

Baking Performance of Durum and Soft Wheat Flour in a Sponge-Dough Breadmaking Procedure

Gary A. Hareland^{1,2} and Dehdra P. Puhr¹

ABSTRACT

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Breadmaking properties were determined for formulations that included durum, soft, and spring wheat flour, using a pound-loaf sponge-dough baking procedure. Up to 60% durum or soft wheat flour plus 10% spring wheat flour could be incorporated at the sponge stage for optimum dough-handling properties. At remix, the dough stage required 30% spring wheat flour. Bread made with 100% spring wheat flour was used as a standard for comparison. Bread made with 60% durum flour exhibited internal crumb color that was slightly yellow. When storing pound bread loaves for 72 hr, crumb moisture content remained unchanged. Crumb firmness and enthalpy increased the most in bread made with 60% soft wheat flour. Crumb firmness

increased the least in bread made with 100% spring wheat flour. Enthalpy changed the least in bread made with 60% durum flour. Crumb moisture content was significantly correlated with crumb firmness ($r = -0.82$) and enthalpy ($r = -0.65$). However, crumb moisture content was specific for each type of flour and a function of flour water absorption; therefore, these correlations should be interpreted with caution. Crumb firmness and enthalpy were significantly correlated ($r = 0.65$). Ball-milling flour resulted in an increase in water absorption of $\approx 2\%$ and in crumb moisture content of $\approx 0.5\%$ but had no effect on either crumb firmness or enthalpy.

Durum wheat has been used primarily to produce pasta products but has the potential for use in breadmaking (reviewed by Boyacioglu and D'Appolonia 1994d). Early cultivars of durum lacked the baking qualities (Quaglia 1988) and gluten properties (Dick and Matsuo 1988) necessary to produce the light, airy loaves of bread characteristic of certain hexaploid wheats. New durum wheat genotypes have been identified, however, that possess better breadmaking potential than the early cultivars (Ereifej and Shibli 1993, Boggini et al 1995, Ciaffi et al 1995).

The use of durum in breadmaking has been limited to certain areas of the world. For example, in the Mediterranean region, numerous types of bread are baked with various quantities of durum (Quaglia 1988). In the United States, commercial production of bread made with durum flour has not been reported.

The breadmaking performance of durum flour has been reported for experimental straight-dough baking methods. Boyacioglu and D'Appolonia (1994a–c) investigated the baking and staling properties of bread made with different grades of durum flour and flour blends. In their straight-dough method, a blend of 25% durum and 75% bread wheat flour produced bread with acceptable characteristics when the flour was enhanced with sodium stearyl lactylate (SSL). Lopez-Ahumada et al (1991) indicated that the most acceptable bread properties were produced with a blend of 40% durum and 60% bread wheat flour when the flour was enhanced with SSL, glycerol monostearate, and other additives. A sponge-dough method was used in baking Italian Altramura bread from a wheat blend containing up to 50% amber durum flour (Quaglia 1988), but the quality characteristics of this type of bread have not been reported.

In typical sponge-dough methods, stronger gluten bread flours commonly are used in the sponge stage, because the sponge is subjected to double mixing and extended fermentation (Pyler 1973). In the dough stage, the remainder of the weaker gluten bread flour is added to the preferment and mixed to optimum development. The hypothesis of the current study was that stronger gluten bread

flour, when used in the dough stage, would adjust for the weaker gluten, nonbread flour used in the sponge stage. The objectives of this study were to optimize the amount of either durum or soft wheat flour that could be incorporated with a strong gluten, spring wheat flour in a sponge-dough baking procedure and to evaluate bread properties during storage.

MATERIALS AND METHODS

Flour Samples

Commercially milled hard red spring (malted) and patent durum wheat flours were obtained from the North Dakota State Mill, Grand Forks. Soft wheat pastry flour was obtained from Cargill, Minneapolis, MN. Flour moisture, protein, water absorption, and starch damage were determined by Approved Methods (AACC 1995). Flour particle size was determined by laser diffraction (Hareland 1994).

Baking Procedure

Preliminary screening tests were conducted on 100-g samples of commercial flours to determine optimum oxidation (L-ascorbic acid, Sigma Chemical Co., St. Louis, MO) and malting (Dotone, Atochem, Buffalo, NY) requirements and optimum sponge fermentation times. Straight-dough and sponge-dough methods were used (AACC 1995). Typically in a sponge-dough formulation, 70% of the total flour is incorporated at the sponge stage and 30% at the dough stage. Hence, the objective was to incorporate up to 70% durum or soft wheat flour in the sponge and 30% hard red spring wheat flour in the dough remix while maintaining satisfactory sponge and dough properties and bread loaf volume. Optimum oxidation and malting requirements were determined by an experienced baker's evaluation of dough stickiness, characteristics of sponge during fermentation, and dough-handling properties after remixing. For comparison, durum and soft wheat flours were used as-is from commercial mills and also were modified by ball-milling to achieve at least a 2% increase in flour water absorption, based on farinograph test results. Spring wheat flour used as-is at 100% in the baking formulation served as the control for comparing the dough handling and baking performance of other flour ratios.

Based on the preliminary screening test results for optimizing sponge conditions, large-scale tests were conducted using a sponge-dough pound-loaf method (Approved Method 10-11 [AACC 1995]). Sponge ingredients included 70% of the total water, 1% instant dry yeast, 0.5% $(\text{NH}_4)_2\text{HPO}_4$, and 40 ppm (60% soft + 10% spring flours and 70% spring flour) and 75 ppm (60% durum + 10% spring flours) of ascorbic acid. Sponge fermentation times were 2, 2, and 3 hr for 60% soft + 10% spring flours, 60% durum + 10% spring flours, and

¹ Research food technologist and physical science technician, USDA/ARS, Hard Red Spring and Durum Wheat Quality Laboratory, North Dakota State University, Fargo 58105. Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by the USDA implies no approval of the product to the exclusion of others that may also be suitable.

² Corresponding author. E-mail: hareland@badlands.nodak.edu Phone: 701/231-7728. Fax: 701/239-1377.

70% spring flour, respectively. Percentages were based on 2,000 g of flour at 14% mb. Commercially milled hard red spring wheat flour was malted to a falling number of 250 sec; durum and soft wheat flours were not malted.

Following the sponge stage, the preferment was remixed (D 300-T Mixer, Hobart Corp., Troy, NY) with the remaining ingredients: 30% hard red spring wheat flour, 30% of the total water, 5% sugar, 3% nonfat dry milk, 3% shortening, and 2% salt. The dough was allowed to rest in a fermentation cabinet (National Mfg. Co., Lincoln, NE) held at 30°C ± 1°C at 86 ± 5% rh.

Three separate batches of bread were baked per flour blend, including both as-is and ball-milled flours. At least six 500-g scaled dough pieces were obtained from each batch of dough. Dough pieces were rounded, allowed to rest for 10 min, molded (experimental molder, Moline Co., Duluth, MN), and placed in Shogren-type pans. Panned doughs were proofed in the fermentation cabinet for 60 min and baked in a rotating oven (Despatch Oven Co., Minneapolis, MN) for 22 min at 204°C. Loaves were cooled for 1 hr, then measured for bread weight and loaf volume (rapeseed displacement).

Two hours after removing bread from the oven, loaves were sliced in a commercial bread slicer. The bread slicer was modified to produce slices of bread 2.5- and 1.25-cm thick from each loaf. Sliced loaves were wrapped in polyethylene bags and stored for up to 72 hr at 22°C ± 2°C.

Internal Bread Crumb Properties

Internal crumb properties were measured on slices of stored bread. Crumb firmness and moisture content were determined in bread stored for 0, 24, 48, and 72 hr. Sections of crumb were tested for changes in enthalpy after 24, 48, and 72 hr of bread storage.

Crumb firmness was measured on slices 2.5-cm thick, three slices per loaf, using a texture analyzer (TA-2, Texture Technologies Corp., Scarsdale, NY) according to Approved Method 74-09 (AACC 1995). Firmness was calculated as the force required to compress crumb 2.5-cm thick with a plunger 3.6-cm diameter to ≈1.0 cm (40% of the crumb thickness) and recording the compression force value (kg) at 25% compression. The compression force value was converted to Newtons (N = kg × 9.8 m/sec²). Crumb moisture content was measured in center plugs (4.5- × 1.25-cm thick), three slices per loaf, by air oven-drying at 130°C for 1 hr (Approved Method 44-15A [AACC 1995]).

Changes in enthalpy were measured in freeze-dried crumb samples with a differential scanning calorimeter/Unix thermal analysis system (DSC-7, Perkin Elmer Corp., Instrument Div., Norwalk, CT). Freeze-dried crumb (≈5 mg) and deionized water (2:1 water-to-crumb ratio) were added to preweighed Al₂O₃ pans (20 µL capacity). Pans were sealed and stored at 20°C overnight to allow for complete hydration of the crumb. Pans with hydrated crumb, as well as a reference pan containing only water, were scanned from 10 to 120°C at a rate of 10°C/min. Enthalpy changes (ΔH = cal/g) were computed from the peak temperature (T_p) of gelatinization with reference to a baseline drawn from the onset temperature (T_o) to the termination

temperature (T_m). Enthalpy changes were converted to joules per gram of freeze-dried crumb (J/g = 4.18 × ΔH).

Analysis of variance (SigmaStat Statistical Software, version 3.0, Jandel Scientific, San Rafael, CA) was used to evaluate differences in bread characteristics of pound loaves with respect to flour formulation, milling treatment, and bread storage properties. All pairwise multiple comparisons were made using the Tukey test procedure.

RESULTS AND DISCUSSION

Flour Properties

The properties of the soft and durum wheat flours (as-is and ball-milled) and the spring wheat flour (as-is) are shown in Table I. Ball-milling had no effect on flour protein content but did cause a ≈2% increase in water absorption. Ball-milling also altered levels of damaged starch and particle size distribution properties, but the effects on bread properties are beyond the scope of this investigation.

Preliminary Screening Tests

Preliminary tests were conducted using a straight-dough baking method with a 2-hr fermentation time to determine the optimum malt and oxidation requirements of the as-is flours (Table II). The optimum requirements were determined primarily by a baker's subjective evaluation of dough-handling properties. Bread loaf volume was determined by rapeseed displacement. The spring wheat flour (malted to a falling number of 250 sec) was used as a standard for comparison. The addition of malt to either the soft or durum flours resulted in sticky doughs, apparently affecting the viscoelastic properties of the starch components, unlike the effect of spring wheat flour. When using the straight-dough method, both the soft and durum flours required oxidation, but no malt, for best dough-handling properties. The loaf volume of bread baked with 100% durum flour, which contained 40 ppm of ascorbic acid, was 545 cm³. Loaf volume of bread baked with spring wheat flour was 828 cm³. These results were similar to those reported by Boyacioglu and D'Appolonia (1994a,b). Bread baked with 100% soft wheat flour, with 40 ppm of ascorbic acid, had a loaf volume of 625 cm³.

A second set of preliminary tests was conducted on as-is flour (100 g), using the sponge-dough baking method, to determine the optimum sponge fermentation time (Table III). Seventy percent of the flour was incorporated at the sponge stage and 30% at the dough stage. Using spring wheat flour, loaf volume increased from 675 to 825 cm³ with sponge fermentation times of 1 and 4 hr, respectively. With a 2-hr sponge fermentation time, bread loaf volumes were similar (700–725 cm³) among soft, durum, and spring wheat flours. However, spring wheat flour exhibited better dough-handling properties. When using either durum or soft wheat flours, dough tended to be over fermented, slack, and sticky at sponge times longer than 2 hr. Bread loaf volumes were larger when using

TABLE II
Malt and Oxidation Requirements
in a Straight-Dough Baking Procedure^a

Wheat Flour ^b	Malt (SKB)	Ascorbic Acid (ppm)	Loaf Volume (cm ³)
Spring	0	40	828
Soft	0	0	550
Soft	15	0	525
Soft	0	40	625
Soft	15	40	625
Durum	0	0	525
Durum	15	0	500
Durum	0	40	545
Durum	15	40	350

^a 100-g loaves.

^b Flour was used as-is from a commercial mill. Spring wheat flour was malted at the mill to a falling number of 250 sec and used as a standard for comparison. Durum and soft wheat flours were not malted.

TABLE I

Properties of Flour Used in the Sponge-Dough Baking Procedure^a

Flour Type	Protein (14% mb)	WA (%)	SD (%)	Particle Size Distribution (µm, % by volume)		
				<10	10–41	>41
Soft _{as-is}	8.2	52.2	2.8	11.4	42.5	46.1
Soft _{bm}	8.2	54.4	5.1	12.5	68.5	19.1
Durum _{as-is}	12.5	63.1	7.9	3.0	10.5	86.5
Durum _{bm}	12.5	65.7	8.5	4.0	16.7	79.3
Spring _{as-is}	13.6	63.6	5.9	4.8	17.1	78.1

^a Commercially milled flour types were received as-is or ball-milled (bm) to achieve an ≈2% increase in farinograph WA (water absorption) at 14% mb. SD = starch damage at 14% mb. Particle size distribution determined by laser diffraction. Hard red spring wheat flour was used as-is as the standard for comparison. Values are means; n = 2.

either soft or durum flours at a 2-hr sponge fermentation time than at a 1-hr sponge fermentation time. Using the sponge-dough procedure, soft wheat flour required 40 ppm of ascorbic acid and durum flour required 75 ppm of ascorbic acid to achieve the best dough-handling properties. When using either durum or soft wheat flours in the sponge-dough procedure, bread had larger loaf volumes compared to the same flours used in the straight-dough procedure. With bread wheat flours, larger loaf volumes more often are achieved when using the straight-dough procedure than when using the sponge-dough procedure.

A third set of preliminary tests was conducted on the as-is flour (100 g), using the sponge-dough baking method, to determine the maximum amount of either durum or soft wheat flour that could be used in the sponge and dough stages (Table IV). A baker's evaluation of the stickiness and firmness of the sponge and extensible and elastic properties of the dough at remixing, sheeting, and panning were criteria for selection of the optimum formulation. From these properties and loaf volume, we concluded that either 60% durum flour or 60% soft + 10% spring flour was optimal for the sponge stage, with 30% spring wheat flour added at the dough stage during remixing. Incorporation of 10% spring wheat flour with either soft or durum flour at the sponge stage led to better sponge tolerance of extended fermentation and improved extensible and elastic properties of remixed dough. Conversely, without additional 10% spring wheat flour, the sponge tended to collapse more easily, and the dough was more sticky, soft, and slack at panning. Based on preliminary data, pound loaves of bread were baked according to

the sponge and dough ingredients and fermentation times discussed earlier. In previous studies, a crumb softener (SSL) was incorporated in durum flour formulations (Lopez-Ahumada et al 1991, Boyacioglu and D'Appolonia 1994b,c). In the current study, a dough softener was not used, because the effects might have masked the true performance of the flour.

In commercial bakeries, sponge times are typically 3–4 hr for strong gluten, spring wheat flours. Thus, the advantage of the sponge-dough method over the straight-dough method is flexibility in fermentation times, which can be partially controlled by temperature. Equally important, the overall quality of bread baked using the sponge-dough method is enhanced in terms of flavor, loaf volume, and crumb grain and texture (Pylar 1973). For durum and soft wheat flour formulations, flexibility in baking would be reduced because of the optimum 2-hr sponge time. However, additional studies are recommended to determine whether bread flavor is actually enhanced.

External Properties of Pound Loaves

The external properties of pound loaves of bread made using the sponge-dough procedure are shown in Fig. 1. Break and shred were similar for all loaves. The crust color of bread made with 60% durum flour was visibly darker than the crust color of bread made with either 100% spring wheat flour or 60% soft wheat flour.

Bread loaf weight, loaf volume, and specific loaf volume were compared (Table V). The mean weight of bread made with 60% soft wheat flour (as-is) was slightly greater than the mean weight of bread made with other flour blends. Generally, the moisture weight loss of the 500-g scaled dough pieces was similar for all flour blends during baking. Mean loaf volume of bread made with 60% durum flour (as-is and ball-milled) was significantly less than the volume of bread made with either the 60% soft (as-is and ball-milled) or 100% spring wheat flour. Ball-milling durum flour resulted in larger mean loaf volume when compared to as-is durum flour. These results indicate that the dilution of spring wheat flour with durum flour slightly reduced the typical light, airy appearance of the bread. This likely resulted from differences in the gluten properties of spring and durum wheat. Ball-milling durum flour may have had a mellowing effect on the dough that resulted in larger baked loaf volumes. Computation of specific loaf volume (cm³/g) indicated no significant differences among flour ratios.

Internal Properties of Pound Loaves

The internal properties of pound loaves of bread are shown in Fig. 2. Bread crumb grain and texture were similar for all flour ratios. Crumb color of bread made with 60% durum flour was slightly

TABLE III
Optimum Sponge Fermentation (SF) Time
in a Sponge-Dough Baking Procedure^a

Wheat Flour ^b	Ascorbic Acid (ppm)	SF Time (hr)	Loaf Volume (cm ³)
Spring	40	4	825
Spring	40	3	790
Spring	40	2	725
Spring	40	1	675
Soft	40	2	700
Soft	40	1	625
Durum	40	2	700
Durum	40	1	615
Durum	75	2	700
Durum	75	1	635

^a 100-g loaves.

^b Flour was used as-is from a commercial mill. Spring wheat flour was used as the standard for comparison

TABLE IV
Optimization of Flour Formulations for Sponge and Dough Stages^a

Flour Added		Ascorbic Acid (ppm)	SF ^b Time (hr)	Loaf Volume (cm ³)
Sponge Stage	Dough Stage			
70% Spring	30% Spring	40	3	775
60% Spring	40% Durum	75	3	705
70% Spring	30% Durum	75	3	675
70% Spring	30% Soft	40	3	710
60% Spring	40% Soft	40	3	685
70% Spring	30% Durum	40	3	750
60% Spring	40% Durum	40	3	760
60% Soft	40% Spring	40	2	605
60% Soft:10% Spring	30% Spring	40	2	675
70% Soft	30% Spring	40	2	665
60% Durum	40% Spring	40	2	700
60% Durum:10% Spring	30% Spring	40	2	705
70% Durum	30% Spring	40	2	660
60% Durum	40% Spring	75	2	690
60% Durum:10% Spring	30% Spring	75	2	750
70% Durum	30% Spring	75	2	695

^a 100-g loaves.

^b Sponge fermentation.

yellow, as expected, because of the xanthophyll pigment present in durum.

Crumb moisture content was measured at 0, 24, 48, and 72 hr after removing bread from the oven and allowing it to cool for 2 hr (Fig. 3). When incorporating either ball-milled durum or soft wheat flour in the sponge formulation (vs. the corresponding as-is flour), crumb moisture content significantly increased by $\approx 0.5\%$, which reflected the 2% increase in flour water absorption. For each flour ratio, crumb moisture content did not change significantly over the 72 hr during which moisture was measured. Hence, freshly baked bread had essentially the same moisture content as bread that was packaged and stored for 72 hr.

Measurements of crumb firmness (Fig. 4) paralleled measurements of crumb moisture content. At 0 hr (2 hr after removal from the oven), crumb firmness was similar in breads that were made with 60% durum and 60% soft wheat flours but was significantly greater than the firmness of bread made with 100% spring wheat flour. At 24, 48, and 72 hr of storage, crumb firmness was significantly greater in bread made with the 60% soft wheat flour than in bread made with either 60% durum or 100% spring wheat flour. Also, crumb firmness of bread made with 60% as-is durum flour was greater than the firmness of bread made with 100% spring wheat flour at 24, 48, and 72 hr of storage. The incorporation of ball-milled flour, rather than as-is flour, in the sponge stage had no effect on crumb firmness. Because ball-milling increased crumb moisture content by $\approx 0.5\%$, the expected result would be a softer crumb. However, the differences observed in crumb firmness may be attributed to the water-binding capacity of the different flour blends. The molecular interaction between water and the starch-protein complex of lower protein flour was potentially weaker than the interaction that occurred in higher protein flour. Thus, more free water was probably associated in bread made with soft wheat flour and more bound water was associated in bread made with spring wheat flour. The protein content of durum flour was intermediate between soft and spring wheat flours (Table I). Differences in protein would not necessarily result in excessive moisture loss from the crumb, especially in packaged bread. Less bound water in the crumb would probably cause an increase in crumb firmness, as enhanced by more rapid recrystallization of the starch complex.

Enthalpy is a measure of starch retrogradation or an index of starch recrystallization in bread during aging (Zeleznaek and Hosney

1987). Figure 5 shows the results of changes in enthalpy in bread stored for 24, 48, and 72 hr (endothermic transitions were not present at 0 hr). When comparing each time interval of the different as-is flour ratios, significant differences occurred in the enthalpy of the bread crumb. Less energy was required to melt the crystalline amylopectin in bread made with 60% durum flour than in bread made with either 100% spring wheat or 60% soft wheat flour. This suggests that the aging process of bread made with 60% durum flour was slower than the aging process of bread made with 100% spring wheat flour, even though the firmness of durum bread was slightly greater during bread storage. The molecular structure of amylopectin, amylose-to-amylopectin ratios, and pentosan content may be different among durum, spring, and soft wheat flours, which may explain differences in differential scanning calorimetry endotherms. However, additional research would be required to investigate these phenomena. As with crumb firmness, changes in enthalpy were not significantly different in bread baked with ball-milled or as-is flours.

Correlation coefficients were established between crumb moisture content and firmness, moisture content and enthalpy, and firmness and enthalpy (Fig. 6). Crumb moisture was significantly correlated

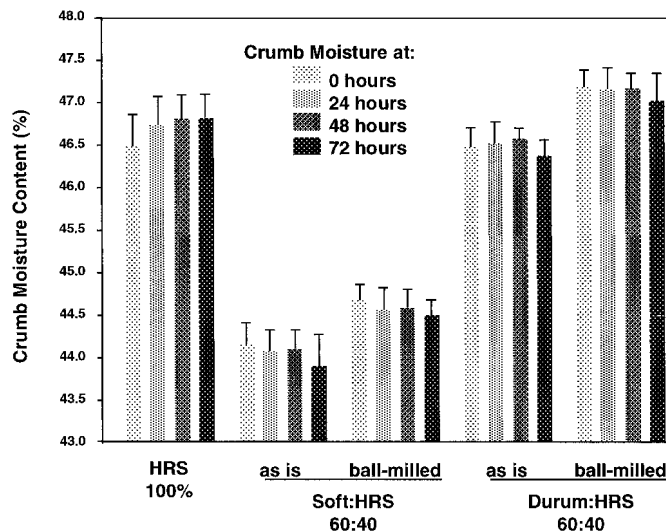


Fig. 3. Crumb moisture content of pound bread loaves made with different ratios of as-is and ball-milled flours using the sponge-dough baking procedure. Mean \pm standard deviation; $n = 18$.

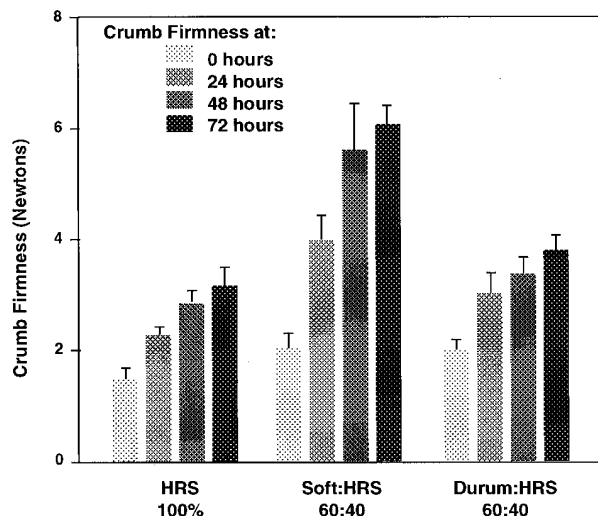


Fig. 4. Crumb firmness of pound bread loaves made with different ratios of as-is flours using the sponge-dough baking procedure. Mean \pm standard deviation; $n = 18$.

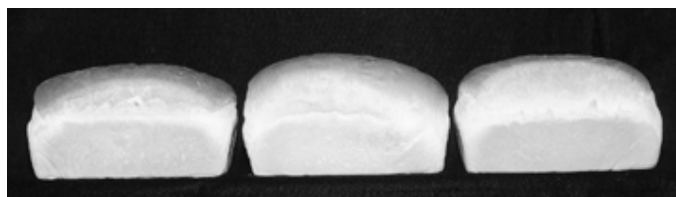


Fig. 1. External characteristics of bread made with 60% durum wheat flour (left), 100% spring wheat flour (center), and 60% soft wheat flour (right).

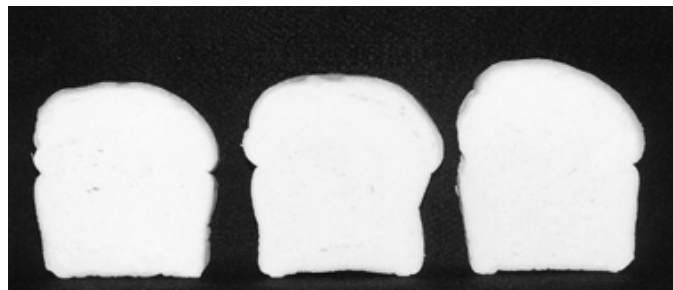


Fig. 2. Internal characteristics of bread made with 60% durum wheat flour (left), 100% spring wheat flour (center), and 60% soft wheat flour (right).

TABLE V
Properties of Pound Loaves of Bread Made Using the Sponge-Dough Procedure^a

Flour Ratio ^b	Loaf Weight (g)	Loaf Volume (cm ³)	SLV ^c (cm ³ /g)
60% Soft _{as-is} + 40% Spring	453.2a	1,975a	4.4
60% Soft _{bm} + 40% Spring	451.1b	1,957a	4.3
60% Durum _{as-is} + 40% Spring	449.0b	1,915c	4.3
60% Durum _{bm} + 40% Spring	450.6b	1,941b	4.3
100% Spring _{as-is}	450.1b	1,960a	4.4

^a Means in the same column followed by the same letter are not significantly different ($P > 0.05$) based on the Tukey test procedure; $n = 18$.

^b Commercially milled soft and durum wheat flours were used either as-is or ball-milled. Spring wheat flour was used as-is in different ratios and as the standard for comparison when used at 100%.

^c Specific loaf volume. Means not significantly different.

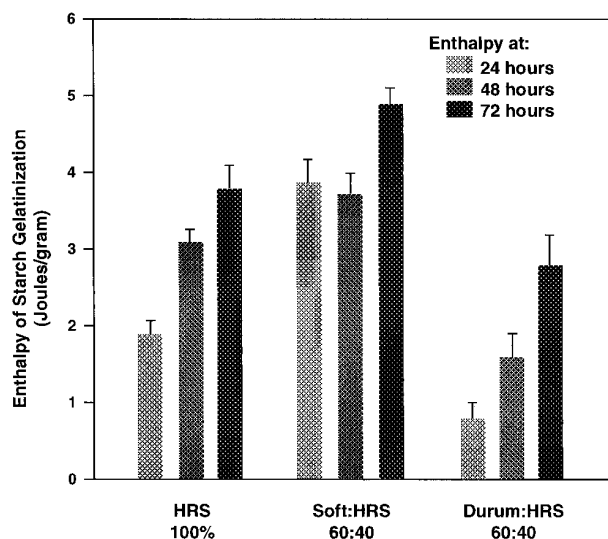


Fig. 5. Changes in enthalpy of freeze-dried crumb samples from pound bread loaves made with different ratios of as-is flours using the sponge-dough baking procedure. Mean \pm standard deviation; $n = 18$.

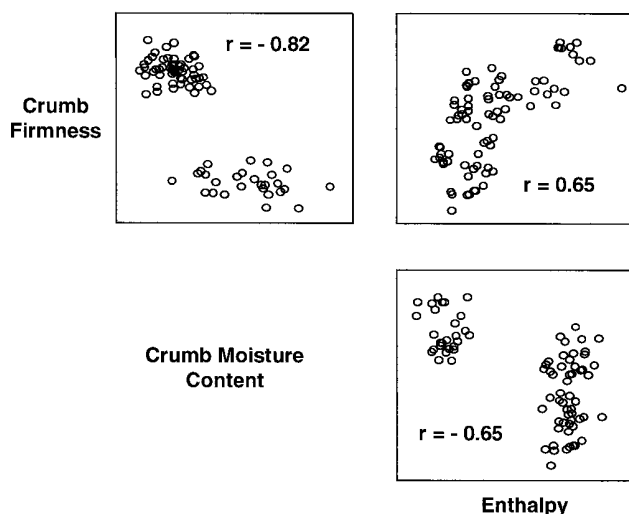


Fig. 6. Correlation coefficients between crumb moisture content and crumb firmness, crumb moisture content and enthalpy, and crumb firmness and enthalpy. Correlation coefficients are significant at $P = 0.05$; $n = 81$.

with crumb firmness ($r = -0.82$) and enthalpy ($r = -0.65$). However, because crumb moisture content was specific for each flour ratio and a factor of flour water absorption, the negative correlations should be interpreted with caution. Crumb firmness and

enthalpy showed a significant positive correlation ($r = 0.65$), which suggests a linear increase between crumb texture and starch retrogradation during bread storage.

CONCLUSIONS

Durum and soft wheat flour have not been adequately tested for breadmaking potential other than in straight-dough experimental baking methods. Acceptable bread properties were achieved when either durum or soft wheat flour was incorporated at 60% levels at the sponge stage of dough development in the sponge-dough baking method used in this study. At these levels, the external properties of the bread were similar to the external properties of bread made with 100% spring wheat flour. The internal properties of the bread during storage were different in terms of crumb firmness and changes in enthalpy.

Bread made with durum flour had a faster firmness rate than bread made with 100% spring wheat flour but exhibited slower changes in enthalpy. Durum flour should have value-added potential in commercial breadmaking operations. Comparatively, bread made with 60% soft wheat flour exhibited acceptable loaf volume and external characteristics, but the rate of crumb firmness and changes in enthalpy indicated a faster rate of staling.

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