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Quality Evaluation for Vegetable Use in Local Soybean Cultivars with Various Seed Coat Color

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ABSTRACT

From the evaluation of physical properties such as springiness, gumminess, adhesiveness, chewiness and hardness by the texture analyzer, vegetable soybean lines with green seed-coat were best as compared with those with black, brown, mixed, and yellow seed-coats. A panel test evaluated on the basis of taste, sweetness, chewiness, and total scores also indicated that soybean lines with green seed-coat were the best. The total scores of panel test was decreased in the order of green> yellow> black> brown seed-coat colored soybean.

The mean value of sucrose content obtained by HPLC analysis was highest in black seed-coat colored soybean, and followed by green, yellow, and brown soybeans. The highest sucrose content (8.22%) was observed in 180362, a soybean line with green seed-coat. The full-season type soybeans showed much higher sucrose content than summer types which are mainly cultivated on farmer's fields for vegetable purposes.

The final 13 lines selected from 300 colored soybeans showed nearly the same panel scores as Miwongreen. However, these lines had a great deal of variation in sucrose content, and much higher readings in texture analysis than Miwongreen, especially in chewiness and hardness which were the most important properties in vegetable soybeans.

Key words : soybeans, vegetable soybeans, colored soybeans, local soybeans, sucrose content, physical properties.

Vegetable soybeans are mainly used in Asian countries such as Korea, Japan, Taiwan, China, and Thailand (Masuda et al., 1991; Masuda, 1994). Vegetable soybeans have been extensively used for a long time for side dishes, cooking-with-rice, and the stuffing of rice cakes in Korea (Hong et al., 1992). Vegetable soybeans are also well known as a good nutritional diet because they have a high content of protein, oil, sucrose, fiber, and vitamin A, B, and C.

Generally, soybeans with black, green, brown, and mixed color seed coats have been used for vegetable or cooking-with-rice purposes in Korea. A great deal of chemical variation in these soybeans has been reported (Guh et al., 1983; Kim et al., 1989; Openshaw & Hardly, 1981; Park, 1974; Shon, 1992). Black soybeans have been reported to have various medicinal effects (Chang, 1988; Lee, 1994).

Physical properties of seeds are especially important in vegetable and cooking-with-rice soybeans because they are used directly without additional cooking. Guh et al. (1983) measured hardness, elasticity, chewiness, cohesiveness, gumminess, adhesiveness, and brittleness by a texture meter for the evaluation of cooking quality in cooking-with-rice soybeans and calculated their correlations based on the panel scores of flabbiness, sweetness, beany taste, toughness, chewiness, wetness, and afterfeel.

Factors affecting the quality of vegetable soybeans are soybean genotype, duration of blanching, time of harvesting, methods and duration of storage after processing, and the seed hardness. Seed hardness can be the most important criterion for the texture of vegetable soybeans (Masuda, 1991).

Eating quality is determined by several factors. Sweetness is determined by the sucrose content, taste by glutamic acid (Masuda et al., 1988; Masuda, 1991; Tsou & Hong, 1991; Yasuhiro, 1991), sourness by organic acid and free amino acid and bitterness by saponin, isoflavonoid, and *l*-arginine (Masuda, 1994).

Shon (1992) reported that the range of sugar content for 1,087 local soybean lines was 8.3~12.5% with a mean of 10.1%, while that of 53 summer type soybean lines was 6.1~10.0% (Chung, 1992). Sugar in vegetable soybeans mainly consists of sucrose, fructose, and glucose with the highest amount being sucrose. The content of total sugar gradually increases at the early stage of pod filling but does show much change at the mid stage of pod filling (Yasuhiro, 1991), and decreases from 35 days after flowering (Tanusi, 1972) with some varietal differences (Chung & Hwang, 1996). In general, the content of vegetable soybeans is somewhat higher than that of dried seeds but does not exceed 6% of fresh grain weight (Masuda, 1991).

It is well known that the content of protein, oil, and sugar in seed grain can greatly affect nutrition and taste in soybeans. The content of sugar showed a positive correlation with protein but a negative one with oil (Openshaw & Handly, 1981). Significant varietal differences in the amount of protein and oil have been reported (Guh et al., 1983; Kim et al., 1989; Park, 1974).

The objective of this study was to obtain basic information for the development of high quality vegetable soybeans by evaluating the color seed-coat local lines for chemical composition, physical properties, and panel tests.

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MATERIALS AND METHODS

Experimental materials consisted of 60 soybean lines and varieties, of which 50 lines were preliminary selected for vegetable purposes from 300 local soybean lines with colored seed-coats from the gene bank of the Rural Development Administration. The local lines were originally collected from farm houses through out the country. In terms of seed-coat colors, the 60 lines and varieties consisted of 8 yellow, 21 black, 8 brown, 21 green, and 2 mixed. Fifty lines were selected based on the major agronomic characteristics suitable for vegetable soybeans at international markets (Shanmugasundaram et al., 1990). These traits included high rate of 2 or 3-seeded pods and bright pod color with grey pubescence, pod length≧4.5 cm, pod width≧1.3 cm, ≧175 pods per 500 g. The other 10 soybean varieties were those recommended or currently being cultivated on farmers' fields. The planting date was May 1 and the planting density was 60×15 cm and 2 plants per hill. Fertilizers were basally applied with rates of 40-70-60 kg/ha for N, P_2O_5, and K_2O, respectively, before the planting. The experimental plot was laid out in a randomized complete block design with 3 replications.

Pods were harvested at the stage of R6 and blanched in a water bath for 6 minutes at 98℃. The blanched pods were quickly chilled to −40℃ and stored at −20℃ for quality analysis. Sucrose content was analyzed by HPLC. Seeds of vegetable soybeans were dried at 70℃ and crushed into a powder. Crude oil was extracted by Soxhlet method and 0.5 g of soy powder was dissolved in 10ml of distilled water. The solution was filtered by Whatman No. 2 and the remnant was centrifuged for 5 minutes at 15,000 rpm. The filtered solution was refiltered by 0.45 μm membrane filter for the final analysis.

The physical properties of vegetable soybeans such as hardness, springiness, chewiness, cohesiveness, gumminess, and adhesiveness were measured by a texture analyzer (TA-XT2) after thawing of frozen pods.

The panel for vegetable soybeans was made by 13 students at the Plant Genetic Laboratory. The items for evaluation were sweetness, taste, chewiness, and total scores. The scores were made based on 1 for the worst, 3 for the medium, and 5 for the best.

RESULTS AND DISCUSSION

Physical properties

Differences in physical properties of seed-coat-color based soybeans groups are shown in Table 1. For springiness which is the power of sustaining original physical forms, there was a decreasing trend of yellow> black> green> brown colored soybeans. Gumminess decreased in the order of yellow> black> brown> green colored soybeans. Adhesiveness decreased in the order of yellow> black> green> brown colored soybeans. Chewiness decreased in the order of yellow> black> brown> green colored soybeans. Cohesiveness was in the order of green> brown> black> yellow colored soybeans. Seed hardness which is the most important characteristic in vegetable soybeans was in the order of yellow> black> brown> green. The green seed-coat-colored soybeans were the best in physical properties including gumminess, adhesiveness, chewiness, and hardness. On the other hand, the yellow seed-coat-colored soybeans which have been the most recommended vegetable soybeans for farmers' fields, were the worst. Therefore, the color of seed coat should be one of the most important factors considered in the development of vegetable soybeans with high quality.

Correlations among the components of physical properties are shown in Table 2. No significant correlation was observed between springiness and other components. Gumminess showed negative correlations with cohesiveness and adhesiveness, but was positive with hardness and chewiness. On the contrary, cohesiveness showed

Table 1. Range and means of components of physical properties for the vegetable soybeans of different seed-coat-colored groups.

	Seed coat color	Springiness	Gumminess	Adhesive-ness	Chewiness	Cohesive-ness	Hardness
Range	Black	0.953~1.005	143.1~334.4	−68.8~−234.6	138.4~331.4	0.245~0.331	4,554.4~1,254.9
	Green	0.914~1.006	105.9~372.1	−207.3~−51.9	96.9~365.3	0.231~0.363	438.4~1,256.1
	Brown	0.938~1.000	140.7~384.4	−167.3~−73.4	141.1~362.2	0.245~0.341	530.2~1,370.8
	Yellow	0.968~1.016	158.2~935.9	−509.7~−73.7	153.5~917.9	0.236~0.330	614.7~1,117.1
Mean	Black (Bl)	0.986	234.3	−139.1	231.4	0.291	802.3
	Green (G)	0.984	216.0	−122.3	210.7	0.310	687.0
	Brown (Br)	0.979	216.5	−113.3	210.7	0.305	718.3
	Yellow (Y)	0.990	317.0	−170.6	375.7	0.293	1086.3
LSD (5%) Between	Y and Br	0.017	108.9	62.5	116.8	0.031	355.9
	Y and Bl, G	0.014	90.5	38.5	97.1	0.025	295.2
	Bl and G	0.007	67.2	51.9	72.1	0.019	219.3

Table 2. Correlations among the components of physical properties of vegetable soybeans.

	Springiness	Gumminess	Cohesiveness	Hardness	Adhesiveness
Gumminess	0.04^{ns}				
Cohesiveness	−0.02^{ns}	−0.27*			
Hardness	0.00^{ns}	0.96**	−0.27*		
Adhesiveness	0.06^{ns}	−0.71**	0.83**	−0.68**	
Chewiness	0.03^{ns}	0.86**	−0.33**	0.84**	−0.65**

* significant at 0.05 probability level.
** significant at 0.01 probability level.
ns : not significant.

negative correlations with hardness and chewiness, but was positive with adhesiveness. Hardness showed negative correlation with adhesiveness but positive one with chewiness. Adhesiveness showed negative correlation with chewiness. However, Guh et al. (1983) reported in their correlation analysis using cooking-with-rice soybeans that there were positive correlations between hardness and chewiness, chewiness and gumminess, and cohesiveness and gumminess but negative correlations between cohesiveness and gumminess, and cohesiveness and chewiness. Consequently, physical properties of vegetable soybeans in this study showed negative correlation between hardness and gumminess, and also negative correlation between cohesiveness and gumminess, thus somewhat different results from those of Guh et al. (1983) which analyzed fully matured soybean seeds used for cooking-with-rice. The difference seemed to be caused by the degree of seed development. Accordingly, physical properties for vegetable soybean should be directed towards those having good chewiness and cohesiveness but low value in hardness.

Panel test

The panel score means of varietal groups classified by seed-coat-colors for sweetness, taste, chewiness, and total scores were 2.32, 2.60, 2.90, and 2.66, respectively. The highest means for sweetness (2.48), taste (2.84), and total score (2.85) were obtained in the green seed-coat-colored soybean group. On the contrary, the highest value for chewiness (3.01) was obtained in the yellow soybean group as in the texture analysis which indicated that yellow soybeans were not suitable for vegetable purposes.

Sucrose content

Sucrose content of vegetable soybeans analyzed by HPLC is shown in Table 4. The range of sucrose content was 1.00~8.22% with a mean value of 3.70%. The mean value of sucrose content was highest (4.12%) in black, 3.74% for green, 3.20% for brown, and 3.33% for yellow seed-coat-colored soybeans. The highest sucrose content (8.22%) was observed in one line (180362) of the green soybean group. This line is considered to be very important as genetic source for the high sucrose content, which is one of the most important factors determining seed quality of vegetable soybeans. On the contrary, Shon (1992) reported that total sugar content of local lines was 10.1% for black, 10.3% for brown, 10.2% for green, and 9.9% for yellow soybeans, respectively. There was greater variation in green soybeans than in yellow soybeans. Chung et al. (1992) reported that total sugar content of summer type soybeans ranged from 6.1 to 10.0%.

Sucrose content between soybean cultivars of different ecotypes was compared, as shown in Table 5. No significant difference in sucrose content was observed not only between the local and recommended cultivars within the full-season type of soybeans but between the full-season

Table 3. Results of panel test for vegetable soybeans of different seed-coat-color groups.

Seed-coat color	Range				Mean			
	Sweetness	Taste	Chewiness	Total score	Sweetness	Taste	Chewiness	Total score
Black	1.85~3.08	1.85~3.31	2.38~3.38	1.85~3.38	2.32	2.64	2.86	2.59
Green	1.62~3.38	1.92~3.46	2.54~3.30	2.15~3.62	2.48	2.84	2.93	2.85
Brown	1.62~2.62	1.92~3.23	2.54~3.08	1.92~2.92	2.26	2.29	2.79	2.51
Yellow	1.46~2.54	2.15~2.92	2.26~3.38	2.38~3.15	2.21	2.62	3.01	2.69
Mean†					2.36	2.71	2.90	2.69
LSD (5%) between yellow and brown					0.33	0.34	0.21	0.34
yellow and black, green					0.28	0.28	0.17	0.28
black and green					0.20	0.21	0.13	0.21

† mean of 60 lines and varieties.

Table 4. Range and means of sucrose contents for vegetable soybeans of different seed-coat-colors.

	Range				Mean				LSD (5%) between
	Black	Green	Brown	Yellow	Black (Bl)	Green (G)	Brown (Br)	Yellow (Y)	Y and Br Y and Bl, G Bl and G
Sucrose (%)	1.00~6.90	1.92~8.22	2.14~4.27	1.67~5.26	4.12	3.74	3.20	3.33	1.38 1.15 0.85

Table 5. Range and means of sucrose contents for vegetable soybeans of different ecotypes.

	Sucrose content (%)	
	Range	Mean
Full-season type		
Local lines	1.00~8.22	3.83
Commercial cultivars	1.67~4.78	3.40
Summer type	1.72~4.92	3.43
LSD (5%) Between summer type and local lines		1.38
summer type and commercial varieties		1.86

and the summer type soybeans. However, sucrose content was generally higher in the full-season type of soybeans, especially in color soybeans compared with that of the summer-type soybeans. The range of sucrose content in local soybeans with seed-coat-color was from 1.00 to 8. 22%, and no significant difference was observed between the full-season and the summer type soybeans. This indicates that the colored seed-coat-local soybeans of the full-season type are much more useful not only for the genetic source of high sugar content but also for the direct use of frozen vegetable soybeans than the summer type soybeans which are currently being cultivated in farmers' fields.

Correlation coefficients between the sucrose contents obtained by HPLC and the panel scores are shown in Table 6. Significantly positive correlation ($r=0.34^{**}$) between sucrose content and sweetness was observed. There was no significant correlation between sucrose content and total panel scores observed because total panel scores were overall evaluated by not only sweetness but by taste,

Table 6. Correlation coefficients between sucrose content by HPLC, and sweetness and total scores by the panel test.

	Sucrose	Sweetness
Sweetness	0.34^{**}	
Total score	0.21^{ns}	0.78^{**}

ns : not significant.
** significant at 0.01 probability level.

chewiness, and hardness. But panel sweetness and taste showed high correlation coefficient ($r=0.78^{**}$), which suggested that sucrose content was a very important factor in determining the quality of vegetable soybeans.

Evaluation for quality of the selected soybean lines

Thirteen lines out of 300 local soybean lines with colored seed-coat were finally selected as shown in Table 7. Selection was based on two criteria; 1) by agronomic evaluation in the first year (Hwang & Lee, 1998) based on the international market standards; 2) by quality evaluation in the 2nd year based on physical properties, panel tests, and chemical compositions of vegetable seed grains.

Compared with Miwongreen which is being cultivated the most widely on farmers' fields, no selecied lines showed significantly higher panel scores in sweetness, taste, and total scores due to high coefficient of variation values (28.5~38.0%) among the panelists. On the contrary, 9 selected lines showed higher sucrose content than Miwongreen. Compared with Miwongreen, physical properties obtained by a texture meter showed similar values for springiness and cohesiveness, significantly higher value for gumminess in 180262, the significantly higher value for adhesiveness in all lines except 173014 and 185209 but lower value for chewiness in all lines. All selected lines except 178219 showed nearly the same or a somewhat lower value for hardness than Miwongreen.

Summing up the panel scores and the analysis of sucrose contents and physical properties, the selected colored seed-coat-local soybean lines, compared with Miwongreen, were shown to have the same quality level in spite of much variation among themselves. These lines are even better in chewiness and hardness which are the most important factors in vegetable soybeans. The selected local lines with colored seed-coats also revealed better eating quality than the current yellow seed-coat vegetable soybean varieties and hence potential to be used as useful breeding material.

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Table 7. Panel, physical, and chemical characteristics for the finally selected vegetable soybean lines.

Line or variety	Panel test				Chemical	Physical properties					
	Sweet -ness	Taste	Chewi -ness	Total score	Sucrose (%)	Springi -ness	Gummi -ness	Adhesive -ness	Chewi -ness	Cohesive -ness	Hard -ness
173014	3.08	3.00	2.77	3.08	4.03	0.994	248.3	−77.2	247.0	0.305	812.5
178219	2.46	2.92	2.85	3.00	3.71	0.957	273.4	−168.2	262.1	0.305	897.7
180262	2.69	2.92	3.08	3.15	2.82	0.987	216.5	−106.8	212.2	0.334	649.5
180212	2.62	2.92	3.08	2.85	2.16	0.936	384.3	−125.3	360.5	0.299	128.0
180356	2.62	2.85	3.15	3.15	4.01	0.989	288.4	−180.4	281.2	0.353	793.5
180358	2.46	3.23	3.31	3.23	3.91	0.988	268.0	−147.5	264.5	0.366	737.3
183928	2.08	2.46	2.77	2.69	4.74	0.960	148.4	−61.2	142.3	0.261	568.8
185207	1.62	1.92	2.69	2.15	1.95	0.965	188.0	−29.7	193.3	0.299	629.5
185226	2.46	2.69	2.85	2.85	3.47	0.951	144.4	−96.8	137.5	0.265	545.3
185230	2.62	2.85	3.08	3.23	3.51	0.989	224.9	−134.8	221.8	0.266	847.8
185234	2.62	2.77	2.92	2.85	5.37	0.991	180.9	−92.3	179.3	0.31	585.2
185308	3.00	3.31	3.00	3.31	5.19	0.994	253.1	−144.7	252.0	0.331	761.8
185339	2.31	2.54	3.08	2.62	2.97	0.958	176.0	−205.7	169.5	0.309	567.0
Miwongreen	2.54	2.92	3.38	3.15	4.92	0.990	208.3	−37.6	769.9	0.234	810.7
LSD (5%)	0.73	0.71	0.65	0.65	−	0.341	76.9	49.5	74.1	0.775	68.2
CV (%)	38.0	33.2	28.5	28.9	−	2.1	20.0	22.6	17.3	15.2	5.4

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