological Properties

Wheat Cultivar	Farinograph: Water Absorption (%)	Farinograph: Peak Time (min)	Farinograph: Stability (min)	Farinograph: Tolerance Index (BU)	Mixograph: Peak Time (min)	Mixograph: Peak Height (mm)	Mixograph: Stability (min)	Mixograph: Tolerance (mm)
ESWW[a]								
Augusta	48.6	0.7	1.3	190	4.3	33.0	6.5	5.0
Chelsea	48.6	1.0	1.7	155	3.3	37.0	3.0	6.0
Frankenmuth	48.9	1.0	3.0	160	2.5	45.1	3.5	8.0
WSWW[a]								
Kmor	48.9	1.0	2.0	160	2.8	48.5	1.8	4.1
Lewjain	51.4	1.1	1.7	115	3.7	43.0	3.5	6.0
Madsen	55.0	1.0	2.6	110	0.8	48.0	3.0	7.0
Malcolm	52.4	1.0	1.8	130	2.4	40.0	2.8	5.0
Stephens	53.3	1.0	2.0	150	2.1	44.0	2.5	4.0
Club								
Crew	51.8	1.0	2.5	150	2.3	40.5	3.1	6.0
Hyak	52.2	1.0	1.6	150	5.5	36.0	9.5	8.0
Rely	49.2	2.0	3.5	100	2.2	44.0	2.5	5.0
Tres	51.0	1.0	1.3	160	1.1	43.0	1.4	3.0
SRW[a]								
Caldwell	49.4	0.8	1.0	165	5.3	33.0	6.4	7.0
Clark	49.3	1.0	3.5	120	3.0	40.2	4.0	7.8
Dynasty	49.0	1.0	3.0	130	3.5	35.0	4.7	6.0
Excel	50.1	1.0	2.0	190	5.0	32.0	3.3	11.5
Freedom	50.4	1.0	4.3	90	3.3	36.0	5.5	5.0

[a] ESWW = eastern soft white winter; WSWW = western soft white winter; SRW = soft red winter.

84.895%; gumminess 1.811–4.248 N; and chewiness 38.307–63.769 N·mm.

Large variations existed in cake firmness among all cultivars tested. Cakes made from Stephens flour were the softest and cakes made from Clark flour were the firmest in texture. However, the adhesiveness of cakes was similar. It was also noticed that cakes made from Clark flour were more cohesive, less elastic, and more gummy than those made from any other cultivar flours; while cakes made from Freedom flour were less cohesive and gummy than those made from any other cultivar flours. Rely flour produced the most elastic cakes; and Lewjain and Tres flours produced the most and least chewy cakes, respectively.

Additionally, it appeared that cakes made from most of ESWW and club wheat flours were less cohesive; cakes made from club wheat flours were generally less gummy; and cakes made from club and SRW wheat flours were generally less chewy. This could explain why club wheats were traditionally presumed to make better quality JSC than soft white wheats (Nagao et al 1987).

Results from cake textural measurement also indicated that some ESWW and SRW wheat cultivars produced JSC with textures similar to those from club wheat flours. These cultivars might be potential substitutes for current wheats purchased by Japanese milling and baking companies.

TABLE IV
Japanese-Type Sponge Cake and AACC Sugar-Snap Cookie Baking Parameters[a]

Wheat Cultivar	Cake Volume (ml)	Batter Viscosity (cp × 1,000)	Cake Score[b]	Cookie		
				Diameter (cm)	Thickness (mm)	Spread Factor[c]
ESWW[d]						
Augusta	1,205	7.0	73	8.74	6.6	13.3
Chelsea	1,185	7.2	73	9.01	6.2	14.6
Frankenmuth	1,095	8.9	72	8.60	6.5	13.2
WSWW[d]						
Kmor	1,122	8.6	83	8.64	6.7	12.9
Lewjain	1,123	8.4	61	8.75	7.1	12.3
Madsen	1,115	7.5	65	8.24	7.5	11.0
Malcolm	1,185	9.9	71	8.41	7.5	11.2
Stephens	1,128	8.6	73	8.26	7.7	10.7
Club						
Crew	1,098	11.0	84	8.46	7.0	12.1
Hyak	1,098	7.6	77	8.35	7.3	11.4
Rely	1,088	9.1	83	8.38	7.0	12.0
Tres	1,143	9.3	73	8.45	7.5	11.3
SRW[d]						
Caldwell	1,188	7.3	72	8.88	7.6	11.8
Clark	1,150	9.8	79	8.44	8.4	10.0
Dynasty	1,218	7.7	82	8.69	7.5	11.6
Excel	1,180	9.4	75	8.89	5.8	15.3
Freedom	1,155	8.5	69	8.78	6.7	13.1

[a] Values are the mean of three replicates.
[b] Determined according to method 10-90 (AACC 1983).
[c] Ratio of cookie diameter to thickness.
[d] ESWW = eastern soft white winter; WSWW = western soft white winter; SRW = soft red winter.

TABLE V
Textural Profile Analysis Results of Japanese-Type Sponge Cakes[a]

Wheat Cultivar	Firmness (N)	Adhesiveness (J)	Cohesiveness	Elasticity (%)	Gumminess (N)	Chewiness (N · mm)
ESWW[b]						
Augusta	0.968	−0.002	2.711	77.662	2.627	52.636
Chelsea	0.871	−0.003	2.672	81.704	2.324	49.346
Frankenmuth	1.072	−0.003	2.679	84.701	2.875	63.197
WSWW[b]						
Kmor	0.866	−0.003	2.929	82.062	2.527	53.776
Lewjain	1.000	−0.003	3.017	80.840	3.030	63.769
Madsen	0.832	−0.002	3.046	78.462	2.538	51.720
Malcolm	0.775	−0.003	2.950	83.038	2.284	49.259
Stephens	0.732	−0.003	2.937	81.316	2.121	44.822
Club						
Crew	0.855	−0.003	2.678	84.245	2.281	49.997
Hyak	0.802	−0.002	2.964	78.429	2.374	48.430
Rely	0.931	−0.003	2.665	84.895	2.478	54.642
Tres	0.775	−0.003	2.380	80.036	1.838	38.307
SRW[b]						
Caldwell	0.828	−0.002	3.326	77.565	2.491	50.032
Clark	1.075	−0.001	3.951	59.449	4.248	47.211
Dynasty	0.809	−0.003	2.792	82.359	2.237	47.822
Excel	0.839	−0.003	3.037	81.184	2.545	53.741
Freedom	0.777	−0.003	2.322	83.993	1.811	39.404

[a] As defined by Bourne (1978). Values are the mean of three replicates.
[b] ESWW = eastern soft white winter; WSWW = western soft white winter; SRW = soft red winter.

Relationship Between Flour Particle Size or Starch Damage and Other Quality Parameters of Patent Flours

Flour particle size was positively correlated with starch damage, alveograph *P/L* value, farinograph water absorption value, and negatively correlated with alveograph *L* and *G* values, mixograph peak time, JSC volume, cake volume per unit of flour protein, SSC diameter, cookie diameter per unit of flour protein, and cookie spread factor (Table VI). Flour starch damage also correlated positively with AWRC, alveograph *P* and *P/L* values, farinograph water absorption value, and negatively with mixograph tolerance value, viscograph peak viscosity, breakdown viscosity and breakdown values, and SSC diameter (Table VI). These results are in good agreement with those of Nemeth et al (1994) except that they did not perform a sponge cake test.

A softer kernel wheat would produce flour with less damaged starch, leading to less water absorption by the flour, and to a higher viscograph peak viscosity for the flour. According to Nagao et al (1976), soft wheat flour with small hydration capacity, fine particle size, and high amylograph viscosity was desirable for making JSC and SSC. Therefore, flours of small particle size and lower starch damage would make good quality SSC as confirmed by the present study and elsewhere (Gaines et al 1988, Nemeth et al 1994). However, flour particle size was more important than starch damage to the quality of JSC based on the present findings.

Relationship Between JSC or SSC Baking Qualities and Quality Parameters of Patent Flours

JSC volume was significantly positively correlated with alveograph *L* value, and negatively correlated with flour particle size, alveograph *P* and *P/L* values, mixograph peak height, and farinograph peak time (Table VII). When the influence of flour protein content was eliminated, the sponge cake volume per unit of flour protein correlated significantly and positively with mixograph peak time and stability time, and negatively with flour particle size and mixograph peak height (Table VII). These results indicated that the alveograph was perhaps a better tool than either mixograph or farinograph to evaluate flour properties that may relate to JSC quality. On the other hand, the mixograph was a more precise tool for evaluating flour properties that may relate to corrected cake volume by flour protein content.

Significant correlations were also observed between sponge cake chewiness and Zeleny sedimentation volume ($r = 0.557$, $P < 0.05$), and between sponge cake elasticity and viscograph breakdown value ($r = -0.537$, $P < 0.05$). These results indicated that the properties of flour proteins and starch played roles in affecting the cake texture.

The SSC diameter was significantly positively correlated with alveograph *L* and *G* values and mixograph peak time, and negatively correlated with flour particle size, starch damage, alveograph *P/L* value, mixograph peak height and farinograph water absorption value (Table VII). These results are consistent with those of Nemeth et al (1994). Similar to JSC baking, SSC diameter per unit of flour protein was significantly positively correlated with mixograph peak time and stability time, and negatively correlated with flour particle size and mixograph peak height (Table VII). There was also a significant negative correlation between cookie spread factor and flour particle size ($r = -0.494$, $P < 0.05$). The prediction of cookie baking quality of soft wheat flours can be achieved by either alveograph or mixograph measurement. However, cookie diameter per unit of flour protein could only be related to mixograph measurement. Therefore, for proper evaluation of the soft wheat baking quality of a flour for sponge cakes or cookies, both alveograph and mixograph tests should be employed. It should be emphasized that the flour particle size was a very important quality parameter to both JSC and SSC qualities, as indicated by their significant inverse correlations (Table VII). Flour protein content did not correlate significantly with JSC volume or SSC diameter for the 17 wheat flours used in the present study ($P > 0.05$), which might be partially related to their relatively narrow range of flour protein contents. Additionally, the quality of flour proteins might also be functional in end-use quality of soft wheat flours.

Because wheat cultivars selected for this study were from vastly different growing regions, it is not clear how large differences in their end-use quality were caused by environmental factors. Using a larger number of samples from more than two years could minimize some influences created by the growing regions. Further studies could be performed to determine whether there are better growing regions for certain soft wheats.

TABLE VI
Correlation Coefficients of Flour Particle Size and Starch Damage with Other Quality Parameters of Patent Flours

Quality Parameter[a]	Particle Size (µm)	Starch Damage (UCD)[b]
Starch damage	0.701**[c]	1.0
AWRC	...[d]	0.597*
P	...	0.610**
L	−0.649**	...
P/L	0.545*	0.542*
G	−0.645*	...
MPT	−0.585*	...
MT	...	−0.509*
FWA	0.769***	0.746***
VPV	...	−0.847***
VBV	...	−0.763***
VB	...	−0.680**
JSCV	−0.553*	...
JSCV/FP	−0.499*	...
SSCD	−0.779***	−0.510*
SSCD/FP	−0.521*	...
SSCSF	−0.494*	...

[a] AWRC = alkaline water retention capacity; *P* = tenacity; *L* = extensibility; *P/L* = ratio of tenacity to extensibility; *G* = swelling index; MPT = mixograph peak time; MT = mixograph tolerance; FWA = farinograph water absorption; VPV = viscograph peak viscosity; VBV = viscograph breakdown viscosity; VB = viscosity breakdown; JSCV = Japanese-sponge cake volume; SSCD = sugar-snap cookie diameter; FP = flour protein; SSCSF = sugar-snap cookie spread factor.
[b] Arbitrary unit used in the Chopin/Dubois method.
[c] *, **, *** = significant at the 5, 1 and 0.1% levels, respectively.
[d] Not significant at the 5% level (data not listed).

TABLE VII
Correlation Coefficients of Japanese-Type Sponge Cake and Sugar Snap Cookie Test Results[a] with Quality Parameters of Patent Flours

Quality Parameter[b]	JSCV	JSCV/FP	SSCD	SSCD/FP
Particle size	−0.553*[c]	−0.499*	−0.779***	−0.521*
Starch damage	...[d]	...	−0.510*	...
P	−0.639**	...	...	...
L	0.492*	...	0.522*	...
P/L	−0.650**	...	−0.535*	...
G	...	...	0.513*	...
MPT	...	0.760***	0.577*	0.807***
MPH	−0.692**	−0.826***	−0.590*	−0.750***
MS	...	0.585*	...	0.581*
FWA	...	...	−0.667**	...
FPT	−0.490*	...	...	...

[a] JSCV = Japanese-sponge cake volume; SSCD = sugar-snap cookie diameter; FP = flour protein.
[b] *P* = tenacity; *L* = extensibility; *P/L* = ratio of tenacity to extensibility; *G* = swelling index; MPT = mixograph peak time;; MPH = mixograph peak height; MS = mixograph stability; FWA = farinograph water absorption; FPT = farinograph peak time.
[c] *, **, *** = significant at the 5, 1 and 0.1% levels, respectively.
[d] Not significant at the 5% level (data not listed).

SUMMARY

Results of this study indicated that there were large variations in short patent flour physicochemical, rheological, and baking properties among 17 soft wheat cultivars. Baking and textural analysis results indicated that some SRW and ESWW wheats could be potential substitutes for WSWW and club wheats for JSC end-use. Both ESWW and SRW wheat short patent flours produced relatively larger diameter cookies than did WSWW and club wheat short patent flours. Correlation analyses indicated that flour particle size was one of the most important properties to flour baking qualities. Flour starch damage affected the quality of cookies more than that of sponge cakes. The sponge cake textures could also be influenced by the properties of flour protein and starch. The alveograph was a good tool for the evaluation of flours used for making JSC and SSC, and the mixograph was an alternate choice, especially for relating flour properties to corrected cake volume and cookie diameter by flour protein content.

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