한작지(Korean J. Crop Sci.), 56(4): 375~384(2011)

Determination of Phenolic Compounds in Adzuki bean (*Vigna angularis*) Germplasm

Eun Hye Kim*, Hong Keun Song*, Yong Jin Park**, Jeong Ran Lee***, Min Young Kim*, and Ill-Min Chung*†

*Department of Applied Life science, College of Life & Environmental Sciences, Konkuk University, Seoul 143-701, Korea
**Department of Plant Resources, Kongju University, Yesan 340-702, Korea
***National Academy of Agricultural Science, RDA, Suwon 441-857, Korea

ABSTRACT The aim of this study was to evaluate 30 phenolic compounds in adzuki bean germplasm. Adzuki 21653 had the highest content of total phenolics compounds (6597 μg g^{-1}) while 104372 had the lowest concentration. The average total phenolic content of Japanese (2432 μg g^{-1}) adzuki beans was higher than that of Korean (2256 μg g^{-1}) adzuki beans. The average total phenolic contents were 2507 μg g^{-1} in small sized adzuki beans from Japan and 2459 μg g^{-1} in those from Korea. In large sized adzuki beans, the average total phenolic contents were 1315 μg g^{-1} in Japanese seeds and 1232 μg g^{-1} in Korean seeds. The average total phenolic contents in medium seeds were 2369 μg g^{-1} in Japanese adzuki beans and 1397 μg g^{-1} in Korean ones. In small seeds, the total phenolic contents of adzuki beans varied from 524 μg g^{-1} to 6597 μg g^{-1} in Japanese ones and from 375 μg g^{-1} to 6569 μg g^{-1} in Korean ones. Japanese and Korean adzuki beans were divided into landraces and wild adzuki beans. In this study, the wild adzuki beans showed higher contents of total phenolics than the native varieties. Specifically, the wild adzuki beans from Korea had the highest concentration of phenolics (3403 μg g^{-1}). All adzuki bean germplasms were measured for their color and were classified into four groups accordingly: A; L < 30, +a, +b; B; L < 30, +a, -b, C; L > 50, +a, +b, D; L > 50, +a, -b. Especially, group B had the highest concentration of total phenolic compounds (2827 μg g^{-1}), whereas group C had the lowest concentration (1882 μg g^{-1}).

Keywords : adzuki bean germplasm; phenolic compounds

Leguminous seeds are an important source of nutrient compounds, such as starch, protein, dietary fiber and minerals (Geil and Anderson, 1994). Adzuki beans are a leguminous crop as well as a popular material in various confections. The consumption of adzuki beans is concentrated in Asia, where the bean has its most important economic value (Yoshida *et al.*, 2008).

Carbohydrates are the major compound in adzuki beans, which also contains fiber, protein, vitamins, and minerals (Tjahjadi *et al.*, 1988). In Asia, boiled adzuki bean juice has been used as a folk remedy to prevent damage associated with aging (Maruyama *et al.*, 2008).

Phenolic compounds have an aromatic ring bearing one or more hydroxy groups (Kim *et al.*, 2006). They are known to present strong antioxidant, anti-mutagenic, and anti-genotoxic activities, which have beneficial effects on humans (Rice-Evans *et al.*, 1996).

The major phenolic compounds include phenolic acids and flavonoids. Flavonoids show differences and variations during ripening and harvesting (Raffo *et al.*, 2004). The antioxidant activities of legumes depends on the variety of the plant and observed variously (Amarowicz and Pegg, 2008).

Previous studies have reported that the phenolic content changes remarkably during the ripening process (Amiot *et al.*, 1986; Romero *et al.*, 2002; Bouaziz *et al.*, 2004). Further, cultivar and altitude are important factors that affect the phenolic content (Blekas *et al.*, 2002). There have been many studies on phenolic compounds in leguminous plants (Shon *et al.*, 2007).

In this study, the phenolic compounds contents of adzuki bean germplasms were analyzed by HPLC. Although adzuki beans are a valuable crop, there has not been sufficient research on their functional materials and characteristics. Thus, this study aims to provide helpful information for breeders and the food industry.

†Corresponding author: (Phone) +82-2-450-3730 (E-mail) imcim@konkuk.ac.kr
<Received 2 November 2011; Revised 9 November 2011; Accepted 21 November 2011>

MATERIALS AND METHODS

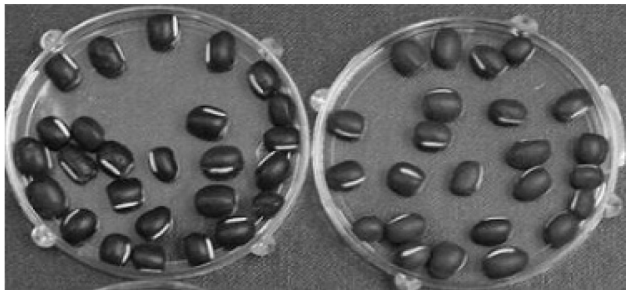
Preparation of adzuki bean germplasm

A total of 150 adzuki bean germplasms were donated from the gene bank of the RDA (Rural Development Administration, Suwon, Gyeonggi-Do, Korea). They were divided into two groups according to origin (Japan and Korea) and 100 seed weight (small (< 12 g), medium (12~18 g), and large (> 18 g) seeds) (Fig. 1) as shown in Appendix 1.

We determined the color values (L: lightness (0 = black, 100 = white), a (-a = greenness, +a = redness), b (-b = blueness, +b = yellowness)) of the 150 adzuki bean germplasms, and the instrumentation used was a Minolta Color Difference Meter (Model CR-310, Minolta Co. Ltd, Osaka, Japan). Calibration was carried out on a standard white plate. All samples were measured three times and classified into four groups according to their color values. The categorization of colors in adzuki beans followed Hunter's color values and is shown in Table 1. The mean color values of adzuki beans from Japan and Korea according to seed size are shown in Table 2.

Small

Medium



Large

Fig. 1. Seeds of adzuki bean germplasm seeds sorted by seed size.

Analysis of phenolic compounds in adzuki bean

Each adzuki bean seed was dried in a freeze-dryer under vacuum conditions (Freezeone 4.5, Labconco, Kansas, Missouri, USA) and then ground up. In this study, methanol (100%), acetonitrile (100%), glacial acetic acid (99.9%), and distilled water were purchased from J. T. Baker (HPLC grade, USA), and hydrochloric acid was purchased from Daejung Co. (Daejung Chemical & Materials Co. Ltd, Siheung, Gyeonggi-Do, Korea). Dimethyl sulfoxide (DMSO), gallic acid, pyrogallol, homogentisic acid, protocatechuic acid, gentisic acid, chlorogenic acid, (+)catechin, *p*-hydroxybenzoic

Table 1. Categorization of colors in adzuki bean germplasm.

Group	L (Lightness)	a (Redness)	b (Yellowness)
A	L < 30	+a	+b
B	L < 30	+a	-b
C	L > 50	+a	+b
D	L > 50	+a	-b

Table 2. Color comparison between Japanese and Korean adzuki beans of different size.

Origins		Japan	Korea
Small	Number of variety	51	43
	Light	25.6	47.3
	Redness	1.9	3.4
	Yellowness	0.7	0.6
Medium	Number of variety	6	10
	Light	25.7	51.5
	Redness	3.4	5.0
	Yellowness	0.6	1.7
Large	Number of variety	4	2
	Light	25.8	39.8
	Redness	4.9	1.3
	Yellowness	1.3	-0.6

acid, *ß*-resorcylic acid, vanillic acid, caffeic acid, syringic acid, vanillin, *p*-coumaric acid, rutin, ferulic acid, veratric acid, *m*-coumaric acid, naringin, hesperedin, *o*-coumaric acid, myricetin, resveratrol, quercetin, *t*-cinnamic acid, naringenin, kaempferol, hesperetin, formononetin, and biochanin A were purchased from Sigma-Aldrich (USA).

Extraction of phenolic compounds from adzuki bean samples followed the method of Wang and Murphy (1994). The extraction solvent was composed of 10 mL of acetonitrile and 2 mL of 0.1 N hydrochloric acid per sample. The ground samples (2 g) were extracted with extraction solvent, followed by stirring for 2 h at room temperature (Green-Sseriker, Vision Scientific Co. Ltd, Bucheon, Gyeonggi-Do, Korea). The extract was filtered through No. 42 Whatman filter paper (125 mm × 100 circles, Maidstone, England) and concentrated using a vacuum evaporator (EYELA, Tokyo Rikakikai, Co. Ltd, Japan) below 40℃. The residues were redissolved with 10 mL of 100% aqueous methanol (HPLC grade, J. T. Baker, USA), filtered through a 0.2 μm nylon membrane syringe filter (17 mm, TITAN, Sunsri, Rockwood, Tennessee, USA), and transferred into a 2 mL vial, followed by analysis by HPLC.

The HPLC system used was an Agilent 1100 (Palo Alto, CA, USA) series system equipped with a photodiode array (PDA) detector. Separation was primarily achieved using a YMC-Pack ODS AM-303 (5 μm, 250 mm × 4.6 mm I.D.) column. The absorbance was measured at 280 nm. HPLC analysis was applied by following the modified method of Kim *et al.* (2006). The mobile phases were 0.1% glacial acetic acid in distilled water (solvent A) and was 0.1% glacial acetic acid in acetonitrile (solvent B). The injection volume was 20 μl, and the gradient was as follows: 0 min, 92% A : 8% B; 0~2 min 90% A : 10% B; 2~27 min, 70% A: 30% B; 27~50 min, 10% A : 90% B; 50~51 min, 0% A : 100% B; 51~60 min, 0% A : 100% B; 60~63 min, 92% A : 8% B. The run time was 63 min and flow rate 1 mL min^{-1}. Genuine standards of 30 phenolic compounds were made in dimethyl sulfoxide and used to establish calibration curves.

Phenolic compounds in adzuki beans were determined based on the retention times of the standards, and the plotting standard concentration was obtained at several concentrations, 25, 50, 100, 150 μg mL^{-1}. High linearity of $r^2 > 0.996$ was obtained from each curve.

RESULTS AND DISCUDSSION

Phenolic compounds in the adzuki bean germplasm

A total of 150 adzuki beans, or red beans, were donated by the gene bank of the RDA (Rural Development Administration, Suwon, Gyonggi-Do, Korea). Among them, 112 adzuki beans were divided into two groups according to their country of origin (Japan and Korea). In addition, they were classified into four groups according to color (Table 1, Table 2). Statistical analyses were conducted by the general linear model procedure (GLM) of 2005 SAS package (Version 9.1, SAS Inst. Inc. Cary, N.C., USA). The experimental design was a completely randomized design (CRD) with duplicates. Least significant difference (LSD) test was based on a 0.05 probability level.

The total phenolic content was the highest in 216530 (Appendix 1) adzuki bean (6596.9 μg g^{-1}) while germplasm 104372 had the lowest concentration. The average total phenolic content of Japanese adzuki beans was higher (2432.4 μg g^{-1}) than that of Korean adzuki beans (2255.5 μg g^{-1}) (Fig. 2).

Figure 3 shows a comparison of the total phenolic content between small, medium, and large sized adzuki beans from Japan and Korea. The mean total phenolic content in small

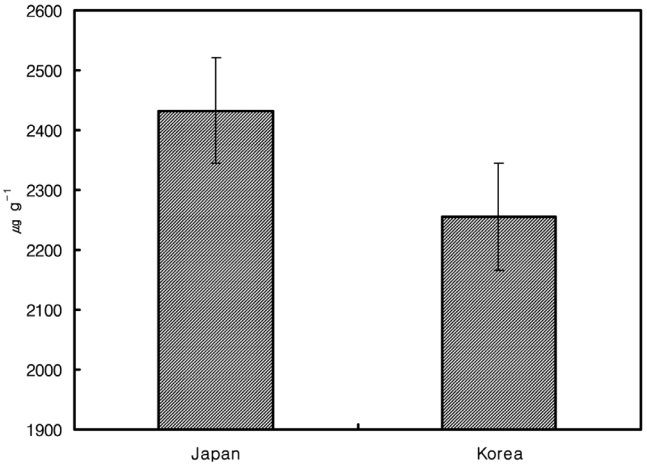


Fig. 2. Comparison of average total phenolic contents between Korean and Japanese adzuki beans of two different regions. Statistical significance was analyzed by least significant difference (LSD) ($p < 0.05$).

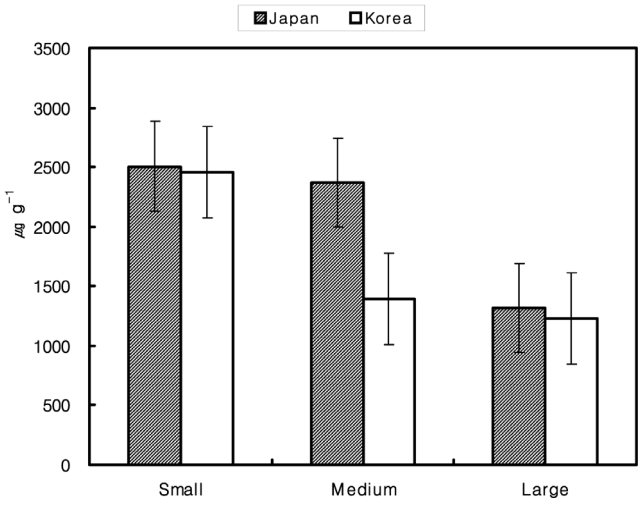


Fig. 3. Average total phenolic contents in small, medium, and large seeds of Japanese and Korean adzuki bean germplasms. Statistical significance was analyzed by least significant difference (LSD) ($p < 0.05$).
(Small seed: < 12 g, Medium seed: 12~18 g, Large seed: > 18 g)

adzuki beans from Japan was 2506.6 μg g^{-1}, whereas that in Korean seeds was 2458.8 μg g^{-1}.

In large adzuki beans, the mean total phenolic contents were 1315.1 μg g^{-1} in Japanese adzuki bean seeds and 1231.9 μg g^{-1} in Korean ones. The average total phenolic contents in medium seeds were 2368.6 μg g^{-1} in Japanese type and 1397.0 μg g^{-1} in Korean.

In small seeds, the total phenolic contents of adzuki beans ranged from 523.8 μg g^{-1} to 6596.9 μg g^{-1} in Japanese and from 374.5 μg g^{-1} to 6569.2 μg g^{-1} in Korean.

In medium seeds, the total phenolic contents varied from 609.4 μg g^{-1} to 3300.3 μg g^{-1} in Japanese adzuki beans and from 401.5 μg g^{-1} to 2825.7 μg g^{-1} in Korean ones. For large seeds, the concentrations of phenolic compounds were as follows: Japan (565.9 μg g^{-1}~2591.3 μg g^{-1}) and Korea (466.2 μg g^{-1}~1997.7 μg g^{-1}).

Small seeds from Japan (6596.9 μg g^{-1}) and Korea (6569.2 μg g^{-1}) had the high levels of phenolic compounds, whereas large Korean adzuki beans had the lowest content (1231.9 μg g^{-1}) (Table 3).

Specifically, Japanese and Korean adzuki bean germplasms were divided into landraces and wild adzuki beans (Table 4). Among the landraces, the average total phenolic contents in adzuki bean germplasm from Japan and Korea were 2088.8 μg g^{-1} and 1753.7 μg g^{-1}, respectively. In wild adzuki beans, the mean concentration of total phenolic compounds

Table 3. Comparison of total phenolic content between small, medium, and large adzuki beans from Japan and Korea.

Origins		Japan	Korea
Small	Number of variety	51	43
	Maximum (μg g^{-1})	6596.9	6569.2
	Minimum (μg g^{-1})	523.8	374.5
	Mean (μg g^{-1})	2506.6	2458.8
	CV (%)	30.5	6.1
	LSD $_{(0.05)}$	1532.5	303.5
Medium	Number of variety	6	10
	Maximum (μg g^{-1})	3300.3	2825.7
	Minimum (μg g^{-1})	609.4	401.5
	Mean (μg g^{-1})	2368.6	1397.0
	CV (%)	9.4	1.3
	LSD $_{(0.05)}$	546.4	41.8
Large	Number of variety	4	2
	Maximum (μg g^{-1})	2591.3	1997.7
	Minimum (μg g^{-1})	565.9	466.2
	Mean (μg g^{-1})	1315.1	1231.9
	CV (%)	9.1	4.2
	LSD $_{(0.05)}$	378.0	220.1

Table 4. Comparison of average total phenolic content between adzuki bean landraces and wild adzuki beans from Japan and Korea.

Origins		Japan	Korea
Land races	Number of variety	29	36
	Maximum (μg g^{-1})	3925.5	5242.5
	Minimum (μg g^{-1})	523.8	374.5
	Mean (μg g^{-1})	2088.8	1753.7
	CV (%)	4.9	6.3
	LSD $_{(0.05)}$	210.5	222.2
Wild	Number of variety	31	16
	Maximum (μg g^{-1})	6596.9	6569.2
	Minimum (μg g^{-1})	1532.8	842.3
	Mean (μg g^{-1})	2714.8	3404.3
	CV (%)	36.0	5.4
	LSD $_{(0.05)}$	1993.0	391.4

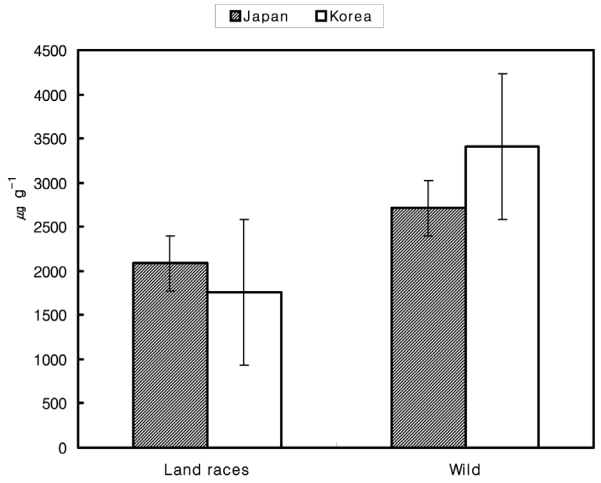


Fig. 4. Average phenolic contents of adzuki bean landraces and wild adzuki beans from Japan and Korea. Statistical significance was analyzed by least significant difference (LSD) ($p < 0.05$).

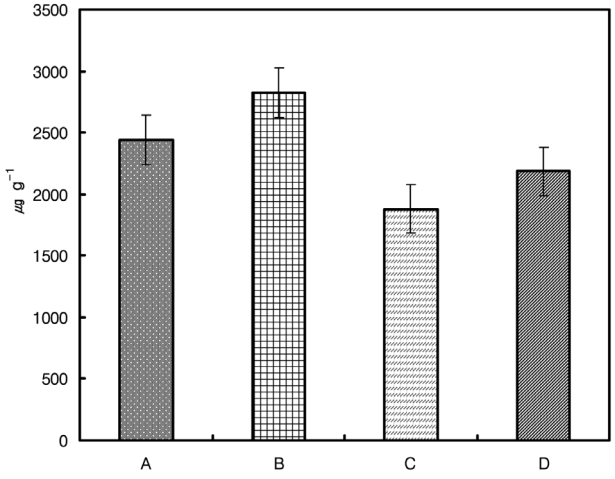


Fig. 5. Comparison of total phenolic content according to seed color value. Statistical significance was analyzed by least significant difference (LSD) ($p < 0.05$). Abbreviations: A; L < 30, +a, +b; B; L < 30, +a, -b, C; L > 50, +a, +b, D; L > 50, +a, -b

was 2714.8 μg g^{-1} in those from Japan and 3404.3 μg g^{-1} in those from Korea. In this study, wild adzuki beans showed higher phenolic contents than the adzuki bean landraces (Fig. 4). Specifically, wild adzuki beans from Korea had the highest total phenolic content (3404.3 μg g^{-1}).

In adzuki bean landraces, the average total phenolic contents varied from 523.8 μg g^{-1} to 3925.5 μg g^{-1} in Japanese adzuki beans and from 374.5 μg g^{-1} to 5242.5 μg g^{-1} in Korean adzuki beans. On the other hand, in wild adzuki beans, the total average phenolic contents ranged from 1532.8 μg g^{-1} to 6596.9 μg g^{-1} in Japanese wild adzuki beans and from 842.3 μg g^{-1} to 6569.2 μg g^{-1} in Korean wild adzuki beans (Table 4).

Whole adzuki bean samples were measured for their color values and classified into four groups accordingly: A; L < 30, +a, +b; B; L < 30, +a, -b, C; L > 50, +a, +b, D; L > 50, +a, -b.

In group A (L < 30, +a, +b), the average total phenolic content was 2439.1 μg g^{-1}, 2826.9 μg g^{-1} in group B (L < 30, +a, -b), 1881.1 μg g^{-1} in the group C (L > 50, +a, +b), and 2184.2 μg g^{-1} in group D (L > 50, +a, -b).

Among the four color values, the concentration of phenolic compounds varied from 523.8 μg g^{-1} to 5642.3 μg g^{-1} in group A, from 1689.0 μg g^{-1} to 6597.0 μg g^{-1} in B group, from 413.3 μg g^{-1} to 5242.5 μg g^{-1} in group C, and from 374.5 μg g^{-1} to 5049.6 μg g^{-1} in group D. Especially, group B (L < 30, +a, -b) had the highest concentration of total phenolic compounds, whereas group C (L > 50, +a, +b) showed the lowest concentration (Fig. 5, Table 5).

In this study, adzuki bean showed the highest concentration of total phenolic compounds in seeds with low lightness values (near black color). A previous study reported that dark colored (black, red, bronze) legumes possess significantly higher phenolic contents than yellow, green or white colored ones. These results suggest that antioxidant activity was strongly correlated with total phenolic content and confirm that total phenolic content is reasonably correlated with seed hull surface color (Xu *et al.*, 2007). Another study showed that black and red beans have the highest antioxidant activities, whereas white bean has weak antioxidant activity (Madhujith *et al.*, 2004; Madhujith and Shahidi, 2005). Therefore, it can be concluded that genetic factors such as seed weight, seed color, and other environmental factors influenced the synthesis and accumulation of phenolic compounds in adzuki bean seeds.

In this study, the average total phenolic content of the small adzuki bean varieties was higher than that of the medium and large varieties. The phenolic compounds were compressed in the small seeds but dispersed at low density in the large sized seeds. Further, the concentration of phenolic compounds was correlated with seed color values.

Table 5. Average total phenolic content according to color.

Color group		Total concentration
A[1)]	Number of variety	54
	Maximum (μg g^{-1})	5642.3
	Minimum (μg g^{-1})	523.8
	Mean (μg g^{-1})	2439.1
	CV (%)	5.7
	LSD $_{(0.05)}$	279.4
B[2)]	Number of variety	26
	Maximum (μg g^{-1})	6597.0
	Minimum (μg g^{-1})	1689.0
	Mean (μg g^{-1})	2826.9
	CV (%)	37.7
	LSD $_{(0.05)}$	2190.5
C[3)]	Number of variety	51
	Maximum (μg g^{-1})	5242.5
	Minimum (μg g^{-1})	413.3
	Mean (μg g^{-1})	1881.1
	CV (%)	7.6
	LSD $_{(0.05)}$	288.1
D[4)]	Number of variety	18
	Maximum (μg g^{-1})	5049.6
	Minimum (μg g^{-1})	374.5
	Mean (μg g^{-1})	2184.2
	CV (%)	4.1
	LSD $_{(0.05)}$	188.1

Abbreviations: 1) L < 30, +a, +b; 2) L < 30, +a, -b; 3) L > 50, +a, +b; 4) L > 50, +a, -b

ACKNOWLEDGEMENT

This work was carried out with the support of "Cooperative Research Program for Agriculture Science & Technology Development (Project No. PJ006983)" Rural Development Administration, Republic of Korea.

REFERENCES

Amarowicz, R. and R. B. Pegg. 2008. Legumes as a source of natural antioxidants. Eur. J. Lipid Sci. Technol. 110 : 865-878.

Amiot, M. J., A. Fleuriet and J. J. Macheix. 1986. Importance and evolution of phenolic compounds in olive during growth and maturation. J. Agric. Food Chem. 34 : 823-826.

Blekas, G., C. Vassilakis, C. Harizanis, M. Tsimidou and D. Boskou. 2002. Biophenols in table olives. J. Agric. Food Chem. 50 : 3688-3692.

Bouaziz, M., M. Chamkha and S. Sayadi. 2004. Comparative study on phenolic content and antioxidant activity during maturation of the olive cultivar Chemlali from Tunisia. J. Agric. Food Chem. 52 : 5476-5481.

Geil, P. B. and J. W. Anderson. 1994. Nutrition and health implications of dry beans: A review. J. Am.Coll. Nutr. 13 : 549-558.

Kim, J. A., W. S. Jung, S. C. Chun, C. Y. Yu, K. H. Ma, J. G. Gwag and I. M. Chung. 2006. A correlation between the level of phenolic compounds and the antioxidant capacity in cooked-with-rice and vegetable soybean (*Glycine max* L.) varieties. Eur. Food Res Technol. 224 : 259-270.

Madhujith, T., M. Naczk and F. Shahidi. 2004. Antioxidant activity of commmon beans (*Phaseolus vulgaris* L.). J. Food Lipids 11 : 220-233.

Madhujith, T. and F. Shahidi. 2005. Antioxidant potential of pea beans (*Phaseolus vulgaris* L.). J. Food Sci. 70 : 82-90.

Maruyama, C., R. Araki, M. Kawamura, N. Kondo, M. Kigawa, Y. Kawai, Y. Takanami, K. Miyashita and T. Shimomitsu. 2008. Azuki bean juice lowers serum triglyceride concentrations in healthy young women. J. Clin. Biochem. Nutr. 43 : 19-25.

Raffo, A., F. Paoletti and M. Antonelli. 2004. Changes in sugar, organic acid, flavonol and carotenoid composition during ripening of berries of three sea buckthorn (Hippophae rhamnoides L.) cultivars. Eur. Food Res Technol. 219 : 360-368.

Rice-Evans, C. A., N. J. Miller and G. Paganga. 1996. Structure antioxidant activity relationships of flavonoids and phenolic acids. Free Radical Biol Med. 20 : 933-956.

Romero, C., M. Brenes, P. García and A. Garrido. 2002. Hydroxytyrosol 4-ß-D-glucoside, an important phenolic compound in olive fruits and derived products. J. Agric. Food Chem. 50 : 3835-3839.

Shon, M. Y., J. Lee, J. H. Choi, S. Y. Choi, S. H. Nam, K. I. Seo, S. W. Lee, N. J. Sung and S. K. Park. 2007. Antioxidant and free radical scavenging activity of methanol extract of chungkukjang. J. Food Comp. Anal. 20 : 113-118.

Tjahjadi, C., S. Lin and W. M. Breene. 1988. Isolation and characterization of adzuki bean (*Vigna anagularis* cv. Takara) proteins. J. Food Sci. 53 : 1438-1443.

Wang, H. J. and P. A. Murphy. 1994. Isoflavone content in commercial soybean foods. J. Agric. Food Chem. 42 : 1666-1673.

Xu, B. J., S. H. Yuan and S. K. C. Chang. 2007. Comparative analyses of phenolic composition, antioxidant capacity, and color of cool season legumes and other selected food legumes. J. Food Sci. 72 : S167-S177.

Yoshida, H., N. Yoshida, Y. Tomiyama, M. Sakai and Y. Mizushina. 2008. Distribution profiles of tocopherols and fatty acids of phospholipids in adzuki bean (*Vigna algularis*). J. Food Lipids 15 : 209-221.

Appendix 1. Characteristics of adzuki bean germplasm.

Sample №	IT №	Variety	Origin	100 seed weight (g)	Type	Color value		
						L	a	b
1	025922			12.40		56.19	10.13	1.04
2	025923			14.90		54.45	7.15	0.24
3	025971	Pingtungjaerae		10.00		54.89	8.79	1.11
4	025974			10.70		55.70	9.34	1.30
5	025975			10.40		54.99	8.52	0.65
6	025980			9.40		55.00	7.20	0.13
7	025981	Yuantsu 64		11.70		53.82	8.39	0.09
8	100814		KOR	12.80	Land race	54.71	8.61	0.28
9	100961		KOR	7.90	Land race	56.44	0.97	0.80
10	101052		KOR	8.30	Land race	54.42	6.95	-0.34
11	102770		KOR	1.54	Wild	53.28	1.95	-0.33
12	103060		KOR	5.30	Land race	56.43	1.78	0.85
13	103249		KOR	2.40	Wild	52.47	3.36	-1.60
14	103859		KOR	10.10	Land race	54.18	7.58	-0.12
15	103919		KOR	12.10	Land race	55.42	10.65	2.89
16	103962		KOR	7.90	Land race	56.67	1.81	-0.10
17	104138		KOR	9.70	Land race	58.19	5.69	-0.22
18	104173		KOR	10.60	Land race	55.64	1.56	-0.15
19	104273		KOR	15.20	Land race	58.88	2.07	1.53
20	104309		KOR	12.20	Land race	54.79	10.57	1.94
21	104372		KOR	7.80	Land race	54.25	3.51	-1.22
22	104549		KOR	8.80	Land race	53.48	8.82	0.13
23	104748		KOR	14.50	Land race	59.63	1.70	1.46
24	104845		KOR	11.90	Land race	55.86	1.54	-0.02
25	105194		KOR	7.50	Land race	60.01	1.41	2.83
26	105290		KOR	13.30	Land race	52.57	3.21	-1.43
27	105333		KOR	8.30	Land race	56.58	6.82	0.69
28	105389		KOR	10.30	Land race	58.26	2.08	1.04
29	108804		KOR	10.70	Land race	53.97	7.01	0.82
30	113259		KOR	8.15	Land race	58.10	2.03	0.89
31	122300		KOR	9.20	Land race	54.98	9.37	1.14
32	142476			7.60		58.47	2.04	2.02
33	142482	A9	PNG	14.90		60.40	1.86	2.62
34	142486		KOR	8.20		55.38	1.89	-0.86
35	162726		KOR	1.67	Land race	58.22	1.86	0.21
36	162775		KOR	2.48	Wild	55.27	1.89	-0.15
37	162777		KOR	7.50	Land race	64.60	1.32	-0.81
38	168016		KOR	11.58	Land race	55.65	6.37	0.62
39	178383		KOR	8.70	Land race	56.92	5.05	0.55
40	178509		KOR	2.51	Wild	56.45	2.25	-0.37
41	180537		KOR	16.30	Land race	57.52	1.65	0.76
42	180584		KOR	10.20	Land race	57.86	2.63	2.30
43	180627		KOR	9.60	Land race	54.38	10.12	1.25
44	180655		KOR	11.80	Land race	59.29	1.94	2.59
45	181956		KOR	11.20	Land race	58.58	2.12	2.06
46	182058			10.95		61.86	2.86	3.84
47	182059			11.04		53.69	9.12	0.36

Appendix 1. (Continued)

Sample №	IT №	Variety	Origin	100 seed weight (g)	Type	Color value		
						L	a	b
48	182087			8.49		55.19	10.80	1.98
49	182089			9.50		55.39	10.17	1.26
50	182092			10.50		54.56	9.71	1.48
51	182093			10.50		54.60	9.28	0.85
52	182095			12.12		55.94	10.49	1.31
53	183275			11.20		56.03	9.88	1.22
54	183276			18.15		55.61	10.44	2.13
55	183278	ID6W		13.40		54.39	10.66	0.88
56	183292			16.25		56.03	10.38	2.51
57	183297	'92AP14		12.59		56.72	9.96	2.25
58	183302			11.12		53.98	8.45	-0.11
59	183308			12.40		53.36	6.48	-0.67
60	183309		PRK	19.40		55.57	1.61	-0.44
61	186306		KOR	10.40	Land race	54.47	10.02	1.32
62	189416		MYS	11.20		60.64	5.53	0.35
63	195176		KOR	12.90	Land race	54.48	8.81	0.83
64	195222		KOR	13.60	Land race	62.97	4.30	0.32
65	203423		AUS	12.20		55.19	9.21	0.59
66	209432		NPL	18.20		55.54	8.56	0.60
67	209444			15.20		38.95	1.65	-1.93
68	211855		KOR	11.70	Land race	55.30	9.55	0.83
69	211857			22.20		56.88	8.67	1.50
70	212898		CHN	14.90		25.23	5.12	0.50
71	215376		JPN	12.20	Improved	26.96	0.84	0.64
72	215444		KOR	2.10	Wild	27.15	0.91	0.52
73	215446		KOR	2.10	Wild	26.56	0.97	0.38
74	215454		KOR	2.20	Wild	26.84	0.95	0.39
75	215457		KOR	2.20	Wild	26.69	0.98	0.66
76	216232		KOR	2.20	Wild	24.88	1.05	-0.24
77	216285		JPN	5.40	Land race	23.93	1.01	-0.63
78	216286		JPN	2.60	Land race	29.97	-0.22	4.99
79	216287		JPN	4.90	Land race	26.33	7.40	1.40
80	216288		JPN	18.10	Land race	25.23	0.49	0.28
81	216289		JPN	4.00	Land race	25.51	0.54	0.27
82	216290		JPN	3.80	Land race	24.58	1.14	-0.01
83	216291		JPN	3.60	Land race	25.16	3.62	0.54
84	216292		JPN	6.40	Land race	27.08	7.78	2.26
85	216293		JPN	23.20	Land race	26.05	7.21	1.50
86	216294		JPN	17.80	Land race	25.63	0.94	0.35
87	216295		JPN	5.10	Land race	25.70	5.94	1.27
88	216296		JPN	18.20	Land race	26.20	7.04	1.97
89	216297		JPN	15.60	Land race	24.73	1.11	-0.25
90	216298		JPN	3.40	Land race	25.09	0.95	0.28
91	216299		JPN	2.70	Land race	24.73	0.94	0.02
92	216300		JPN	3.70	Land race	25.09	1.09	0.08
93	216301		JPN	2.60	Land race	26.47	5.54	1.36
94	216302		JPN	15.30	Land race	24.85	1.21	0.35

Appendix 1. (Continued)

Sample №	IT №	Variety	Origin	100 seed weight (g)	Type	Color value		
						L	a	b
95	216303		JPN	3.60	Land race	28.24	1.79	4.13
96	216304		JPN	3.90	Land race	25.06	0.69	0.25
97	216305		JPN	3.80	Land race	25.46	0.87	0.26
98	216306		JPN	4.00	Land race	25.63	6.82	1.20
99	216307		JPN	14.90	Land race	25.34	5.29	0.96
100	216308	SHOUNAGON	JPN	11.70	Land race	26.97	10.21	2.44
101	216309	CHUUNAGON	JPN	15.10	Land race	25.96	6.02	0.86
102	216355		KOR	15.60	Improved	25.80	5.56	0.47
103	216356		KOR	18.40	Improved	24.06	0.94	-0.77
104	216517		JPN	2.60	Wild	24.93	0.94	-0.40
105	216518		JPN	2.50	Wild	24.56	1.04	-0.57
106	216519		JPN	2.20	Wild	24.17	0.96	-1.07
107	216520		JPN	2.00	Wild	24.15	0.92	-0.54
108	216521		JPN	2.40	Wild	25.42	0.87	-0.07
109	216522		JPN	2.00	Wild	25.26	0.99	0.16
110	216523		JPN	2.70	Wild	25.06	0.95	0.23
111	216524		JPN	2.40	Wild	24.96	0.85	-0.14
112	216525		JPN	24.40	Wild	23.90	0.98	-0.92
113	216526		JPN	2.40	Wild	28.79	1.54	4.15
114	216527		JPN	5.4	Wild	25.55	3.05	0.89
115	216528		JPN	2.30	Wild	28.49	1.16	3.80
116	216529		JPN	2.20	Wild	24.83	1.18	-0.19
117	216530		JPN	2.30	Wild	24.80	0.91	-0.38
118	216531		JPN	2.00	Wild	25.82	1.20	1.10
119	216532		JPN	2.50	Wild	24.10	0.99	-0.80
120	216533		JPN	2.40	Wild	25.34	1.06	0.14
121	216534		JPN	2.80	Wild	25.20	0.82	-0.05
122	216535		JPN	2.30	Wild	24.66	1.04	-0.24
123	216536		JPN	2.50	Wild	24.37	0.89	-0.67
124	216537		JPN	2.50	Wild	25.86	0.79	0.18
125	216538		JPN	2.80	Wild	25.66	1.13	0.52
126	216539		JPN	2.70	Wild	24.63	0.97	-0.17
127	216540		JPN	2.60	Wild	25.37	1.06	0.33
128	216541		JPN	2.70	Wild	25.91	0.98	0.32
129	216542		JPN	3.70	Wild	24.63	0.97	-0.45
130	216543		JPN	2.70	Wild	24.41	0.96	-0.35
131	216544		JPN	3.70	Wild	28.55	1.02	3.73
132	216545		JPN	2.90	Wild	29.75	0.77	5.12
133	216546		JPN	3.10	Wild	24.78	0.98	-0.22
134	216547		JPN	2.10	Wild	26.01	4.57	0.40
135	216962		CHN	12.10		26.60	7.04	0.95
136	217333		CHN	18.50	Improved	25.72	1.07	0.38
137	217579		KOR	1.80	Wild	24.66	1.21	-0.21
138	217580		KOR	1.50	Wild	27.01	1.48	1.33
139	217581		KOR	3.20	Wild	25.19	1.03	0.08
140	217582		KOR	1.70	Wild	30.41	2.22	5.37
141	218027		JPN	3.20	Land race	27.09	1.84	2.57

Appendix 1. (Continued)

Sample №	IT №	Variety	Origin	100 seed weight (g)	Type	Color value		
						L	a	b
142	218030		KOR	1.70	Wild	24.49	1.24	-0.26
143	218031		KOR	1.90	Wild	26.49	1.13	0.38
144	218032		KOR	2.20	Wild	26.52	1.13	0.45
145	218064		CHN	7.50	Land race	26.09	4.81	0.35
146	220693		KOR	7.60	Land race	27.49	0.84	1.33
147	221513		KOR	12.30	Improved	32.98	1.80	8.06
148	221986		JPN	13.36	Land race	25.63	5.80	0.95
149	224582		JPN	2.60	Land race	24.62	0.93	-0.33
150	224583		JPN	2.80	Land race	24.25	0.96	-0.77