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Influences of Protein Characteristics on Processing and Texture of Noodles from Korean and US Wheats

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Abstract

Protein characteristics of Korean wheat were evaluated to determine the effects of protein content and quality on processing, and textural properties of white salted noodles compared to US wheat flours with various wheat classes and commercial flours for making noodles. Protein quality parameters, which were independent of protein content and included SDS sedimentation volume with constant protein weight, mixograph mixing time, and proportion of 50% 1-propanol insoluble protein, of Korean wheat flours with 2.2 + 12 subunits in high molecular weight glutenin subunit compositions were comparable to those of commercial flours for making noodles. Parameters related to noodle making, including optimum water absorption, thickness and color of noodle dough sheet, correlated with protein content and related parameters, including SDS sedimentation volume with constant flour weight, mixograph water absorption, and gluten yield. No significant relationship was found in protein parameters independent of protein content. The hardness of cooked noodles from Korean wheats was lower than that of US wheat flours compared to similar protein content of commercial noodle flours. Adhesiveness, springiness, and cohesiveness of cooked noodles from Korean wheats were similar to US wheat flours. Hardness of cooked noodles correlated with protein content and related parameters.

Key words: wheat, protein quality, white salted noodles

Introduction

Quality of white salted noodles depends largely on flour characteristics and on conditions used during noodle preparation because noodles are generally prepared from wheat flour, water, and salt through mixing, sheeting, and cutting processes (Oh et al. 1985a; Nagao 1992). There has been little information regarding the protein characteristics requirements of wheat for production of white salted noodles, although protein quality as related to bread baking has been extensively studied and well established. The evaluation of protein characteristics related to noodle making can help to develop wheat cultivars suitable for white salted noodles in breeding programs.

Wheat flour with around 10% protein content is acceptable for making white salted noodles (Nagao et al. 1977; Hou 2001). Protein content has a negative relationship with noodle color and a positive relationship with hardness of cooked noodles (Baik et al. 1994b; Hatcher et al. 1999; Kruger et al. 1994; Miskelly 1984; Miskelly and Moss 1985; Morris et al. 2000; Oh et al. 1985b; Ross et al. 1997; Toyokawa et al. 1989; Yun et al. 1996). Sedimentation volume and mixograph mixing time exhibits a positive relationship with the texture of cooked noodles (Baik et al. 1994b; Huang and Morrison 1988; Yun et al. 1996). Both protein content and protein quality, as determined by SDS sedimentation volume based on constant protein weight, mixograph mixing time, proportion of salt soluble protein, and score of HMW-GS compositions correlated with optimum water absorption of noodle dough and hardness of cooked white salted noodles (Park et al. 2003).

Korean wheat cultivars generally have high grain yield, early maturation, semi-dwarf, and moderate vernalization. Recently, enhancement of end-use quality of Korean wheat has been a very important consideration to increase consumption of Korean wheat products. Korean wheat has a unique genetic background related to protein; for example a high frequency of 2.2 + 12 subunits of high molecular weight (Hong and Park 1998). Several Korean wheat cultivars showed a similar texture of cooked noodles compared to commercial flours for noodle making in Korea and Japan (Park et al. 2002). However, little information is available

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for selecting wheat based on protein quality. Therefore, the objectives of this study were to determine the influences of protein content and quality on processing characteristics of flour and textural properties of noodles, and to elucidate protein quality of wheat suitable for or required for making white salted noodles through comparison with commercial noodle flours and US wheat flours with different protein contents and qualities.

Materials and Methods

Materials

Eight Korean wheat cultivars and 11 US wheat flours, including five soft wheats and six hard wheats, obtained from the Western Wheat Quality Laboratory (Pullman, WA) were used for this study. Korean wheat cultivars used in this study are leading winter cultivars with over 500kg/10 a grain yield in paddy, early June maturation, and ca. 70cm culm length. US wheat cultivars are cultivated in the Northwest US \with different protein content and quality. Wheat was milled using Bühler experimental mill, and flour of about 60% extraction was prepared by blending millstreams. Two commercial wheat flours, Com1 and Com2, suitable for making udon noodles, were obtained from Nissin Flour Milling (Tokyo, Japan). One commercial wheat flour for making Korean dry noodles (Com3) was provided by Dr. W. J. Park, U.S. wheat associates in Seoul, South Korea, through the wheat marketing center (Portland, OR, USA).

Analytical methods

Moisture and protein content of wheat flour were determined according to Approved Method 44-15A and 46-30 (AACC 2000). The SDS sedimentation test was performed according to the procedure of Baik et al. (1994a). The SDS sedimentation volume of flour was determined both on a constant flour weight (3g) basis and on a constant protein (300mg) basis. The flour mixing characteristics were determined using a 10 g mixograph (National Mfg. Co., Lincoln, NE, USA), according to the AACC Approved Methods 54-40A (AACC 2000). The proportion of 50% 1-propanol insoluble proteins of wheat flours was determined according to the procedures of Fu and Sapirstein (1996) with some modifications. Alcohol soluble protein was extracted from 5.0g (db) of flour at room temperature with 25.0, 15.0, and 10.0 ml of 50% (v/v) 1- propanol for 1, 0.5, and 0.5 hr with brief vortexing every 15 min, respectively. After centrifugation (3,000mg) for 10 min, the residue was washed two times with 15.0 and 10.0 ml of deionized and distilled water for 2 min. After centrifugation, the three, 50% 1-propanol residues were pooled and freeze-dried. Proportion of protein was calculated by protein content of lyophylized samples multiplied by the weight of flours. Wet gluten of wheat flours was isolated according Approved Methods 38-10 (AACC 2000). After they were lyophilized, the protein quantity of dry gluten was determined and multiplied by the weight of the gluten. The gluten yield was calculated by dividing the protein quantity of the isolated gluten by flour weight. To determine the composition of high molecular weight glutenin subunits (HMW-GS), protein was extracted from 40 mg of flour with 500$\mu\ell$ of extraction buffer [0.125 M Tris-HCl, pH 6.8, 1% (w/v) SDS, 6.7% (v/v) glycerol, 0.003% (w/v) bromophenol blue, and 5% (v/v) β-mercaptoethanol] by shaking for 2 hr at 23 °C. SDS-PAGE of HMW-GS was run according to the procedures described by Laemmli (1970). The separating gel (pH 8.3) was prepared from 12% SDS-polyacrylamide with 1.27% bisacrylamide. After running the SDS-PAGE for 12 hr at 20 mA/gel, the gel was stained overnight with a commassie blue R-250 and destained in 10% trichloroacetic acid. The HMW-GS subunits were evaluated with the scoring system proposed by Payne et al. (1987).

Noodle making and texture of cooked noodles

White salted noodles were prepared with optimum water absorption of noodle dough. The optimum water absorption for making white salted noodles was determined based on appearance of the dough and dough sheet, and handling properties of the dough sheet during the noodle making process by experienced personnel through trial and error. Commercial wheat flour, which required 35% absorption to make uniform, smooth, and nonsticky dough, was used as a reference for comparison to other flours during the determination of optimum water absorption for making noodles.

Flour (100g, 14% mb) was mixed with the predetermined amount of sodium chloride solution in a pin mixer (National Mfg. Co., Lincoln, NE, USA) for 4 min, with a head speed of 86 rpm. The concentration of sodium chloride solution for making noodles with different absorption was adjusted to have 2.0% sodium chloride in the noodle dough. Dough was passed through the rollers of a noodle machine (Ohtake Noodle Machine Mfg. Co., Tokyo, Japan) at 8 rpm and a 3 mm gap; dough was folded and put through the sheeting rollers. The folding and sheeting were repeated twice. The dough sheet was rested for 1 hr and then put through the sheeting rollers three times at progressively decreasing gaps of 2.40, 1.85, and 1.30 mm. Immediately after the last sheeting, the thickness of the dough sheet was measured by a micrometer dial thickness gauge (Peacock Dial Thickness Gauge G, Ozaki Mfg. Co., Ozaki, Japan). A piece of noodle sheet was placed in plastic bags for determination of color. The rest of the dough sheet was cut through no. 12 cutting rolls into strips about 30 cm in length. The color of the dough sheet was measured by Minolta CM-2002 (Minolta Camera Co., Ltd, Osaka, Japan) with an 11 mm measurement aperture. The color differences of noodle sheets were recorded as CIE-LAB L (lightness), a (redness-greenness), and b (yellowness-blueness) values. The rest of the dough sheet was cut through No. 12 cutting rollers into noodle strands of about 30 cm in length, with a 0.3×0.2 cm cross section.

Textural properties of cooked noodles

Raw noodles (20g) were cooked at the determined cooking time in 500 ml of boiling distilled water for 18 min and then rinsed with cold water. Two replicates of cooked noodles were evaluated by texture profile analysis (TPA) using a TA-XT2

Texture Analyser (Stable Micro Systems, Haslemeres, England) within 5 min after cooking. A set of five strands of cooked noodles was placed parallel on a flat metal plate and compressed crosswise twice to 70% of their original height using a 3.175 mm metal blade at a speed of 1.0 mm/sec. From force-time curves of the TPA, hardness, springiness, cohesiveness, and adhesiveness were determined according to the description of Park et al. (2002).

Statistical analysis

The statistical analysis of the data was performed by the SAS software (SAS Institute, Cary, NC, USA) using Fisher's least significant difference procedure (LSD), analysis of variance (ANOVA), and Pearson correlation coefficient. All data were determined at least in duplicate and all were averaged.

Results and Discussion

Protein characteristics of korean wheat flours

Protein characteristics of Korean wheats, US wheats with various classes and Com1, 2, and 3 are summarized in Table 1. Protein content of flours was 10.19-15.25% in Korean wheat flours, 8.94-12.20% in soft wheat cultivars, and > 13.59% in hard wheats, except in Nuwest (10.88%). Protein content of Uri (10.19%) was similar to that of Com1, 2, and 3 (10.10-10.79%). SDS sedimentation volume performed with constant flour weight (3.0g) of Korean wheat flours was higher (> 44.00 ml) than soft wheat flours (< 36.50 ml) and Com1, 2, and 3 (< 36.50 ml), which was similar to hard wheat flours (32.50-73.50 ml). SDS sedimentation volume with constant flour weight significantly increased as protein content increased in both Korean and US wheat flours. The difference in SDS sedimentation volume with constant protein weight (300mg), which is less influenced by protein content than SDS sedimentation test based on flour weight, was smaller than SDS sedimentation volume with constant flour weight. SDS sedimentation volume based on constant protein weight of Korean wheat flours was 39.00-58.50 ml and was similar to that of US wheat flours (31.50-46.00ml). SDS sedimentation volume with constant protein content of Eunpa, Geuru, and Uri was similar to Com1, 2, and 3 (38.50-40.00ml). Compared to wheat flours with similar protein content of US and commercial noodle flours, Korean wheat flours showed higher SDS sedimentation volume with constant flour weight and constant protein weight. There was no consistent difference in SDS sedimentation volume based on constant protein weight as protein content of flours increased in both Korean and US wheat flours.

Mixograph water absorption of Korean wheat flours (60.00-66.00%), except in Uri (53.00%), was higher than that of soft wheats (< 57.00%) and was similar to that of hard wheat flours (60.00-65.50%), except in Nuwest, which had 57.50% of mixograph

Table 1. Protein Characteristics of Korean wheats, US wheats with various classes, and commercial wheat flours for making noodles.

Class[a]	Cultivar	Protein (%)	SDSF[b] (ml)	SDSP[c] (ml)	Mixograph[d]		Proportion of 50PI Proteine(%)	Gluten Yield (%)	HMW-GS Compositions[f]		
					Abs (%)	Time (Sec)			Glu-A1	Glu-B1	Glu-D1
Korean	Alchan	12.03	75.50	58.50	60.00	375.00	37.34	7.83	2*	7+8	5+10
	Eunpa	15.25	64.50	39.00	62.50	180.00	31.09	10.31	N	7+9	2.2+12
	Geuru	13.23	56.00	39.00	61.00	145.00	33.15	9.13	N	7+8	2.2+12
	Jinpoom	11.37	55.50	45.50	60.00	180.00	31.79	7.75	N	7+8	2.2+12
	Keumkang	13.85	68.50	47.50	63.00	337.50	34.25	8.79	2*	7+8	5+10
	Olgeuru	11.60	58.00	47.50	60.50	172.50	30.68	7.61	2*	7+8	2.2+12
	Tapdong	14.63	75.00	49.50	66.00	320.00	35.91	10.23	2*	7+8	5+10
	Uri	10.19	44.00	43.00	53.00	202.50	32.68	6.14	N	7+8	2.2+12
US Soft	Alpowa	8.94	31.00	44.50	54.00	60.00	34.33	6.35	N	7+9	5+10
	OR939526	11.86	32.50	35.00	57.00	90.00	31.44	8.66	2*	7+9	2+12
	Stephens	12.20	32.50	34.00	57.50	85.00	29.93	8.75	2*	7+9	2+12
	Treasure	10.30	24.50	33.50	54.50	95.00	32.72	6.84	2*	6+8	2+12
	Vanna	11.66	36.50	40.50	57.00	85.00	32.37	7.91	1	17+18	2+12
US Hard	IDO377S	13.59	32.50	31.50	60.00	180.00	36.01	10.12	2*	17+18	5+10
	Klasic	14.89	44.00	40.00	62.00	330.00	37.66	11.66	1	17+18	5+10
	Nuwest	10.88	34.00	35.50	57.50	205.00	37.62	8.23	2*	7+9	5+10
	WA7839	16.91	69.00	44.00	65.00	195.00	36.22	12.93	2*	17+18	5+10
	Winsome	14.24	48.50	36.00	62.00	210.00	36.34	10.86	2*	17+18	5+10
	WPB926	17.45	73.50	46.00	65.50	200.00	35.39	12.91	2*	17+18	5+10
COM	Com1[g]	10.10	29.00	39.00	60.00	210.00	34.46	7.38	1	17+18	2+12
	Com2	10.17	30.00	38.50	60.00	225.00	34.39	7.77	1/2*	7+8/17+18	2+12/5+10
	Com3	10.79	36.50	40.00	60.00	197.50	34.10	7.78	1/2*	7+8	5+10
	LSD[h]	0.04	2.35	2.36	0.79	10.77	0.97	0.20	-	-	-

[a] Korea = Korean wheat; Soft = US soft wheat; Hard = US hard wheat; COM = Commercial noodle flours for white salted noodles.
[b] SDSF = SDS sedimentation test was conducted on a constant flour weight (3 g).
[c] SDSP = SDS sedimentation test was conducted on a constant protein weight (300 mg).
[d] Abs = Water absorption of 10 g mixograph, Time = Mixing time of 10 g mixograph.
[e] Proportion of 50% 1-propanol insoluble (50PI) protein.
[f] Nomenclature according to Payne and Lawrence (1983); Null = null allele.
[g] Com1 and Com2 = Commercial noodle flour from Japan; Com3 = Commercial noodle flour from Korea.
[h] Least significant difference ($P < 0.05$). Differences between two means exceeding this value are significant.

water absorption. Compared to wheat flours with similar mixograph water absorption of commercial noodle flours, Korean wheat flours showed higher protein content and SDS sedimentation volumes. Commercial noodle flours had smaller particle size of flours and higher damaged starch content than laboratory milled flours (Park and Baik 2002), which contributed to the relatively high mixograph water absorption. Mixograph mixing time of Korean wheat flours was much longer, 145.0-375.0 sec, than soft wheat flours (< 95.0sec) and similar to that of hard wheat flours (180.0-330.0sec). Uri and Nuwest, which were similar in protein content and SDS sedimentation volume with constant protein weight to Com1, 2 and 3, had similar mixograph mixing time to Com1, 2, and 3 (60.00%). Mixograph water absorption significantly increased as protein content increased in both Korean and US wheat flours. Mixograph mixing time also significantly increased as protein content increased in US wheat flours, but no significant relationship was found in Korean wheat flours.

The proportion of 50% 1-propanol insoluble (50PI) protein, which was essentially free of monomeric proteins and comprised mainly glutenin (Fu and Sapirstein 1996), was 30.68- 37.34% in Korean wheat flours, 29.33-34.33% in soft wheat flours and > 35.39% in hard wheat flours. For Alchan, Keumkang, and Tapdong, the proportion of 50% 1-propanol insoluble protein was similar to that of hard wheat flours, which was similar to that of Com1, 2, and 3 (> 34.10%). As mixograph mixing time increased in both Korean and US wheat flours, the proportion of 50PI protein significantly increased. The proportion of 50PI protein also significantly increased as SDS sedimentation volume with constant protein weight increased in Korean wheat flours. Gluten yield of flours was 6.14-10.31% in Korean wheat flours, 6.35 -8.75% in soft wheat flours, and > 10.12% in hard wheat flours, except in Nuwest (8.23%). Gluten yield of Com1, 2, and 3 was 7.38-7.78%, and was similar to the range of gluten yield in soft wheat flours. Korean wheat flours with 60.00% of mixograph water absorption, Alchan, Jinpoom, and Olgeuru, had similar gluten yield of Com1, 2, and 3. Gluten yield increased as protein content increased in both Korean and US wheat flours.

Genetic variations of high molecular weight glutenin subunits (HMW-GS) compositions in Korean, US wheat and Com1, 2, and 3 are also summarized in Table 1. In *Glu-A1* loci, null allele, associated with poor rheological properties, was mostly found in Korean wheat. A high frequency of 2* subunit was found among US soft and hard wheat cultivars. In *Glu-B1* loci, Korean wheats had a high frequency of 7 + 8 subunits, while 17 + 18 subunits mostly found in hard wheats and soft wheat showed a higher frequency of the subunits 7 + 9. In *Glu-D1* loci, all of the hard wheat cultivars had the subunits 5 + 10, but soft wheats had a high frequency of the subunits of 2 + 12, except Alpowa. Shewry et al (1992) proposed that wheat varieties with good bread baking quality might require allelic subunits 1 or 2* on the *Glu-A1* locus, 17 + 18 or 7 + 8 on the *Glu-B1* locus, and 5 + 10

Table 2. Characteristics of noodle dough sheet and texture profile analysis parameters of cooked noodles prepared from Korean wheats, US wheats with various classes, and commercial wheat flours for making noodles.

Class[a]	Cultivar	Noodle Dough Sheet[b]		Color of Noodle Sheet[c]			Texture Profiles of Cooked Noodles			
		Abs (%)	Thick(mm)	L*	a*	b*	Hardness(N)	Adhesiveness (N×mm)	Springiness (Ratio)	Cohesiveness (Ratio)
Korean	Alchan	35.00	1.84	77.57	1.01	16.47	4.54	-0.06	0.90	0.64
	Eunpa	33.00	1.83	75.74	1.40	18.11	5.58	-0.06	0.90	0.62
	Geuru	35.00	1.79	73.54	1.21	16.40	5.47	-0.08	0.90	0.62
	Jinpoom	35.00	1.76	78.86	0.94	17.17	4.93	-0.08	0.89	0.61
	Keumkang	33.00	1.85	78.29	1.07	16.75	5.47	-0.08	0.90	0.61
	Olgeuru	35.00	1.68	79.55	0.69	16.47	4.24	-0.05	0.91	0.63
	Tapdong	33.00	1.89	77.65	1.25	16.25	5.22	-0.07	0.91	0.63
	Uri	37.00	1.69	79.23	0.87	16.92	4.15	-0.06	0.89	0.63
US Soft	Alpowa	36.00	1.64	81.30	0.31	16.48	4.45	-0.06	0.89	0.62
	OR939526	35.00	1.71	77.73	0.98	22.85	5.22	-0.06	0.91	0.64
	Stephens	34.00	1.69	78.60	0.81	21.93	4.85	-0.04	0.93	0.62
	Treasure	35.00	1.67	79.89	0.73	18.02	4.64	-0.06	0.92	0.61
	Vanna	34.00	1.67	78.92	0.76	21.15	4.94	-0.06	0.90	0.61
US Hard	ID0377S	33.00	1.82	79.52	0.63	18.24	5.21	-0.06	0.91	0.64
	Klasic	31.00	2.01	81.61	0.73	15.25	5.42	-0.05	0.90	0.66
	Nuwest	35.00	1.70	79.43	0.08	21.74	4.94	-0.07	0.91	0.61
	WA7839	32.00	1.89	75.06	1.49	19.54	6.28	-0.07	0.91	0.61
	Winsome	34.00	1.87	78.53	0.87	16.98	5.29	-0.06	0.91	0.65
	WPB926	32.00	1.93	76.22	1.20	17.98	6.73	-0.09	0.91	0.60
COM	Com1[d]	35.00	1.67	82.03	-0.11	18.49	3.79	-0.03	0.92	0.65
	Com2	35.00	1.73	81.36	-0.28	18.32	4.17	-0.03	0.92	0.64
	Com3	35.00	1.73	81.16	0.34	17.79	3.95	-0.03	0.92	0.66
	LSD[e]	-	0.03	1.20	0.17	1.02	0.21	0.02	0.02	0.01

[a] Korea = Korean wheat; Soft = US soft wheat; Hard = US hard wheat; COM = Commercial noodle flours for white salted noodles.
[b] Abs = Water absorption of noodle sheet; Thick = Thickness of noodle dough sheet.
[c] L* = lightness; a* = redness-greenness; b* = yellowness-blueness.
[d] Com1 and Com2 = Commercial noodle flour from Japan; Com3 = Commercial noodle flour from Korea.
[e] Least significant difference ($P < 0.05$). Differences between two means exceeding this value are significant.

on the *Glu-D1* locus. They also proposed 2 + 12 subunits were related to poor rheological properties in bread making. Alchan, Keumkang, and Tapdong, which has 2*, 7 + 8, and 5+10, can be used for making bread based on the HMW-GS composition. Other Korean wheat flours had 2.2 + 12 at *Glu-D1* loci, which are very frequently found in Korean and Japan cultivars (Payne et al. 1983; Hong and Park 1998). These subunits could be associated with flour texture and particle size of flours in Japan wheat cultivars (Nakamura et al. 1990; Oda et al. 1992). Korean wheats with 2.2 + 12 subunit of HMW-GS showed lower SDS sedimentation volume and mixing time of mixograph than 5 + 10 at *Glu-D1* loci in our previous study (2002). In Com1, 2, and 3, two alleles were identified at *Glu-A1* loci (1 and 2*), two at *Glu-B1* loci (7 + 8 and 17 + 18), and two at *Glu-D1* loci (2 + 12 and 5 + 10). Com2 and 3 could be mixtures of soft and hard wheat flours, since their composition of HMW-GS contained both 2 + 12 and 5 + 10 at *Glu-D1* loci, and 7 + 8 and 17 + 18 at *Glu-B1*.

Figure 1 shows that the differences of SDS sedimentation volume with constant protein weight, proportion of 50PI protein, and mixograph mixing time according to the HMW-GS compositions of Korean, US, and Com1, 2, and 3. Korean wheats with 5 + 10 subunits had higher SDS sedimentation volume with constant flour weight (51.83 ± 5.86 ml) than Korean wheats with 2.2 + 12 subunits (42.80 ± 3.82 ml), which was similar to that of US wheat flours with 5 + 10 subunits (39.64 ± 5.48 ml), Com1, 2, and 3 (39.17 ± 0.76 ml) and higher than 2 + 12 subunits (35.75 ± 3.23 ml). Korean wheats with 2.2 + 12 subunits (176.00 ± 20.66 sec) showed similar mixograph mixing time to that of Com1, 2, and 3, and US wheats with 5 + 10 subunits (210.83 ± 13.77 sec and 197.14 ± 78.52 sec, respectively) and shorter than that of Korean wheats with 5 + 10 subunits (344.17 ± 28.10 sec). In the proportion of 50PI protein, Korean wheats with 2.2 + 12 subunits (31.88 ± 1.04%) were similar to US wheats with 2 + 12 subunits (31.61 ± 1.25%) and Korean wheats with 5 + 10 subunits were similar to US wheats with 5 + 10 subunits and Com1, 2, and 3 (36.22 ± 1.18% and 34.32 ± 0.19%, respectively).

Characteristics of noodle dough sheet

Optimum water absorption of noodle dough, thickness, and color of noodle dough sheet of Korean wheat flours, US wheats, and Com1, 2, and 3 are summarized in Table 2. Optimum water absorption of noodle dough was 33- 37% in Korean wheat flours, 34- 36% in soft wheat flours, and < 35% in hard wheat flours. Compared to wheat flours with similar protein content and SDS sedimentation volume, optimum water absorption of noodle dough from Korean wheat flours was higher than that of US wheat flours. Further evaluation of flour characteristics related to water holding capacity should be required to elucidate high water absorption in noodle processing with Korean wheat flours. Optimum water absorption of noodle dough prepared from Korean wheat flours was negatively correlated with protein content (r = -0.922, $P < 0.01$), SDS sedimentation volume based on flour weight (r = -0.743, $P < 0.05$), mixograph water absorption (r = -0.923, $P < 0.01$), and gluten yield (r = -0.888, $P < 0.01$), and

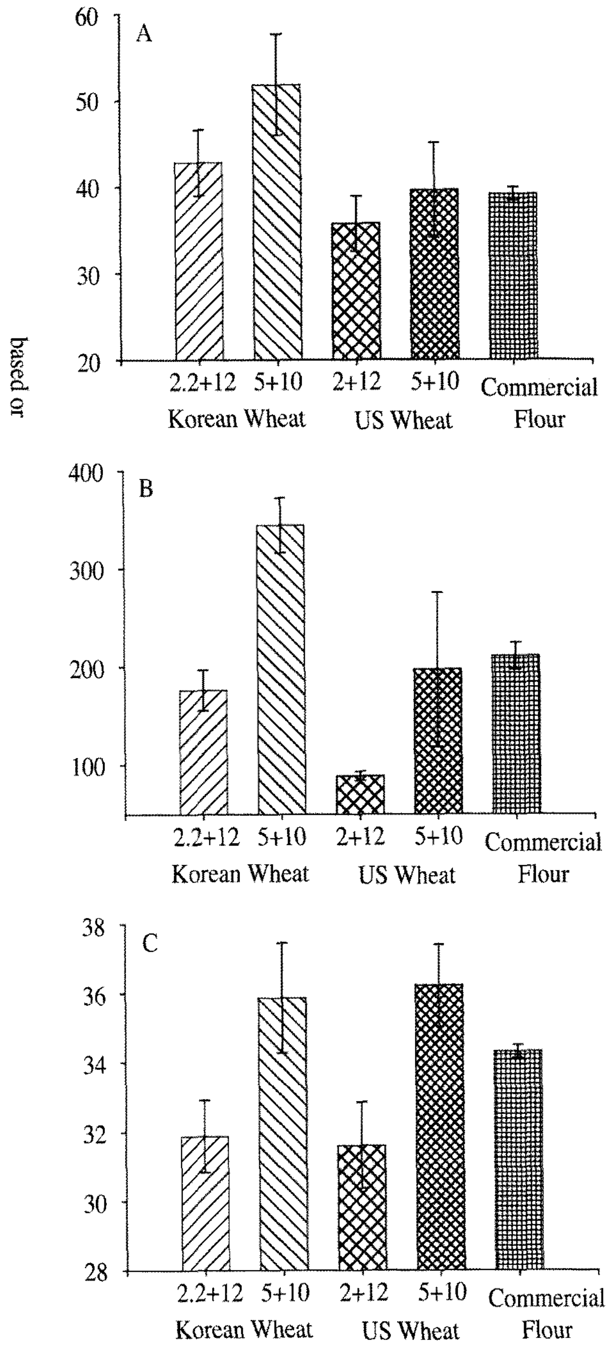

Fig. 1. The difference of SDS sedimentation volume with constant protein weight (A), proportion of 50% 1-propanol insoluble (50PI) protein (B), and mixograph mixing time (C) according to the high molecular weight glutenin compositions of Korean, US, and commercial flours for noodle making.

these relationships were the same in US wheats (Table 3). Optimum water absorption of noodle dough prepared from US wheat flours negatively correlated with mixograph mixing time (r = -0.768, $P < 0.01$), but there were no significant relationships in Korean wheats. There was no significant relationship in SDS sedimentation volume with constant protein content and proportion of 50PI protein between Korean and US wheat flours. Optimum water absorption of noodle dough decreased as protein content increased, since flours with low protein content require more

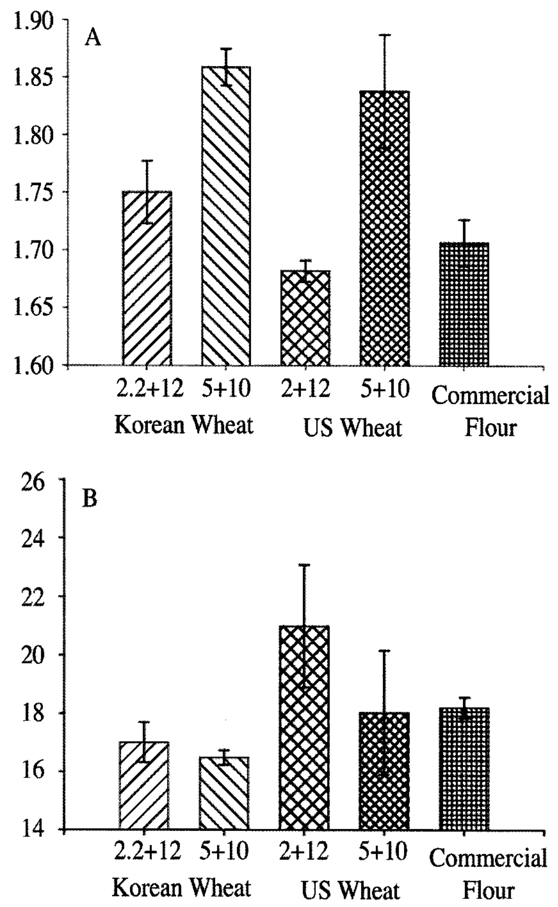

Fig. 2. The difference of thickness of noodle dough sheet (A) and b* value of noodle dough sheet (B) according to the high molecular weight glutenin compositions of Korean, US, and commercial flours for noodle making.

water to form a uniform protein matrix and make a continuous noodle sheet with good handling properties (Park and Baik 2002).

The thickness of noodle dough sheets prepared with optimum water absorption was 1.68-1.89 mm in Korean wheat flours, 1.64-1.71 mm in soft wheat flours, and > 1.82 mm in hard wheat flours, except for Nuwest (1.70 mm). Com1, 2, and 3 had 35% water absorption of noodle dough, and thickness of dough sheets was 1.67-1.73 mm. In Korean wheats with 2.2 + 12 subunits in HMW-GS compositions (1.75 ± 0.06 mm), the thickness of the noodle dough sheet was similar to that of Com1, 2, and 3 (1.71 ± 0.03 mm; Fig 2-A). The noodle dough sheet from Alchan, Keumkang, and Tapdong, which had 5 + 10 subunits in HMW-GS, was thicker than other Korean wheats and similar to that of US wheats. There was a positive correlation of thickness of noodle dough sheet with protein content, SDS sedimentation volume with constant flour weight, mixograph water absorption, and gluten yield for both Korean and US wheat flours (Table 3). In the noodle dough sheet prepared from US wheat flours, there were positive relationships in thickness with mixograph mixing time and the proportion of 50PI protein, but no significant relationship was found in Korean wheats.

In the color of the noodle sheet prepared from Korean wheat flours, L* value of noodle sheets prepared with optimum water absorption was 73.54-79.55, a* value of noodle dough was 0.69-1.40, and b* value was 16.25-18.11. Com1, 2, and 3 showed higher L* and b* values (> 81.16 and > 17.79) and lower a* values (< 0.34) than those of noodle sheet from Korean wheat flours. The noodle sheet from US soft wheats with 2 + 12 subunits in HMW-GS compositions showed higher b* value (1.71 ± 0.03 mm) than noodle sheet from Korean wheat flours (Fig. 2-B). Protein content, SDS sedimentation volume with constant flour weight, and mixograph water absorption negatively correlated with L* value of noodle dough sheet prepared from US wheat flours (r = -0.644, $P < 0.05$, r = -0.721, $P < 0.05$, and r = -0.613, $P < 0.05$, respectively) and positively correlated with a* value of US wheat flours (r = 0.763, $P < 0.01$, r = 0.716, $P < 0.05$, and r = 0.676, $P < 0.05$, respectively), but no significant relationships between protein characteristics and L* value of noodle dough sheet from Korean wheat flours was found (Table 4). Protein content and gluten yield of Korean wheat flours positively correlated with a* value of noodle dough sheet (r = 0.859, P < 0.01, and r = 0.857, P < 0.01, respectively). There was no significant relationship between b* value noodle dough sheet and protein characteristics in Korean and US wheat flours. Significant relationships between protein content and color characteristics of noodle sheets were reported in several previous studies in white salted noodles (Baik et al. 1995; Yun et al. 1996; Park and Baik 2002).

Textural properties of cooked noodles

The hardness of cooked white salted noodles prepared from Korean wheat flours was 4.15-5.58 N (Table 2). In the cooked noodles from Olgeuru and Uri (4.24 and 4.15 N), the hardness was similar to that of Com1, 2, and 3 (3.79-4.17 N) which produced a much softer texture of white salted noodles than Korean and

Table 3. Correlation coefficients between protein characteristics and noodle processing parameters, including optimum water absorption of noodle dough and thickness of noodle dough sheets.

Parameters	Optimum Water Absorption			Thickness of Dough Sheet		
	All (n=22)	Korean (n=8)	US(n=11)	All (n=22)	Korean (n=8)	US(n=14)
Protein	-0.866***	-0.922**	-0.885***	0.861***	0.793*	0.880***
SDS sedimentation volume based on flour weight	-0.430*	-0.743*	-0.689*	0.655***	0.849**	0.721*
SDS sedimentation volume based on protein weight	-0.013	-0.020	-0.307	0.275	0.276	0.309
Mixograph water absorption	-0.758***	-0.923**	-0.855***	0.794***	0.764*	0.893***
Mixograph mixing time	-0.368	-0.353	-0.768**	0.667***	0.651	0.885***
Proportion of 50% 1-propanol insoluble protein	-0.362	-0.156	-0.450	0.568**	0.658	0.642*
Gluten yield	-0.889***	-0.888**	-0.887***	0.850***	0.773*	0.918***

* indicates significance at the 0.05 level, ** at the 0.01 level, and *** at the 0.001 level.

Table 4. Correlation coefficients between protein characteristics and color of noodle dough sheets prepared from optimum water absorption.

Parameters[a]	Color of Noodle Dough Sheet								
	Lightness (L*)			Redness-Greenness (a*)			Yellowness-Blueness (b*)		
	All (n=22)	Korean (n=8)	US(n=11)	All (n=22)	Korean (n=8)	US(n=11)	All (n=22)	Korean (n=8)	US(n=11)
Protein	-0.640**	-0.561	-0.644*	0.722***	0.859**	0.763**	-0.115	0.242	-0.222
SDSF	-0.657***	-0.137	-0.721*	0.733***	0.434	0.716*	-0.422	-0.209	-0.209
SDSP	-0.186	0.445	-0.282	0.315	-0.326	0.338	-0.507*	-0.508	-0.323
Mixograph water absorption	-0.437*	-0.314	-0.613*	0.440*	0.563	0.676*	-0.278	-0.107	-0.257
Mixograph mixing time	0.005	0.234	0.021	0.123	0.098	0.123	-0.529*	-0.365	-0.480
50 PI protein	0.101	-0.078	0.085	-0.123	0.211	-0.136	-0.284	-0.547	-0.551
Gluten yield	-0.501*	-0.607	-0.584	0.541**	0.857**	0.697*	-0.029	0.185	-0.258

[a]SDSF = SDS sedimentation test was conducted on a constant flour weight (3 g), SDSP = SDS sedimentation test was conducted on a constant protein weight (300 mg), 50 PI protein = proportion of 50% 1-propanol insoluble protein.

* indicates significance at the 0.05 level, ** at the 0.01 level, and *** at the 0.001 level.

US wheat flours. Compared to similar protein content of Com1, 2, and 3 hardness of cooked noodles from Korean wheats was lower than that of soft and hard wheat flours. As the protein content increased in Korean and US wheat flours, the hardness of cooked noodles increased. Noodles prepared from wheat flours with low protein content are more fragile than those with high protein content, since the protein network in the low protein noodles is weaker than in high protein noodles. Adhesiveness, springiness, and cohesiveness of cooked noodles from Korean wheats were similar to US wheat flours. Com1, 2, and 3 showed higher adhesiveness, springiness, and cohesiveness than other Korean and US wheat flours. Olgeuru showed similar adhesiveness and springiness of cooked noodles to Com1, 2, and 3 although cohesiveness of cooked noodles from Olgeuru was lower than that of Com1, 2, and 3. No consistent difference in textural properties of cooked noodles between Korean and US wheat flours with different HMW-GS compositions.

The hardness of cooked noodles from Korean and US wheat flours correlated positively with protein content of wheat flours (r = 0.862, $P < 0.01$, and r = 0.942, $P < 0.001$, respectively; Fig 3-A). In cooked noodles, the hardness was positively correlated with SDS sedimentation volume with constant flour weight and mixograph water absorption in US wheat flours (r = 0.947, $P < 0.001$, and r = 0.928, $P < 0.001$, respectively), but no significant relationship was found in Korean wheat flours. The relationship between protein content as well as SDS sedimentation volume with constant flour weight and hardness of cooked white salted noodles was reported by many previous researchers (Oh et al. 1985b; Baik et al. 1994a; Yun et al. 1996; Ross et al. 1997). The hardness of cooked noodles correlated positively with gluten yield in Korean and US wheat flours (r = 0.855, $P < 0.01$, and r = 0.916, $P < 0.001$, respectively). However, in cooked noodles prepared from Korean and US wheat flours, hardness was not correlated with SDS sedimentation volume with constant protein weight, mixograph mixing time, and proportion of 50PI protein; these parameters were independent of protein content. The adhesiveness of cooked noodles from US wheat correlated negatively with SDS sedimentation volume with constant flour weight (r = -0.656, $P < 0.05$). However, there was no significant relationship between protein content and quality and other texture profiles of cooked noodles.

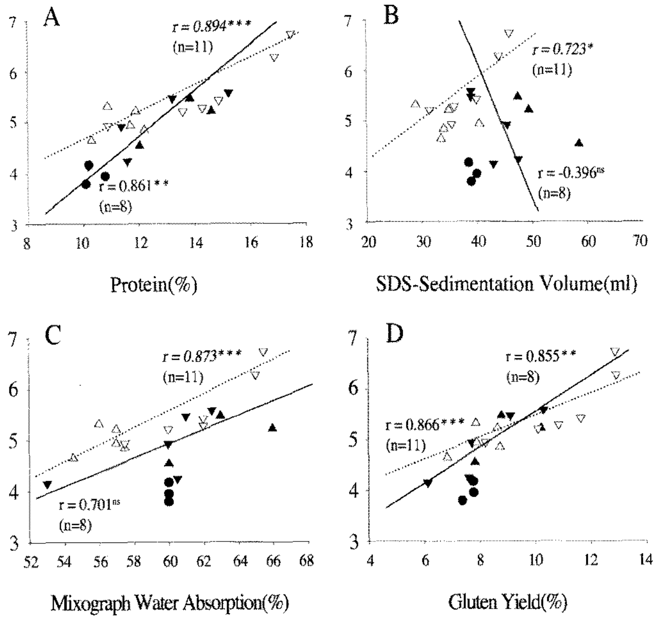

Fig. 2. The difference of thickness of noodle dough sheet (A) and b* value of noodle dough sheet (B) according to the high molecular weight glutenin compositions of Korean, US, and commercial flours for noodle making.

Conclusion

Protein content related parameters of Korean wheat flours with 2.2 + 12 subunits in HMW-GS compositions were more comparable to those of US hard wheat flours than those of US soft wheat flours, which were similar to commercial noodle flours. Among these Korean wheat flours, Uri and Olgeuru showed similarities to the noodle processing and texture properties of cooked noodles prepared from commercial noodle flours. HMW-GS composition, especially 2.2 + 12, sedimentation volume and mixogram could be used as a selection criteria for white salted noodles in breeding programs and small sample methods in the early cycle of the process should be developed to increase the efficiency of selection.

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