Evaluation of Korean Noodle Quality of Korean Winter Wheat over Years and Locations

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ABSTRACT : Noodle texture parameters of Korean style wet and dry noodles and relationships between noodle quality and flour characteristics were evaluated for two years, 1997 and 1998, and at two locations, Suwon and Deokso, using Korean winter wheat cultivars and lines. No significant difference for chewiness was found between cultivars over locations. Noodles made from flours from 1997 showed significantly higher chewiness than those from 1998. Chewiness of cooked noodles showed positively significant correlations with protein content and SDS sedimentation volume and negatively significant correlations with starch peak viscosity and flour swelling volume. Korean winter wheat cultivars, except for Gobunmil, Keumkangmil Tapdongmil, Suwon 265 and Suwon 280, showed chewiness of cooked noodles similar to commercial flours used for noodle making in Korea and Japan.

Keywords: Korean style noodles, dry noodles, wet noodles, chewiness, texture profile analysis (TPA)

Noodles prepared with various ingredients, size and shapes are important foods in many Asian countries because of simple preparation process, low price, and easy and fast cooking. There are regional preferences for noodle color, size, shape, texture, flavor, shelf life and ease of cooking, which depend not only on flour characteristics, but also on the specific process used to manufacture the noodles, as well as the inclusion of other raw materials or chemical additives (Dick and Matsuo, 1988). White salted noodles, prepared from mixtures of flour, water and salt have been especially popular in Korea and Japan. The functional properties of noodle making and quality have been less studied than those of bread making. Therefore, it is necessary to evaluate the flour properties related to noodle quality, to determine the suitability of wheat flours for noodle making, and to develop objective methods such as screening tests in wheat breeding programs.

Texture is the primary quality attribute of white salted noodles. Texture depends largely on flour characteristics and on conditions used during noodle preparation (Oh *et al.*, 1983, 1985a, 1985c; Toyokawa *et al.*, 1989a). Texture profile analysis (TPA) is a sensitive and reproducible objective test, and TPA parameters effectively differentiate between the various wheat flours used in production of oriental noodles (Baik *et al.*, 1994). Although flour quality parameters for bread making are similarly important for noodle making, the influence of flour properties in noodles is greater than in bread making because of the simple formula and processing in white salted noodles (Nagao, 1992).

Two major components of flours, proteins and starches, play important roles in noodle texture, and their properties are used as indices for the evaluation and prediction of noodle quality. Oda *et al.* (1980) reported the importance of starch on Japanese noodle texture, and Oh *et al.* (1985b) reported the relationship between flour protein content and cutting stress of cooked noodles. They also reported that gluten influenced the strength of cooked noodles and their surface firmness, and that the effect of prime starch on noodle texture is insignificant with the interchanging of the corresponding flour fractions of good and poor quality flours. Prime and tailing starch fractions have been reported as being most responsible for noodle texture by the fractionation and reconstitution of flour components (Toyokawa *et al.*, 1989a). Increased concentrations of amylose in starch have been shown to decrease the water binding of cooked noodles and to increase the firming and the loss of elasticity (Toyokawa *et al.*, 1989b). Protein content and quality should be considered in the evaluation of suitability of flours for making oriental noodles because protein content and quality parameters are highly correlated with TPA parameters (Baik *et al.*, 1994). In addition, noodle elasticity and eating quality have been closely correlated with mixing time and flour protein content (Yun *et al.*, 1996).

Genotypes have a large effect on noodle color and noodle physical properties (Crosbie and Lambe, 1993). Milling properties and noodle making properties of soft wheats can be distinguished by genotypes, but environment has strong influence on grain condition; grain condition has the most influence on milling characteristics, while environment has the most influence on baking characteristics, with softer ker-

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nel wheats producing better end-use characteristics (Gaines et al., 1996). Lang et al. (1998) reported that superior noodle color was correlated with low protein and proposed that dual-purpose hard white spring wheats could improve noodle characteristics while maintaining good bread making quality.

High grain yield and early maturation are the major consideration in Korean wheat breeding program. Recently, importance of end-use quality of wheat has become important, and development of screening methods suitable to accurate prediction of flour quality has received more attention by wheat breeders than ever. Although noodles are popularly consumed in Korea, there is little information about noodle texture of Korean style noodles made with Korean wheats. This study is aimed at the evaluation of relationships among flour characteristics and properties of Korean style noodle texture made from Korean winter wheats and determination of selection criteria for high noodle quality in Korean wheat breeding programs.

MATERIALS AND METHODS

Materials

A set of Korean winter wheat cultivars and lines were harvested at Suwon (Upland Crop Experimental Farm of National Crop Experiment Station) in 1997 and another set of materials was produced at Suwon (Upland Crop Experimental Farm of National Crop Experimental Station) and Deokso (Korea University Research Farm) in 1998.

Those two sets of wheat samples were milled with a Bühler experimental mill with 65% flour extraction. Three flours, cvs ID377S, Klasic and Penawawa, and three standard wheat flours, Japanese and Chinese noodle flours and hard red spring wheat flour for baking (JPN, CHN and HRS, respectively) were obtained from Western Wheat Quality Laboratory (WWQL), Washington State University, Pullman, U.S.A. Three Korean commercial wheat flours (COM1 is suitable for bread in Korea and COM2 and 3 are used for noodles and cookies), obtained from Daehan Flour Mills Co. Ltd., Korea were also included in sample analyses as a reference. ID377S and Penawawa have been used as udon flours due to good protein and starch quality. Klasic is a hard white wheat with high protein and quality.

Noodle making

The formula for Korean style noodle making process was performed according to the method described by Toyokawa *et al.* (1989a) with some modifications. The procedure of noodle making is as follows: 300 g of flour (13.5% moisture basis) were mixed to 34% absorption with a 6% sodium chloride solution in a KitchenAid mixer for 2 min at slow speed and then for 4 min at medium speed. The dough was passed through the rolls of a noodle machine (Hyundai Menki Mfg. Co., Seoul, Korea) at a 3.00 mm gap and the dough sheet was then folded and put through the sheeting roll twice. After 2 hr resting time, the noodle sheet was put through the sheeting rolls five times at progressively smaller gap settings of 2.50, 2.00, 1.50, 1.25 and 1.00 mm. The sheet was cut through no. 28 cutting rolls into strips approximately 30 cm long with a 1.00×1.10 mm cross section. For testing of wet cooked noodles, half of the sheet was kept in plastic bags and stored at 4°C until cooked. For the dry noodle test, the other part of the sheet was dried for 2 days at room temperature.

Texture of cooked noodles

Wet Korean style noodles (30 g) were cooked in boiling distilled water (1 L) for 210 sec and rinsed with cold water for one min. Dry Korean style noodles were cooked for 420 sec. The measurement of TPA of cooked noodles was based on the procedures described by Baik *et al.* (1994) with a Texture Analyser (TA-XT2*i*, Version 1.17, Stable Micro Systems, England). Sets of five strands of cooked noodles were placed between HDP/PFS probe (pasta firmness/stickiness rig) and a flat metal plate. The test was performed with a load cell pressure of 5 kg, at a test speed of 1.0 mm/sec with, and a test distance of 60% strain of sample height.

From force-time curves of the TPA, the hardness, springiness, cohesiveness, gumminess, chewiness and adhesiveness were determined according to the description of Baik *et al.* (1994).

Analytical methods

Data of protein content, SDS sedimentation volume, swelling and pasting properties of starch and flours, high molecular weight glutenin subunits compositions and friabilin of Korean winter wheat cultivars and lines were obtained from our previous reports (Park *et al.*, 2001a; 2001b).

Statistical analysis

Data analyses were performed with the SAS Package (SAS, 1995) using analysis of variance (ANOVA), Fishers least significant difference procedure (LSD) and Pearson correlation coefficient.

RESULTS AND DISCUSSION

Texture of cooked noodles

Texture profile analysis (TPA) parameters of Korean style cooked wet and dry noodles measured the samples grown at Suwon for two years, 1997 and 1998; the samples harvested at two locations, Suwon and Deokso, grown in 1998 are summarized in Tables 1 and 2. In Korean style wet noodles, hardness ranged from 36.82 N for Urimil to 47.00 N for Gobunmil. Adhesiveness ranged from -0.610 N for Suwon 279 to -0.430 N for Keumkangmil. Cohesiveness ranged from 0.480 for Suwon 276, 278, 279 and 280 to 0.540 for Suwon 274. Springiness ranged from 0.835 mm for Urimil to 0.900 mm for Keumkangmil. Gumminess ranged from 18.32 N for Suwon 276 to 23.73 N for Tapdongmil. Chewiness ranged from 15.73 (N×mm) for Suwon 276 to 21.11 (N×mm) for Tapdongmil. In dry noodles, hardness ranged from 37.03 N for Urimil to 47.86 N for Suwon 280. Adhesiveness ranged from -0.605 N for Suwon 275 to -0.265 N for Suwon 277. Cohesiveness ranged from 0.455 for Suwon 278 to 0.525 for Alchanmil. Springiness ranged from 0.845 mm for Urimil to 0.910 mm for Keumkangmil. Gumminess ranged from 17.97 N for Suwon 276 to 23.58 N for Suwon 280. Chewiness ranged from 15.42 (N×mm) for Urimil to 20.95 (N×mm) for Suwon 280.

Urimil showed lower hardness than other cooked noodles over years, and Gobunmil and Tapdongmil had higher hardness than others over years in cooked wet noodles. However, there were no significant differences between cultivars over locations in hardness. There were also no significant differences between cultivars over years and locations in

Table 1. Texture profile analysis parameters of cooked wet noodles over years and locations of Korean winter wheat cultivars and lines.

	Texture Profile Analysis of Cooked Wet Noodles†					
	HD (N)	AD (N)	CO Ratio	SP (mm)	GU (N)	CH (N×mm)
Year						
1997	43.30	-0.53	0.50	0.87	21.71	18.87
1998	41.91	-0.52	0.50	0.87	20.97	18.33
LSD‡	0.45	0.02	0.01	0.01	0.32	0.41
Location						
Suwon	41.78	-0.52	0.50	0.87	20.78	18.13
Deokso	42.34	-0.52	0.50	0.87	21.01	18.38
LSD	0.50	0.02	0.01	0.01	0.33	0.36
Cultivar/Line						
Alchanmil	41.37ghi§	-0.525cde	0.515bc	0.875abcde	21.24cd	18.58de
Chokwang	40.80hi	-0.555def	0.500bcde	0.855def	20.35efg	17.43gh
Eunpamil	41.47ghi	-0.580efg	0.510bcd	0.870abcde	21.13cde	18.35efg
Geurumil	43.41de	-0.510bcd	0.495cde	0.875abcde	21.24cd	18.64de
Gobunmil	47.00a	-0.535cde	0.495cde	0.880abcde	23.07a	20.29ab
Keumkangmil	42.86def	-0.430a	0.520ab	0.900a	22.18b	20.01bc
Olgeurumil	40.12ij	-0.510bcd	0.490de	0.865bcdef	19.56gh	16.91h
Tapdongmil	47.23a	-0.485bc	0.505bcd	0.890abc	23.73a	21.11a
Urimil	36.82l	-0.535cde	0.520ab	0.835f	19.03hi	15.79i
Suwon258	41.28ghi	-0.460ab	0.490de	0.850def	20.03fg	16.93h
Suwon261	40.92hi	-0.550def	0.490de	0.880abcd	19.91fg	17.53fgh
Suwon265	45.16bc	-0.510bcd	0.495cde	0.895ab	22.18b	19.74bc
Suwon274	39.17jk	-0.510bcd	0.540a	0.880abcd	21.05cde	18.48def
Suwon275	42.46efg	-0.525cde	0.500bcde	0.845ef	21.17cde	17.93efg
Suwon276	37.96kl	-0.600fg	0.480e	0.860cdef	18.32i	15.73i
Suwon277	41.61fgh	-0.550def	0.490de	0.890abc	20.46def	18.07efg
Suwon278	43.51de	-0.545def	0.480e	0.875abcde	20.93de	18.37defg
Suwon279	43.92cd	-0.610g	0.480e	0.880abcd	21.05cde	18.37defg
Suwon280	45.63b	-0.460ab	0.480e	0.880abcd	21.86bc	19.32cd

†HD=hardness, AD=adhesiveness, CO=cohesiveness, SP=springiness, GU=gumminess, CH=chewiness.
‡Least significant difference (P=0.05).
§ Values followed by same letters are not significantly different at $P < 0.05$.

Table 2. Texture profile analysis parameters of cooked dry noodles over years and locations of Korean winter wheat cultivars and lines.

	Texture Profile Analysis of Cooked Dry Noodles†					
	HD (N)	AD (N)	CO Ratio	SP (mm)	GU (N)	CH (Nxmm)
Year						
1997	40.86	-0.41	0.51	0.88	20.60	18.05
1998	40.26	-0.43	0.50	0.88	19.97	17.53
LSD‡	0.52	0.03	0.01	0.01	0.34	0.40
Location						
Suwon	40.47	-0.43	0.49	0.88	19.95	17.48
Deokso	41.11	-0.36	0.49	0.89	20.15	17.93
LSD	0.50	0.02	0.01	0.01	0.38	0.40
Cultivar/Line						
Alchanmil	38.03jkl§	-0.420de	0.525a	0.880bcd	20.00efg	17.71defg
Chokwang	39.15hij	-0.340bc	0.490bc	0.870cdef	19.08hij	16.66ij
Eunpamil	37.67kl	-0.365cd	0.510ab	0.890abc	19.10hij	16.99ghi
Geurumil	39.16hij	-0.365cd	0.490bc	0.885abc	19.22hi	16.96ghi
Gobunmil	45.24b	-0.415de	0.505abc	0.905ab	22.85a	20.64a
Keumkangmil	43.49c	-0.275ab	0.505abc	0.910a	21.89b	19.91b
Olgeurumil	43.16cd	-0.515fg	0.480cde	0.855def	20.47def	17.51efgh
Tapdongmil	41.08efg	-0.360cd	0.510ab	0.885abc	20.81cde	18.345cd
Urimil	37.03l	-0.535g	0.500abc	0.845f	18.33jkl	15.42k
Suwon258	40.10gh	-0.360cd	0.500abc	0.890abc	19.79fgh	17.56defgh
Suwon261	40.92fg	-0.320abc	0.500abc	0.880bcd	20.21ef	17.82def
Suwon265	42.18de	-0.340bc	0.510ab	0.875cde	21.43bc	18.78c
Suwon274	38.44ijk	-0.545gh	0.505abc	0.885abc	19.29ghi	17.07fghi
Suwon275	43.31cd	-0.605h	0.485bcd	0.850ef	21.02cd	17.93de
Suwon276	37.50kl	-0.410de	0.480cde	0.870cdef	17.97l	15.62k
Suwon277	39.21hij	-0.265a	0.520a	0.890abc	20.25def	18.05cde
Suwon278	41.49ef	-0.380cd	0.455e	0.890abc	18.82ijk	16.80hij
Suwon279	39.30hi	-0.380cd	0.460de	0.880bcd	18.25kl	16.11jk
Suwon280	47.86a	-0.460ef	0.490bc	0.890abc	23.58a	20.95a

†HD=hardness, AD=adhesiveness, CO=cohesiveness, SP=springiness, GU=gumminess, CH=chewiness.
‡Least significant difference ($P = 0.05$).
§Values followed by same letters are not significantly different at $P<0.05$.

adhesiveness, cohesiveness or springiness. Tapdongmil showed higher gumminess and chewiness than others over years. Urimil showed lower chewiness than other cooked wet noodles over years, but there were no significant differences between cultivars over locations in gumminess and chewiness. Noodles made from flours harvested in 1997 showed significantly higher hardness, gumminess and chewiness than those from 1998, but there were no significant differences in any TPA parameters, except hardness, over locations. Urimil showed lower hardness than other cooked dry noodles over years, and Gobunmil and Suwon 280 had higher hardness than others over years and locations, respectively. Suwon 277 showed lower cohesiveness than other cooked dry noodles over years, Alchanmil had higher cohesiveness than others over years, and Suwon 280 had higher gumminess than others over locations. Gobunmil, Keumkangmil and Suwon 280 showed higher chewiness than other cooked dry noodles over locations.

TPA parameters of cooked wet and dry noodles obtained from WWQL and three Korean commercial wheat flours are shown in Tables 3 and 4. CHN, COM1, Klasic and Penawawa showed higher hardness than other flours, and Penawawa and Klasic showed higher springiness, gumminess and chewiness than those of others in cooked wet noodles. COM3 had lower gumminess and chewiness than others in cooked wet noodles, and showed lower hardness, adhesiveness, cohesiveness, gumminess and chewiness than those of others in cooked dry noodles. COM1 had higher chewiness than that of other flours in cooked dry noodles. CHN showed higher TPA parameters than other noodle flours,

Table 3. Texture profile analysis parameters of cooked wet noodles of flours obtained from Western Wheat Quality Lab and Korean commercial flours.

Sample‡	Texture Profile Analysis of Cooked Wet Noodles†					
	HD (N)	AD (N)	CO Ratio	SP (mm)	GU (N)	CH (N×mm)
JPN	37.53	-0.407	0.513	0.860	19.25	16.50
CHN	49.52	-0.513	0.470	0.873	23.15	20.30
Penawawa	49.97	-0.413	0.533	0.917	26.67	24.50
ID377S	45.68	-0.337	0.533	0.913	24.33	22.25
Klasic	49.05	-0.343	0.553	0.920	27.12	24.96
COM1	51.38	-0.657	0.517	0.887	26.50	23.51
COM2	39.08	-0.377	0.527	0.887	20.59	18.20
COM3	33.37	-0.410	0.543	0.870	18.09	15.72
LSD§	1.55	0.054	0.022	0.020	0.79	0.76

†HD=Hardness, AD=Adhesiveness, CO=Cohesiveness, SP=Springiness, GU=Gumminess, CH=Chewiness.
‡JPN=Japanese Noodle Flour, CHN=Chinese Noodle Flour, COM1 =Korean Commercial Flour for Bread, COM2=Korean Commercial Flour for Noodle, COM3=Korean Commercial Flour for Cookies.
§Least significant difference (P=0.05). Differences between two means exceeding this value are significant.

Table 4. Texture profile analysis parameters of cooked dry noodles of flours obtained from Western Wheat Quality Lab and Korean commercial flours.

Sample‡	Texture Profile Analysis of Cooked Dry Noodles†					
	HD (N)	AD (N)	CO Ratio	SP (mm)	GU (N)	CH (N×mm)
JPN	38.42	-0.397	0.520	0.847	20.08	16.98
CHN	48.23	-0.477	0.507	0.893	24.27	21.70
Penawawa	44.11	-0.293	0.513	0.943	22.65	21.37
ID377S	40.42	-0.263	0.527	0.927	21.34	19.82
Klasic	44.35	-0.340	0.490	0.933	21.80	20.38
COM1	45.35	-0.337	0.527	0.917	23.90	21.95
COM2	37.89	-0.393	0.543	0.897	20.68	18.52
COM3	33.92	-0.490	0.463	0.900	15.67	14.09
LSD§	1.22	0.055	0.022	0.031	0.94	0.94

†HD=Hardness, AD=Adhesiveness, CO=Cohesiveness, SP=Springiness, GU=Gumminess, CH=Chewiness.
‡JPN=Japanese Noodle Flour, CHN=Chinese Noodle Flour, COM1 =Korean Commercial Flour for Bread, COM2=Korean Commercial Flour for Noodle, COM3=Korean Commercial Flour for Cookies.
§Least significant difference (P=0.05). Differences between two means exceeding this value are significant.

JPN and COM2. There were no differences in TPA parameters between JPN and COM2.

In cooked wet noodles, Chokwang, Olgeurumil, Urimil, Suwon 274 and Suwon 276 showed similar hardness to JPN and COM2. Korean winter wheats, except for Gobunmil, Keumkangmil and Tapdongmil, similar chewiness to JPN and COM2. Gobunmil, Keumkangmil, Olgeurumil, Tapdongmil, Suwon 265, Suwon 275, Suwon 278, and Suwon 280 showed higher hardness than that of JPN and COM2 in cooked dry noodles. Korean winter wheat cultivars, except for Gobunmil, Keumkangmil and Suwon 265, showed similar chewiness to JPN and COM2. In adhesiveness, cohesiveness, springiness and gumminess, there were no differences between standard noodle flours and Korean winter wheats in cooked noodles.

TPA parameters of cooked noodles could reflect textural differences of Korean style wet and dry noodles. Especially, hardness and chewiness could be used in evaluation of textural properties of Korean style noodles. Alchanmil, Chokwang, Olgeurumil, Suwon 274 and Urimil showed similar patterns of TPA parameters to JPN and COM2 in this study. The evaluation of TPA parameters should be considered for obtaining better noodle quality in Korean style noodles.

Relationships between texture parameters of cooked noodles and flour characteristics

Fig. 1 shows the relationships between cultivar means over years and locations of protein content and quality and TPA parameters of Korean style cooked noodles. The differences of coefficient degree and distribution between cooked wet and dry noodles were considered to be mainly due to the differences in cooking time and conditions. Of the TPA parameters, hardness and chewiness showed higher significant correlations than other parameters, and the correlation coefficients between hardness and chewiness had higher values than those of between other parameters. Chewiness is the product of (hardness×cohesiveness) springiness; it is thus a single parameter that incorporates three of the important textural characteristics (Baik *et al.*, 1994). Positive correlations between flour protein content and hardness and chewiness of cooked wet noodles were found ($r = 0.612$, $P<0.01$ and $r = 0.588$, $P<0.01$, respectively). SDS sedimentation volume showed positive correlations with chewiness of cooked dry noodles ($r = 0.480$, $P<0.05$). Fig. 2 shows the relationships between cultivar means over years and locations of swelling and pasting properties and TPA parameters of Korean style cooked noodles. Peak viscosity of starch and flour swelling volume showed negative correlations with chewiness of cooked wet noodles ($r = -0.573$, $P<0.01$ and $r = -0.623$, $P<0.01$). Fig. 3 shows that the difference of chewiness of cooked noodles according to the presence and absence of 1Dx2.2 + 1Dy12 subunits of HMW-GS (2.2-presence and absence lines), and friabilin (friabilin-presence and absence lines). In wet cooked noodles, 2.2-absence lines showed higher chewiness (19.68 N± 1.22 N) than that (17.94± 1.33 N) of 2.2-presence lines. In dry cooked noodles, 2.2-absence

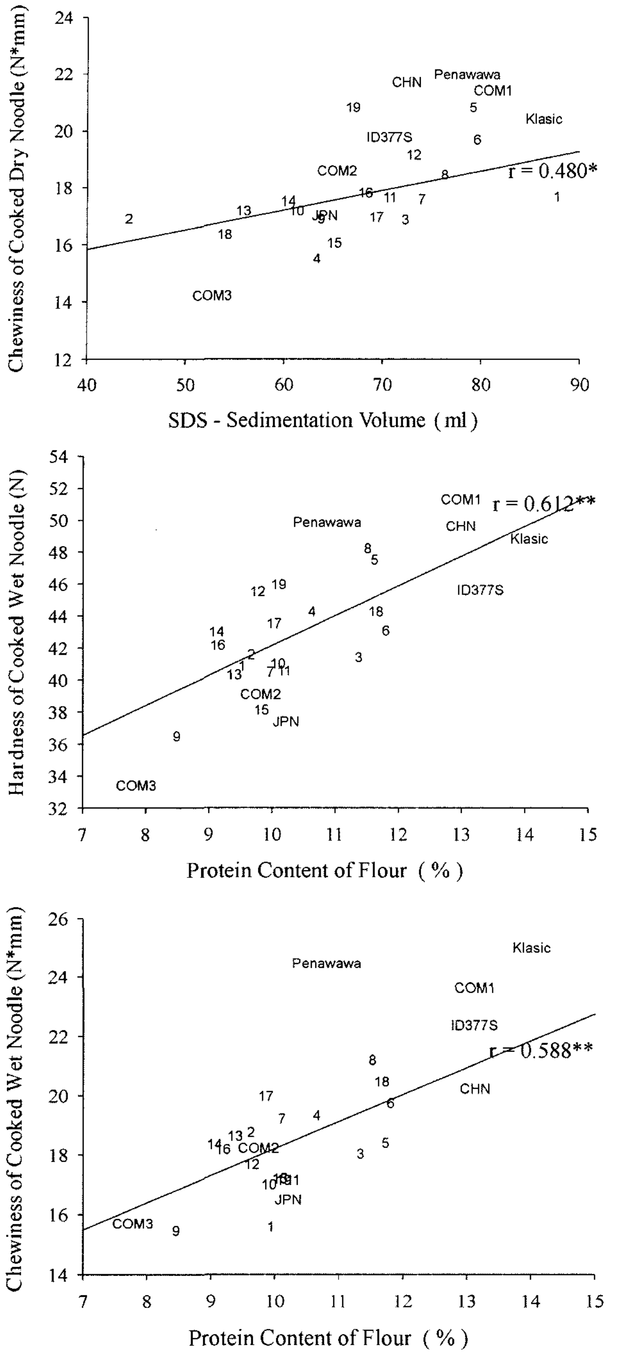

Fig. 1. The relationships between cultivar means of protein content of flour, SDS-sedimentation volume and hardness and chewiness of cooked wet and dry noodles. 1; Alchanmil, 2; Chokwang, 3; Eunpamil, 4; Geurumil, 5; Gobunmil, 6; Keumkangmil, 7; Olgeurumil, 8; Tapdongmil, 9; Urimil, 10; Suwon 258, 11; Suwon 261, 12; Suwon 265, 13; Suwon 274, 14; Suwon 275, 15; Suwon 276, 16; Suwon 277, 17; Suwon 278, 18; Suwon 279, 19; Suwon 280, JPN; Japanese Noodle Flour, CHN; Chinese Noodle Flour, HRS; Hard Red Spring Wheat, COM1; Commercial Flour for Bread in Korea, COM2; Commercial Flour for Noodle in Korea, COM3; Commercial Flour for Cookies in Korea. r = Correlation Coefficients (n=19).

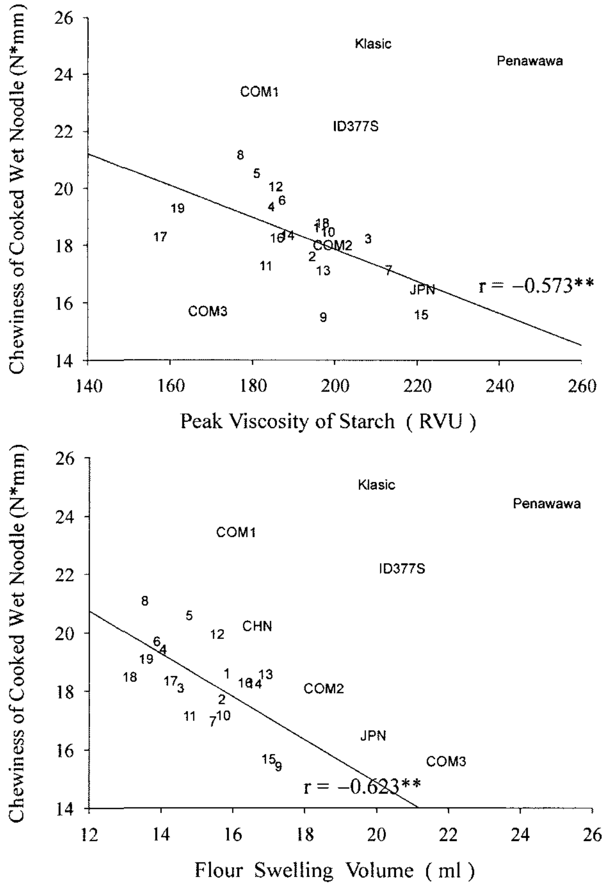

Fig. 2. The relationships between cultivar means of peak viscosity of starch, flour swelling volume and chewiness of cooked wet noodle. 1; Alchanmil, 2; Chokwang, 3; Eunpamil, 4; Geurumil, 5; Gobunmil, 6; Keumkangmil, 7; Olgeurumil, 8; Tapdongmil, 9; Urimil, 10; Suwon 258, 11; Suwon 261, 12; Suwon 265, 13; Suwon 274, 14; Suwon 275, 15; Suwon 276, 16; Suwon 277, 17; Suwon 278, 18; Suwon 279, 19; Suwon 280, JPN; Japanese Noodle Flour, CHN; Chinese Noodle Flour, HRS; Hard Red Spring Wheat, COM1; Commercial Flour for Bread in Korea, COM2; Commercial Flour for Noodles in Korea, COM3; Commercial Flour for Cookies in Korea. r=Correlation Coefficients (n=19).

lines showed higher chewiness (18.87 N ± 1.39 N) than that (17.33 ± 1.29 N) of 2.2-presence lines. But there was no difference between friabilin-presence and friabilin-absence lines in cooked wet and dry noodles.

Several investigations have reported that pasting properties of starch were responsible for superior noodle quality (Moss, 1980; Oda *et al.*, 1980; Crosbie, 1991; Crosbie *et al.*, 1992). Flour swelling volume has been negatively correlated with alkaline noodle firmness and elasticity, and positively correlated with surface smoothness of cooked noodles (Ross *et al.*, 1997). Baik *et al.* (1994) proposed that both protein content and protein quality should be considered in predict-

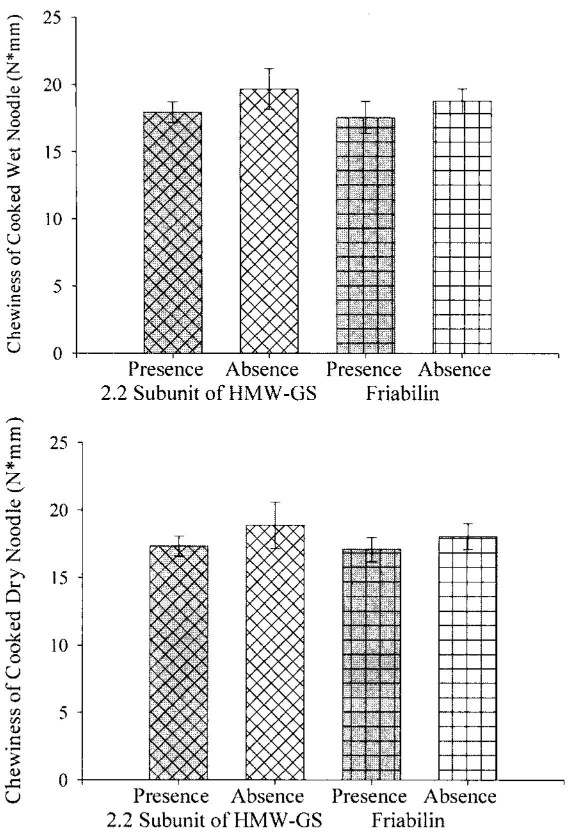

Fig. 3. The difference of chewiness of cooked wet and dry noodles according to the presence or absence of 1Dx2.2 + 1Dy12 subunit of high molecular weight glutenin subunit (2.2 subunit of HMW-GS) and friabilin in Korean winter wheat cultivars.

ing the textural properties of noodles. Recently, Lang *et al.* (1998) proposed the possibility of developing dual purposes wheats with the improvement of noodle characteristics while maintaining good bread baking qualities.

With these correlations between flour characteristics and TPA parameters, hardness and chewiness should be good criteria for the evaluation of cooked noodles in Korean style noodles, as these parameters, were influenced by both protein content and quality. Also, flour swelling volume and starch pasting properties were highly correlated with noodle texture. Because the low protein content and the low amylose content of starch had an effect on the high flour swelling volume and starch pasting properties, protein content and quality as well as starch properties, should be considered to improve noodle texture of Korean style noodles. Although there were no significant differences of noodle texture for the lines with different protein subunits, these biochemical markers still should be considered for the selection criteria in early generations of Korean wheat breeding programs. Therefore, protein content damaged starch content, SDS-sedimentation volume, starch peak viscosity and flour swelling volume could be used as potential predictors to evaluate flour qualities related to bread and noodle making in Korean wheat breeding programs. The overcoming of limited genetic variation in amylose content with genetic recombination using genetic resource with null in granule-bound starch synthase should be also considered for the improvement of noodle quality and further study of dual purpose in breads and noodles is also required for increasing of consumption of Korean wheats.

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