Role and Contribution of Starch and Protein Contents and Quality to Texture Profile Analysis of Oriental Noodles[1]

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Cereal Chem. 71(4):315-320

ABSTRACT

Starch characteristics (swelling power and amylograph values) and protein content and properties (sodium dodecyl sulfate sedimentation, mixograph, and alveograph values) of 12 flours, including Japanese and Chinese noodle standards, were determined and then related to textural properties of three types of oriental noodles (udon, Cantonese, and instant). Noodle texture was evaluated by texture profile analysis (TPA) using the Instron universal testing machine. High starch swelling power and amylograph peak viscosity and breakdown are prerequisites in production of satisfactory Japanese udon noodles, provided the protein is not excessively high or strong (as in the cv. Klasic). In the other types of oriental noodles, the starch characteristics may not be critical, but protein that is relatively higher or stronger than that in udon noodles is desirable. TPA of noodles, except for adhesiveness, was a sensitive and reproducible objective test for the evaluation of textural properties of oriental noodles. Multivariate analysis of variance of five TPA parameters effectively differentiated between the various wheat flours for production of the three main types of noodles. Both protein content and protein quality parameters were highly correlated with TPA parameters. TPA parameters were more highly and more meaningfully correlated with sodium dodecyl sulfate sedimentation values than they were with protein content. The results suggest that both protein content and protein quality should be considered in the evaluation of suitability of flours for making oriental noodles.

Oriental noodles differ widely in many aspects such as ingredients, mode of preparation, size of strand, color, texture, and type of noodle. Consequently, different tests and different requirements are necessary to predict the suitability of wheats and flours in making oriental noodles.

Flour properties related to the production of oriental noodles include: 1) wheat hardness and milling properties, such as particle size and flour yield (Toyokawa et al 1989b, Konik et al 1992); 2) starch characteristics, including amylose-amylopectin ratio, starch pasting properties, and swelling power (Toyokawa et al 1989b, Crosbie 1991, Crosbie et al 1992, Konik et al 1992); 3) protein content and protein quality parameters, such as sodium dodecyl sulfate sedimentation, mixograph, and alveograph values (Oh et al 1985a,b; Huang and Morrison 1988; Konik et al 1992); and 4) color characteristics, including pigmentation and discoloration (Moss 1971, Oh et al 1985a, Kruger and Reed 1988).

Because texture is a critical characteristic of oriental noodles (Toyokawa et al 1989a), and both starch (Nagao et al 1977, Oda et al 1980, Toyokawa et al 1989a, Crosbie 1991) and protein (Oh et al 1985 a,b) play a major role in governing textural properties, their contribution to noodle texture is of great importance. Sensory testing of noodle texture is a direct and ultimate method for evaluating the final product. For some purposes, however, such as screening large numbers of plant breeder's samples and understanding the role of specific components that govern textural properties of noodles, the sensory test is unrealistic.

This article describes a texture profile analysis (TPA) using an Instron universal testing machine (UTM) as an objective test to evaluate noodle texture. Based on the textural characteristics, as determined by TPA, the role and contribution of both starch and protein to the texture of oriental noodles are evaluated.

MATERIALS AND METHODS

Materials

Three cultivars of soft white winter (SWW) wheat and three cultivars of club wheat, grown in four locations in the state of Washington in 1991–92, were blended according to cultivar. Wadual, a dual-purpose SWW cultivar, was a composite of 10 isogenic lines grown in Royal Slope, WA, in 1990. A hard white spring (HWS) wheat was grown in the state of Montana in 1991. Two samples of the HWS cultivar Klasic, obtained from wheat growers, were grown in two locations in the state of Washington in 1992.

Wheat samples were milled to about 60% flour extraction on a Buhler experimental mill. Two commercial wheat flours (Chinese noodle standard and Japanese noodle standard) were obtained from Nisshin Flour Milling Company, Tokyo, Japan, through the Washington Wheat Commission, Spokane, WA.

Analytical Methods

Approved method 44-15A (AACC 1983) was used to measure moisture contents of samples. Protein (N × 5.7) was determined by combustion with a nitrogen determinator (Leco Corporation, St. Joseph, MI).

Near-infrared spectroscopy (NIRS) hardness of wheat flours was determined by the Technicon 400 InfraAnalyzer (Bran + Luebbe, Inc., Buffalo Grove, IL).

Alkaline water-retention capacity test was performed according to the procedure of Kitterman and Rubenthaler (1971).

The sodium dodecyl sulfate (SDS) sedimentation test was performed according to the procedure of Axford et al (1979), with some modifications. The test was performed on a constant protein (300 mg) basis rather than a constant weight (5 g) basis as in the original SDS sedimentation test. The original test does not differentiate between high-protein strong flours, which all have very high SDS sedimentation values. When the test is performed on a constant protein basis, satisfactory differentiation between all flours is possible. However, results on a constant protein basis have to be converted to a constant weight basis, as all other tests are run on a constant weight basis.

The procedure of Crosbie (1991) was used to determine the swelling power of primary starch. Primary starch was prepared by the gluten hand-washing method (AACC approved method 38-10). Each washed-out starch was purified three times by washing with distilled water and by centrifugation.

Amylograph

Thermal properties of starch were determined with a Brabender amylograph by a modification of the method of Shuey and Tipples (1980). Starch (40 g, dry basis) was suspended in 450 ml of distilled water. The starch slurry was heated at a rate of 1.5°C/min from 30°C to the temperature at which a peak in the pasting curve

[1]Presented at the AACC 78th Annual Meeting, Miami Beach, FL, October 1993.

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TABLE I
Characteristics of Wheat Flours

Samples	NIRS[a] Hardness Score	Protein (%)	SDS[b] (ml)	AWRC[c] (%)	Mixogram Mixing Time (sec)	Alveograph *W*
Soft White						
Nugaines	27.8	10.1	42.8	57.3	180	140
Daws	37.8	10.5	42.1	60.6	160	148
Stephens	31.8	10.6	32.8	53.9	150	87
White Club						
Tres	39.4	10.5	17.3	53.1	75	29
Hyak	40.4	10.8	40.4	56.1	170	173
Rely	38.9	10.1	24.6	53.2	100	55
Wadual	31.9	13.5	53.4	53.5	180	236
Hard white spring	72.4	13.7	51.7	70.0	150	322
Japanese noodle standard	42.2	10.3	32.5	70.2	255	195
Chinese noodle standard	59.1	13.1	43.8	76.5	240	332
Klasic 1	28.6	13.9	82.1	81.3	375	443
Klasic 2	27.3	13.7	87.2	79.7	390	454

[a] Near-infrared reflectance spectroscopy.
[b] Sodium dodecyl sulfate sedimentation volume.
[c] Alkaline water-retention capacity.

TABLE II
Swelling Power and Amylograph Values of Starches

Samples	Swelling Power (%)	Amylograph Values, BU	
		Peak Viscosity	Breakdown
Soft White			
Nugaines	13.6	620	0
Daws	13.0	600	0
Stephens	13.0	520	0
White Club			
Tres	13.7	640	10
Hyak	12.9	580	10
Rely	13.5	610	10
Wadual	14.3	760	10
Hard white spring	12.5	520	0
Japanese noodle standard	17.2	800	60
Chinese noodle standard	13.8	620	20
Klasic 1	17.9	710	110
Klasic 2	17.2	790	190

appeared. That temperature was maintained for 30 min, then the starch slurry was cooled at a rate of 1.5°C/min to 50°C and held at that temperature for 30 min. Peak viscosity and breakdown data were obtained from the pasting curve.

Mixogram

A 10-g mixograph (National Mfg., Lincoln, NE) was used to determine the mixing characteristics of the flours used in this study (AACC method 54-40A).

Alveograph Measurements

The alveograph test was performed according to the AACC method 54-30. For data recording, a pressure transducer was connected to the tube between the alveograph chamber and the manometer, according to the method of Addo et al (1990). The transducer output was read under computer control, and the alveograph parameters were recorded.

Noodle Making

For each of the three types of noodles, 300 g of flour (14% moisture basis) was mixed to 33% absorption with a salt or alkaline solution. Udon noodles were made according to a modification of the method of Toyokawa et al (1989a). Flour (300 g) and 99 ml of a 6.25% sodium chloride solution were mixed in a Hobart mixer for 30 sec at slow speed and then for 4 min at medium speed. The dough was passed through the rollers of a noodle machine (Ohtake Noodle Machine Mfg. Co., Tokyo, Japan) at a 3-mm gap; it was then folded and put through the sheeting rolls twice. The dough sheet was rested for 1 hr and then put through the sheeting rolls three times at progressively smaller gap settings of 2.60, 2.33, and 2.00 mm. The sheet was cut through no. 12 cutting rolls into strips ~30 cm in length, with a 0.3- × 0.2-cm cross-section.

Ingredients for making Cantonese noodles included 300 g of flour and 99 ml of an alkaline solution (2.7% sodium carbonate and 0.3% potassium carbonate). For making instant noodles, 300 g of flour and 99 ml of a brine solution (5.18% sodium chloride, 0.26% sodium carbonate, and 0.26% potassium carbonate) were used. A procedure similar to that for making udon noodles was employed to prepare Cantonese and instant noodles, except for the reduction step of the noodle dough sheet. The noodle dough sheet was reduced four times at progressively smaller gap settings of 2.60, 2.33, 2.00, and 1.50 mm to make Cantonese noodles and 2.60, 2.33, 2.00, and 1.20 mm to make instant noodles. Both Cantonese and instant noodle dough sheets were cut through no. 20 cutting rolls with 1.5-mm grooves. Fresh instant noodles were steamed at atmospheric pressure for 3 min and fried in palm oil at 148°C for 1 min. Free lipids in instant noodles were determined by exhaustive extraction in a Soxhlet apparatus with petroleum ether and evaporation of solvent. Noodles were kept in plastic bags and stored at 4°C until cooked.

UTM Tests of Cooked Noodles

Noodles (30 g) were cooked in 1 L of boiling distilled water (18 min for udon, 6 min for Cantonese, or 4 min for instant noodles) and rinsed with cold water. Three replicates of cooked udon noodles (two replicates for both Cantonese and instant noodles) were prepared. Each time, three replicates of UTM measurements were taken within 5 min after cooking. TPA of cooked noodles was performed according to the procedure of Peleg (1976) with a UTM (model 1350, Instron Corp., Canton, MA) fitted with a 90-kg load cell. The test was performed at a maximum load of 24.5 N and a crosshead speed of 0.8 mm/sec. A set of five strands of cooked noodles was placed parallel on a flat metal plate and, using the 5-mm metal blade attached to the UTM, they were compressed crosswise twice in the same place to 70% of their original height. Thinner blades (3 mm) had a cutting rather than compressing action; compression to 50% did not differentiate well between samples; and compression to 90% had an undesirable cutting action. From the force-time curve of TPA, the hardness (height of the peak) and the springiness (recovered height after first compression) were determined. Adhesive force was the negative force between the first and the second peak. Additional textural parameters were calculated using equations of Bourne (1968) and Peleg (1976). Cohesiveness is the ratio between the area under the second peak and the area under the first peak; gumminess is the product of hardness and cohesiveness;

and chewiness is the product of gumminess and springiness. The relationship between textural and sensory properties of oriental noodles was the subject of a study by Oh et al (1983).

Statistical Analysis

Data were statistically analyzed with a computer software package (SAS 1986) using analysis of variance, Fisher's least significant difference (LSD) procedure, Pearson correlation coefficient, and multivariate analysis of variance (MANOVA). All determinations were made at least in duplicate and all were averaged.

RESULTS AND DISCUSSION

Flour Characteristics

Flour characteristics, which are related directly or indirectly to protein contents and protein quality, are summarized in Table I.

The NIRS hardness score (a reflection of particle size) was highest in the HWS sample (72.4). Soft white winter (SWW), club, Wadual (SWS), and two samples of Klasic showed relatively low NIRS hardness scores. NIRS hardness values of the two standard flours (Japanese and Chinese) were highest except for HWS. Low NIRS scores were observed in the two samples of the Klasic wheat, which is known to vary widely in wheat hardness.

Protein contents of flours fell into two groups: 1) ranging from 10.1 to 10.8% in soft white and club wheats and comparable to the Japanese noodle standard (10.3%); and 2) ranging from 13.5 to 13.9% in Wadual, the sample of HWS, and the two samples of Klasic and comparable to the protein content in the Chinese noodle standard (13.1%).

SDS sedimentation volume is affected by both protein content and protein quality. SDS sedimentation volumes (constant weight basis) of flours were low in soft white, club wheats, and the Japanese noodle standard, and they were high in Wadual, the sample of HWS, and the two samples of Klasic. Large variations in SDS sedimentation were observed among flours that were similar in protein content (HWS and Klasic or Daws and Stephens), indicating that their protein qualities were different.

Alkaline water-retention capacity (an index of protein quality) ranged from 53.1 to 60.6% in soft white, club, and Wadual (SWS), and it ranged from 70.0 to 81.3% in the rest. Interestingly, Wadual, which was high in protein content, showed a relatively low alkaline water-retention capacity value; the opposite was observed in the Japanese noodle standard.

Mixograph mixing times of SWW, club, Wadual, and the HWS wheat flours were 180 sec or below. The two Klasic samples required the longest mixing time. Mixograph mixing times of the two standard flours were intermediate and similar, and much longer than those of SWW, club wheats, Wadual, and HWS.

Alveograph W values represented two groups: those up to 195 (the Japanese noodle standard) and those above 195 (including the Chinese noodle standard at 332). Alveograph W values of flours were correlated with protein contents and SDS sedimentation volumes; W values were relatively low in SWW and club wheat (except for Hyak) and high in Wadual, the HWS, and especially, the two Klasic wheats.

As expected, the two club wheats (Tres and Rely) showed low SDS sedimentation values, mixogram mixing times, and alveograph W values. Unusually high values for those three parameters were found in Hyak.

Swelling Power and Amylograph Parameters of Primary Starch

Swelling powers of starches showed small differences among the three SWW, the three club wheats, Wadual, the HWS, and the Chinese noodle standard; the range was 12.5–14.3% (Table II). High, similar values (17.2–17.9%) were observed in the starches of the Japanese noodle standard and the two Klasic samples.

Amylograph peak viscosity and breakdown of starches (obtained from amylogram curves) are summarized in Table II. Peak viscosity and breakdown were low in starches of the soft white and club wheats, HWS, and Chinese noodle standard. Wadual had a high peak viscosity but not a substantial breakdown. The two Klasic samples resembled the Japanese noodle standard both in peak viscosity and in breakdown.

There were significant correlations between swelling power and amylograph peak viscosity ($r = 0.841$, $P < 0.001$) and between swelling power and breakdown of starch ($r = 0.845$, $P < 0.001$), which is in agreement with the report of Crosbie (1991). Interestingly, both the swelling power and the amylograph parameters of the Chinese noodle standard were significantly lower than those of the Japanese noodle standard.

TPA of Oriental Noodles

Parameters for udon, Cantonese, and instant fried noodles, obtained from TPA of cooked oriental noodles, are summarized in Tables III–V. TPA using the UTM was sensitive and reproducible; coefficients of variation were less than 8% among replicates for the TPA parameters, except for adhesive force. Variability in surface conditions of the UTM attachment and of cooked noodles make it difficult to obtain reproducible data for adhesive force. TPA parameters of cooked noodles varied considerably

TABLE III
Texture Profile Analysis Parameters[a] for Cooked Udon Noodles

Noodle	HD (N)	AD (N)	CO Ratio	SP (mm)	GU (N)	CH (N·mm)
Soft White						
Nugaines	18.6	−0.269	0.334	1.43	6.21	8.86
Daws	19.2	−0.312	0.336	1.40	6.42	8.96
Stephens	17.5	−0.211	0.329	1.34	5.74	7.71
White Club						
Tres	16.2	−0.185	0.321	1.22	5.17	6.27
Hyak	20.1	−0.247	0.313	1.46	6.29	9.16
Rely	17.7	−0.275	0.301	1.31	5.33	6.95
Wadual	22.2	−0.249	0.361	1.45	8.00	11.61
Hard white spring	21.0	−0.283	0.357	1.58	7.52	11.85
Japanese noodle standard	18.5	−0.228	0.319	1.37	5.88	8.03
Chinese noodle standard	21.1	−0.243	0.338	1.53	7.13	10.88
Klasic 1	22.2	−0.176	0.398	1.35	8.91	12.00
Klasic 2	22.3	−0.123	0.391	1.52	8.69	13.61
LSD[b]	0.80	0.0589	0.0170	0.054	0.252	0.478

[a] HD = hardness; AD = adhesive force; CO = cohesiveness (ratio between area under the second peak and area under the first peak); SP = springiness; GU = gumminess; CH = chewiness.
[b] Least significant difference ($P = 0.05$). Differences between two means exceeding this value are significant.

TABLE IV
Texture Profile Analysis Parameters[a] for Cooked Catonese Noodles

Noodle	HD (N)	AD (N)	CO Ratio	SP (mm)	GU (N)	CH (N·mm)
Soft White						
Nugaines	13.5	−0.202	0.385	0.98	5.17	5.06
Daws	13.1	−0.222	0.401	0.98	5.24	5.16
Stephens	12.1	−0.160	0.393	0.94	4.77	4.49
White Club						
Tres	11.7	−0.139	0.398	0.85	4.65	3.94
Hyak	13.8	−0.230	0.392	1.05	5.42	5.65
Rely	12.6	−0.181	0.393	0.88	4.96	4.35
Wadual	17.9	−0.219	0.439	1.14	7.85	8.97
Hard white spring	15.4	−0.348	0.417	1.09	6.40	6.95
Japanese noodle standard	13.4	−0.171	0.399	0.92	5.34	4.89
Chinese noodle standard	15.0	−0.281	0.419	1.07	6.29	6.74
Klasic 1	16.7	−0.137	0.448	1.03	7.47	7.72
Klasic 2	16.6	−0.150	0.452	1.06	7.51	7.95
LSD[b]	0.78	0.0328	0.0092	0.048	0.333	0.423

[a] HD = hardness; AD = adhesive force; CO = cohesiveness (ratio between area under the second peak and area under the first peak); SP = springiness; GU = gumminess; CH = chewiness.
[b] Least significant difference ($P = 0.05$). Differences between two means exceeding this value are significant.

among the cultivars, which indicated that the parameters reflected textural differences of noodles.

When the udon noodles were made from the high-protein dual-purpose Wadual, the HWS, the Chinese noodle standard, or the two Klasic samples, they had higher scores for hardness, cohesiveness, gumminess, and chewiness. Those of the low-protein SWW and club wheats, including the Japanese noodle standard, had lower values (Table III). Springinesses did not differ consistently between the hard and the soft wheats. Unusually high values of hardness and chewiness in Hyak (club) were considered to be mainly due to its strong protein characteristics. The Japanese noodle standard was close to SWW wheat flours with regard to hardness, cohesiveness, springiness, gumminess, and chewiness.

Textural properties of Cantonese noodles showed trends similar to those of udon noodles: higher scores of TPA parameters for Wadual, the HWS, the Chinese noodle standard, and the two Klasic samples than for SWW and club wheats and the Japanese noodle standard (Table IV). When the Chinese standard was considered as standard for the Cantonese noodle, the HWS (based on TPA parameters) was closest to the Chinese noodle standard.

While TPA parameters of instant noodles showed general trends similar to those of both udon and Cantonese noodles, their individual scores varied more widely among the samples than did those of udon and Cantonese noodles, probably due to effects of more complex modes of processing, including steaming and frying (Table V). Thus, for instance, standard deviation of hardness among the samples in instant noodles was 2.96, compared with 1.98 in udon and 1.98 in Cantonese noodles. With regard to TPA parameters, the Chinese noodle standard flour yielded noodles similar to those of both Wadual and the HWS.

TABLE V
Texture Profile Analysis Parameters[a] for Cooked Instant Fried Noodles

Noodle	HD (N)	AD (N)	CO Ratio	SP (mm)	GU (N)	CH (N·mm)
Soft White						
Nugaines	14.1	−0.509	0.288	0.92	4.02	3.73
Daws	15.4	−0.487	0.316	0.96	4.84	4.63
Stephens	12.8	−0.513	0.281	0.86	3.59	3.04
White Club						
Tres	11.7	−0.492	0.258	0.81	3.00	2.43
Hyak	16.6	−0.476	0.309	1.03	5.13	5.25
Rely	12.4	−0.521	0.235	0.88	2.91	2.57
Wadual	19.8	−0.638	0.370	1.06	7.34	7.75
Hard white spring	18.9	−0.606	0.333	1.01	6.33	6.36
Japanese noodle standard	15.9	−0.482	0.248	0.99	3.92	3.84
Chinese noodle standard	19.2	−0.475	0.355	1.10	6.81	7.47
Klasic 1	18.6	−0.495	0.396	1.22	7.38	9.00
Klasic 2	19.2	−0.516	0.394	1.18	7.56	8.91
LSD[b]	1.16	0.1118	0.0304	0.100	0.520	0.699

[a] HD = hardness; AD = adhesive force; CO = cohesiveness (ratio between area under the second peak and area under the first peak); SP = springiness; GU = gumminess; CH = chewiness.

[b] Least significant difference ($P = 0.05$). Differences between two means exceeding this value are significant.

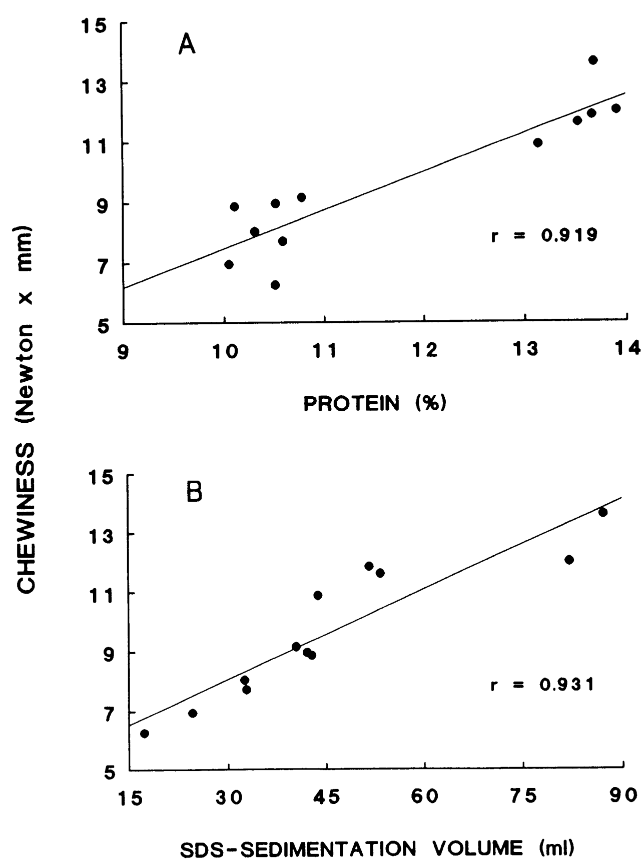

Fig. 1. Texture profile analysis (using the Instron universal testing machine) measuring relationships between protein contents (**A**) and sodium dodecyl sulfate (SDS) sedimentation values (**B**) of flours and the chewiness of cooked udon noodles.

Effect of Starch on Noodle Texture

Several investigations reported that starch pasting properties, including high peak viscosity (Moss 1980, Crosbie 1991, Crosbie et al 1992), high breakdown (Oda et al 1980), and swelling power (Endo et al 1988), are responsible for superior noodle quality. Similarly, starch swelling power and swelling volume were highly correlated with softness, elasticity, and total texture score in the white Japanese noodles (Crosbie 1991). There is, however, little evidence that the role of starch is equally as important in the other types of noodles. Statistical analysis of the correlations between starch properties (swelling power and amylograph parameters) and TPA textural properties provided little insight into those relationships. In all three types of noodles, the TPA better reflects the contributions of protein to texture than it does the contributions of starch to texture. For example, of the 30 linear correlation coefficients between any of the five TPA parameters and either peak viscosity or breakdown for the three types of noodles, 12 were insignificant and 18 were significant at the 5% level only. On the other hand, of the 60 linear correlation coefficients between any of the five TPA parameters and protein content, SDS, mixograph mixing time, and alveograph *W* values for the three types of noodles, three were insignificant and seven were significant at the 5% level; 50 were significant at the 1% level. Also, low values of starch swelling power and amylograph parameters in the Chinese noodle standard (Table II) indicate that, while high starch pasting properties and swelling power may be responsible for high quality of Japanese white, salted udon noodles, they may be less critical in governing the quality of Cantonese and instant noodles.

Effect of Protein Content and Protein Quality on Noodle Texture

Figure 1A shows the linear relationship between flour protein content and chewiness of cooked udon noodles. Chewiness is the product of (hardness × cohesiveness) × springiness; it is thus a single parameter that incorporates three of the important textural characteristics. While there is a high correlation for the total range, when the two groups (which were significantly different in protein contents) are considered separately, the power of predicting chewiness on the basis of the protein content is insignificant, especially for the low-protein flours. A more meaningful linear relationship is illustrated between SDS sedimentation volume and chewiness of cooked udon noodle (Fig. 1B). Similar results were obtained for the other two types of noodles. SDS-sedimentation values of flours are affected by protein content and protein quality. The relationships between SDS sedimentation and chewiness of udon noodles were higher than those between protein content and chewiness of udon noodles, which supports the hypothesis that both protein content and protein quality should be considered in predicting the textural properties of noodles.

MANOVA for Starch Properties, Flour Characteristics, and TPA Parameters

Some starch properties and protein content and protein quality parameters (SDS sedimentation volume, mixograph mixing time, and alveograph *W* value) were correlated with most TPA parameters in all three types of noodles. There was no significant correlation between alkaline water-retention capacity of flours and TPA parameters of noodles. Linear correlations between individual starch or protein parameters and TPA parameters reflect, however, only some of the desirable textural properties of oriental noodles. Therefore, to select flour samples that are closest to standard flours, based on multidependent variables, MANOVA was performed using computer software (GLM with CONTRAST, SAS 1986) on starch and protein characteristics and on TPA parameters.

Starch properties of flours were compared to those of the Japanese and Chinese noodle standard flours, based on their swelling power and amylograph peak viscosity. In these comparisons, the lower the *F* value, the closer the similarity to the standard. As expected (Table II), only Klasic 2 was not different from the Japanese noodle standard (Table VI). Compared to the Chinese noodle standard, no differences were found among Nugaines, Tres, and Rely (Table VI).

Flour samples were compared to the two standard flours (Japanese and Chinese noodle standard) with regard to three protein characteristics (content, SDS sedimentation volume, and mixograph mixing time) by MANOVA test. Alveograph *W* value was not included in the MANOVA of flour characteristics because the alveograph test requires relatively large amounts of sample (250 g) and is significantly affected by the water absorption capacity of a flour. Also, inclusion of alveograph *W* value in the MANOVA test did not improve differentiation among flours. The *F* values from each comparison are given in Table VII. When the three protein characteristics are considered, all flours are significantly different from the corresponding standards. Still, compared to the Japanese noodle standard, relatively low *F* values were observed for SWW wheats, with the lowest *F* value for Stephens. Compared to the Chinese noodle standard, both Wadual and the HWS had relatively small *F* values.

In the MANOVA for TPA parameters, each flour sample was compared to standard flours (Japanese noodle standard for udon noodles and Chinese noodle standard for both Cantonese and instant noodles) with regard to five parameters (hardness, cohesiveness, springiness, gumminess, and chewiness) in the three types of oriental noodles. The *F* values of MANOVA are reported in Table VIII. For udon noodles, small *F* values were found between the three SWW wheats and the Japanese noodle standard. Notably, Stephens was not different from the Japanese noodle standard. For Cantonese noodles, no difference was found between the HWS and the Chinese noodle standard. Thus, the results of MANOVA for TPA parameters were consistent, except for Klasic, with the results of MANOVA for the three protein characteristics (Table VII). It would seem that the steaming and frying processes reduced some source of the variability among flours while they decreased reproducibility. Consequently, Stephens, Tres, and Rely are significantly different from the Chinese noodle standard, and Nugaines and Daws have relatively high *F* values that are similar to that of the Japanese noodle standard.

The SWW and club samples, except for Hyak, were similar in protein contents and starch characteristics. The protein strength in Hyak was higher than that in the other club wheat flours. The limitation of the SWW and club wheats in production of udon noodles is that peak viscosity and breakdown are too low. The low protein contents and strength of the SWW and club wheats disqualifies them for production of Cantonese and instant noodles. Wadual, HWS, and Klasic are inadequate for production of udon noodles: the first two because of inadequate starch characteristics, and Klasic because of excessive protein strength. For production of Cantonese and instant noodles, Klasic does not have adequate hardness and particle size expected from its protein content. This was expressed in the difference in free oil content

TABLE VI
***F* Values of MANOVA[a] for Swelling Power and Amylograph Peak Viscosity of the Starch**

Flours	Japanese Noodle Standard	Chinese Noodle Standard
Soft White		
Nugaines	304.38***[b]	0.03
Daws	396.42***	5.81*
Stephens	787.88***	112.45***
White Club		
Tres	251.95***	2.79
Hyak	460.70***	15.65***
Rely	342.04***	0.97
Wadual	11.50**	229.12***
Hard white spring	771.78***	105.73***
Japanese noodle standard	...	306.58***
Chinese noodle standard	306.58***	...
Klasic 1	118.21***	54.33***
Klasic 2	0.25	289.18***

[a] Multivariate analysis of variance.
[b] *, **, *** = significant at least at the 5, 1, and 0.1% level, respectively.

TABLE VII
***F* Values of MANOVA[a] for Three Flour Characteristics (Protein Content, Sodium Dodecyl Sulfate Sedimentation Volume, and Mixograph Mixing Time)**

Flours	Japanese Noodle Standard	Chinese Noodle Standard
Soft White		
Nugaines	104.02***[b]	1,039.70***
Daws	145.27***	804.30***
Stephens	43.53***	1,226.56***
White Club		
Tres	483.44***	2,670.12***
Hyak	156.40***	716.32***
Rely	225.87***	2,317.53***
Wadual	2,558.53***	183.95***
Hard white spring	2,552.31***	176.83***
Japanese noodle standard	...	1,441.29***
Chinese noodle standard	1,441.29***	...
Klasic 1	7,000.35***	2,588.31***
Klasic 2	7,675.95***	3,121.78***

[a] Multivariate analysis of variance.
[b] *** = significantly different at least at the 0.1% level.

TABLE VIII
***F* Values of MANOVA[a] for Five Texture Profile Analysis Parameters (Hardness, Cohesiveness, Springiness, Gumminess, and Chewiness) of Oriental Noodles**

Flours	Udon vs. Japanese	Cantonese vs. Chinese	Instant vs. Chinese
Soft White			
Nugaines	3.41*[b]	14.84**	3.23
Daws	2.93*	8.03**	3.58
Stephens	0.54	20.01***	4.61*
White Club			
Tres	19.84***	31.26***	6.18*
Hyak	4.43**	5.78*	1.48
Rely	6.29**	26.14***	4.66*
Wadual	31.05***	7.17*	0.42
Hard white spring	29.04***	0.19	0.54
Japanese noodle standard	...	14.47**	3.59
Chinese noodle standard	16.81***	...	...
Klasic 1	96.44***	6.91*	1.54
Klasic 2	67.16***	6.94*	0.57

[a] Multivariate analysis of variance.
[b] *, **, *** = significantly different at least at the 5, 1, and 0.1% level, respectively.

TABLE IX
Linear Correlation Coefficients for Instant Noodles

Samples	Protein vs. Hardness	Protein vs. Noodle Oil	Hardness vs. Noodle Oil
All	0.232 NS[a]	0.744**[b]	0.330 NS
Without Klasic	0.631*	0.658*	0.685*

[a] Not significant.
[b] *, ** = significantly different at least at the 5 and 1% level, respectively.

as affected by hardness and protein content. The free lipid contents in instant noodles produced from the 12 flours ranged from 17.1 to 27.9%. The linear correlation coefficients among the three parameters were affected by the protein content and particle size (as determined by NIRS hardness) and by the fact that Klasic was high in protein but low in hardness (Table IX).

CONCLUSIONS

Because each protein characteristic may provide different types of information about noodle texture, overall consideration of protein characteristics is mandatory for predicting noodle texture. Requirements for both starch and protein characteristics differ for different types of noodles, and all have to be met to produce good quality oriental noodles. Finally, two other characteristics are required before a cultivar can be considered suitable for release: wheat hardness (as reflected by flour particle size) and minimum discoloration.

Specifically, high amylograph peak viscosity and breakdown and high swelling power of starch are important for high-quality Japanese white, salted noodles. However, those starch characteristics may be less critical in other types of oriental noodles (such as Cantonese and instant).

TPA of noodles, determined using the UTM, was sensitive and reproducible as an objective test for the evaluation of textural properties (except for adhesiveness) of oriental noodles. MANOVA of five TPA parameters differentiated between textural characteristics among three types of oriental noodles (udon, Cantonese, and instant) made from 12 wheat flours (including two standards).

Both protein content and protein quality were highly correlated with TPA parameters. TPA parameters were more highly and more meaningfully correlated with the SDS sedimentation volumes (constant weight basis) than they were with protein content. The results suggest that both protein content and protein quality should be considered in the evaluation of suitability of flours in making oriental noodles. Protein content and several protein quality parameters, such as SDS sedimentation volume and mixograph mixing time, can be partial predictors of textural properties of oriental noodles.

ACKNOWLEDGMENT

The financial support of the Washington Wheat Commission is gratefully acknowledged. Wheat samples were provided by Cal F. Konzak, Department of Crops & Soils, Washington State University, and Robert E. Allan, USDA/ARS. Sung K. Ahn and J. Richard Alldredge (program in statistics at Washington State University) are thanked for critical review of the manuscript.

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[Received October 25, 1993. Accepted March 14, 1994.]