Comparison of Asian Noodles from Some Hard White and Hard Red Wheat Flours[1]

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ABSTRACT

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Asian noodles were prepared by an objective laboratory method that included adding optimum water to the dry ingredients, mixing the ingredients to homogeneous salt distribution, and sheeting of the dough under low shear stress. The lightness (L^*) values of alkaline- and salt-noodle doughs made from 65% extraction hard white wheat flours (except KS96HW115 flour at ≈70% extraction) were higher than those from 60% extraction hard red wheat flours (except Karl 92 flour at ≈70% extraction). A hard white spring wheat, ID377s, and a Kansas line of hard white winter wheat, KS96HW115, to be released in 2000, gave the highest L^* values for dough sheets stored for 2 and 24 hr at 25°C. Cooking losses were 5–9 percentage points higher for alkaline noodles than salt noodles, but the cooking yields of the two types of Asian noodles were almost the same. Cooked alkaline noodles made from a high-swelling flour (SP_{93} ≈21 g/g) gave higher tensile strength than those made from several low-swelling flours (SP_{93} ≈15 g/g) with the same protein contents (≈12.5%). However, the cooked salt noodles gave the same tensile strength.

In recent years, hard white wheats have been released by breeders for cultivation in the Great Plains and Western states of the United States. All other factors being equal, white wheats yield more flour than red wheats when milled to a standard color (Li and Posner 1989). They also show fewer visible bran specks in farina and flour, which is a critical factor for making pasta and noodles. Bran from hard white wheats, being light in color and low in bitterness, will compete with bran from soft white wheats as a source of dietary fiber in cereal foods. Major export markets for white wheats include the Middle East, Southeast Asia, and Central and South America, where flat breads, noodles, and tortillas, respectively, are important staple foods that preferably are made from white wheats.

In Asian noodles, a white-pericarp kernel is a necessary but not a sufficient criterion in selecting a wheat. It also must be low in polyphenol oxidase, an enzyme that causes browning discoloration in raw noodle dough over time (Lang et al 1998, Kruger et al 1994). Noodles must appear bright white or bright yellow for acceptance in the Asian market.

A third criterion of a top-quality wheat for white salt noodles (1–2% sodium chloride, pH 5.7–6.1), especially in Japan and Korea, is high swelling of the flour in a hot, dilute, aqueous suspension (Crosbie et al 1992, Jun et al 1998). Hot water swelling of wheat flour is primarily attributable to wheat starch and is controlled first by cultivar and second by environment (crop year and location) as opposed to location (Konik et al 1994; Morris et al 1997a,b).

Australian white wheats containing high-swelling starch, which are used extensively for white salt (sodium chloride) noodles, have lacked the Wx-B1 protein bound to their starch granules (Yamamori et al 1994). This waxy protein is one of three granule-bound starch synthases (GBSS) present in a hexaploid wheat. Absence of all three waxy proteins (Wx-A1, Wx-B1, and Wx-D1) produces waxy wheat (Yamamori and Nakamura 1994, Chibbar et al 1997, Graybosch 1998), and absence of one or two GBSS in a partial waxy wheat reduces the amylose level by up to 4 or 10 percentage points, respectively (Graybosch et al 1998, Demeke et al 1999).

Seib (1997) and Ross et al (1997) have presented a model to explain how starch swelling improves the quality of cooked salt noodles. In salt noodles prepared from high-swelling wheat flours containing 9–10% protein, the starch near the surface swells to release more amylose between granules during cooking. Upon cooling, the amylose-rich phase between the gluten fibrils and starch granules forms a gel that imparts a smooth surface. In the interior of the noodle, the extra swelling of the starch causes more water to be imbibed, which increases noodle yield and gives a soft elastic bite.

In cooked alkaline (sodium or potassium carbonate) noodles, surface smoothness was correlated positively with increased flour swelling, whereas firmness and elasticity were correlated negatively (Konik et al 1994, Ross et al 1997). The total texture score of cooked alkaline noodles was correlated negatively to flour swelling volume (Crosbie et al 1999). On the other hand, increased protein level and increased protein strength (SDS sedimentation values) were correlated negatively to surface smoothness of alkaline noodles but positively to firmness and elasticity.

The objective of this investigation was to compare the properties of noodle flours, doughs, and cooked noodles prepared from some U.S. hard white and hard red wheats. The flours differed in extraction rate (65% for white vs. 60% for red wheats) and varied in swelling power and the browning rates of doughs. We chose to investigate the use of the hard wheats in both alkaline and salt noodles because some noodle makers may use a single flour to produce both types. The growing locations of the wheats were not identified and the wheats were from a single crop year, so the properties of doughs and noodles should be considered indicators of quality differences between hard red and white wheats.

MATERIALS AND METHODS

Materials

Hard winter wheats of the 1997 crop year, grown in Hutchinson or Hays, KS, were obtained from T. J. Martin, Agricultural Research Center, Hays, KS, and included the hard whites, Betty, Heyne, and KS96HW115, and the hard reds, Jagger, Karl 92, and Ike. The wheat line KS96HW115 has been chosen for release in 2000. The hard white winter wheat OroBlanco was obtained from the American White Wheat Producers, Atchison, KS. A hard white winter wheat, NuWest, and a hard white spring wheat, Idaho 377s, both grown in 1997, were obtained, respectively, from L. Talbert, Montana State University, Bozeman, MT, and E. Souza, University of Idaho, Moscow, ID. Two control flours, one each of top-quality alkaline- and salt-noodle flours were requested and obtained from Nippon Flour Mills Co. Ltd, Atsugi, Japan. The white wheats were tempered to 15% moisture content (wb) and, except for

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KS96HW115, were milled to 65% extraction on a Miag laboratory mill (Uzwil, Switzerland) (Posner and Hibbs 1997). The red wheats, except Karl 92, were milled to 60% extraction. Karl92 and KS96HW115 were obtained in insufficient quantities to mill on the Miag. Instead, they were milled on a Buhler laboratory mill to 70.4 and 70.8% flour extractions, respectively. Corn starch was Argo brand purchased from a supermarket. All chemicals were reagent grade.

Methods

Protein (N × 5.7) was measured by combustion (FP-2000 protein/nitrogen analyzer, Leco Corp, St. Joseph, MI), and moisture, ash, and falling number were determined by Approved Methods 44-15A, 08-01, and 56-81B (AACC 2000). Total starch and damaged starch were determined by AACC Methods 76-12 and 76-31, respectively, using kits from Megazyme International Ireland Ltd (Bray, Ireland). Amylose contents were determined by concanavalin A precipitation of amylopectin (Yun and Matheson 1990), again with a kit from Megazyme. Particle-size distributions were determined laser-diffraction particle-analyzer (Lecotrac-LTS150, Leco Corp.) equipped with a recirculator, an on-line ultrasonic probe, and an interfaced computer with Lecotrac software. Wheat flour (≈0.1 g) was added to 2-propanol (300 mL) circulated at 40 mL/sec through a standard cell; the ultrasonic device was energized for 60 sec before particle-size measurement. Corn starch was measured as a reference standard using the spherical instead of the irregular particle mode. The software converted the diffracted light data to particle diameters between 0.7 and 700 μm, and the volume percentages of particles in a channel were calculated assuming that the particles were spheres. Duplicate analyses were done on flour and starch particles, and the mean values at each size were recorded. Lightness (L^*) and red-green (a^*, ±) and yellow-blue (b^*, ±) hues of flours and doughs were measured using a chromameter (model CR210, Minolta, Osaka, Japan) (Miskelly 1984, Kruger et al 1992). Color measurements were made in triplicate on flours, and in three locations across a dough sheet with five readings at each location. Swelling power at 93°C of a flour (0.45g/30 mL of water) was measured in triplicate as described by Crosbie (1992), and SP$_{93}$ was determined as the weight of the gel phase divided by dry weight.

Soluble and insoluble polymeric proteins in wheat flours were determined in 50% aqueous 1-propanol by the method of Bean et al (1998). The soluble and insoluble levels were expressed as percentages of total protein, but the total polymeric protein level was expressed as a percentage based on the weight of flour at 14% mb. Unless otherwise stated assays were performed in duplicate.

Noodle Making

Noodle-making absorptions of flours were determined from the maximum farinograph consistency generated by a flour-water dough. Water (4.70, 3.25, 1.55, 1.05, 0.75, and 0.5 mL) was added incrementally from a burette to flour (50 g, 14% mb) in a 50-g

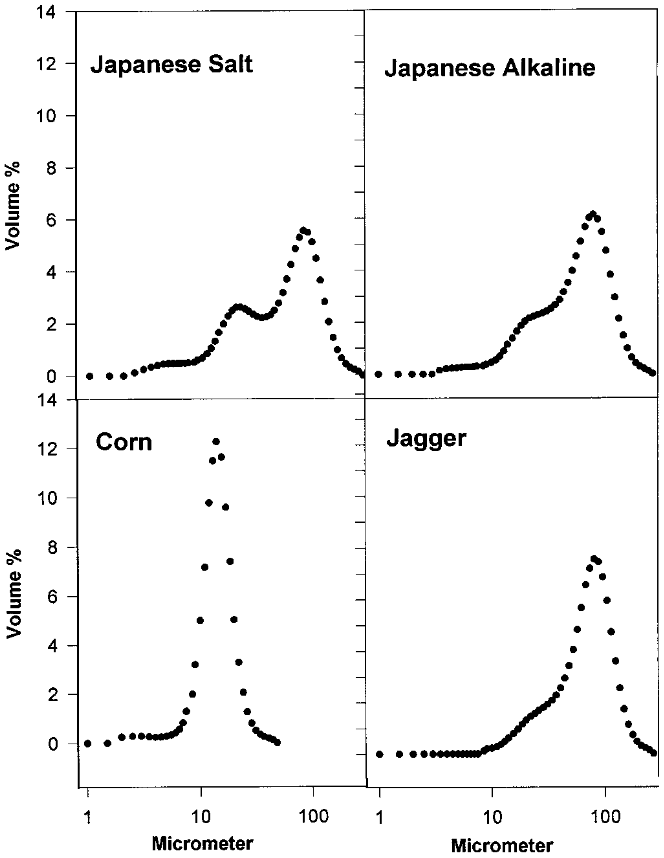

Fig. 1. Particle-size distributions of commercial noodle flours from Japan and of one hard wheat flour (Jagger) determined in 2-propanol. Corn starch control sample.

TABLE I
Properties of Hard Wheat Flours Used to Make Asian Noodles

	Protein (%)														
		Polymeric[a] (%)				Starch (%)			Particle Size, μm (%)			Color			
Wheat	**Total**	**S**	**I**	**T**	**Ash (%)**	**Total**	**Damaged**	**Amy[b]**	**<40**	**40–114**	**>114**	L^*	a^*	b^*	**SP_{93} (g/g)[c]**
Hard white wheat flour (65% extraction)															
Betty	12.6	10.5	40.0	6.36	0.35	73.9	8.1	25.3	23	67	10	91.5	–1.6	7.3	15.5
Heyne	12.8	13.4	36.2	6.35	0.38	75.1	5.6	24.6	29	62	9	91.9	–1.9	8.1	15.2
KS96HW115[d]	11.3	13.0	35.4	5.47	0.42	77.5	9.5	26.0	31	62	7	92.2	–1.8	7.4	15.6
OroBlanco	10.9	12.5	38.3	5.54	0.39	77.0	6.4	25.5	29	62	9	91.8	–1.9	8.0	15.6
NuWest	11.2	10.9	40.0	5.70	0.33	73.2	6.8	25.6	25	65	10	91.3	–2.0	8.3	15.9
Idaho377s	8.1	15.7	36.4	4.22	0.38	81.3	8.9	25.6	24	64	12	91.8	–2.2	8.0	18.5
Commercial[e]	11.3	13.0	36.7	5.61	0.35	76.2	7.8	25.1	33	58	9	92.0	–2.1	8.6	15.8
Hard red winter wheat flour (60% extraction)															
Jagger	12.6	10.4	41.0	6.48	0.37	78.0	8.2	26.7	22	67	11	91.2	–1.9	8.7	15.0
Karl92[d]	11.9	10.4	43.8	6.44	0.46	75.4	8.5	27.4	30	64	6	91.6	–1.4	6.8	16.2
Ike (Hutch)	12.6	11.5	41.5	6.68	0.30	76.1	6.6	21.0	24	66	10	91.2	–1.7	7.7	21.0
Ike (Hays)	10.3	14.3	37.7	5.36	0.33	78.0	6.7	22.5	25	65	10	91.5	–2.0	7.7	21.1
LSD[f]	0.2	0.4	2.3	0.17	0.07	1.0	0.5	1.2	3	3	3	0.4	0.2	0.2	0.4

[a] S, soluble polymeric protein; I , insoluble polymeric protein; T, total polymeric protein; % S and I based on flour protein; % T based on flour weight.

[b] Amylose.

[c] Swelling power of flour determined at 93°C and 1.5% in water.

[d] Milled to ≈70% flour extraction.

[e] Commercial Japanese alkaline noodle flour.

[f] Least significant difference ($P < 0.05$).

farinograph bowl, and each mixture was stirred for 1 min. Beyond those initial additions of water ≤28% based on flour, more water was added in 0.5-mL increments followed by 2 min of stirring after each addition, and the process repeated until dough consistency began to decrease. Noodle making absorption was estimated by adding 3% to the absorption (in percent based on flour) required to generate the maximum consistency (Guan 1998).

Noodles were made from flour (200 g, 14% mb) and optimum water, plus sodium carbonate (2.0 g) or sodium chloride (4.0 g) for yellow alkaline and white salt noodles, respectively. The flour was placed in a Hobart N-50 mixer, and with the mixer set at slow speed, the solution (≈70 mL) of sodium salt in water was pumped (E. Series, Manostat Corp., NY) onto the flour at a rate of 1.6 mL/sec. After the salt solution was added, the mixer was kept on low speed for an additional 1.5 min, then the dough clinging to the mixer arms was scraped down with a plastic tool. Finally, the dough was mixed at medium speed for 3.0 min.

The mixed dough was allowed to rest for 30 min in a covered container and pressed through the rolls of a laboratory noodle machine (Ohtake Noodle Machine Mfg. Co., Tokyo, Japan) to form the initial dough sheet. With the roll gap set at 4.0 mm, a short length of flexible plastic tubing was used to plug the roll-gap, and the crumbly dough then was fed uniformly into the well formed by the plugged gap and the roll surfaces. The initial dough sheet was formed and cut into two equal lengths, which were stacked atop each other both in the same machine direction. The dough stack with nominal thickness of 8 mm then was sheeted six more times successively through gap settings of 4.0, 2.36, 1.60, 1.23, 1.06, and 1.00 mm. Those settings theoretically gave linear declines in reduction ratio of ≈9% between sheeting steps 1 and 2, ≈18% between steps 2 and 3, and so forth, according to the expression $R_i = R_1 - 0.0895\ (i - 1)$, where R_i is the reduction ratio (in decimal form) at an iteration; R_1 is the reduction ratio of the first sheeting step, which in this case was 4 mm/8 mm = 0.5; and i equals the iteration. Using the mixing and sheeting conditions given above, Guan (1998) found uniform color (L^*, b^*) and uniform salt distribution in dough sheets. This sheeting protocol was chosen to impart minimum shear stress on a dough sheet. Thickness was measured at 10 locations along a final dough sheet using a caliper, and the mean is reported. A 15-cm length of a dough sheet was cut, and color was measured within 5–6 min and after 2 and 24 hr of holding in a sealed zip-loc bag at 25°C.

The final noodle sheet was passed immediately through a No. 150 roll cutter to produce noodles with a nominal width of 2.5 mm. The raw noodles were placed in a zip-lock bag and stored at 5°C for no longer than 72 hr before cooking. Two batches of noodles, one containing sodium chloride and the other sodium carbonate, were prepared from each flour.

Noodle Properties

Raw noodles (10.0 g as-is, mb) were cooked for 5.0 min in distilled water (150 mL) maintained at a rolling boil. The mixture was transferred to a colander and drained for 30 sec, the cooked noodles placed in cold water (150 mL) for several minutes, and then drained again for 30 sec. The yield of cooked noodles was calculated from the wet weight of cooked noodles divided by the dry weight (6.2–6.6g) of the raw noodles and expressed as a percentage. The cooking water was evaporated at 130°C for 5 hr, and the residue was reported as percent cooking loss based on the dry weight of a raw noodle.

Tensile strength and breaking length of cooked noodles were determined (Guan 1998) on individual strands with a special noodle clamp and an L-shaped hook probe attached to a texture analyzer (TA-XT2, Texture Technologies Corp., Scarsdale, NY; Stable Micro Systems Haslemere, Surrey, UK). The probe was attached to a load cell rated up to 5,000 *g*-force, and the instrument was interfaced with an IBM computer (486 DX-66) and run by SMS3-Stable Micro System (Texture Technologies) software. Instrument settings were test mode, measure force (tension); option, return to start; trigger point, 1.0 g; pretest speed, 2.0 mm/sec; posttest speed, 5.0 mm/sec; test speed, 5 mm/sec; and total distance, 50 mm.

The noodle clamp was fabricated with a polystyrene base shaped like a prism, but with a notched apex. Lying atop the two inclined planes of the prism were two stainless steel lobes hinged in opposite directions to the base. The hinges were spring-loaded with a strip-spring, and the noodle contact surfaces were lined with wire cloth. The clamping force on a strand originated from a combination of the mass of a metal lobe and the spring force. When a noodle strand was clamped by the two lobes, the center of the noodle formed an inverted V about 30 mm long that was engaged by an L-shaped probe. The L-shaped probe was fashioned from 3-mm stainless steel rod, and the short and long lengths of the L were 23 and 47 mm, respectively (Guan 1998). Tensile loading was applied, and the tensile forces at break and break length were recorded.

TABLE II
Properties of Hard White and Hard Red Wheat Flours and Alkaline Noodles[a]

			Noodles									
	Flour (14% mb)		Lightness[c] (L^*)			Yellowness (b^*)			Cooking		Tensile Test[d]	
Wheat	**Protein (%)**	**Abs[b] (%)**	**0.1 hr**	**2 hr**	**24 hr**	**0.1 hr**	**2 hr**	**24 hr**	**Loss (%)**	**Yield (%)**	**TF (*g*-force)**	**BK (mm)**
Hard white wheat flour (65% extraction)												
Betty	12.6	33	86.0	80.4	75.1	14.6	23.1	25.5	14	337	95	32
Heyne	12.8	32	84.8	78.9	74.2	17.5	28.2	29.8	18	335	83	27
KS96HW115[e]	11.3	32	86.2	81.7	78.3	17.6	27.3	30.2	14	332	71	25
OroBlanco	10.9	35	85.0	79.2	75.7	17.0	27.5	31.0	14	353	80	29
NuWest	11.2	33	83.9	79.9	77.2	20.2	29.9	32.1	14	350	86	27
Idaho377s	8.1	39	85.9	82.9	80.9	21.7	29.7	31.6	19	377	50	26
Commercial[f]	11.3	32	87.4	84.9	81.9	20.6	25.0	27.5	18	295	77	33
Hard red wheat flours (60% extraction)												
Jagger	12.6	33	84.7	78.9	73.6	16.7	25.7	27.0	17	334	92	30
Karl92[e]	11.9	35	83.9	77.7	72.5	15.1	24.5	26.4	17	333	92	35
Ike (Hutch)	12.6	33	83.2	77.7	73.2	18.3	26.2	28.4	12	348	116	40
Ike (Hays)	10.3	34	84.1	79.2	74.3	17.8	25.7	27.3	16	368	74	39
LSD[g]	0.2	1	0.6	0.9	0.6	1.0	0.8	0.9	2	12	7	6

[a] All noodles were made with 1% sodium carbonate; raw noodles were cooked in 15 parts of boiling water for 5 min until no white core was visible.

[b] Noodle-making absorption.

[c] Green-blue values (a^*) for all noodles ranged between –1 to –2.

[d] Tensile test on cooked noodle: TF, tensile force (*g*-force); BK, break length (mm).

[e] Milled to ≈70% extraction.

[f] Commercial alkaline noodle flour from Japan.

[g] Least significant difference ($P < 0.05$).

Eight strands of raw noodles each 80 mm long were cut at random from a batch of noodles. The strands were cooked in boiling distilled water (150 mL) for 5.0 min, at which time the white core had disappeared. After collecting by straining, the noodles were placed in distilled water (150 mL) at 25°C, held for 1 min, and collected again by straining. After draining for 30 sec, the noodles were held in a covered petri dish. One strand was positioned in the clamp described above, and an increasing tensile load was applied until breakage occurred. Tensile testing and storing of the data in the computer required ≈40 sec/strand. Seven replicates were measured, and the high and low values discarded, so that data were the means for five strands.

Compression force was measured on cooked salt noodles. The L-shaped hook probe was used in combination with a flat surface to measure compression force on a single strand. After the trigger force of 0.5 g was generated, each of seven strands was compressed 50% of its thickness. The probe speed was 0.5 mm/sec. The mean of the seven replicated determinations was reported for a sample.

Statistical Methods

Means and least significant differences (LSD) were calculated by analysis of variance software (SAS Institute, Cary, NC) with $P < 0.05$. Data for the commercial noodle flours were not included in calculations of LSD.

To determine repeatability, alkaline noodles were prepared on five different days by Lianfu Zhao from the Heyne wheat flour with 2.0% sodium carbonate and 32% absorption based on flour at 14.0% mb. The mean and standard deviations of properties measured were noodle color at 0.1 hr, L^* 81.7 ± 0.4, a^* –6.2 ± 0.1, b^* 27.0 ± 0.6; noodle color at 24 hr, L^* 75.3 ± 0.2, a^* –5.0 ± 0.1, b^* 32.1 ± 0.3; cooking loss (dry basis of raw noodle), 17.4 ± 1.4%; cooking yield 319 ± 11%; tensile strength 85 ± 5 *g*-force, and tensile break distance 28 ± 3 mm.

RESULTS AND DISCUSSION

Noodle Flours

The hard red wheats milled on the Miag laboratory mill to 60% extraction gave ash values of 0.30–0.37%, and the hard white wheats milled to 65% extraction gave ash values of 0.33–0.39% (Table I). By milling to different extraction rates the lightness (L^*) and hue (a^* and b^*) values of the flours from the red and white wheats were similar, as expected from the results of Li and Posner (1989). The granulations of the hard wheat flours were coarser than those of the commercial, high-quality, alkaline-noodle flour (Fig. 1, Table I) and salt-noodle flour, which showed the finest granulation. Heyne and OroBlanco gave flour of somewhat finer granulation among the red and white wheats. Corn starch, which was measured as a control, showed a unimodal distribution of particle sizes with a mean diameter of 15 µm in *n*-propanol. A unimodal distribution was measured by light microscopy (Senti 1967). However, the mean diameter of corn starch measured in water in that study was 17 µm. The two wheats milled on the Buhler laboratory mill to ≈70% extraction, KS96HW115 and Karl92, gave ash values of 0.42 and 0.46%, respectively, and somewhat finer granulations.

The protein levels of the flours were 8.1–12.8%. Total polymeric proteins (Bean et al 1998) in all wheats were ≈50% of the protein in the flours (sum of S and I values, Table I). Thus, the total level of polymeric proteins in a flour was directly proportional to total protein. Insoluble (50% aq. 1-propanol) polymeric protein, however, varied 35–44% of total protein.

The swelling powers of flours from Ike and Idaho 377s were elevated (Table I). Ike wheat is null for the *Wx-A1* and *Wx-B1* alleles (Graybosch et al 1998), whereas Idaho 377s carries a null allele for *Wx-B1* (E. Souza, *personal communication*). The double null for Ike wheat changed amylose level to 21–23%, which was lower than the amylose level of 25–27% for the wild types represented by Betty, Heyne, Jagger, Karl 92, and KS96HW115 (Table I). A reduced amylose level is accompanied by increased swelling of wheat starch (Graybosch et al 1998) and wheat flour (Wang and Seib 1996, Morris et al 1997b). Even though OroBlanco (Graybosch et al 1998) and Idaho 377s are both null for the *Wx-B1* allele and their flours showed amylose levels almost the same as those of the wild type, OroBlanco flour did not show enhanced swelling as did that of Idaho 377s.

Compared with the experimental flours, the top-quality alkaline noodle flour obtained from Japan contained 11.3% protein with 36.7% being insoluble, 25.1% amylose, and a nonelevated swelling power of 15.8 g/g. The Japanese noodle flour was more finely granulated (Table I) than the laboratory milled flours, which probably was due to fine sieving.

Noodle Making

Optimum noodle making absorption range was 32–39% (Table II). More water generally was required with the low protein flours to generate a continuous protein network and make a noodle sheet, so

TABLE III
Properties of Hard White and Hard Red Wheat Flours and Salt Noodles[a]

		Dough							Noodles				
		Lightness[c] (L^*)			Yellowness (b^*)				Cooking				
Wheat	Flour Protein[b]	0.1 hr	2 hr	24 hr	0.1 hr	2 hr	24 hr	Thickness (mm)	Loss (%)	Yield (%)	CS[d] (*g*-force)	TF[d] (*g*-force)	BK[d] (mm)
Hard white wheat flour (65% extraction)													
Betty	12.6	82.5	81.4	79.0	22.8	24.4	24.9	1.7	4.6	333	43	58	33
Heyne	12.8	83.1	81.8	79.7	25.9	29.0	30.6	1.6	4.9	321	42	53	30
KS96HW115[e]	11.3	84.2	83.6	81.5	24.1	26.5	28.1	1.6	6.5	338	34	43	23
OroBlanco	10.9	83.0	81.9	79.5	25.0	26.8	28.4	1.6	5.6	344	43	50	23
NuWest	11.2	83.6	81.4	79.1	23.0	27.7	29.1	1.6	4.1	324	43	54	25
Idaho377s	8.1	85.8	84.2	81.9	22.7	25.2	26.2	1.5	6.6	372	24	33	21
Commercial[f]	8.7	85.3	82.8	81.4	23.6	27.7	28.5	1.6	5.5	356	38	46	29
Hard red wheat flours (60% extraction)													
Jagger	12.6	82.0	80.2	77.0	24.3	27.6	28.8	1.7	4.8	325	42	58	27
Ike (Hutch)	12.6	80.5	79.3	77.4	25.7	27.3	28.0	1.6	4.1	342	27	54	31
Ike (Hays)	10.3	83.6	81.5	79.0	21.9	26.5	27.8	1.5	4.6	359	27	42	28
LSD[g]	0.2	1.0	1.0	0.6	0.9	0.9	0.9	0.1	0.8	8	2	2	4

[a] All noodles were made with 2% sodium chloride; raw noodles were cooked in 15 parts of boiling water for 5 min until no white core was visible.
[b] 14% mb.
[c] Green-blue values (a^*) for all noodles ranged between –1 to –2.
[d] CS, compressive strength (*g*-force); TF, tensile force (*g*-force); BK, break length (mm).
[e] Milled to ≈70% extraction.
[f] Commercial salt noodle flour from Japan.
[g] Least significant difference ($P < 0.05$).

low protein flours required more water for noodle making. White salt noodles with 1–2% sodium chloride can be prepared at the same absorption as yellow alkaline noodles made with 1–2% sodium carbonate (Guan 1998).

Table III shows that the final thickness of dough sheets exiting the roll gap of 1.0 mm was 1.5–1.7 mm for white salt noodles because of the elastic nature of the flour proteins. The thicknesses of the alkaline dough sheets inadvertently were not measured. Dough sheets for a salt noodle made with a high protein flour containing a high level of insoluble (50% aq. 1-propanol) polymeric protein (e.g., Betty and Jagger) showed increased elastic response at the rolls.

The insoluble polymeric protein in a wheat flour is correlated positively with mixing time and tolerance in a dough (Bean et al 1998). Wheat flours from Ike, Betty, NuWest, Jagger, and Karl 92 had higher percentages of insoluble polymeric proteins (35–37% of total flour protein, Table I). Hatcher et al (1999) found that an alkaline (1% kansui, or 9:1 [w/w] sodium carbonate to potassium carbonate) noodle dough made at 28–34% absorption from a soft wheat flour (protein 9.8%) required less work to sheet than two hard wheat flours (protein 10.8–12.5%), but the work to sheet the doughs with 1% sodium chloride were about equal. Edwards et al (1996) reported that work to sheet a water dough at 28–34% absorption was directly related to the strength of the dough's farinograph mixing curve at 57–64% absorption, and that adding 1% sodium chloride generally increased work requirements above the water doughs but not addition of 1% kansui. More data on the sheeting properties of noodle doughs with variable protein is needed.

Noodle Color

The lightness (*L**) of an alkaline noodle dough decreases with increasing dough absorption and protein content (Miskelly and Moss 1985, Oh et al 1985, Kruger et al 1992, Baik et al 1995). Noodle makers, like bread bakers, use an optimum absorption in a dough (Chen 1996, Guan 1998). Comparison of noodle color at optimum absorption may be closely associated with color in the marketplace. The low protein level in Idaho 377s flour contributed positively to its color profile.

Alkaline noodle dough sheets from the hard white wheat flours were at least as light (*L**), if not lighter, than those from the hard red wheat flours even though the hard red wheat flours had a 5% lower extraction rate (Table II). When the noodle dough sheets were aged 5–6 min to 24 h at 25°C in sealed polyolefin bags, a decline of ≈10 units occurred in *L** values except for KS96HW115 (–7.9), NuWest (–6.7), Idaho 377s (–5.0), and the high-quality alkaline noodle flour from Japan (–5.5). Most of the decline in *L** values occurred during the first 2 hr of aging. The decreased rate of darkening of some doughs indicated reduced levels of polyphenol oxidase in their flours. This enzyme occurs predominantly in the bran of wheat (Kim et al 1991), so browning of the noodle dough from KS96HW115 flour of 70% extraction would likely be higher than that of its 65% extraction flour. Another possibility is that the KS96HW115, NuWest, Idaho377s, and the Japanese noodle flour contained increased levels of bleaching enzymes such as lipoxygenase that release hydrogen peroxide. However, the initial (0.1 hr) yellowness values of NuWest (*b** 20.2), Idaho 377s (*b** 21.7), and the Japanese commercial (*b** 20.6) noodle doughs were the highest among the various doughs (Table II). If bleaching enzymes were the cause of extra lightness (*L**) in noodle doughs, the yellowness should have been reduced.

Yellowness (*b**) of freshly made (0.1 hr) alkaline noodle dough sheets was high, as already stated, for NuWest, ID 377s, and the Japanese alkaline noodle flours; low for Betty and Karl 92; and intermediate for the other flours. Aging the dough sheets for 24 hr at room temperature increased *b** by 10–14 units for all samples, except for the Japanese commercial flour, because of increased browning over the first 2 hr especially.

White salt-noodle dough sheets made from 65% extraction flours of KS96HW115 and Idaho 377s white wheats also were brighter than those from the 60% extraction flours of Jagger and Ike red wheat (Table III). Freshly made salt-noodle doughs showed lower *L** values and higher *b** values than alkaline-noodle doughs, but after 24 hr of aging, the salt noodles had higher *L** values and similar or lower *b** values.

Cooking Quality and Cooked Texture of Noodles

Cooking losses of raw alkaline noodles were 5–15 percentage points higher than losses for raw salt noodles made from the same flours (Tables II and III), both calculated based on the dry solids in raw noodles. Yet the yields of the two types of noodles, excluding those from the commercial noodle flours, were similar (means 340 and 347%, respectively) for salt and alkaline noodles. Over 80% of sodium chloride is lost from a cooked white salt-noodle (Liang 1999), which would account for about one-third of the average cooking loss of 5.1%. The loss of sodium carbonate from an alkaline noodle during cooking is not known. Sodium chloride restricts the swelling of starch (Rutenberg and Solarek 1984), and sodium carbonate may be even more effective in reducing starch swelling than an equal weight of sodium chloride (Moss et al 1986). Somehow, the alkaline salt is able to boost the uptake of water in the cooked noodle.

From a mass balance using the mean cooked yields (alkaline 347%, salt 340%, based on 87 or 88 g of dry solids in noodles) and mean cooking losses (alkaline 15.5%, salt 5.1%), and assuming that both salts are lost completely into the cooking water, the average moisture content of cooked alkaline noodles was 76% compared with an average of 72% for cooked salt noodles. The alkaline noodles may contain increased void volume where extra water resides upon cooking. Voids have been found in noodles (Moss et al 1987), and a higher average yield (219%) of cooked alkaline noodles (0.9% sodium and 0.1% potassium carbonate) was reported by Moss et al (1986) for five (hard and soft) wheat flours compared with the average (192%) of salt (1.0% sodium chloride) noodles. Those yields, which were calculated based on the wet weight of noodles made at 32% absorption, are in the same order of magnitude found in this work (means of 223 and 220% for raw alkaline and salt-noodles). The authors did not report cooking loss or moisture content in the cooked noodles. In our study, yields of cooked salt and alkaline noodles were elevated for the partial waxy wheats, OroBlanco, Idaho 377s, and Ike, and also for the wild types KS96HW115 (salt) and NuWest (alkaline). The yield of cooked salt noodles from the commercial salt noodle flour was much higher (356 vs. 295) than for the alkaline noodles made from the commercial alkaline noodle flour (Tables II and III). Also, the cooking yield of the alkaline noodles made from the commercial alkaline noodle flour was lower than for the experimental flours (Table II). Perhaps the finer granulation of the commercial noodle flour compared with those milled in the laboratory (Fig. 1) (Jun et al 1998) gave noodles with fewer voids than the experimental flours.

Tensile testing was used to estimate the texture properties of the cooked noodles. High values of tensile strength and breaking distance in noodles are associated with noodle-eating texture (Guan 1998). The cooked alkaline noodles were generally stronger (50–116 *g*-force) than the cooked salt noodles (33–58 *g*-force), which agrees with the cutting stress data of Hatcher et al (1999). Alkaline noodles made from the high protein (12.6%) Ike flour showed the highest tensile strength (116 *g*-force) and the highest breaking length (40 mm), whereas those made from the low protein (8.1%) ID377s flour had the lowest tensile strength (50 *g*-force) and lowest breaking strength (26 mm). Noodles made from experimental white wheat KS96HW115 also showed a somewhat low tensile strength and breaking length, whereas those made from other wheats were intermediate. Interestingly, alkaline noodles made from the Japanese commercial flour had intermediate tensile strength but a high breaking length.

The high tensile strength of alkaline noodles made from Ike 12.6% protein flour appears to be linked to the high swelling power of its starch, which during cooking would cause release of some amylose from inside the swollen starch granules. The amylose released in between starch granules would gel when the noodles were cooled, which would add to the elastic nature of the cooked noodle. The amylose also could form strong bonds between the gluten strands that form the dough network, thereby strengthening the network as proposed for noodles by Ross et al (1997) and for bread by Martin and Hoseney (1991). Contrary to our instrumental data, sensory analysis has indicated that alkaline noodle flours in Japan should contain low to moderately low-swelling starches (Crosbie et al 1999).

Surprisingly, the white salt noodles prepared from high-swelling Ike flour (protein 12.6%) did not have higher tensile strength than those made from low-swelling Jagger, Betty, and Heyne flours (protein 12.6–12.8%). Moreover, the compressive strength of the salt noodles made from Ike flour was low compared with those made from flours of all other wheats except Idaho 377s. The hot water swelling powers of Jagger, Betty, and Heyne flours (15.0–15.5 g/g) were ≈25% below that of Ike flour (21.0 g/g). Somehow, in the high protein Ike flour, the swelling of starch added no further tensile strength to the sodium chloride noodle, but did to the sodium carbonate noodle. The protein in cooked noodles would be expected to increase tensile strength. However, upon denaturation by cooking, the contribution of protein to noodle strength may depend mostly on the level present.

Ross et al (1997) made alkaline noodles from 62 Australian white wheat flours with 10.4–11.1% protein, 37 from 15 lines with a full complement (wild type) of waxy proteins, and 25 from 10 lines null for the *Wx-1B* allele. Flour swelling volumes at 93°C were 18.3 mL/g for the null lines versus 14.1 mL/g for the wild types. A taste panel concluded that the alkaline noodles from the high-swelling flours had reduced firmness and elasticity but had improved surface smoothness. The difference in the results of that group and our results may be due to the ≈2% lower protein in the Australian flours. Reducing the protein in a flour would be expected to elevate the influence of starch swelling properties on the texture of the cooked noodles.

CONCLUSIONS

From the standpoint of noodle color, the most promising hard white winter wheat from Kansas is the line KS96HW115 due for release in 2000. That line, thought to be low in polyphenol oxidase, gave alkaline and salt noodles with reduced tensile strength, although that may have been a consequence of the somewhat low level of protein (11.3%) in the one sample of flour tested. The line KS96HW115 is a wild type with all three waxy proteins, and its flour showed low swelling power. Further comparison of KS96HW115 samples with variable protein levels to double nulls such as Ike wheats are needed to determine whether the latter have tensile and compressive strength advantages for alkaline noodles over wild type wheats.

ADDENDUM

The white wheat line KS96HW115, which is a hard winter wheat, was released by the State of Kansas with the name “Lakin”.

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