Noodles. VII. Investigating the Surface Firmness of Cooked Oriental Dry Noodles Made from Hard Wheat Flours[1]

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ABSTRACT

Centura, a hard red winter wheat cultivar, was harvested two years in different locations. The wheat flours from both crops showed good noodle-making and breadmaking performance. When a hard and a soft wheat flour were premixed into an elastic dough and subsequently made into noodles, the surface firmness of the cooked noodles decreased with the period of premixing. At noodlemaking absorption, Centura and Western white wheat flours gave little gluten development during mixing compared to flour from a commercial mixture of hard red winter wheats.

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Oriental dry noodles made from hard red winter (HRW) wheat flours are stronger than those from soft wheat and give a higher yield of cooked noodles with increased chewiness. But the HRW wheat noodles appear less white than soft white wheat noodles, require a longer time to cook, and have a less firm and smooth surface (Oh et al 1985a,c). Such noodles are undesirable because they have a rough mouthfeel, and they may cause a residue of broth or sauce to be deposited on the lips when the strands are sucked into the mouth.

Hard wheats grown in the Great Plains are selected for their agronomic, milling, and breadmaking properties. Approximately 100 samples of flour from HRW wheats grown in 1984 were made into dry noodles in our laboratory. Only two gave noodles with a firm surface after cooking: Centura, a cross between Agent and Centurk, released by the state of Nebraska in 1984; and TX79A2729, an experimental cultivar (Tam W-103 × KS73167) from the state of Texas. The two varieties are significant because they indicate hard wheats can be made into good bread and good dry noodles.

The objectives of this investigation were to determine whether the firm surface of dry noodles made from Centura and TX79A2729 could be reproduced in another crop year and location and to investigate why most HRW wheats give dry noodles with a poor surface firmness when cooked.

MATERIALS AND METHODS

Materials

Flours were of 70–72% extraction from the following wheats: commercial hard red winter (CHRW) wheats grown in the Great Plains, one harvested in 1984 and the other in 1985, and obtained from Ross Industries, Cargill Inc., Wichita, KS; western white (WW), a 9:1 mixture of soft white and white club grown in the northwestern United States in 1984, and obtained from the USDA, ARS, Western Wheat Quality Laboratory, Pullman, WA; Centura (CT), grown in Nebraska in 1984 and in Kansas in 1985, and obtained from the Nebraska and Kansas Agricultural Experiment Stations; and TX79A2729 (TX), grown in Texas in 1984 and 1985, and obtained from the Texas Agricultural Experiment Station, College Station.

Wheats were tempered to 16% moisture and milled into straight-grade flours on the Buhler pilot mill at Kansas State University. Chemicals were all reagent grade.

Analytical Methods

All analyses were done with a minimum of two replications. AACC methods (1983) 44-15A, 46-11A, and 08-01 were used to measure moisture, protein (N × 5.7), and ash, respectively. Mixograms were recorded at optimum absorption (Finney and Shogren 1972) using a 10-g bowl (TMCO-National Mfg. Co., Lincoln, NE). Dough properties were measured with the extensigraph (Brabender Instruments, Inc., South Hackensack, NJ), and bread (pup loaves) was made according to AACC methods 54-10 and 10-10B, respectively. The damaged starch in flour was measured by AACC method 76-30A.

Noodle Making

The optimum absorption for noodle making was determined by the mixograph method (Oh et al 1986). Briefly, in this method 2× 1 ml aliquots of 10% sodium chloride solution were injected into 10 g (14% mb) of flour using a hypodermic syringe, followed by 0.5 to 0.1 ml aliquots of water. Between incremental additions of fluid, this dough was mixed for 1 min. Mixograph absorption was defined by the total water added when gluten began to develop strongly (Oh et al 1986).

Dry noodles were made by a modification of the method of Oh et al (1983). Wheat flour (200 g, 14% mb) was placed in the mixer bowl (Hobart N-50, Hobart Mfg. Co., Troy, OH) fitted with the flat-beater agitator. While the flour was agitated at a speed setting of 1, 74 or 76 ml of water containing 4 g of sodium chloride was added in small increments over a period of 30 sec. In the case of noodles made at alkaline pH, the water also contained 0.6–3.0 g of sodium bicarbonate (0.3–1.5% based on flour). Mixing was continued an additional 30 sec on speed 1, and then 4 min on speed 2 to give nodules of dough with diameters less than 3 mm. After resting 30 min in a sealed plastic bag, the nodules were pressed into an initial dough sheet (180 × 5.4 × approximately 200 mm) by passage through the rolls (roll diameter = 180 mm; roll speed = 8 rpm) of the Ohtake laboratory noodle machine (Ohtake Noodle Machine Mfg. Co., Tokyo, Japan). The dough was sheeted in four steps in the same direction starting from an initial gap of 5.4 mm. A 30% gap reduction was used in successive sheeting steps, with the final gap at 1.3 mm. Immediately after sheeting, the dough sheet was cut into 2.5-mm noodle strips that were hung to dry in a Demaco lab dryer (model 25, De Francisci Machine Corp., Brooklyn, NY). The drying temperature was held constant at 45°C while humidity was linearly decreased from 85 to 65% over 10 hr.

To measure noodle thickness, 10 noodle strands were selected at random before and after drying and their thickness determined with a pocket dial gauge (no. 1010, The L. S. Starrett Co., Athol, MA). The coefficient of variation (CV) of noodle thickness was 5.5% for fresh noodles and 3.7% for dry noodles.

Color and Breaking Stress of Uncooked Noodles

Noodle color was measured (Oh et al 1985b) using the Agtron

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reflectance spectrometer (model M-500-A, Magnuson Engineers Inc., San Jose, CA). A special black plastic disk (160 mm diameter) with a 30 × 80 mm rectangular opening was used to position 12 dry noodle strands over the viewing area of the spectrometer. Breaking stress was measured using the Instron universal testing instrument (model 1130, Instron Corp., Canton, MA), as described by Oh et al (1985b). The CV for color was 1.4% and that for breaking stress 3.5%.

TABLE I
Properties of Flours from Wheats[a] Harvested in 1984

Property	Soft Wheat Flour WW	Hard Wheat Flours CHRW	CT	TX
Protein, N × 5.7, %	9.7	12.3	12.6	12.4
Ash, %	0.49	0.45	0.47	0.42
Agtron color, %	85	67	73	69
Starch damage, %	3.2	8.1	4.8	5.2
Extensigraph[b]				
Extensibility (cm)	11.0	16.3	17.2	15.8
Resistance to extension, BU	252	593	310	418
Bread loaf volume, cm^3/g of flour protein	47.1	73.0	65.3[c]	70.9[c]

[a] WW, Western white; CHRW, commercial mixture of hard red winter; CT, Centura; and TX, experimental cultivar TX79A2729. Data are based on two replicates and expressed on a 14% mb.
[b] Measured after 45 min resting of dough.
[c] The volume per gram of protein in the 1985 flour was 66.8 for CT and 71.2 for TX.

Cooked Noodles

Noodles (10 g, db) were cooked in 500 ml of gently boiling tap water with occasional stirring. Optimum cooking time, cooking loss, and cooked weight of noodles were measured by conventional methods (Oda et al 1980, Shibata and Chinone 1978). The CV for optimum cooking time, cooking loss, and cooked weight were 1.5, 5.7, and 4.5%, respectively. Cutting stress (CV = 4.3%), surface firmness (CV = 4.8%), and sensory evaluation of cooked noodles were performed as described by Oh et al (1983, 1985a). In measuring surface firmness, the units in the method reported by Oh et al (1985a) should read grams-force on the ordinate.

Scanning Electron Microscopy

For scanning electron microscopy (SEM), noodle specimens were frozen quickly in a mixture of dry ice and 2-methyl butane and dried in a tissue freeze-dryer (Edward High Vacuum Inc., Grand Island, NY) at −60° C. The specimens were attached to stubs with silver paste and coated under vacuum with approximately 60 Å of carbon, followed by 100 Å of gold-palladium. Samples were viewed and photographed with an ETEC Autoscan SEM (Perkin-Elmer Electron Beam Technology, Hayward, CA) at 10 kV of accelerating voltage.

Effect on Noodle Quality of Predeveloping Gluten and of Adding Sodium Bicarbonate

Doughs from WW and CHRW wheat flours (300 g) were mixed at their optimum absorptions of 50 and 54%, respectively, for 5, 10, and 15 min using a pin mixer (sized for 1-lb. doughs, TMCO-National Mfg. Co.). Optimum mixing times for the doughs were 8

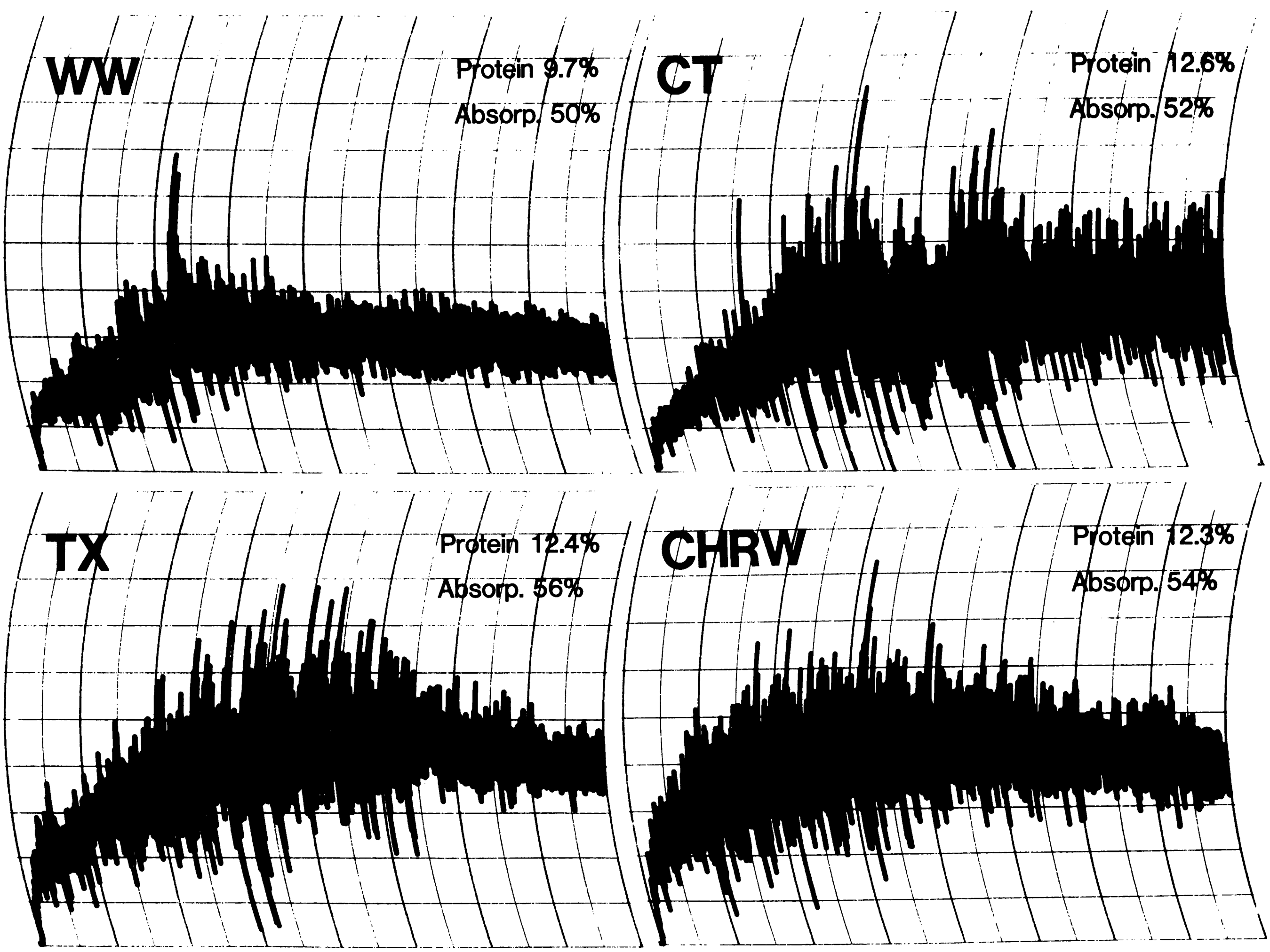

Fig. 1. Mixograms of straight-grade flours (10 g) at breadmaking absorptions for the four 1984 wheats: experimental cultivar TX79A2729 (**TX**), a commercial mixture of hard red winter (**CHRW**), Centura (**CT**), and western white (**WW**).

and 10 min, respectively, for WW and CHRW flours. The doughs were frozen, lyophilized, and ground to pass a 60-mesh sieve. The flours containing developed gluten were rehydrated to 14% moisture by exposure to 95% relative humidity at 30°C in a proofing cabinet, then made into dry noodles.

Noodle doughs were mixed as described above using CHRW wheat flour at 38% absorption with 0, 0.3, 1.0, and 1.5% (flour basis) sodium bicarbonate, to give doughs with pH 5.9, 7.3, 8.7, and 9.7, respectively.

RESULTS AND DISCUSSION

Flour and Dough Properties

Protein and starch damage were, respectively, approximately 3 and 2–5 percentage points higher in the three hard wheat flours than in the soft wheat (WW) flour; ash was similar (0.42–0.49%) in all flours (Table I). The initial slopes of mixograms (Fig. 1) at 50–56% absorption showed that CT and TX wheat flours hydrated more slowly than CHRW wheat flour, and slightly more rapidly than WW flour. CT flour required the longest mixing time and had the greatest tolerance to overmixing. Resistance to extension of doughs decreased in the order CHRW > TX > CT > WW, which was the identical order of loaf volume per unit of flour protein (Table I). With respect to all HRW wheat flours examined by Finney (1985), the CHRW and TX flours had very good loaf-volume potential, whereas the CT flour was moderately good in loaf-volume potential for the two crop years. The report of the Wheat Quality Council (1982) stated that NE77682 (released as Centura in 1984) gave good overall baking quality. Our breadmaking and noodle-making data (discussed below) showed it was possible to grow HRW wheats with good to excellent quality for both bread and Oriental dry noodles.

Noodle Making

The absorptions used to make noodles were as follows: TX, 37%; CHRW, 38%; CT, 38%; and WW, 38%. Although those absorptions were 3–6% higher than used by other investigators (Dexter et al 1979, Oh et al 1986, Moss et al 1987), Oda (1984) reported 30–43% absorption is used in making noodles. In this investigation, noodle properties depended much more on the type of flour than on absorption, and the properties of the noodles varied in the same direction when absorption was increased from 34 to 38% in WW and CHRW flours (Table II). Experimental difficulty was encountered in sheeting, cutting, or drying when absorptions were below 34% or above 46%.

The characteristics of the noodles from the four flours (1984 crop) are given in Table III. The dried noodles from CT and TX wheat flours were more opaque and whiter than those from CHRW wheat flour, but the whitest noodles were from WW flour. The breaking stress of the dried noodles from the CT flour was about 50% below those of the CHRW and TX noodles. The CT noodles cooked faster (12 min) than the others from hard wheats (13–14 min), but slower than the soft wheat noodles (10 min). The weight gain of cooked hard-wheat noodles was 12–28% greater, and their chewiness and cutting stress were generally higher than those of the soft-wheat noodles. Still, the cutting stress of cooked CT noodles was close to that of WW noodles.

Among noodle quality characteristics, surface firmness is important in cooked noodles. Almost all HRW wheats give Oriental dry noodles that have a soggy and rough surface after cooking. The surface firmness of cooked noodles varied from 34.3 for CHRW noodles to 51.4 grams-force/mm for WW wheat noodles (Table III). The surface firmness of the cooked noodles from CT, WW, and TX was judged to be very good to excellent, whereas the surface of CHRW noodles was poor. The sensory panel preferred the CT and TX noodles over the CHRW noodles because of the excellent to good surface firmness. Among the three

TABLE II
Effect of Noodle-Making Absorption on the Characteristics of Dry and Cooked Noodles Made from Hard (CHRW) and Soft (WW) Wheat Flours

Water Absorption (%)	Dry Noodle: Color		Dry Noodle: Breaking Stress[a] (g/mm²)		Cooked Noodle: Cutting Stress[a] (g/mm²)		Cooked Noodle: Surface Firmness[b] (g/mm)	
	WW	CHRW	WW	CHRW	WW	CHRW	WW	CHRW
34	85.2	61.7	1,885	2,769	19.3	28.4	47.9	31.7
38 (optimum)	89.9	63.1	1,984	3,012	20.5	30.8	51.4	34.3
42	86.5	65.8	2,107	3,239	18.2	32.1	49.6	31.8
46	84.4	66.3	2,135	3,267	15.5	33.5	47.2	29.3
LSD[c] ($P = 0.05$)	1.3	1.5	87	112	0.9	1.4	1.8	2.2

[a] In previous publications from our laboratory, the unit of stress was grams-force/mm², which can be converted to kilopascal (1,000 N/m²) by multiplying by the factor 9.8.

[b] Surface firmness ≥50, 50–45, 45–40, 40–35, and ≤35 g/mm was judged to be excellent, very good, good, fair, and poor, respectively (Oh et al 1985a). The units of grams-force/mm can be converted to N/m by multiplying by the factor 9.8.

[c] Average of three replicates.

TABLE III
Quality Characteristics of Dry and Cooked Noodles Made from Four Wheat Flours[a] (1984 Crop)

Noodle Characteristic	Soft Wheat Flour WW	Hard Red Winter Wheat Flours: CHRW	CT	TX	LSD[b]
Noodlemaking absorption, %	38	38	38	37	...
Dried noodle					
Color	89.9	63.1	83.2	79.8	1.9
Breaking stress, g/mm²	1,984	3,012	2,142	3,210	104
Cooking properties					
Cooking time, min	10	14	12	13	0.8
Cooking loss, %	9.8	10.7	8.2	6.8	1.0
Cooked weight gain, %	177	227	198	212	9
Cooked noodle					
Cutting stress, g/mm²	20.5	30.8	22.1	31.3	1.3
Surface firmness, g/mm	51.4	34.3	52.9	48.2	2.7
Sensory test					
Surface texture[c]	8.8	6.2	8.5	7.9	0.5
Chewiness, sec[d]	14.7	21.3	17.6	22.1	2.5
Total score[e]	8.5	6.2	8.8	7.4	0.7

[a] WW, Western White; CHRW, commercial mixture of hard red winter,; CT, Centura; TX, TX79A2729.

[b] All data were replicted two to six times. Least significant difference at $P = 0.05$.

[c] Judged by mouthfeel and scored from 1 to 10. The higher the score, the firmer the texture.

[d] Time in seconds required to masticate 10 g of cooked noodles at the rate of one chew per second to a consistency small enough to swallow.

[e] Overall preference indicated by panelist on a structured scale from 1 (least preferred) to 10 (most preferred).

HRW wheat flour noodles, the noodles from CT wheat had quality characteristics closest to those of WW noodles.

Surface Firmness of Cooked Noodles Versus Crop Year of CT and TX Wheats

Samples of CT grown in Nebraska in 1984 and in Kansas in 1985, when made into dry noodles, both had good surface firmness after cooking (about 50 g/mm, Table IV). The good breadmaking potential of the 1984 and 1985 CT wheat was shown in Table I. Those findings indicate that the good surface firmness of the CT variety may be under genetic control. In contrast, the 1984 TX variety gave a very good surface firmness, but the 1985 TX sample was somewhat less desirable. Commercial 1984 and 1985 HRW wheats gave cooked noodles with poor surface firmness (about 32 g/mm).

Surface Firmness of Noodles and Development of Gluten

Moss and co-workers (1987) used microscopy to indicate that a continuous protein matrix (developed gluten) is required for good eating quality in Hokkien, Cantonese, and instant fried noodles. Most gluten development occurred during reduction rolling of noodle dough, not during mixing or the initial pressing of dough into a thick sheet (Dexter et al 1979, Moss et al 1987). In breadmaking it is well known that gluten development occurs during dough mixing at 60–65% absorption. Furthermore, some separation of a gluten-rich and starch-rich phase occurs at optimum development of a bread dough (Moss 1972), so that full development of gluten for breadmaking is a more extensive change of flour structure than development for noodle making. Gluten development does not occur during wetting and mixing of semolina at 27% moisture or during pasta pressing (Matsuo et al 1978). Development does occur when mixing semolina at >45% absorption (Dexter and Matsuo 1979).

We found in Oriental dry noodles made with no alkalizing agent, flours that readily interacted with limited water to give some gluten development during mixing also gave noodles whose surface became soggy and watery during cooking. Noodle mixograms were run to determine differences in the hydration of flour at low absorption. In that test, if the flour absorbed water without cohesion between flour particles, then little resistance occurred between the mixograph pins, and the width of the mixogram was narrow. It should be pointed out that the noodle mixograms shown in Figure 2, compared with those in Oh et al (1986), were obtained using slightly more water initially added between the 1-min mixing periods. Thus, noodlemaking absorption in this work could not be predicted from the regression equation of Oh et al (1986).

In the absorption range (37–38%) used here for noodlemaking, the mixograms in Figure 2 were narrower for the 1984 WW and CT flours than for the CHRW and TX flours. Moreover, the curves for CT and WW had practically the same width between 10–42% absorption despite their difference in protein content (9.7 vs. 12.6%). The narrowness of the curves indicated limited formation of gluten fibrils occurred when either the CT or WW was mixed with 38% water for noodlemaking. On the other hand, the CHRW showed some cohesiveness in its dough at 35% (Fig. 2), which was 3% below the absorption used to make noodles. The TX dough also showed some cohesiveness at its noodle-making absorption of 37%, and even at 35% and above. The slow hydration of the CT and TX flours compared to the CHRW flour was observed also in the conventional mixograms (Fig. 1).

At noodlemaking absorption, the water added to the CHRW wheat flour was presumably absorbed strongly at the outer surface of the flour particles causing some release of gluten fibrils and some degree of gluten development between flour particles. Dexter and Matsuo (1979) previously observed that during wetting and mixing of a durum flour, with 35% absorption the surface of the flour particles contained free starch granules and isolated jagged pieces of protein. The lack of cohesiveness between flour particles during

TABLE IV
Characteristics of Noodles Made from Three Wheats[a] Grown in Two Crop Years

		Dry Noodle		Cooked Noodle			
Wheat Flour	Crop Year	Color	Breaking Stress (g/mm²)	Cooking Time (min)	Cooked Weight Gain (%)	Cutting Stress (g/mm²)	Surface Firmness (g/mm)
WW	1984	89.9	1,984	10	177	20.5	51.4
CHRW	1984	63.1	3,012	14	227	30.8	34.3
	1985	66.7	3,215	14	218	29.5	30.9
CT	1984	83.2	2,142	12	198	22.1	52.9
	1985	83.5	2,396	12	201	23.6	48.8
TX	1984	79.8	3,210	13	212	31.3	48.2
	1985	75.9	3,514	13	205	31.2	42.1
LSD[b]		1.0	109	1	18	2.1	4.2

[a] WW, Western white; CHRW, commercial mixture of hard red winter; CT, Centura; TX, TX79A2729.
[b] Average of three replicates ($P = 0.05$)

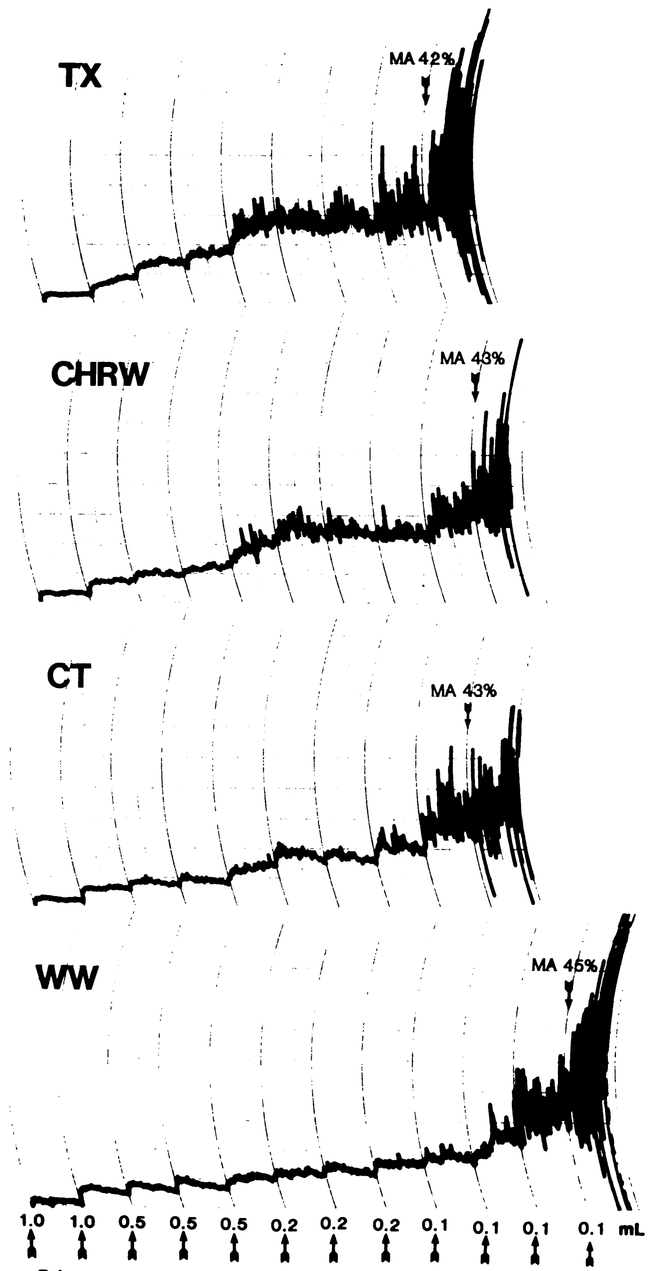

Fig. 2. Mixograms to predict noodlemaking absorption of the straight-grade flours (10 g) from the four 1984 wheats: experimental cultivar TX79A2729 (**TX**), a commercial mixture of hard red winter (**CHRW**), Centura (**CT**), and western white (**WW**). Mixograph absorption (**MA**) for a noodle flour is indicated by the arrow.

wetting and mixing of WW and CT flour with 35–39% water indicated their flour particles did not release gluten fibrils, which would allow the water to penetrate and hydrate the interior of the flour particles.

The even distribution of moisture in the WW and CT flours during mixing and standing of the moistened flour eventually allowed development of a uniform protein matrix during the fixed number of sheeting steps. On the other hand, the gluten fibrils released at the surface of the CHRW flour particles competed strongly for the limited water. Consequently, water may not have been distributed uniformly in moistened CHRW flour, and the limited sheeting steps probably failed to give a uniform noodle structure. The inhomogeneous noodles probably contained weak or high stress planes that lead to dislodging of flour particles at or immediately under the surface of noodles during cooking.

Predevelopment of gluten in the CHRW and WW flours was detrimental to surface firmness (Fig. 3). In this experiment the bread-type doughs were under- and overmixed as well as optimally mixed at their optimum absorptions (Fig. 1), freeze-dried, and the flours processed into noodles. The noodle mixograms in Figure 4 show that the "gluten-developed" WW flour became cohesive at a lower absorption than did the native WW flour. This result supports the hypothesis that in noodlemaking, formation of partially developed gluten on the surface of flour particles during the mixing step causes the limited water to be associated with the partially developed gluten and prevents complete development of a noodle dough in the rolling step. In this experiment, when noodle doughs were mixed from the flours containing developed gluten, either the predevelopment of the doughs caused too much segregation of starch and gluten, or the gluten particles in the premixed flour, once they captured some of the first water added to the flour, then captured an even greater proportion of the remaining water added to a flour. Apparently, once the developed gluten captured some of the limited water, it would only slowly release the water to other particles in the flour. Either proposed mechanism would account for the reduced surface firmness of the cooked noodles.

The uniform protein network in a cooked WW noodle can be seen in Figure 5. The protein network in the cooked CHRW noodle appeared less uniform and gave more stress cracks during preparation of the noodle for SEM.

The interaction of limited water with soft and hard wheat flours has been shown to differ (Doescher 1986, Hoseney et al 1986). More moisture was needed to change the protein in soft wheat flour from a glassy to a rubbery state at 25°C than for hard wheat flour. Furthermore, the gluten behaved differently towards water when isolated from the flour. Those data confirm the slow hydration of gluten in soft wheat flours during noodle making.

Noodle Thickness

The thickness of noodles indicated the CHRW dough was more elastic at 37–38% absorption than the other doughs. The fresh and dry noodles from CHRW wheat flour expanded approximately twice as much in thickness after sheeting and drying as did the noodles from the CT and WW wheat flours (Table V). The elastic character of the CHRW noodle dough is in agreement with the hypothesis that the CHRW noodle dough contained flour particles that developed gluten on their surfaces.

The specific volume of the CHRW wheat noodles was 3–5%

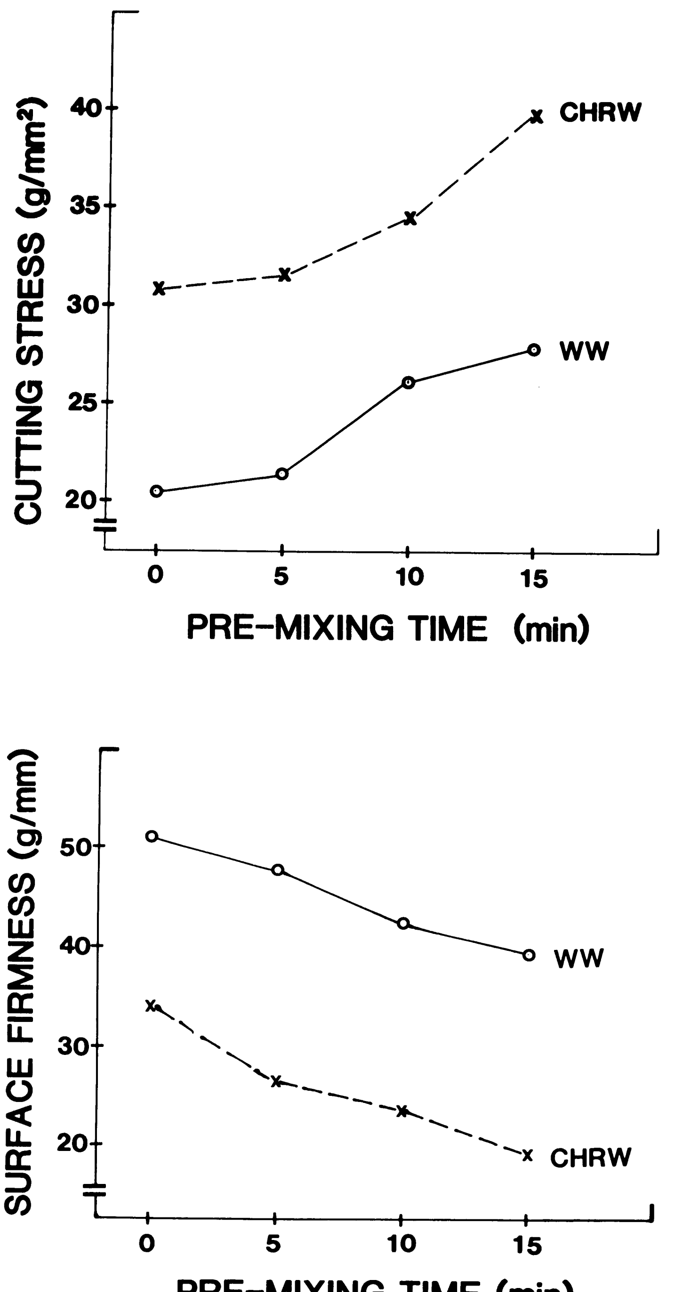

Fig. 3. Cutting stress (top) and surface firmness (bottom) of cooked noodles made from predeveloped western white (**WW**) wheat and commercial hard red winter (**CHRW**) wheat flours.

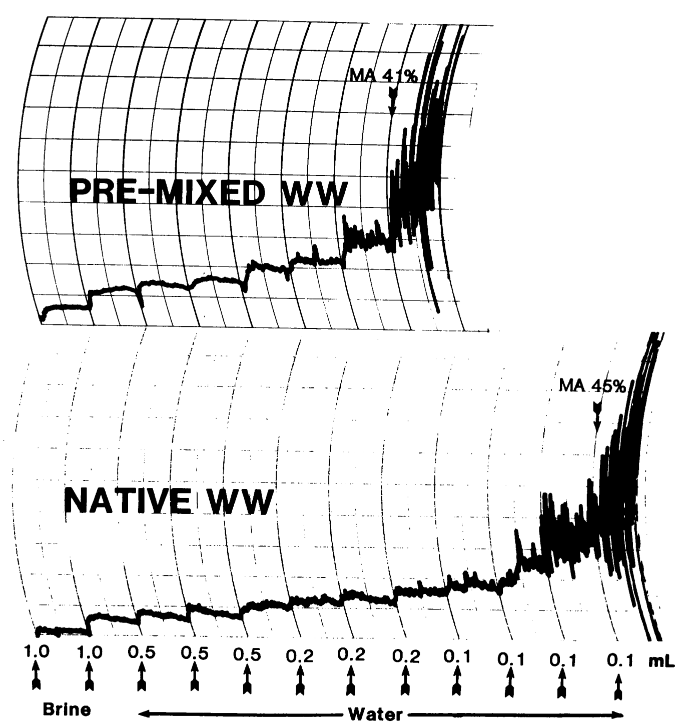

Fig. 4. Noodle mixogram of predeveloped western white (**WW**) wheat flour compared to that of the native WW flour.

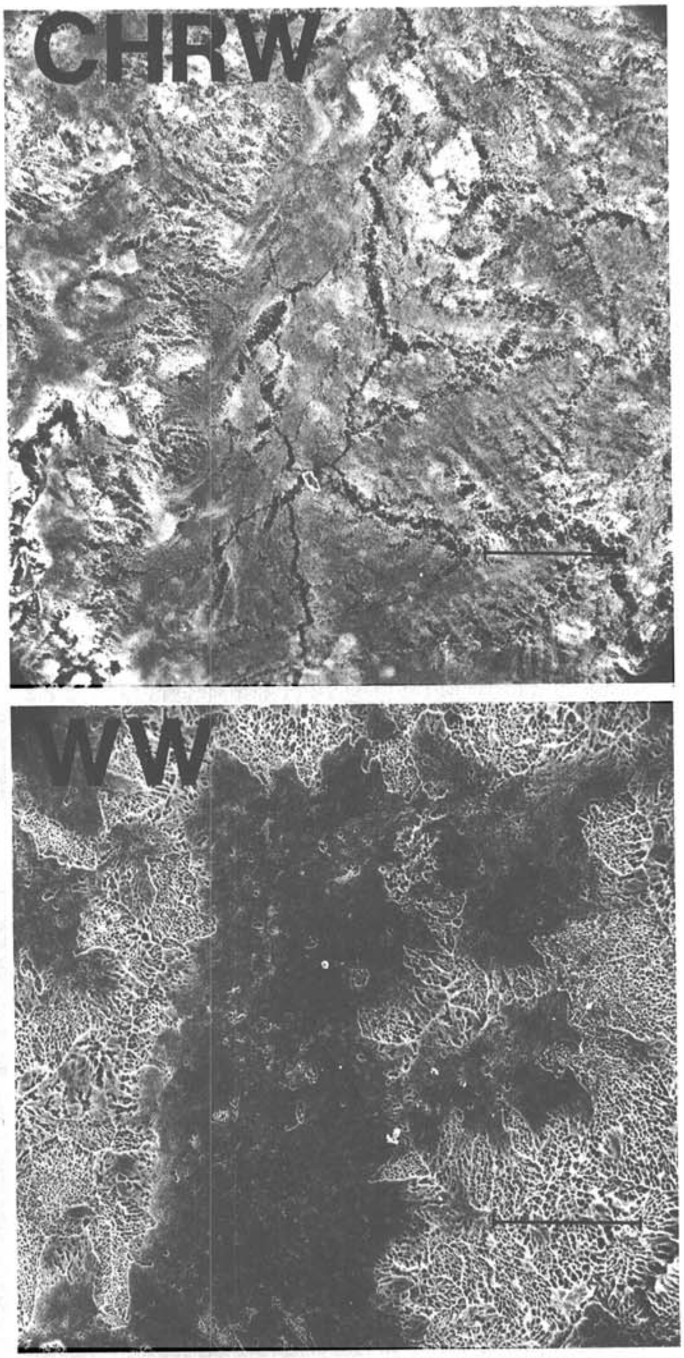

Fig. 5. Scanning electron micrograph of the rolled surface of cooked noodles made from (top) commercial hard red winter (**CHRW**) wheat flour and (bottom) western white (**WW**) wheat flour. The bar indicates 10 μm.

below that of the other noodles, which in part may explain its longer cooking time (14 min) compared to the other noodles (10–13 min) (Table V). However, the extended cooking time of hard wheat noodles does not account for their poor surface firmness (Oh et al 1985a).

Role of Salts Added to Noodle Dough

Gluten development is known to be delayed in bread doughs above pH 9.6 (Hoseney 1985) and in noodle doughs at pH 11.4 (Moss et al1986). Sodium chloride also delays gluten development. One may speculate that addition of *kan-sui* (alkalizing salts) or sodium chloride to flour prevents development of gluten on the outside of flour particles during mixing and resting of noodle doughs. The alkaline salts are more effective than sodium chloride (Moss et al 1987), and therefore are more widely used on strong flours. Dexter et al (1979) found a more uniform development of gluten using 2% sodium chloride than water in Japanese noodles made from a hard spring wheat flour (9.4% protein), whereas *kan-sui* gave a continuous matrix in Cantonese noodle dough made from a 12.5% protein flour. The same phenomenon that causes the carbonate salts to delay hydration of gluten in noodle flours also appears to prevent excessive swelling of starch during cooking of the noodle (Moss et al 1986).

Increasing the dough pH of CHRW wheat noodles from 5.9 to 7.3 with sodium bicarbonate gave a slight improvement in surface firmness (Table VI), probably because cooking water at pH $>$ 8 is known (Oh et al 1985a) to be detrimental to surface firmness. However, extra sheeting to increase gluten development in the noodles at pH 8.3 and 9.7 gave some improvement in surface firmness (Table VI).

TABLE V
Variation in Thickness and Volume of Dry Noodles

Dimensions	Wheat Flour[a] WW	CHRW	CT	TX	LSD[b] ($P = 0.05$)
Thickness, mm					
Fresh noodles	1.58	1.89	1.68	1.80	0.12
Dry noodles	1.48	1.71	1.54	1.62	0.09
Thickness expansion,[c] %					
Fresh noodles	21.5	45.4	29.2	38.5	7.6
Dry noodles	13.8	31.5	18.5	24.5	4.5
Width, mm					
Fresh noodles	2.61	2.88	2.70	2.73	0.11
Dry noodles	2.25	2.37	2.28	2.32	0.09
Specific volume,[d] cm^3/10 g	7.2	6.7	7.0	6.9	0.1

[a] WW, Western white; CHRW, commercial mixture of hard red winter; CT, Centura; TX, TX79A2729.
[b] Average of three replicates.
[c] Thickness expansion was calculated by dividing the difference between the thickness of the uncooked (fresh or dried) noodle and the final roller gap of 1.3 mm by the final roller gap (1.3 mm).
[d] Volume was determined for 10 g (db) of dry noodles by the water displacement method using a volumetric cylinder.

TABLE VI
Increase of Dough pH and Noodle Properties

Wheat Flour[a]	pH: Alkaline Water	pH: Dough	Dry Noodle: Color	Dry Noodle: Breaking Stress (g/mm^2)	Cooked Noodle, Normal Sheeting: Cutting Stress (g/mm^2)	Cooked Noodle, Normal Sheeting: Surface Firmness (g/mm)	Cooked Noodle: Surface Firmness After Extra Sheeting[b] (g/mm)
WW	6.7	6.2	89.9	1,984	20.5	51.4	53.5
CHRW control	6.7	5.9	63.1	3,012	30.8	34.3	35.9
CHRW with 0.3% $NaHCO_3$	7.5	7.3	65.6	2,485	32.1	38.4	39.5
CHRW with 1.0% $NaHCO_3$	7.9	8.3	70.1	1,956	34.2	33.6	36.0
CHRW with 1.5% $NaHCO_3$	8.4	9.7	69.5	1,834	31.8	31.5	34.7
LSD[c] ($P = 0.05\%$)			1.3	64	1.5	2.8	2.5

[a] WW, Western white; CHRW, commercial mixture of hard red winter.
[b] Initial dough sheet was folded and sheeted four times and then the normal process followed.
[c] Average of three replicates.

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