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Genotypic and Environmental Effects on Cookie Quality of Korean Winter Wheat

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ABSTRACT : Cookie baking properties and relationships between cookie baking properties and flour characteristics were evaluated for two years, 1997 and 1998, and at two locations, Suwon and Deokso, with Korean winter wheat cultivars and lines. Cookie baking parameters, except for cookie diameter and top grain score, were influenced by locations and years. Chokwang, Suwon 274, Suwon 275, Suwon 277 and Urimil showed larger cookie diameter and excellent top grain score compared to the other Korean winter wheat cultivars and lines. Among the flour characteristics, protein content, damaged starch content, alkaline water retention capacity and flour swelling volume showed high positive correlation coefficients with cookie baking parameters. Friabilin-present lines showed larger cookie diameter, suitable surface structure of cookie and softer snapping force than the friabilin-absent lines.

Keywords : wheat, flour, cookie-baking, cookie diameter, snapping force, alkaline water retention capacity (AWRC)

Cookies are products made from soft wheats. Research on cookie baking and cookie flour quality have been carried out for the utilization of soft wheats. Cookies are prepared with a formula high in both sugar and shortening and relatively low in water. Because of this formula, the typical cookie dough does not have elasticity. The most widely used cookie baking procedure is the micro-baking procedure developed by Finney *et al.* (1950). This micro test requires only 40 g of flour, and two cookies are baked from a dough mix. The advantages of this method that it is are easy to perform with sufficient accuracy, is reproducible and it is very sensitive to changes of flour characteristics.

Cookie baking and flour qualities are generally evaluated by two major indicators, cookie diameter and cookie texture. Flour that produces a cookie of large diameter with a uniform and good top grain pattern is considered to be good cookie flour. Finney *et al.* (1987) reviewed that cookie diameter could be attributed to the amount of tailings starch fractions, a heterogeneous component consisting of hydrophilic substances such as hemicelluloses and damaged starch. Cookies made from soft wheat flour have a large diameter, whereas cookies made from hard wheats are small in diameter (Hoseney *et al.*, 1988). Starch damage has been shown to have a negative relationship with cookie diameter (Aboud *et al.*, 1985a; Gaines *et al.*, 1988), and cookie diameters and cookie quality are affected more by the content of protein than by the quality (Souza *et al.*, 1994). Gaines (1985) reported that cookie diameter was positively associated with softer textured wheats having lower protein contents. Gaines et al. (1988) reported that cookie diameter was increased by more flour moisture content and also proposed that wheat quality evaluators should consider the kernel hardness of soft wheats because hard kernel texture yields relatively high levels of starch damage upon milling, and this property likely results in more dough handling problems than softer kernel texture.

Flours with a low alkaline water retention capacity are generally considered to have good cookie quality potential. Yamazaki (1953) reported that alkaline water retention capacity (alkaline water retention capacity) is a powerful method for the evaluation of potential cookie baking quality in soft winter wheat. For assessing cookie quality, an early generation micro alkaline water retention capacity test was introduced by Kitterman and Rubenthaler (1971). Highly negative correlations between alkaline water retention capacity and cookie diameter have been found (Yamazaki, 1954; Yamazaki *et al.*, 1977; Aboud *et al.*, 1985a; Doescher *et al*, 1987; Basset *et al.*, 1989).

Kernel hardness is also a key determinant of cookie quality because kernel hardness affects cookie flours and cookie baking quality in relation to damaged starch granules, which absorb more water than sound starch granules. The qualitative contribution of starch surface protein to quality differences among soft and hard wheats was recently studied. Out of starch granule proteins, friabilin (15 kDa protein) was abundant in all soft wheat starch granules, whereas friabilin was scarce in hard wheat starches and absent in durum wheat (Jolly *et al.*, 1993). Although the relationship between friabilin and the control of kernel hardness is unknown to date, the relationship between the occurrence of friabilin and

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kernel hardness remains unbroken in many studies.

Recently, Souza *et al.* (1994) reported that a glutenin rank sum (GRS) calculated according to a modified scoring system of Payne *et al.* (1987) was negatively correlated with cookie diameter. The relationship between high molecular weight glutenin subunits (HMW-GS) and cookie diameter have been reported by some studies (Czuchjowska *et al.*, 1996; Huo *et al.*, 1996; Finney and Bains, 1999). An investigation of HMW-GS and friabilin of Korean winter wheat cultivars and lines was performed in our previous study (Park *et al.*, 2001a).

Cookie texture is another important factor, since it affects consumer acceptance. Flour millers, product developers, bakers and cultivar quality evaluators would benefit from the development of instrumental techniques for measuring cookie texture based on reproducible and statistically sound principles of materials testing (Gaines *et al.*, 1992). Cookies made from soft wheats generally produce tenderer texture than those of hard wheats. Although the factors responsible for this difference between good and poor cookie texture is not clearly understood, flour properties might influence cookie texture. The evaluation of cookie hardness is mainly performed with a snap test, known as the three-point break, triple-beam snap (Gaines *et al.*, 1992). Cookie hardness is affected by moisture content in cookies (Zabik *et al.*, 1979). Soft wheats usually produces a tenderer cookie than do hard wheats, because soft wheats have low protein content and weak gluten (Gaines, 1985). Gaines *et al.* (1992) proposed that the three-point break techniques could be more reliable if brittleness is the major interest in product texture.

Genotype, environment and their interactions on end-use qualities of wheat should be considered for enhancing cultivar quality. In soft red winter wheats, highly significant differences have been detected among environments and genotypes for quality variables, and their interaction was highly significant (Baenzinger *et al.*, 1985; Basset *et al.*, 1989; Schuler *et al.*, 1995). Pomeranz et al. (1985) reported that influence of genotype on kernel hardness was found to be greater than environment, and genotypes were considered as relatively stable for hardness across environments. Gaines *et al.* (1996) reported that milling properties and cookie baking quality of soft wheats could be distinguished by genotype, but that environment had a strong influence on grain condition, which had the most influence on milling and baking characteristics.

High grain yield and early maturation are the major consideration in Korean wheat breeding programs. 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 rean wheat breeders. There is no information about cookie baking quality of Korean wheats. This study is aimed at the evaluation of the relationship among flour characteristics and cookie baking qualities of Korean winter wheats and determination of selection criteria for high cookie quality in wheat breeding programs of Korea.

MATERIALS AND METHODS

A set of Korean winter wheat cultivars and lines (Table 1) was harvested at Suwon (Upland Crop Experimental Farm of National Crop Experiment Station) in 1997 and another set of materials (Table 2) was produced at Suwon (Upland Crop Experimental Farm of National Crop Experimental

Table 1. Cookie baking parameters of Korean winter wheat cultivars and lines over years and locations.

	Cookie Baking Parameters			
	Diameter (mm)	Thickness (mm)	Top Grain Score	Snapping Force (N)
Year				
1997	84.93	8.46	4.31	36.44
1998	85.03	8.31	4.33	33.33
LSD[†]	0.22	0.03	0.20	0.71
Location				
Suwon	84.29	8.61	4.04	37.66
Deokso	84.26	8.74	4.09	38.68
LSD	0.13	0.03	0.15	1.26
Cultivar/Line				
Alchanmil	84.21de[‡]	8.51fgh	3.25gh	35.85fg
Chokwang	88.89b	7.71ij	5.00c	25.08i
Eunpamil	80.24h	9.12cd	3.33g	42.07cde
Geurumil	81.37fgh	9.05cd	4.33d	37.85efg
Gobunmil	80.79gh	9.23bc	2.67i	44.17cd
Keumkang-mil	83.40e	8.90de	3.25gh	40.00def
Olgeurumil	86.06c	8.32h	5.00c	33.46gh
Tapdongmil	81.79fg	9.38b	3.00h	46.83bc
Urimil	90.42a	7.85i	6.00a	30.05hi
Suwon258	83.66de	9.18bc	4.00e	49.82b
Suwon261	81.34fgh	9.66a	2.67i	51.76ab
Suwon265	83.86de	8.37gh	4.00e	30.13hi
Suwon274	88.79b	7.55j	5.67b	28.26hi
Suwon275	88.93b	7.63ij	5.50b	29.67hi
Suwon276	84.77d	8.60fg	4.0e	36.24fg
Suwon277	88.75b	7.61ij	5.67b	28.06hi
Suwon278	81.70fg	8.72ef	3.67f	38.89def
Suwon279	80.78gh	9.70a	3.00h	55.65a
Suwon280	82.16f	9.24bc	3.33g	39.57def

[†]Least significant difference (P=0.05).
[‡]Values followed by same letters are not significantly different at P<0.05.

Table 2. Cookie parameters of flours from Western Wheat Quality Lab and Korean commercial flours.

Sample	Cookie Baking Parameters			
	Diameter (mm)	Thickness (mm)	Top Grain Score	Snapping Force (N)
JPN†	80.18	9.68	4.33	44.66
CHN	74.59	10.77	2.00	86.17
HRS	76.54	10.35	2.00	66.85
Penawawa	84.55	8.59	4.00	51.49
ID377S	79.74	10.21	2.00	87.52
Tres	84.13	9.09	4.33	54.30
Rely	84.28	8.10	5.67	44.06
COM1	76.59	10.28	2.00	69.74
COM2	80.72	9.92	4.00	54.03
COM3	85.90	8.54	6.00	36.70
LSD‡	0.46	0.13	0.56	3.16

†JPN=Japanese Noodle Flour, CHN=Chinese Noodle Flour, COM1 =Korean Commercial Flour for Bread, COM2=Korean Commercial Flour for Noodles, COM3=Korean Commercial Flour for Cookies.
‡Least significant difference ($P = 0.05$).

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. Four samples of flours from ID377S, Penawawa, Tres and Rely, and three standard wheat flours, Japanese and Chinese noodle flours (JPN and CHN) and hard red spring wheat flour for baking (HRS), were obtained from Western Wheat Quality Laboratory (WWQL), Washington State University, Pullman, U.S.A. Three Korean commercial flours for bread, noodles and cookies (COM1, 2 and 3, respectively), 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. Tres and Rely are club wheats and have been used for cookie baking.

The cookie formula and baking procedures were followed as described by Finney *et al.* (1950) in micro method III. Baked cookies were rested for 2 hr at room temperature and then the cookie diameter and thickness were measured. The top grain of the cookie was evaluated on a 6 point scales of 1 to 6, in which 1 and 6 represent unsatisfactory and outstanding crumb grain, respectively. For cookie hardness, the three-point break test was performed as described by Gaines *et al.* (1992) using a Texture Analyser (TA-XT2*i*, Version 1.17, Stable Micro Systems, England). Maximum peak force was measured when the cookies were snapped by an HDP/VB probe (blade set) on a separated bottom support. Cookie hardness was calculated according to the equation described by Gaines *et al.* (1992), and snapping force (F) was calculated as follows:

$$F = (2/3\sigma bh^2) / L$$

where σ is the maximum force at failure, b is the width of the product, h is the thickness of the product, and L is the distance between the bottom supports. The test was performed with a load cell pressure of 5 kg, at a test speed of 0.8 mm/sec and at a test distance of 20% strain.

Data of protein content, damaged starch content, alkaline water retention capacity, flour swelling volume, high molecular weight glutenin subunits compositions and friabilin of Korean winter wheat cultivars and lines were obtained from our previous studies (Park *et al.*, 2001a; 2001b).

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

RESULTS AND DISCUSSION

Cookie baking parameters of Korean winter wheats are summarized in Table 1. Cookie diameter for cultivars over years and locations ranged from 80.24 mm for Eunpamil to 90.42 mm for Urimil. Cookie thickness for cultivars ranged from 7.55 mm for Suwon 274 to 9.70 mm for Suwon 279. Top grain score varied from 2.67 for Gobunmil to 6.00 for Urimil. Snapping force varied from 25.08 N for Chokwang to 55.65 N for Suwon 279.

Good quality cookie flours should have high flour yield, low protein content, small particle size, low alkaline water retention capacity and large cookie diameter. There are generally significant relationships among cookie flour characteristics and cookie baking parameters. Theses traits are heritable and are important parameters in soft wheat breeding programs (Patterson and Allen, 1981). Highly significant differences were detected among environments and cultivars for each of the cookie flours and baking traits, and genotype × environment interactions were highly significant for all of the traits (Baenzinger *et al.*, 1985; Basset *et al.*, 1989).

There were no statistically significant differences between cultivars over years and locations in cookie diameter and top grain score. The cookie flours of 1997 showed significantly higher values in cookie thickness and snapping force when compared with those wheats harvested in 1998. Flours harvested at Deokso showed significantly higher cookie thickness and snapping force than those harvested at Suwon. Although limited numbers of Korean winter wheat cultivars and lines were evaluated at only two locations, cookie baking parameters, except for cookie diameter and top grain

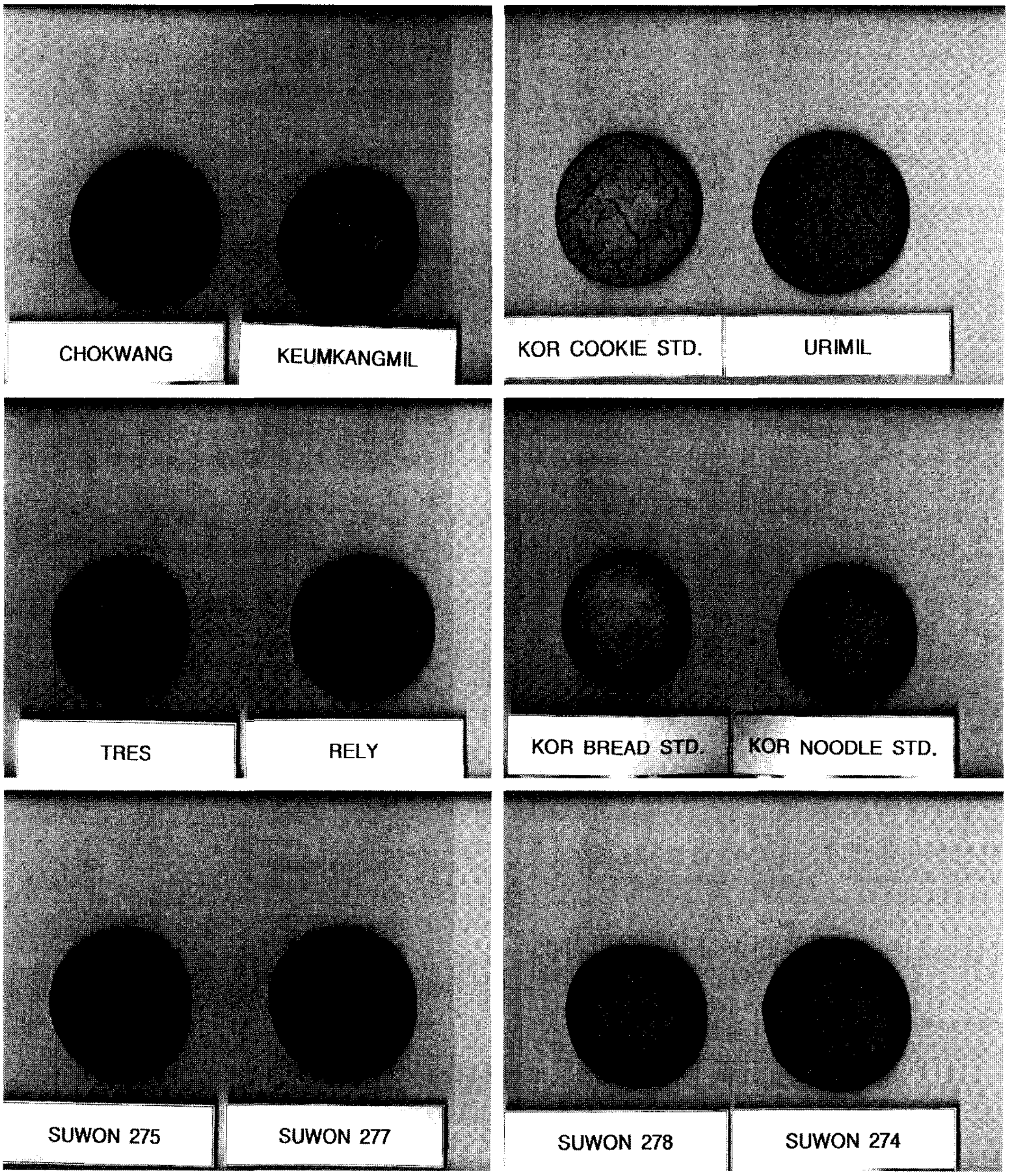

Fig. 1. The comparison of cookie diameter and top grain of Korean winter wheat cultivars and lines. KOR COOKIE STD, Korean commercial flours for cookies; KOR NOODLE STD, Korean commercial flours for noodles; KOR BREAD STD, Korean commercial flours for bread.

score, were influenced by locations and years.

Cookie baking parameters of five flours obtained from WWQL and three Korean commercial wheat flours are summarized in Table 2. Rely and Korean commercial flours for cookies (COM3) showed larger cookie diameter, more suitable top grain and lower snapping force than those of others. Chinese noodle flours (CHN), hard red spring wheat standard flours for bread baking (HRS) and Korean commercial flours for bread (COM1) showed smaller cookie diameter, improper top grain and higher snapping force than others. Cookie baking parameters of Chokwang, Suwon 274, Suwon 275, Suwon 277 and Urimil were similar to those of Rely and COM3 (Fig. 1). These Korean winter wheat cultivars and lines indicated lower protein content, damaged starch content and alkaline water retention capacity than those of other Korean winter wheat cultivars and lines (Park *et al.*, 2001b).

Results from this study indicate that cookie diameter and top grain score can be used for the prediction of cookie baking quality of Korean winter wheat cultivars and lines

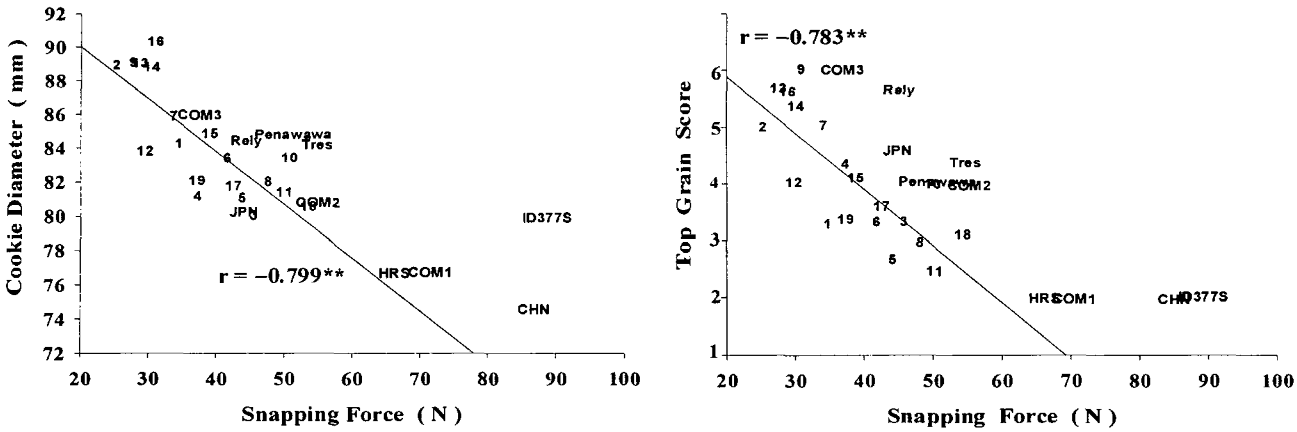

Fig. 2. The relationship between cultivar means over years and locations of cookie baking parameters in Korean winter wheat cultivars and lines. 1; Alchanmil, 2; Chokwang, 3; Eunpamil, 4; Geurumil, 5; Gobunmil, 6; Keumkangmil, 7; Olgeurumil, 8; Tapdongmil, 9; Urimil, 10; Suwon 258, 11; Suwon 261, 12; 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 Flours for Bread, COM1; Korean Commercial Flour for Bread, COM2; Korean Commercial Flour for Noodles, COM3; Korean Commercial Flour for Cookies. r = Correlation coefficients (n=19).

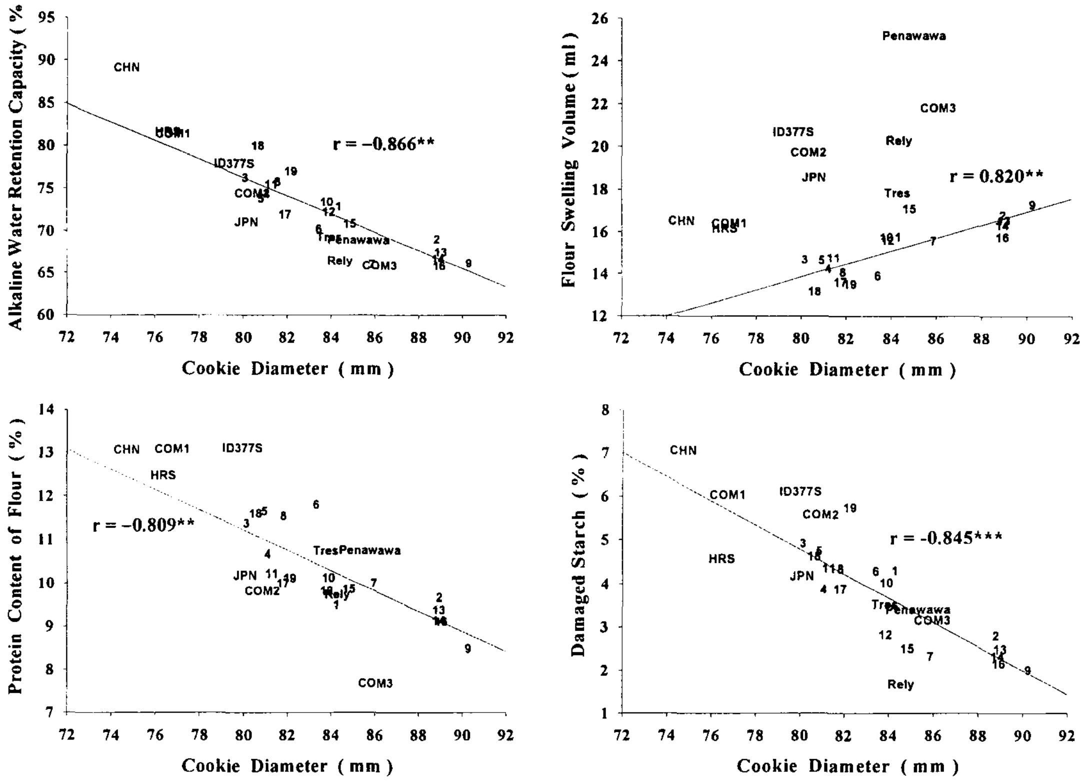

Fig. 3. The relationship between cultivar means of protein content of flour, damaged starch, alkaline water retention capacity, flour swelling volume and cookie diameter. 1; Alchanmil, 2; Chokwang, 3; Eunpamil, 4; Geurumil, 5; Gobunmil, 6; Keumkangmil, 7; Olgeurumil, 8; Tapdongmil, 9; Urimil, 10; Suwon 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 Standard Flours for Bread, COM1; Korean Commercial Flour for Bread, COM2; Korean Commercial Flour for Noodles, COM3; Korean Commercial Flour for Cookies. r = Correlation coefficients (n=19).

because of their significant correlations with flour characteristics and other cookie baking parameters. Fig. 2 shows the relationship between cultivars of cookie baking parameters means over years and locations. There were significant correlations between cookie diameter and snapping force (r= -0.799, P<0.01) and between top grain score and snapping force (r=-0.783, P<0.01). Fig. 3 shows the relationship between cultivar means over years and locations of flour characteristics and cookie diameter. Means of cookie diameter of the nineteen Korean winter wheat cultivars and lines were highly correlated with protein content (r=-0.809, P<0.01), damaged starch content (r=-0.845, P<0.01), alkaline water retention capacity (r=-0.866, P<0.01) and flour swelling volume (r=0.820, P<0.01). These characteristics of flour showed significant correlations to top grain score of cookie. Top grain score showed negative correlation to protein content, damaged starch and alkaline water retention capacity (r= -0.778, P<0.01, r=-0.808, P<0.01 and r=-0.806, P<0.01, respectively). There was a positive relationship between top grain score and flour swelling volume (r=0.749, P<0.01). Fig. 4 shows the relationship between cultivar means over years and locations of flour characteristics and snapping force. Means of snapping force of the nineteen Korean winter wheat cultivars and lines were correlated with flour protein content (r=0.731, P<0.01), damaged starch content (r= 0.571, P<0.05), alkaline water retention capacity (r=0.748, P <0.01) and flour swelling volume (r=-0.648, P<0.01).

The negative relationship between cookie diameter and protein content and damaged starch content in this study are in agreement with previous review reports on cookie baking quality (Patterson and Allen, 1981; Finney *et al.*, 1987; Hoseney *et al.*, 1988). Starch properties, such as amylose content and swelling and pasting properties of starch, showed no relationship with cookie baking parameters in this study (*unpublished data*), which are in agreement with some previous reports (Aboud and Hoseney, 1984, Aboud *et al.*, 1985b, Miller and Hoseney, 1997). There was a negatively significant correlation between amylose content and

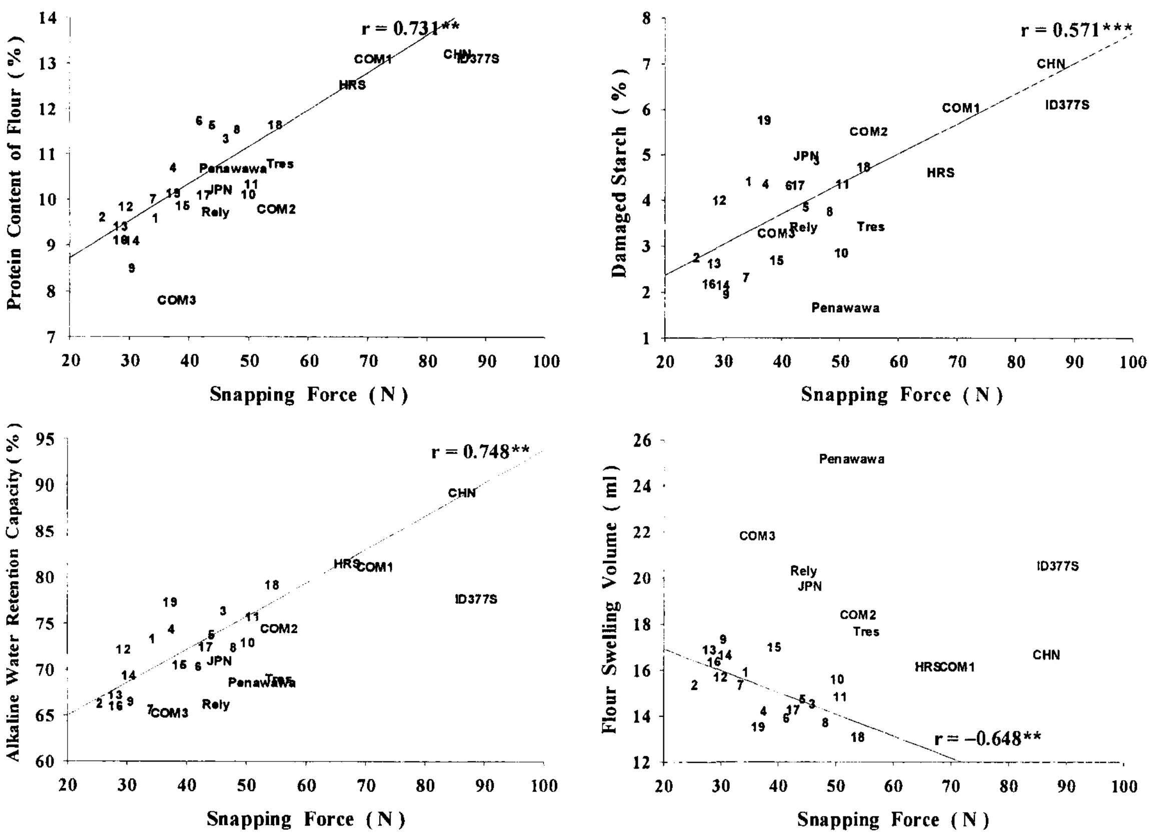

Fig. 4. The relationship between cultivar means of protein content of flour, damaged starch, alkaline water retention capacity, flour swelling volume and snapping force. 1; Alchanmil, 2, Chokwang, 3; Eunpamil, 4; Geurumil, 5; Gobunmil, 6; Keumkangmil, 7; Olgeurumil, 8; Tapdongmil, 9; Urimil, 10; Suwon 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 Standard Flours for Bread, COM1; Korean Commercial Flour for Bread, COM2; Korean Commercial Flour for Noodles, COM3; Korean Commercial Flour for Cookies. r = Correlation coefficients (n=19).

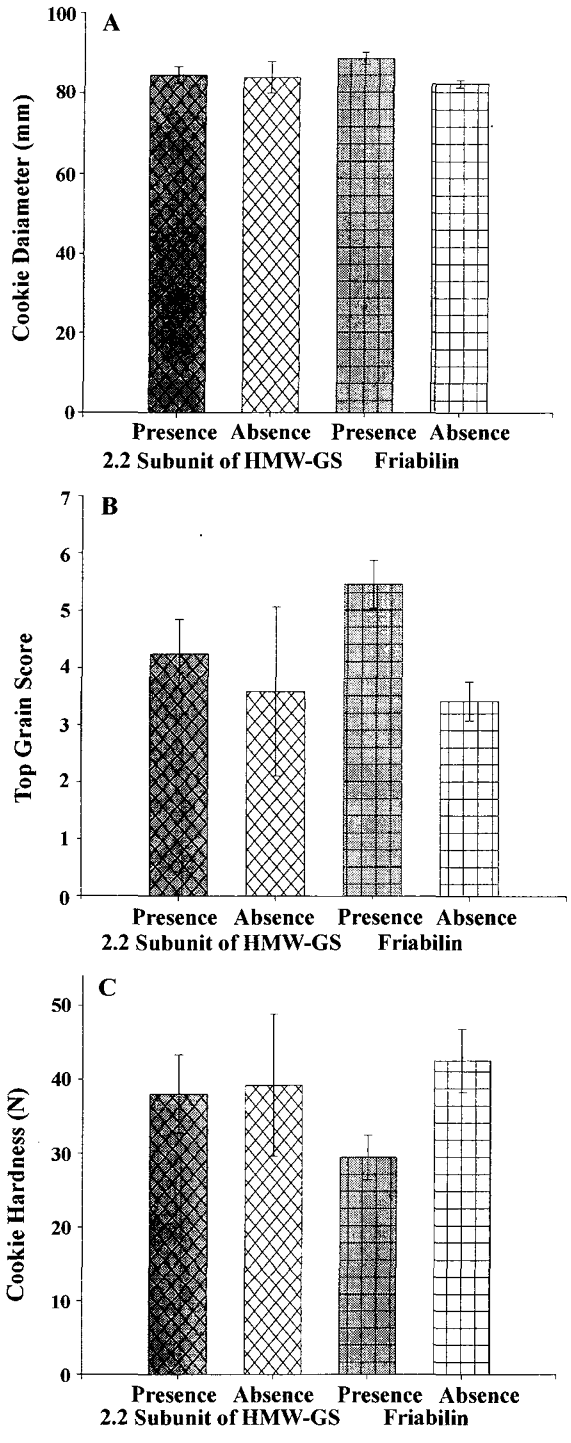

Fig. 5. The difference of cookie parameters, cookie diameter (A), top grain score (B) and snapping force (C) according to the presence or absence of 1D×2.2+1Dy12 subunit of high molecular weight glutenin subunit (2.2 subunit of HMW-GS) and friabilin in Korean winter wheat cultivars and lines.

cookie diameter. This phenomenon might have resulted from the limited genetic variation of amylose content in Korean winter wheat cultivars and lines (Park *et al.,* 2001a).

Fig. 5 shows the difference of cookie baking parameters according to the presence and absence of 1D × 2.2+1Dy12 subunits of HMW-GS (2.2-presence and absence) and friabilin (friabilin-presence and friabilin-absence). There were no significant differences in cookie baking parameters, cookie diameter, top grain score and snapping force between 2.2-presence and absence lines. However, friabilin-presence lines showed higher cookie diameter (88.65 mm 1.45) and top grain score (5.46 ± 0.40) and lower and snapping force (29.41 N 2.89) than those of friabilin-absence lines (82.29 ± mm ± 1.52, 3.42 ± 0.56 and 42.53 N ± 7.09, respectively). High protein content and damaged starch content of friabilin-absence lines might influence unsuitable cookie baking quality.

CONCLUSIONS

Among cookie baking parameters, cookie diameter and top grain of cookie surface should be considered in evaluating cookie quality. Lower low protein content, damaged starch content and alkaline water retention capacity may also be considered for better cookie quality in Korean wheat breeding programs. Friabilin could be used as a powerful selection marker in early generation of Korean wheat breeding programs for better cookie quality. Chokwang, Urimil, Suwon 274, Suwon 275 and Suwon 277 could be used as parental plants in breeding programs for better cookie quality because of their larger cookie diameter and excellent top grain score than other Korean winter wheat cultivars and lines.

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