Korean J. Plant Res. 31(3):237-253(2018)
https://doi.org/10.7732/kjpr.2018.31.3.237

Print ISSN 1226-3591
Online ISSN 2287-8203

Original Research Article

Antioxidant and Biological Activity in the Leaves of Adzuki Bean (*Vigna angularis* L.)

Kyung Jun Lee[1], Jung-Ro Lee[1], Myoung-Jae Shin[1], Gyu-Taek Cho[1], Ho-Sun Lee[2], Kyung-Ho Ma[1], Gi-An Lee[1] and Jong-Wook Chung[3]*

[1]National Agrobiodiversity Center, National Institute of Agricultural Sciences (NAS), RDA, Jeonju-Si 54874, Korea
[2]International Technology Cooperation Center, RDA, Jeonju-Si 54875, Korea
[3]Department of Industrial Plant Science & Technology, Chungbuk National University, Cheongju 28644, Korea

Abstract - The adzuki bean (*Vigna angularis* L.) is a red-grained legume that has a number of essential nutrients and is used in traditional dishes in Asia. Adzuki bean industrial by-products are also a potential low-cost source of some unique bioactive polyphenols. Hence, here, the authors aimed to perform a comparative study of the phytochemical profiles of the leaves and seeds of the adzuki bean and compare their antioxidant, α-glucosidase inhibition, and tyrosinase inhibition activity. The authors assessed antioxidant activity by DPPH, ABTS, FRAP, PR, TPC, and SOD assays, which showed wide variation, respectively. From the relative antioxidant capacity index results, 10 adzuki bean landraces were selected to compare for phytochemicals and bioactivity using leaf and seed extracts. Antioxidant, α-glucosidase inhibition, and tyrosinase inhibition activity in the leaf extracts were higher than in the seed extracts, and there were more flavonols and isoflavones in the leaf extracts than in the seed extracts. This study demonstrated that adzuki bean leaf extracts could be a new natural antioxidant or antidiabetic agent and a skin whitener and can also be used in industrial applications.

Key words – Adzuki bean leaves, Antioxidant, By-products, α-glucosidase inhibition activity, Tyrosinase inhibition activity

Introduction

The adzuki bean (*Vigna angularis* L.) is cultivated around the world, mainly in Asiatic countries, as a diverse food source (Gohara *et al*., 2016; Rho *et al*., 2003). In China and Korea, the bean has been used to treat diuretic dysfunction and other diseases such as dropsy and beriberi (Gohara *et al*., 2016; Kim and Chung, 2013; Luo *et al*., 2016). Adzuki beans leaves are also used as medicine and in side dishes in Korea (Moon *et al*., 2015). *Sikryochanyo*, the Korean traditional medical book, describes that adzuki bean leaves help treat and prevent diabetes (Kim and Chung, 2013). Although previous studies reported on characteristics of the adzuki bean such as antioxidant activity and phenolic and flavonoid content (Gohara *et al*., 2016; Han *et al*., 2015; Luo *et al*., 2016; Park *et al*., 2011; Woo *et al*., 2016), few study authors have analyzed the bean's leaves.

Reactive oxygen species (ROS) are oxygen-derived molecules that include the superoxide anion, hydroxyl, peroxyl, alkoxyl, nitric oxide, singlet oxygen, hydrogen peroxide, and hypochlorous acid (Fang *et al*., 2002). ROS damage cellular constituents such as DNA, proteins, amino acids, and lipids (Zou and ChangSam, 2014), and damage caused by ROS is an important risk factor in the pathogenesis of numerous chronic diseases such as asthma, inflammatory arthropathies, diabetes, Parkinson's and Alzheimer's diseases, cancers, and human aging (Chiavaroli *et al*., 2011). Many have reported the beneficial health effects of antioxidants contained in some food (Kim *et al*., 2012; Kim *et al*., 2017; Maynard *et al*., 2003; Sabe *et al*., 2012). Antioxidant uptake from food is recommended because the antioxidants in foods are considered to detoxify ROS in the human body (Terashima *et al*., 2013). Some researchers have reported that some antioxidant compounds are present in bound form in food matrices (Acar *et al*., 2009; Gökmen *et al*., 2009; Serpen *et al*., 2007; Serpen *et al*., 2008). Although these food-antioxidant complexes are not easily absorbed from the intestine, they are likely important for gastrointestinal tract health (Terashima *et al*., 2013).

*Corresponding author. E-mail : jwchung73@chungbuk.ac.kr
Tel. +82-43-261-2524

Flavonoids are a general name for a group of chemicals that includes anthocyanins, pro-anthocyanins, flavonols, and isoflavones (Luo *et al*., 2016). Flavonoids provide color to plants and attract pollinators and seed dispersers. They include antioxidants to protect plants against UV radiation, attract insects, act as signaling molecules to facilitate nitrogen fixation, and defend against bacterial and fungal attack, and their bitter or astringent taste repels birds and other animals (Croteau *et al*., 2000; Kim and Cha, 2017; Wildmann, 2001; Winkel-Shirley, 2001; Winkel-Shirley, 2002). Several beneficial health properties of dietary flavonoids have been recognized in humans due to their antioxidant and antiproliferative effects, which protect the body from various pathologies such as cancers and cardiovascular and inflammatory diseases (Middleton *et al*., 2000; Nijveldt *et al*., 2001).

The aim of this study was to evaluate the potential of adzuki bean leaf extracts, by-products of adzuki bean production, as alternative sources of phytochemicals, antioxidants, antidiabetics, and skin whitening. For this purpose, we analyzed the antioxidant activity, flavonoid content, and α-glucosidase and tyrosinase inhibition activity and compared these with the same activity in adzuki bean seed extracts. This paper is the first attempt to assess the flavonoid content and bioactivity in adzuki bean leaf extracts.

Materials and Methods

Collection of plant material

We obtained 223 Korean adzuki bean landraces (KABLs) from the National Agro-biodiversity Center (http://genebank.rda.go.kr), NAS, Rural Development Administration, Republic of Korea. The KABLs had been cultivated with conventional cultural practices in the NAS experimental field during 2015. Fully matured leaves and seeds of KABL from the plants were dried at room temperature and stored at 4℃.

Adzuki bean extraction for antioxidant activity

We added 100 milligrams of each ground sample to 1 ㎖ of 75% EtOH and sonicated the samples for 1 h. Then, we centrifuged the mixtures at 13,000 rpm for 10 min. We collected the clear supernatants in new tubes and used them for antioxidant activity assays.

DPPH assay

We assessed the extracts' DPPH radical-scavenging activity using a previously published method with slight modifications (Lee and Lee, 2004). Briefly, we added DPPH solution (150 μl; 150 μM in anhydrous EtOH) to 100 ㎕ of sample solution. The mixture was shaken vigorously and left to stand at 25℃ in the dark for 30 min. We measured absorbance at 517 ㎚ using a spectrophotometer (Epoch; Bio-Tek, Winooski, VT, USA), and the results are expressed as IC_{50} (㎕ sample volume) values.

ABTS assay

We estimated ABTS radical-scavenging activity using a previously described method with some modifications (Re *et al*., 1999). Briefly, we generated the ABTS radical cation by adding 7 mM ABTS to 2.45 mM potassium persulfate followed by overnight incubation in the dark at room temperature. We diluted the ABTS cation solution with methanol (MeOH) to obtain absorbance of 0.7 ± 0.02 at 735 ㎚, and we added the diluted radical cation solution (190 ㎕) to 10 ㎕ of sample solution. After 6 min of incubation, we measured absorbance at 735 ㎚ with the spectrophotometer. The results are expressed as ascorbic acid equivalents (ASC) per gram of dry weight (㎎ ASC/g).

Ferric reducing antioxidant power assay

We determined ferric reducing antioxidant power (FRAP) using the method published by (Singh *et al*., 2012) with minor modifications. Briefly, we prepared the FRAP reagent by mixing 0.1 M acetate buffer at pH 3.6 (100 ㎖), 10 mM tripydyltriazine (TPTZ) solution in 40 mM HCl (10 ㎖), and 20 mM ferric chloride solution (10 ㎖). We prepared the FRAP reagent freshly and warmed it to 37℃, and then we mixed 10 microliters 300 ㎕ reagent and recorded the absorbance at 593 ㎚ after 30 min incubation at 37℃. The results are expressed as ㎎ ASC/g.

Reducing power assay

We determined reducing power using a previously published method with slight modifications (Yen and Duh, 1993). Briefly, we mixed a 0.1 ㎖ aliquot of the extract with 0.5 ㎖ phosphate buffer (0.2 M, pH 6.6) containing 1% $K_3Fe(CN)_6$ and incubated the mixture at 50℃ for 20 min. After centrifugation at 200 g for 10 min, we mixed the upper layer (10 ㎕) with 390 ㎕ of

1% ferric chloride. We monitored absorbance at 700 ㎚ using a spectrophotometer, and the results are expressed as ㎎ ASC/g.

SOD assay

We measured the superoxide anion scavenging activity as described by (Robak and Gryglewski, 1988) with some modifications. We generated the superoxide anion radicals in 100 ㎕ of Tris-HCl buffer (16 mM, pH 8.0) containing 0.3 mM nitroblue tetrazolium (NBT), 50 ㎕ NADH (0.936 mM) solution, and 100 ㎕ sample + 50 ㎕ Tris-HCl buffer (16 mM, pH 8.0). We initiated the reaction by adding 50 ㎕ phenazine methosulfate solution to the mixture and incubating at 25℃ for 5 min and then measured the absorbance at 560 ㎚. The results are expressed as IC_{50} (㎕ sample volume).

Total polyphenol content assay

We measured total polyphenol content using a modified Folin–Ciocalteu method (Waterhouse, 2001). We added Folin –Ciocalteu reagent (100 ㎕) to 100 ㎕ of sample solution and allowed it to react at room temperature for 3 min. After we added 100 ㎕ of 2% sodium carbonate, we incubated the mixture at room temperature for 30 min. We measured absorbance at 750 ㎚ on a spectrophotometer using distilled water as the blank. Total phenolic content was reported as milligrams of gallic acid equivalents (GAE) per gram of dry weight sample (㎎ GAE/g)

Analysis of flavonol content in KABL

We transferred 1 gram of each sample into 5 ㎖ polypropylene tubes and mixed this with 2.5 ㎖ of 80% methanol containing 1.2M hydrochloric acid for hydrolysis. We briefly vortexed the mixture and then incubated it at 80℃ for 2 h with tube inversion for mixing the samples with extract solution at 15-min intervals. After incubation, we centrifuged the samples at 14 000 rpm for 3 min and transferred the supernatant into 2 ㎖ Eppendorf tubes. We collected the supernatant and filtered it using a 0.45 ㎛ syringe filter prior to analysis with an Agilent 1260 Infinity HPLC system (Agilent Technologies, Santa Clara, CA, USA). HPLC conditions were as follows: solvent A, 0.1% TFA/H2O; solvent B, CH3CN; gradient, 20% (B), 20-50% (B) in 5 min, 50-100% (B) in 6, hold at 100% (B) for 1 min, re-equilibrate at 20% (B) for 3 min; column temperature, 30℃; and flow rate, 0.40 ㎖/min. The filter detector was set at 370 ㎚.

Analysis of isoflavone content in KABLs

We added 1 gram of each sample to 2 ㎖ of 80% MeOH and sonicated this for 1 h. We hydrolyzed the sample in each tube using 150 ㎕ of 2N NaOH. After mixing for 10 min, we neutralized the solution with 50 ㎕ of glacial acetic acid and centrifuged the sample at 3,000 rpm for 5 min. We collected the supernatant and filtered it using a 0.45 ㎛ syringe filter prior to analysis with the Agilent 1260. We performed the analysis using a Cosmosil 2.5 Cholester (3.0 ㎜× 75 ㎜, 2.5 ㎛; Nacalai Tesque, Inc., Kyoto, Japan). HPLC conditions were as follows: solvent A, 0.1% TFA/H2O; solvent B, 0.1%TFA/ CH3CN; gradient, 10% (B) for 0.35 min, 10-30% (B) in 3.96 min, hold at 30% (B) for 0.36 min, re-equilibrate at 10% (B) for 1.8 min; column temperature, 30℃; and flow rate, 0.58 ㎖ /min. The filter detector was set at 254 ㎚.

α-Glucosidase inhibition activity assay

We measured α-glucosidase inhibition activity as described by (Zhang *et al*., 2015). First we premixed each sample (10 ㎕) with 10 ㎕ α-glucosidase (1.1 U/㎖) for 10 min at 37℃; then we added pAPG/MPA/AuNPs (60 ㎕) into the mixed solution and continuously incubated it for 20 min at 37℃. After that, we added PDBA (30 ㎕) to the resulting mixture to obtain its final concentration of 3.00 mM. Lastly, we allowed the reaction solution to stand at room temperature for 15 min. We recorded the absorbance for each sample using UV-vis spectroscopy with the calculated IC_{50}. The inhibitory ratio (%) was expressed as follows:

Inhibitory ratio (%)
= (A650/A520-A'650/A'520)/(A'650/A'520)*100

where A650/A520 was the ratio of the absorbance at 650 ㎚ to that at 520 ㎚ in the presence of both the sample and the enzyme and A'650/A'520 was the ratio of the absorbance at 650 nm to that at 520 ㎚ in the presence of the enzyme. The results are expressed as IC_{50} (㎕ sample volume).

Determination of Tyrosinase inhibition activity

We determined tyrosinase activity using L-tyrosine as a substrate. First, we mixed 70 ㎕ of L-tyrosine (0.03%) with 70 ㎕ 0.05M PBS (pH 6.8). Then, we added 60 ㎕ of sample and

10 ㎕ of tyrosinase (125U/㎖) solution and incubated this at 37℃ for 10 min. After that, we immediately incubated the solution on ice for 5 min. We monitored absorbance at 475 ㎚ using a spectrophotometer. We calculated tyrosinase inhibition activity as follows:

Inhibition (%) = ((A-B)/A)*100

where A was without sample and B was with sample and substrate. The results are expressed as IC_{50} (㎕ sample volume).

Data analysis

We used least significant difference (LSD) and correlation analysis to determine differences among the 223 KABLs using SPSS Statistics 20 (SPSS Inc., Chicago, IL, USA). The integration of antioxidant capacity results derived from different chemical methods (Sun and Tanumihardjo 2007) allowed us to calculate the relative antioxidant capacity index (RACI).

Results

The distribution of antioxidant activity in leaf extracts from the 223 KABLs

The distribution of antioxidant activity in the leaf extracts of the KABLs is presented in Table 1 and additional Table S1. Among five antioxidant activities, DPPH showed the highest variation (coefficient of variation [CV]: 81.2 %), and ABTS was the lowest (CV: 6.9 %). DPPH and SOD ranged 12.6 to 178.5 and 7.8 to 33.5 (㎕, IC_{50}), respectively. ABTS, FRAP, and RP ranged from 7.4 to 12.5, 0.39 to 6.03, and 0.37 to 2.06 ㎎ ASC/g, respectively, and TPC's range was 2.9 to 14.7 ㎎ GAE/g.

Each antioxidant activity assay showed different ranges for the 223 KABLs (Table S1): the accessions with the most antioxidant activity were IT025842 in DPPH; IT142500 in ABTS; IT142625 in FRAP; IT142500 in TPC; IT142613 in RP; andIT120273 in SOD, and the accessions with the least activity were IT142514 in DPPH; IT142561 in ABTS; IT025789 in FRAP; IT120278 in TPC; IT025789 in RP; and IT025885 in SOD.

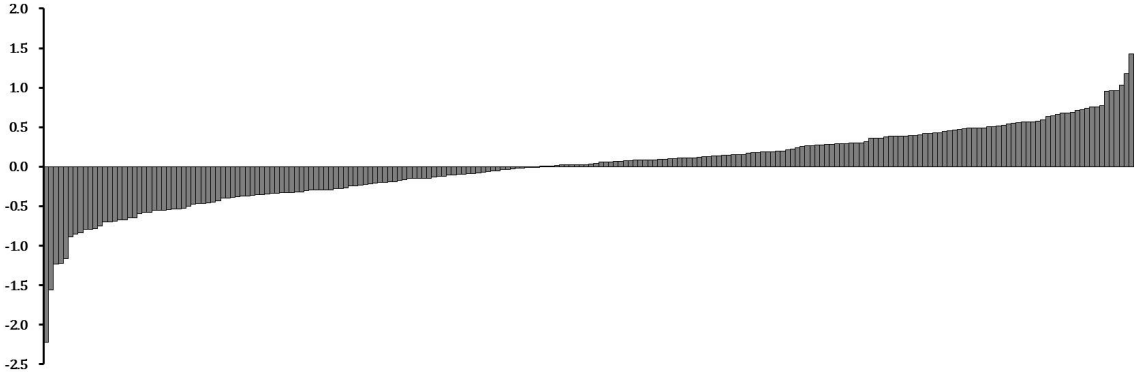

Fig. 1. Relative antioxidant capacity of leaf extracts of 223 Korean adzuki bean landraces.

Table 1. Descriptive statistics for antioxidant activity in the leaf extracts from 223 Korean adzuki bean landraces

	Min	Max	Mean	SD[z]	Skewness	Kurtosis	CV[y] (%)
DPPH[x] (㎕, IC_{50})	12.6	178.5	30.8	25.0	2.438	7.561	81.2
ABTS[w] (㎎ASC/g)	7.4	12.5	11.7	0.8	-2.031	5.052	6.9
FRAP[v] (㎎ASC/g)	0.39	6.03	3.12	1.05	0.279	0.154	33.6
TPC[u] (㎎GAE/g)	2.9	14.7	8.4	2.2	-0.147	-0.161	25.7
RP[t] (㎎ASC/g)	0.37	2.06	0.95	0.17	1.241	9.609	17.5
SOD[s] (㎕, IC_{50})	7.8	33.5	12.3	3.9	2.185	6.095	31.7

[z]SD: standard deviation, [y]CV: coefficient of variation, [x]DPPH: DPPH radical-scavenging activity, [w]ABTS: ABTS radical-scavenging activity, [v]FRAP: ferric reducing antioxidant power, [u]TPC: total polyphenol content, [t]RP: reducing power, [s]SOD: superoxide anion scavenging activity.

Integrating the antioxidant capacity results derived from different chemical methods allowed us to calculate RACIs, and the results are shown in Fig. 1. We found that IT142500 had the highest RACI, 1.42, followed by IT142476 (1.18), and IT142507 (1.03), with IT142561 having the lowest, -2.23.

Selecting adzuki bean landraces with high or low antioxidant activity using RACI

In order to confirm the relation among antioxidant activity, phytochemical contents, α-glucosidase inhibition activity, and tyrosinase inhibition activity, we selected 10 KABLs with high or low antioxidant activity based on the RACI results (Table S2), and we present the distribution of antioxidant activity in the leaf extracts from the 10 KABLs in Table 2. Among the five antioxidant activity assays, DPPH, FRAP, TPC, RP, and SOD were significantly higher in the high antioxidant group than in the low group, whereas ABTS showed no significant difference between the two.

Comparison of flavonoid content between the high and low antioxidant groups

In order to compare the contents of phytochemicals between the high and low antioxidant groups, we measured six flavonoids (kaempferol, quercetin, myricetin, daidzein, glycitein, and genistein) related to antioxidant activity in 10 the selected landraces using HPLC. Among the six detected flavonoids, daidzein (36.1–67.3%, average of 51.9% in detected flavonoids) was the most abundant (Table 3). The daidzein, genistein, and glycitein content in the 10 selected KABLs ranged from 533.2 (IT142507, high group) to 3959 (IT142561, low group), 92.8 (IT120225, high) to 379.1 (IT142561, low), and 137.7 (IT025789, low) to 1068 (IT142500, high) μg/100g dried sample, respectively.

Table 2. Descriptive statistics for antioxidant activity in the leaf extracts from 10 selected Korean adzuki bean landraces according to RACI

	DPPH[z] ($\mu\ell$, IC_{50})	ABTS[y] (㎎ASC/g)	FRAP[x] (㎎ASC/g)	TPC[w] (㎎GAE/g)	RP[v] (㎎ASC/g)	SOD[u] ($\mu\ell$, IC_{50})
HG[t]	14.5 ± 1.8	12.2 ± 0.5	4.8 ± 0.4	11.9 ± 2.1	1.1 ± 0.1	9.9 ± 1.7
LG	31.6 ± 15.0	10.1 ± 2.0	1.2 ± 0.8	6.2 ± 0.8	0.6 ± 0.2	19.2 ± 4.9
	*[s]	ns[r]	**	**	**	**

[z]DPPH: DPPH radical-scavenging activity, [y]ABTS: ABTS radical-scavenging activity, [x]FRAP: ferric reducing antioxidant power, [w]TPC: total polyphenol content, [v]RP: reducing power, [u]SOD: superoxide anion scavenging activity, [t]HG: high antioxidant group, IT142500. IT142476, IT142507, IT120265, and IT120225, LG: low antioxidant group, IT142560, IT025789, IT025962, IT142561, and IT142559. [s*,**]: Significance at $p \leq 0.05$ and 0.01, respectively, [r]ns: not significant.

Table 3. The flavonoid contents in the leaf extracts of 10 selected Korean adzuki bean landraces (μg/100g)

	IT	Kaempferol	Myricetin	Quercetin	Daidzein	Genistein	Glycitein
	IT142500	235.8 ± 21.2	605.6 ± 2.0	473.3 ± 43.0	3450.6 ± 147.1	294.0 ± 68.4	1068.0 ± 60.8
	IT142476	259.4 ± 21.3	333.7 ± 5.7	304.3 ± 16.2	2211.5 ± 116.4	270.5 ± 49.0	468.6 ± 39.2
HG[z]	IT142507	64.5 ± 2.7	200.5 ± 25.1	641.9 ± 29.5	533.2 ± 37.8	113.0 ± 5.7	407.3 ± 8.9
	IT120265	237.2 ± 41.4	559.1 ± 9.7	371.6 ± 59.6	2576.5 ± 387.8	246.7 ± 6.0	1003.7 ± 190
	IT120225	97.0 ± 4.6	247.2 ± 39.6	503.8 ± 15.4	981.0 ± 68.4	92.8 ± 19.6	379.6 ± 38.8
	IT142560	136.5 ± 24.4	55.0 ± 13.6	746.8 ± 53.8	1712.8 ± 326.6	143.6 ± 29.4	157.6 ± 51.9
	IT025789	103.1 ± 3.4	61.4 ± 0.6	373.7 ± 25.7	1297.3 ± 102.5	104.6 ± 18.5	137.7 ± 47.8
LG	IT025962	42.4 ± 1.7	227.1 ± 10.4	378.7 ± 27.2	640.2 ± 82.2	94.5 ± 2.8	391.8 ± 11.8
	IT142561	90.3 ± 7.3	216.0 ± 17.1	793.1 ± 50.6	3959.7 ± 103.6	379.1 ± 68.7	446.4 ± 40.3
	IT142559	106.3 ± 11.8	134.3 ± 18.2	691.0 ± 99.2	2172.7 ± 102.6	213.7 ± 29.0	278.0 ± 21.5
$LSD_{0.05}$[y]		33.6	32.7	87.8	332.6	68.6	128.3

[z]HG, high antioxidant group, IT142500. IT142476, IT142507, IT120265, and IT120225, LG: low antioxidant group, IT142560, IT025789, IT025962, IT142561, and IT142559.

[y]$LSD_{0.05}$: least significant difference at $p<0.05$.

Among the flavonols, kaempferol, myricetin, and quercetin content ranged from 42.4 (IT025962, low) to 259.4 (IT142476, high), 55.0 (IT142560, low) to 605.6 (IT142500, high), and 304.3 (IT142476, high) to 793.1 (IT142561, low) ㎍/100g dried sample, respectively.

Comparison of α-glucosidase and tyrosinase inhibition activity between the high and low antioxidant groups

We tested the leaf extracts from the 10 KABLs we selected for their α-glucosidase and tyrosinase inhibition activity (Table 4); among the 10, IT142507 showed the lowest inhibition activity for both enzymes. AGC and TIA were higher in the high antioxidant group than in the low group except for IT142507 and IT 120225. AGC in the high group ranged from 0.34 to 0.55 (IC_{50}, ㎍/㎖) and from 0.40 to 0.48 (IC_{50}, ㎍/㎖) in the low group. TIA in the high and low groups ranged from 0.53 to 0.83 and 0.58 to 0.69 (IC_{50}, ㎍/㎖), respectively.

Table 4. α-glucosidase inhibition and tyrosinase inhibition activity in the leaf extracts of 10 selected Korean adzuki bean landraces

	IT	α -glucosidase inhibition activity (㎍, IC_{50})	Tyrosinase inhibition activity (㎍, IC_{50})
HG[z]	IT142500	27.9 ± 1.2	45.6 ± 0.5
	IT142476	28.5 ± 2.0	44.4 ± 0.6
	IT142507	46.0 ± 4.6	68.5 ± 1.6
	IT120265	29.8 ± 1.2	47.5 ± 0.2
	IT120225	35.0 ± 1.6	53.2 ± 0.9
LG	IT142560	37.4 ± 2.2	52.5 ± 0.5
	IT025789	39.0 ± 2.4	54.4 ± 0.9
	IT025962	40.1 ± 2.4	57.5 ± 0.8
	IT142561	32.9 ± 2.1	47.9 ± 1.0
	IT142559	35.2 ± 1.9	51.5 ± 0.9
$LSD_{0.05}$[y]		3.3	1.2

[z]HG: high antioxidant group, IT142500. IT142476, IT142507, IT120265, and IT120225, LG: low antioxidant group, IT142560, IT025789, IT025962, IT142561, and IT142559.
[y]$LSD_{0.05}$: least significant difference at $p<0.05$.

Table 5. Correlations among antioxidants, α-glucosidase inhibition activity, tyrosinase inhibition activity, and phytochemical contents

	DPPH[z]	ABTS[y]	FRAP[x]	TPC[w]	RP[v]	SOD[u]	AGC[t]	TI[s]	Kaempferol	Myricetin	Quercetin	Daidzein	Genistein
ABTS	-0.112												
FRAP	**-0.691*** [r]	0.531											
TPC	**-0.722***	0.530	**0.953****										
RP	**-0.725***	0.334	**0.851****	**0.745***									
SOD	0.491	-0.520	**-0.826****	**-0.694***	**-0.909****								
AGC	0.234	-0.064	-0.355	-0.39	-0.445	0.382							
TI	0.078	0.105	-0.105	-0.153	-0.215	0.133	**0.960****						
Kaempferol	-0.317	0.340	0.516	**0.634***	0.455	-0.361	**-0.834****	**-0.739***					
Myricetin	-0.553	0.308	**0.739***	**0.797****	**0.718***	**-0.741***	**-0.677***	-0.474	**0.710***				
Quercetin	0.386	-0.500	-0.365	-0.435	-0.259	0.294	0.279	0.210	-0.433	-0.434			
Daidzein	-0.196	-0.309	0.114	0.186	0.225	-0.118	**-0.765****	**-0.771****	0.531	0.475	0.238		
Genestein	-0.286	-0.266	0.246	0.278	0.344	-0.226	**-0.728***	**-0.705***	0.534	0.488	0.202	**0.955****	
Glycitein	-0.518	0.236	**0.669***	**0.747***	**0.661***	**-0.688***	-0.625	-0.426	**0.656***	**0.985****	-0.324	0.520	0.514

[z]DPPH: DPPH radical-scavenging activity, [y]ABTS: ABTS radical-scavenging activity, [x]FRAP: ferric reducing antioxidant power, [w]TPC: total polyphenol content, [v]RP: reducing power, [u]SOD: superoxide anion scavenging activity, [t]AGC: α -glucosidase inhibition activity, [s]TI: tyrosinase inhibition activity.
[r]*,**Pearson's correlation p-value of * < 0.05 and **< 0.01.

Correlations among antioxidant activity, phytochemicals, and α-glucosidase and tyrosinase inhibition activity in adzuki bean extracts

Table 5 shows the correlations among antioxidant activity, phytochemicals, α-glucosidase and tyrosinase inhibition activity; among them, ABTS showed no correlations with other factors. For five antioxidants, DPPH, FRAP, TPC, RP, and SOD, we detected positive or negative correlations among them, but there were no significant correlations for AGC or TIA activity. AGC and TIA did show a high positive correlation between the two ($r=0.960$, $p<0.01$). Among six flavonoids, kaempferol, myricetin and glycitein showed correlations with antioxidant activity. We detected negative correlations for AGC and TIA with kaempferol, daidzein, and genistein, and myricetin showed a negative correlation with AGC only.

Comparison of antioxidant activity, phytochemicals, and α-glucosidase and tyrosinase inhibition activity between leaf and seed extracts

To confirm the potential uses for adzuki bean leaves, we compared leaf (LEs) and seed (SEs) extracts from the 10 selected KABLs based on phytochemical content and antioxidant and α-glucosidase and tyrosinase inhibition activity (Table S2 and S3). Among them, DPPH and FRAP showed no significant differences between the LEs and SEs (Table 6). For antioxidant activity, there was only more RP in the SEs (1.4 ± 0.3 ㎎ASC/g) than in the LEs (0.8 ± 0.3 ㎎ASC/g). There were, respectively, 2.3 and 4.2 times more AGC and TIA in the LEs (35.2 ± 5.7 and 52.3 ± 7.0 (㎕, IC_{50}), respectively) than in the SEs (81.0 ± 32.0 and 221.1 ± 134.2 ($\mu\ell$, IC_{50}), respectively). For the six detected flavonoids, there was 133 times more daidzein in the LEs than in the SEs.

Discussion

For centuries, farming communities have continuously contributed to the evolution, enrichment, and maintenance of landrace diversity on farms (Brush, 1995; Jarvis *et al*., 2008). However, little has been done to understand the landrace diversity or to improve these landraces (Sthapit and Rao, 2009). suggested that landraces can be effectively improved by simple trait selection if they offer sufficient natural variations in their populations. In this study, we evaluated the antioxidant activity, phytochemical content, and α-glucosidase and tyrosinase inhibition activity in the leaf extracts of Korean adzuki bean landraces to identify their potential as new industrial resources. Our results revealed that the leaf extracts of these KABLs had different physiological activities and phytochemical contents. The success of a breeding program depends on the existence of genetic variability available to breeders (Hoisington *et al*., 1999). Landraces contain important genetic variability, which determines their ability to adapt to changes in their environments (Frankel *et al*., 1995). In addition,

Table 6. Antioxidants, α-glucosidase inhibition activity, tyrosinase inhibition activity, and six phytochemical contents between leaf and seed extracts of adzuki bean landraces

	DPPH[z] ($\mu\ell$, $IC50_{50}$)	ABTS[y] (㎎ASC/g)	FRAP[x] (㎎ASC/g)	TPC[w] (㎎GAE/g)	RP[v] (㎎ASC/g)	SOD[u] ($\mu\ell$, IC_{50})	AGC[t] ($\mu\ell$, IC_{50})
LE[r]	23.0 ± 13.5	11.1 ± 1.8	3.0 ± 2.0	9.0 ± 3.4	0.8 ± 0.3	14.5 ± 6.0	35.2 ± 5.7
SE	23.6 ± 12.4	2.6 ± 0.1	2.3 ± 0.7	3.6 ± 1.2	1.4 ± 0.3	70.6 ± 8.2	81.0 ± 32.0
	ns[q]	**	ns	**	**	**	**
	TI[s] ($\mu\ell$, IC_{50})	Kaempferol (μg/100g)	Myricetin (μg/100g)	Quercetin (μg/100g)	Daidzein (μg/100g)	Genistein (μg/100g)	Glycitein (μg/100g)
LE	52.3 ± 7.0	137.3 ± 78.1	264 ± 188	527.8 ± 177	1953.6 ± 1152.1	195.2 ± 100.3	473.9 ± 317.3
SE	221.1 ± 134.2	2.7 ± 1.0	14.5 ± 15.5	12.2 ± 7.1	14.7 ± 3.6	7.2 ± 4.9	44.4 ± 24.2
	**	**	**	**	**	**	**

[z]DPPH: DPPH radical-scavenging activity, [y]ABTS: ABTS radical-scavenging activity, [x]FRAP: ferric reducing antioxidant power, [w]TPC: total polyphenol content, [v]RP: reducing power, [u]SOD: superoxide anion scavenging activity, [t]AGC: α -glucosidase inhibition activity, [s]TI: tyrosinase inhibition activity, [r]LE: leaf extracts, SE: seed extracts.
[q]**: Significance at $p \leq 0.01$, ns: not significant.

landraces provide useful variability for breeding provided that they are accompanied by characterization and agronomic evaluation (Allard, 1996; Frankel *et al*., 1995). This information is essential for the correct conservation of genetic variability and for the accessions to be of use in breeding programs (Vilaro *et al*., 2004). Our results could contribute to more efficient conservation and utilization of adzuki bean landraces.

In this study, the leaf extracts from the adzuki bean landraces had more efficient antioxidant activity than did the seed extract. Other studies reported that flavonoids are present in leaf extracts but absent in seed extracts (Archana *et al*., 2012; Nanna *et al*., 2013) ; their authors' suggested that antioxidant, antimicrobial, and anti-inflammatory plant activity may be due to the presence of flavonoids. Flavonoids and total polyphenols are important secondary plant metabolites present at high levels in plants under stress (Koh *et al*., 2009; Stanojevic *et al*., 2009) because they play roles in reducing the oxidative stress caused by ROS (Patil and Jadhav, 2013). Flavonoids are free radical scavengers that prevent oxidative cell damage (Salah *et al*., 1995). Although our result did not show significant correlations between antioxidant activity and flavonoid content, we suggest that the higher flavonoid content in the leaf than the seed extracts might be responsible for the leaf extracts' high antioxidant activity.

Plant antioxidants have been purported to have anti-aging properties and may prevent numerous diseases such as cancer, diabetes, and neurodegenerative diseases (Bansal *et al*., 2013). In our study, we measured the antioxidant activity of 223 Korean adzuki bean landraces using various methods. Additionally, based on the antioxidant activity findings, we evaluated the α -glucosidase and tyrosinase inhibitor activity in the leaf and seed extracts of the landraces. We found more α-glucosidase and tyrosinase inhibition activity in the leaf extracts, by 2.3 and 4.2 times, respectively, than in the seed extracts, although there were no significant correlations between antioxidant activity and α-glucosidase and tyrosinase inhibitor activity. Shoots and leaves have been reported to have higher phenolic content than that in other plant parts (Bernardi *et al*., 2008), and (Shaik *et al*., 2011) reported that leaf extracts of *Lessertia frulescens* showed more phenolics, flavonoids, alkaloids, and saponins than did seed extracts. In particular, (Oleszek and Stochmal, 2002) reported that flavonoid content in the seeds was characteristically low. Our results agreed with the previous studies: The phytochemical content in the leaf extracts was greater than in the seed extracts, resulting in more antioxidant and α-glucosidase and tyrosinase inhibitor activity.

α-Glucosidase inhibitors are potential agents for diabetes therapy given that glucosidases are involved in several important and relevant biological processes (Fontana Pereira *et al*., 2011). Our results showed that the flavonoid content in the leaf extracts was higher than in the seed extracts. In addition, among six flavonoids, kaempferol, myricetin, daidzein, and genistein had negative correlations with α-glucosidase inhibition activity (IC_{50}). Flavonoids are naturally occurring phenolic compounds that are widely distributed in plants, and some of them have been described as glucosidase inhibitors (Cazarolli *et al*., 2009). Tadera *et al*. (2006) reported that anthocyanidin and isoflavone and flavonol groups were potent α-glucosidase inhibitors and cyanidin, myricetin, quercetin, genistein, kaempferol, and daidzein especially showed higher α-glucosidase inhibition activity. Other studies reported that some flavonoids such as quercetin, kaempferol, and daidzein are strong glucosidase inhibitors (Fontana Pereira *et al*., 2011; Kim *et al*., 2000). (Andrade-Cetto *et al.* (2008) reported that high flavonoid content in some plant extracts efficiently inhibits α-glucosidase activity.

In our study, we analyzed the tyrosinase inhibition activity of leaf and seed extracts from the adzuki bean, and we found higher tyrosinase inhibition, which could have been because of the higher flavonoid content in the leaf extracts than in those from the seeds (Matsuda *et al*., 1996). reported that several flavonoid derivatives including quercetin, myricetin, and myricetin-glucoside had varying degrees of inhibitory activity toward tyrosinase. Many flavonols and flavones such as quercetin, kaempferol, galangin, luteolin, chrysin, baicalein, and luteolin-7-O-glucoside were reported to have weak tyrosinase inhibitory activity (Kubo *et al*., 2000). In addition, Chang *et al.* (2007) reported that five isolated isoflavones such as daidzein, glycitein, and genistein showed tyrosinase inhibitory activity.

In this study, we evaluated the phytochemical content and *in vitro* antioxidant, α-glucosidase inhibition, and tyrosinase inhibition activity in the leaf extracts of Korean adzuki bean landraces using various methods for the first time. KABLs contain high phytochemicals and exhibited strong bioactivity. With the present study, we demonstrated that leaf extracts of adzuki beans are a new source of natural antioxidants, cosmetics,

and medicines that could be used in industrial applications, which will strongly increase the utilization of adzuki bean by-products. This study laid a good foundation for developing and utilizing adzuki bean by-products as a new source.

Acknowledgments

This study was carried out with the support of the "Research Program for Agricultural Science & Technology Development (Project No. PJ010883)". It was also supported by the 2017 Postdoctoral Fellowship Program of the National Institute of Agricultural Science funded by the Rural Development Administration, Republic of Korea.

References

Acar, O.C., V. Gokmen, N. Pellegrini and V. Fogliano. 2009. Direct evaluation of the total antioxidant capacity of raw and roasted pulses, Nuts and Seeds. Eur. Food Res. Technol. 229:961-969.

Allard, R.W. 1996. Genetic basis of the evolution of adaptedness in plants. Euphytica 92:1-11.

Andrade-Cetto, A., J. Becerra-Jiménez and R. Cárdenas-Vázquez. 2008. Alfa-glucosidase-inhibiting activity of some Mexican plants used in the treatment of type 2 diabetes. J. Ethnopharmacol. 116:27-32.

Archana, P., T. TSamatha, B. Mahitha, Chamundeswari and N. RamaSwamy. 2012. Preliminary phytochemical screening from leaf and seed extracts of *Senna Alata* L. roxb-an ethnomedicinalplant. Int. J. Pharm. Biol. Res. 3:82-88.

Bansal, S., S. Choudhary, M. Sharma, S.S. Kumar, S. Lohan, V. Bhardwaj, N. Syan and S. Jyoti. 2013. Tea: A native source of antimicrobial agents. Food Res. Int. 53:568-584.

Bernardi, A.P.M., J.D. Nunes, M.K. Marchioro, L.M.G. Rosa, G.L. von Poser and S.B. Rech. 2008. Phenolic compounds profiles during *ex vitro* acclimatization of micropropagated *Hypericum polyanthemum*. Plant Physiol. Bioch. 46:694-700.

Brush, S.B. 1995. *In-situ* conservation of landraces in centers of crop diversity. Crop Sci. 35:346-354.

Cazarolli, L.H., P. Folador, M.G. Pizzolatti and F.R.M.B. Silva. 2009. Signaling pathways of kaempferol-3-neohesperidoside in glycogen synthesis in rat soleus muscle. Biochimie 91: 843-849.

Chang, T.S., H.Y. Ding, S.S.K. Tai and C.Y. Wu. 2007. Mushroom tyrosinase inhibitory effects of isoflavones isolated from soygerm koji fermented with *Aspergillus Oryzae* Bcrc 32288. Food Chem. 105:1430-1438.

Chiavaroli, V., C. Giannini, S. De Marco, F. Chiarelli and A. Mohn. 2011. Unbalanced oxidant-antioxidant status and its effects in pediatric diseases. Redox Rep. 16:101-107.

Croteau, R., T.M. Kutchan and N.G. Lewis. 2000. Natural products (secondary metabolites): *In* Buchanan, B., W. Gruissem and R. Jones (eds.), Biochemistry and Molecular Biology of Plants, American Society of Plant Physiologists 24:1250-1319.

Fang, Y.Z., S. Yang and G.Y. Wu. 2002. Free radicals, antioxidants, and nutrition. Nutrition 18:872-879.

Fontana, Pereira D., L.H. Cazarolli, C. Lavado, V. Mengatto, M.S.R.B. Figueiredo, A. Guedes, M.G. Pizzolatti and F.R.M.B. Silva. 2011. Effects of flavonoids on α-glucosidase activity: Potential targets for glucose homeostasis. Nutrition 27:1161-1167.

Frankel, O., A.D.H. Brown and J.J. Burdon. 1995. The conservation of plant biodiversity. Cambridge University Press, Cambridge, UK.

Gökmen, V., A. Serpen and V. Fogliano. 2009. Direct measurement of the total antioxidant capacity of foods: The 'Quencher' approach. Trends Food Sci. Technol. 20:278-288.

Gohara, A.K., A.H.P. de Souza, S.T.M. Gomes, N.E. de Souza, J.V. Visentainer and M. Matsushita. 2016. Nutritional and bioactive compounds of adzuki bean cultivars using chemometric approach. Cienc. Agrotec. 40:104-113.

Han, K.H., T. Kitano-Okada, J.M. Seo, S.J. Kim, K. Sasaki, K. Shimada and M. Fukushima. 2015. Characterisation of anthocyanins and proanthocyanidins of adzuki bean extracts and their antioxidant activity. J. Funct. Foods 14:692-701.

Hoisington, D., M. Khairallah, T. Reeves, J.-M. Ribaut, B. Skovmand, S. Taba and M. Warburton. 1999. Plant genetic resources: What can they contribute toward increased crop productivity? Proc. Natl. Acad. Sci. 96:5937-5943.

Jarvis, D.I., A.H.D. Brown, P.H. Cuong, L. Collado-Panduro, L. Latournerie-Moreno, S. Gyawali, T. Tanto, M. Sawadogo, I. Mar, M. Sadiki, N.T.N. Hue, L. Arias-Reyes, D. Balma, J. Bajracharya, F. Castillo, D. Rijal, L. Belqadi, R. Ranag, S. Saidi, J. Ouedraogo, R. Zangre, K. Rhrib, J.L. Chavez, D.J. Schoen, B. Sthapit, P. De Santis, C. Fadda and T. Hodgkin. 2008. A global perspective of the richness and evenness of traditional crop-variety diversity maintained by farming

communities. Proc. Natl. Acad. Sci. USA 105:5326-5331.

Kim, J.-S., C.-S. Kwon and K.H. Son. 2000. Inhibition of alpha-glucosidase and amylase by luteolin, a flavonoid. Biosci. Biotechnol. Biochem. 64:2458-2461.

Kim, J., J. Hong, H.K. Jung, Y.S. Jeong and K. Cho. 2012. Grape skin and loquat leaf extracts and acai puree have potent anti-atherosclerotic and anti-diabetic activity *in vitro* and *in vivo* in hypercholesterolemic zebrafish. Int. J. Mol. Med. 30:606-614.

Kim, M.-H. and H.-K. Chung. 2013. Review of food therapy and development of diet therapy program for diabetes mellitus in「Sikryochanyo」. J. Kor. Soc. Diet. Cult. 28: 562-575.

Kim, S.M, J.H. Park, H.O. Boo, S.G. Song and H.Y. Park. 2017. *In vitro* comparision of biological activities of solvent fraction extracts from *Orostachys japonicus*. Korean J. Plant Res. 30:133-143.

Kim, S. and H. Cha. 2017. Comparison of the total phenolic and flavonoid contents and antioxidant activities of four kinds of sand dune plants living in taean, Korea. Korean J. Plant Res. 30:8-16.

Koh, E., K.M.S. Wimalasiri, A.W. Chassy and A.E. Mitchell. 2009. Content of ascorbic acid, quercetin, kaempferol and total phenolics in commercial broccoli. J. Food Compos. Anal. 22:637-643.

Kubo, I., I. Kinst-Hori, S.K. Chaudhuri, Y. Kubo, Y. Sánchez and T. Ogura. 2000. Flavonols from heterotheca inuloides: Tyrosinase inhibitory activity and structural criteria. Bioorg. Med. Chem. 8:1749-1755.

Lee, D.J. and J.Y. Lee. 2004. Antioxidant activity by DPPH assay. Korean J. Crop Sci. 49:187-194.

Luo, J.Q., W.X. Cai, T. Wu and B.J. Xu. 2016. Phytochemical distribution in hull and cotyledon of adzuki bean (*Vigna Angularis* L.) and mung bean (*Vigna radiate* L.), and their contribution to antioxidant, anti-inflammatory and anti-diabetic activities. Food Chem. 201:350-360.

Matsuda, H., M. Higashino, Y. Nakai, M. Iinuma, M. Kubo and F.A. Lang. 1996. Studies of cuticle drugs from natural sources. IV. Inhibitory effects of some arctostaphylos plants on melanin biosynthesis. Biol. Pharm. Bull. 19:153-156.

Maynard, M., D. Gunnell, P. Emmett, S. Frankel and G.D. Smith. 2003. Fruit, vegetables, and antioxidants in childhood and risk of adult cancer: The Boyd Orr cohort. J. Epidemiol. Commun. H. 57:218-225.

Middleton, E., C. Kandaswami and T.C. Theoharides. 2000. The effects of plant flavonoids on mammalian cells: Implications for inflammation, heart disease, and cancer. Pharmacol. Rev. 52:673-751.

Moon, H.-K., Y.-J. Lee, M.-R. Park and G.-Y. Kim. 2015. Development of native local foods in Sangju by storytelling-combined - a Case of 'General Jeong's Table'. J. Kor. Soc. Food Cult. 30:562-575.

Nanna, R.S., M. Banala, A. Pamulaparthi, A. Kurra and S. Kagithoju. 2013. Evaluation of phytochemicals and fluorescent analysis of seed and leaf extracts of *Cajanus Cajan* L.. Int. J. Pharm. Sci. Rev. Res. 22:11-18.

Nijveldt, R.J., E.L.S. Van Nood, D.E. Van Hoorn, P.G. Boelens, K. Van Norren and P.A.M. Van Leeuwen. 2001. Flavonoids: A review of probable mechanisms of action and potential applications. Am. J. Clin. Nutr. 74:418-425.

Oleszek, W. and A. Stochmal. 2002. Triterpene saponins and flavonoids in the seeds of *Trifolium* species. Phytochemistry 61:165-170.

Park, Y.M., J.B. Jeong, J.H. Seo, J.H. Lim, H.J. Jeong and E.W. Seo. 2011. Inhibitory effect of red bean (*Phaseolus angularis*) hot water extracts on qxidative DNA and cell damage. Korean J. Plant Res. 24: 130-138.

Patil, A.B. and A.S. Jadhav. 2013. Flavonoids an antioxidants: A review. Int. J. Pharm. Biol. Sci. Res. Develop. 2:7-20.

Re, R., N. Pellegrini, A. Proteggente, A. Pannala, M. Yang and C. Rice-Evans. 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Bio. Med. 26:1231-1237.

Rho, C.W., S.Y. Son, S.T. Hong, K.H. Lee and I.M. Ryu. 2003. Agronomic characters of Korean adzuki beans (*Vigna angularis* (Willd.) Ohwi & Ohashi). Korean J. Plant. Res. 16:147-154

Robak, J. and R.J. Gryglewski. 1988. Flavonoids are scavengers of superoxide anions. Biochem. Pharmacol. 37:837-841.

Sabe, A.B., O.M. Onakoya and A.A. Oyagbemi. 2012. Hepato-protective and *in vivo* antioxidant activities of ethanolic extract of whole fruit of *Lagenaria Breviflora*. J. Basic Clin. Physiol. Pharm. 23:27-32.

Salah, N., N.J. Miller, G. Paganga, L. Tijburg, G.P. Bolwell and C. Riceevans. 1995. Polyphenolic flavanols as scavengers of aqueous phase radicals and as chain-breaking antioxidants. Arch. Biochem. Biophy. 322:339-346.

Serpen, A., E. Capuano, V. Fogliano and V. Gokmen. 2007. A new procedure to measure the antioxidant activity of insoluble food components. J. Agr. Food Chem. 55:7676-7681.

Serpen, A., V. Gokmen, N. Pellegrini and V. Fogliano. 2008.

Direct measurement of the total antioxidant capacity of cereal products. J. Cereal Sci. 48:816-820.

Shaik, S., N. Singh and A. Nicholas. 2011. Comparison of the selected secondary metabolite content present in the cancer-bush *Lessertia (Sutherlandia) frutescens* L. extracts. Afr. J. Tradit. Complement.Altern. Med. 8:429-434.

Singh, V., N. Guizani, M.M. Essa, F.L. Hakkim and M.S. Rahman. 2012. Comparative analysis of total phenolics, flavonoid content and antioxidant profile of different date varieties (*Phoenix dactylifera* L.) from Sultanate of Oman. Int. Food Res. J. 19:1063-1070.

Stanojevic, L., M. Stankovic, V. Nikolic, L. Nikolic, D. Ristic, J. Canadanovic-Brunet and V. Tumbas. 2009. Antioxidant activity and total phenolic and flavonoid contents of *Hieracium Pilosella* L. extracts. Sensors-Basel 9:5702-5714.

Sthapit, B.R. and V.R. Rao. 2009. Consolidating Community's role in local crop development by promoting farmer innovation to maximise the use of local crop diversity for the well-being of people. Acta. Hortic. 806:669-676.

Sun, T. and S.A. Tanumihardjo. 2007. An integrated approach to evaluate food antioxidant capacity. J. Food Sci. 72:R159-R165.

Tadera, K., Y. Minami, K. Takamatsu and T. Matsuoka. 2006. Inhibition of alpha;-glucosidase and alpha-amylase by flavonoids. J. Nutr. Sci. Vitaminol. 52:149-153.

Terashima, M., A. Fukukita, R. Kodama, H. Miki, M. Suzuki, M. Ikegami, N. Tamura, A. Yasuda, M. Morikawa and S. Matsumura. 2013. Evaluation of antioxidant activity of leafy vegetables and beans with myoglobin method. Plant Cell Rep. 32:349-357.

Vilaro, N., M. Rebuffo, C. Miranda, C. Pritse and T. Abadie 2004. Characterization and analysis of a collection of *Avena Sativa* L. from Uruguay. PGR Newsletters FAO-Bioversity 140:23-31.

Waterhouse, A.L. 2001. Determination of total phenolics. In: Current protocols in food analytical chemistry. John Wiley & Sons, Inc.

Wildmann, R. 2001. Nutraceuticals: A Brief review of historical and teleological aspects handbook of nutraceuticals and functional foods, CRC Press, Boca Raton:1-12.

Winkel-Shirley, B. 2001. Flavonoid biosynthesis. A colorful model for genetics, biochemistry, cell biology, and bio-technology. Plant Physiol. 126:485-493.

Winkel-Shirley, B. 2002. Biosynthesis of flavonoids and effects of stress. Curr. Opin. Plant Biol. 5:218-223.

Woo, K.S., S.B. Song, J.Y. Ko, Y.-B. Kim, W.H. Kim and H.-S. Jeong. 2016. Antioxidant properties of adzuki beans, and quality characteristics of sediment according to cultivated methods. Kor. J. Food Nutr. 29:134-143.

Yen, G.C. and P.D. Duh. 1993. Antioxidative properties of methanolic extracts from peanut hulls. J. Am. Oil Chem. Soc. 70:383-386.

Zhang, J., Y. Liu, J. Lv and G. Li. 2015. A colorimetric method for α-glucosidase activity assay and its inhibitor screening based on aggregation of gold nanoparticles induced by specific recognition between phenylenediboronic acid and 4-aminophenyl-A-D-glucopyranoside. Nano Res. 8:920-930.

Zou, Y.P. and K.C. ChangSam. 2014. Antioxidant and anti-proliferative properties of extract and fractions from small red bean (*Phaseolus Vulgaris* L.). J. Food Nutr. 1:1-11.

(Received 12 January 2018; Revised 19 April 2018; Accepted 28 May 2018)

Table S1. Antioxidant activities of leaf extracts of 223 Korean adzuki bean landraces

#	IT	DPPH(ul, IC50)	ABTS (mgASC/g)	FRAP (mgASC/g)	TPC (mgGAE/g)	RP (mgASC/g)	SOD (ul, IC50)
1	IT120213	18.6 ± 1.0	11.1 ± 0.5	4.3 ± 0.2	10.8 ± 0.4	1.0 ± 0.1	10.2 ± 0.4
2	IT120217	17.5 ± 0.8	9.4 ± 0.2	1.8 ± 0.1	7.1 ± 0.4	1.1 ± 0.0	8.8 ± 0.3
3	IT120225	17.5 ± 0.8	12.0 ± 0.2	4.1 ± 0.0	9.1 ± 1.7	1.2 ± 0.1	8.0 ± 0.2
4	IT120226	17.7 ± 0.9	12.0 ± 0.1	3.5 ± 0.2	12 ± 1.2	0.9 ± 0.1	10.1 ± 0.2
5	IT120233	15.5 ± 0.4	11.8 ± 0.2	2.5 ± 0.1	6.6 ± 1.2	0.8 ± 0.0	9.1 ± 0.3
6	IT120236	16.1 ± 0.5	10.4 ± 0.7	4.2 ± 0.1	10.5 ± 0.9	0.9 ± 0.1	9.6 ± 0.3
7	IT120237	16.9 ± 0.8	11.0 ± 0.0	3.2 ± 0.1	7.0 ± 0.1	0.9 ± 0.0	8.1 ± 0.1
8	IT120238	14.8 ± 0.8	10.5 ± 0.3	2.5 ± 0.1	9.6 ± 0.4	0.9 ± 0.0	8.3 ± 0.1
9	IT120242	28.7 ± 3.2	11.3 ± 0.1	1.6 ± 0.0	7.7 ± 0.5	0.9 ± 0.0	9.4 ± 0.2
10	IT120247	15.3 ± 0.6	12.2 ± 0.1	3.0 ± 0.2	8.6 ± 0.6	1.1 ± 0.1	8.1 ± 0.1
11	IT120248	15.6 ± 1.6	10.6 ± 0.2	2.9 ± 0.3	10.1 ± 0.9	1.0 ± 0.1	8.2 ± 0.4
12	IT120249	13.3 ± 0.5	11.6 ± 0.2	4.0 ± 0.0	9.9 ± 0.9	1.0 ± 0.1	9 ± 0.9
13	IT120251	34.9 ± 3.3	11.0 ± 0.6	4.0 ± 0.3	10.3 ± 0.7	1.0 ± 0.1	8.6 ± 0.2
14	IT120252	18.6 ± 1.7	10.9 ± 0.3	3.0 ± 0.2	9.5 ± 1.0	0.9 ± 0.0	9.2 ± 0.1
15	IT120253	15.7 ± 0.5	12.1 ± 0.3	3.1 ± 0.2	8.8 ± 0.4	1.1 ± 0.0	10 ± 0.2
16	IT120255	42.1 ± 1.9	11.9 ± 0.3	2.3 ± 0.2	9.1 ± 0.5	1.0 ± 0.1	9.2 ± 0.3
17	IT120257	62.3 ± 5.7	11.1 ± 0.4	4.4 ± 0.2	8.9 ± 0.1	1.1 ± 0.1	8.6 ± 0.2
18	IT120265	13.6 ± 0.6	11.3 ± 0.3	3.7 ± 0.2	11.0 ± 0.7	1.2 ± 0.0	8.6 ± 0.0
19	IT120273	13.3 ± 0.2	11.6 ± 0.2	3.8 ± 0.3	9.9 ± 0.6	0.9 ± 0.1	7.8 ± 0.2
20	IT120275	13.2 ± 0.5	10.1 ± 0.5	3.5 ± 0.1	6.4 ± 0.2	1.1 ± 0.0	8.1 ± 0.1
21	IT120277	65.3 ± 9.3	12.3 ± 0.1	3.6 ± 0.3	7.5 ± 0.4	1.2 ± 0.1	9.5 ± 0.4
22	IT120278	41.3 ± 6.0	12.4 ± 0.1	4.1 ± 0.1	2.9 ± 0.2	1.1 ± 0.1	8.9 ± 0.2
23	IT120281	42.4 ± 4.8	12.2 ± 0.1	2.4 ± 0.2	3.0 ± 0.1	0.9 ± 0.1	10.2 ± 0.2
24	IT120285	21.3 ± 1.1	12.1 ± 0.2	2.8 ± 0.0	3.4 ± 0.3	1.0 ± 0.1	8.8 ± 0.4
25	IT120286	17.0 ± 0.5	12.1 ± 0.1	3.9 ± 0.1	4.5 ± 0.2	1.2 ± 0.0	10.9 ± 0.3
26	IT120287	16.2 ± 0.1	12.3 ± 0.1	2.7 ± 0.1	5.3 ± 0.1	1.0 ± 0.0	11.7 ± 0.3
27	IT120289	37 ± 4.6	11.5 ± 0.3	2.7 ± 0.1	3.4 ± 0.1	1.1 ± 0.0	9.6 ± 0.3
28	IT120290	28.6 ± 3.1	10.9 ± 0.7	2.1 ± 0.0	7.6 ± 0.2	1.0 ± 0.0	9.3 ± 0.5
29	IT120292	20.9 ± 0.4	11.5 ± 0.3	2.7 ± 0.1	6.4 ± 0.4	0.9 ± 0.0	8.7 ± 0.3
30	IT120298	18.3 ± 0.6	12.2 ± 0.1	2.2 ± 0.1	4.3 ± 0.2	1.2 ± 0.1	8.8 ± 0.2
31	IT120302	22.2 ± 0.5	12.1 ± 0.1	2.1 ± 0.1	6.0 ± 0.1	0.8 ± 0.0	11.5 ± 0.4
32	IT120305	17.3 ± 0.4	12.1 ± 0.2	1.2 ± 0.1	5.2 ± 0.2	0.7 ± 0.0	11.1 ± 0.1
33	IT120320	19.0 ± 0.8	11.1 ± 0.7	1.9 ± 0.1	10.4 ± 0.6	0.8 ± 0.0	9.4 ± 0.4
34	IT120321	16.1 ± 0.6	10.9 ± 0.7	1.2 ± 0.1	7.1 ± 0.3	0.7 ± 0.1	9.6 ± 0.2
35	IT120334	15.6 ± 0.2	11.6 ± 0.8	1.5 ± 0.1	8.6 ± 0.6	0.8 ± 0.1	11.8 ± 0.9
36	IT120335	17.8 ± 0.6	11.2 ± 0.5	1.3 ± 0.1	7.9 ± 0.3	0.7 ± 0.0	10.4 ± 0.8
37	IT120338	16.3 ± 0.5	12.3 ± 0.1	2.1 ± 0.2	9.0 ± 0.2	0.8 ± 0.0	12.9 ± 1.1
38	IT120345	26.6 ± 0.8	9.5 ± 0.9	2.0 ± 0.1	8.7 ± 0.4	0.9 ± 0.1	11.9 ± 1.1
39	IT120353	35.8 ± 2.0	11.8 ± 0.2	3.0 ± 0.1	9.8 ± 0.5	1.2 ± 0.1	12.2 ± 0.9
40	IT120354	76.2 ± 10.6	11.8 ± 0.3	3.1 ± 0.2	8.1 ± 0.4	1.1 ± 0.1	12.5 ± 0.4
41	IT120369	17.8 ± 0.1	12.2 ± 0.1	4.0 ± 0.4	9.5 ± 0.3	1.0 ± 0.1	12.3 ± 1.1
42	IT120375	18.9 ± 0.3	11.4 ± 0.3	1.5 ± 0.1	9.7 ± 0.6	0.7 ± 0.0	13.0 ± 0.7
43	IT120376	22.7 ± 1.2	9.4 ± 0.4	2.8 ± 0.1	7.6 ± 0.3	0.9 ± 0.1	11.6 ± 0.8
44	IT120382	15.2 ± 1.2	10.8 ± 0.5	2.9 ± 0.2	7.8 ± 0.4	0.8 ± 0.1	13.3 ± 1.0
45	IT120383	14.7 ± 0.1	11.2 ± 0.2	2.4 ± 0.2	6.7 ± 0.5	0.9 ± 0.1	12.1 ± 0.8
46	IT120396	14.9 ± 0.2	11.7 ± 0.1	3.0 ± 0.2	8.0 ± 0.5	1.2 ± 0.1	10.8 ± 0.6
47	IT120398	14.3 ± 0.1	11.5 ± 0.4	4.5 ± 0.4	6.5 ± 0.1	1.0 ± 0.0	9.7 ± 0.5
48	IT120399	49.8 ± 5.0	9.1 ± 0.6	3.8 ± 0.0	6.9 ± 0.5	0.9 ± 0.0	8.8 ± 0.2
49	IT120401	94.7 ± 11.7	10.0 ± 0.7	2.8 ± 0.1	6.5 ± 0.3	1.0 ± 0.0	10.6 ± 0.6
50	IT120402	17.1 ± 0.9	12.2 ± 0.1	2.0 ± 0.1	8.4 ± 0.8	0.9 ± 0.0	11.4 ± 0.5
51	IT120405	15.4 ± 0.8	11.3 ± 0.4	2.7 ± 0.2	9.2 ± 0.3	0.9 ± 0.0	11.2 ± 0.5
52	IT120410	15.3 ± 0.3	10.6 ± 0.2	3.4 ± 0.0	10.3 ± 0.5	1.0 ± 0.1	10.8 ± 0.4

Table S1. Continued

#	IT	DPPH(ul, IC50)	ABTS (mgASC/g)	FRAP (mgASC/g)	TPC (mgGAE/g)	RP (mgASC/g)	SOD (ul, IC50)
53	IT120411	30.2 ± 2.2	10.9 ± 0.4	2.3 ± 0.1	10.3 ± 0.1	1.0 ± 0.1	10.6 ± 0.4
54	IT120415	17.2 ± 0.3	12.0 ± 0.2	2.2 ± 0.1	8.6 ± 0.4	0.9 ± 0.1	10.4 ± 0.4
55	IT120422	17.4 ± 0.2	12.2 ± 0.2	2.6 ± 0.2	11.9 ± 0.2	0.9 ± 0.1	12.6 ± 0.6
56	IT120424	17.0 ± 0.2	12.2 ± 0.1	2.9 ± 0.2	10.5 ± 0.3	1.0 ± 0.1	9.4 ± 0.4
57	IT120425	16.5 ± 0.2	12.0 ± 0.1	1.4 ± 1.2	8.5 ± 0.6	0.7 ± 0.0	9.4 ± 0.4
58	IT120427	15.8 ± 0.0	12.1 ± 0.1	3.3 ± 0.1	10.5 ± 0.4	1.0 ± 0.1	10.2 ± 0.3
59	IT120431	19.9 ± 0.2	12.2 ± 0.0	3.0 ± 0.2	8.8 ± 0.3	1.0 ± 0.1	8.7 ± 0.4
60	IT120437	22.9 ± 0.8	12.2 ± 0.1	2.0 ± 0.1	10.3 ± 0.3	0.9 ± 0.1	11.5 ± 0.8
61	IT120459	24.2 ± 1.2	12.3 ± 0.1	1.6 ± 0.1	9.5 ± 0.4	0.8 ± 0.0	11.4 ± 0.6
62	IT120461	55.5 ± 4.6	12.2 ± 0.1	2.8 ± 0.2	10.0 ± 0.6	1.0 ± 0.1	11.1 ± 0.3
63	IT120464	76.3 ± 9.0	12.3 ± 0.1	2.3 ± 0.0	9.3 ± 0.4	0.9 ± 0.0	10.2 ± 0.3
64	IT120465	46.2 ± 1.8	12.3 ± 0.1	3.4 ± 0.2	10.5 ± 0.9	0.9 ± 0.1	8.2 ± 0.2
65	IT120468	28.8 ± 0.8	12.0 ± 0.1	1.5 ± 0.1	8.6 ± 0.8	0.8 ± 0.0	9.7 ± 0.3
66	IT120469	15.5 ± 0.1	12.1 ± 0.4	2.8 ± 0.2	9.6 ± 0.3	1.0 ± 0.1	11.3 ± 0.5
67	IT120470	56.4 ± 7.5	12.0 ± 0.3	3.4 ± 0.2	8.7 ± 0.6	0.9 ± 0.1	9.0 ± 0.3
68	IT120472	14.3 ± 0.2	12.2 ± 0.1	3.1 ± 0.3	6.2 ± 0.3	1.1 ± 0.1	13.6 ± 0.3
69	IT120478	13.8 ± 0.1	12.2 ± 0.1	2.9 ± 0.3	8.8 ± 1.5	1.0 ± 0.1	10.5 ± 0.7
70	IT120482	56.0 ± 7.8	12.3 ± 0.1	4.2 ± 0.3	11.2 ± 0.6	1.1 ± 0.1	11.9 ± 0.1
71	IT120483	88.6 ± 3.5	11.7 ± 0.4	2.5 ± 0.1	10.4 ± 0.4	0.9 ± 0.1	11.9 ± 0.2
72	IT120490	47.6 ± 6.7	12.1 ± 0.3	3.5 ± 0.2	7.1 ± 0.2	1.2 ± 0.1	9.7 ± 0.2
73	IT120491	30.2 ± 1.8	11.9 ± 0.2	2.8 ± 0.1	6.5 ± 0.5	1.1 ± 0.1	11.3 ± 0.2
74	IT120493	34.5 ± 0.7	10.1 ± 0.8	3.0 ± 0.0	8.7 ± 0.8	0.9 ± 0.0	9.5 ± 0.1
75	IT120502	45.1 ± 2.5	11.4 ± 0.5	3.4 ± 0.2	9.3 ± 0.1	1.1 ± 0.0	11.1 ± 0.2
76	IT120512	15.4 ± 0.7	12.0 ± 0.2	3.2 ± 0.1	6.8 ± 0.5	0.8 ± 0.1	10.0 ± 0.2
77	IT120522	17.7 ± 1.7	12.1 ± 0.2	3.3 ± 0.2	9.4 ± 0.5	1.2 ± 0.0	10.2 ± 0.1
78	IT120531	40.7 ± 3.1	10.8 ± 0.2	3.7 ± 0.2	8.5 ± 0.4	0.9 ± 0.1	9.0 ± 0.2
79	IT120532	15.8 ± 0.4	12.4 ± 0.1	3.2 ± 0.2	11.8 ± 0.1	1.1 ± 0.1	12.5 ± 0.5
80	IT120541	34.7 ± 1.7	12.2 ± 0.2	4.1 ± 0.1	10.0 ± 0.5	1.0 ± 0.0	10.0 ± 0.3
81	IT120548	14.9 ± 0.1	12.3 ± 0.1	3.8 ± 0.2	8.0 ± 0.3	1.0 ± 0.0	10.2 ± 0.2
82	IT120550	16.2 ± 0.1	12.2 ± 0.3	2.4 ± 0.1	7.1 ± 0.3	1.0 ± 0.0	11.7 ± 0.5
83	IT120551	14.3 ± 0.2	12.1 ± 0.1	2.0 ± 0.1	9.5 ± 0.5	0.9 ± 0.1	12.4 ± 0.1
84	IT120553	14.2 ± 0.6	12.3 ± 0.0	2.8 ± 0.1	7.3 ± 0.5	1.0 ± 0.0	11.6 ± 0.9
85	IT120554	79.4 ± 2.7	12.1 ± 0.0	1.4 ± 0.1	6.7 ± 0.4	0.9 ± 0.0	11.8 ± 0.8
86	IT120555	102.6 ± 8.2	12.2 ± 0.1	2.6 ± 0.2	5.2 ± 0.3	0.9 ± 0.1	11.2 ± 0.6
87	IT120559	41.3 ± 5.5	12.4 ± 0.1	2.6 ± 0.1	10.1 ± 0.2	1.0 ± 0.1	11.7 ± 0.2
88	IT120561	16.0 ± 0.3	12.3 ± 0.0	1.8 ± 0.2	9.5 ± 0.5	0.8 ± 0.1	9.9 ± 0.0
89	IT120563	32.4 ± 1.7	12.5 ± 0.1	5.3 ± 0.2	8.4 ± 0.2	1.0 ± 0.0	10.6 ± 0.3
90	IT120564	40.4 ± 3.8	12.2 ± 0.1	5.6 ± 0.2	9.0 ± 0.1	1.0 ± 0.0	9.5 ± 0.1
91	IT120566	28.0 ± 1.0	11.4 ± 0.1	3.0 ± 0.1	10.0 ± 0.4	1.0 ± 0.1	11.2 ± 0.2
92	IT120568	25.2 ± 1.6	10.4 ± 0.7	2.9 ± 0.0	7.3 ± 0.3	1.0 ± 0.0	8.3 ± 0.4
93	IT120570	123.8 ± 7	9.9 ± 0.4	3.1 ± 0.1	6.1 ± 0.4	1.0 ± 0.1	13.3 ± 1.3
94	IT120572	25.2 ± 0.6	11.4 ± 0.4	2.6 ± 0.1	8.2 ± 0.5	0.9 ± 0.1	14.9 ± 0.6
95	IT120574	20.3 ± 0.6	12.4 ± 0.2	3.0 ± 0.2	9.4 ± 0.9	1.0 ± 0.0	11.5 ± 0.5
96	IT120577	28.8 ± 1.8	12.3 ± 0.3	2.3 ± 0.1	5.9 ± 0.2	0.9 ± 0.0	8.5 ± 0.4
97	IT120578	87.6 ± 5.5	12.3 ± 0.1	4.0 ± 0.1	6.3 ± 0.5	0.7 ± 0.1	10.1 ± 0.4
98	IT120592	131.5 ± 3.6	12.3 ± 0.2	3.3 ± 0.2	6.0 ± 0.2	0.8 ± 0.1	10.0 ± 0.7
99	IT120593	17.7 ± 0.8	12.3 ± 0.1	2.9 ± 0.2	6.5 ± 1.2	1.0 ± 0.1	10.9 ± 1.1
100	IT120594	82.8 ± 6.0	12.3 ± 0.1	2.9 ± 0.3	7.5 ± 0.4	0.9 ± 0.1	13.2 ± 1.4
101	IT120595	15.3 ± 0.9	12.2 ± 0.1	2.2 ± 0.1	8.7 ± 1.0	0.9 ± 0.0	9.7 ± 0.2
102	IT120596	15.4 ± 0.7	12.5 ± 0.1	2.9 ± 0.1	9.8 ± 0.8	0.9 ± 0.1	9.4 ± 0.2
103	IT120597	80.4 ± 11.4	12.5 ± 0.1	4.3 ± 0.2	7.3 ± 1.0	0.9 ± 0.1	10.4 ± 0.5
104	IT120601	13.6 ± 0.1	12.5 ± 0.1	5.1 ± 0.3	8.9 ± 0.5	1.0 ± 0.1	15.8 ± 1.0

Table S1. Continued

#	IT	DPPH(ul, IC50)	ABTS (mgASC/g)	FRAP (mgASC/g)	TPC (mgGAE/g)	RP (mgASC/g)	SOD (ul, IC50)
105	IT142476	13.4 ± 0.3	12.5 ± 0.1	5.4 ± 0.2	12.7 ± 0.5	1.1 ± 0.1	11.6 ± 0.5
106	IT142497	14.1 ± 0.0	12.3 ± 0.1	3.7 ± 0.1	10.5 ± 1.1	1.0 ± 0.1	10.1 ± 0.4
107	IT142499	16.7 ± 0.9	12.4 ± 0.1	3.8 ± 0.2	8.1 ± 0.1	0.9 ± 0.1	9.5 ± 0.5
108	IT142500	14.9 ± 0.4	12.5 ± 0.1	5.7 ± 0.4	14.7 ± 1.0	1.0 ± 0.1	9.7 ± 0.3
109	IT142503	21.1 ± 2.5	11.9 ± 0.4	2.3 ± 0.2	11.0 ± 0.8	0.9 ± 0.1	11.1 ± 0.3
110	IT142504	80.3 ± 6.8	12.1 ± 0.2	2.2 ± 0.2	11.0 ± 0.4	0.8 ± 0.0	11.1 ± 0.4
111	IT142505	43.4 ± 0.6	12.4 ± 0.1	3.5 ± 0.1	10.7 ± 0.7	0.9 ± 0.0	9.0 ± 0.2
112	IT142507	13.0 ± 0.2	12.5 ± 0.2	4.9 ± 0.2	12.0 ± 0.6	1.0 ± 0.0	11.6 ± 0.1
113	IT142508	80.0 ± 6.9	12.4 ± 0.1	4.4 ± 0.2	12.6 ± 0.3	1.2 ± 0.1	10.4 ± 0.5
114	IT142511	16.4 ± 1.1	11.3 ± 0.3	3.5 ± 0.2	11.3 ± 0.4	1.0 ± 0.1	11.3 ± 0.8
115	IT142513	37.3 ± 2.2	12.1 ± 0.1	2.4 ± 0.1	10.6 ± 0.1	0.9 ± 0.0	10.3 ± 0.5
116	IT142514	178.5 ± 6.3	12.4 ± 0.1	2.8 ± 0.3	12.5 ± 0.8	0.9 ± 0.0	10.6 ± 0.4
117	IT142515	16.7 ± 0.2	9.3 ± 0.4	1.9 ± 0.1	12.2 ± 0.5	0.8 ± 0.0	10.2 ± 0.1
118	IT142517	52.2 ± 0.0	12.2 ± 0.2	3.3 ± 0.1	11.4 ± 0.6	0.9 ± 0.0	10.2 ± 0.9
119	IT142519	25.7 ± 1.2	12.2 ± 0.1	4.3 ± 0.3	7.4 ± 0.1	0.9 ± 0.1	10.1 ± 0.4
120	IT142520	66.9 ± 3.8	12.0 ± 0.2	3.4 ± 0.3	10.5 ± 0.2	0.8 ± 0.1	11.2 ± 1.0
121	IT142523	27.5 ± 3.5	12.1 ± 0.3	2.5 ± 0.1	9.9 ± 0.1	0.8 ± 0.1	23.1 ± 1.7
122	IT142524	15.0 ± 0.2	11.8 ± 0.3	1.2 ± 0.1	9.5 ± 0.4	0.5 ± 0.1	10.3 ± 1.1
123	IT142525	12.8 ± 0.1	12.2 ± 0.2	4.2 ± 0.3	9.6 ± 0.4	1.1 ± 0.1	14.0 ± 0.9
124	IT142526	52.7 ± 7.5	11.8 ± 0.5	2.8 ± 0.3	8.9 ± 0.3	0.9 ± 0.1	10.7 ± 0.3
125	IT142537	36.0 ± 3.7	10.0 ± 0.9	3.0 ± 0.2	9.3 ± 0.6	0.9 ± 0.1	13.5 ± 0.9
126	IT142538	38.0 ± 5.4	10.8 ± 0.4	3.6 ± 0.3	9.0 ± 0.4	1.0 ± 0.1	12.3 ± 0.4
127	IT142545	45.9 ± 5.2	12.2 ± 0.4	2.2 ± 0.1	8.6 ± 0.6	0.8 ± 0.1	12.4 ± 0.2
128	IT142551	13.6 ± 0.3	11.9 ± 0.3	2.6 ± 0.2	8.4 ± 0.2	0.7 ± 0.0	15.0 ± 0.3
129	IT142553	14.1 ± 0.3	11.4 ± 0.7	3.2 ± 0.2	8.4 ± 0.1	0.7 ± 0.0	13.4 ± 0.6
130	IT142554	18.1 ± 1.7	9.4 ± 1.0	2.1 ± 0.1	7.9 ± 0.9	0.8 ± 0.0	12.5 ± 1.0
131	IT142557	99.8 ± 8.9	12.0 ± 0.3	3.6 ± 0.4	5.9 ± 0.5	0.9 ± 0.1	12.5 ± 0.4
132	IT142559	50.4 ± 11	12.4 ± 0.1	1.1 ± 0.1	5.0 ± 0.4	0.6 ± 0.0	14.2 ± 0.4
133	IT142560	42.3 ± 2.2	9.0 ± 1.0	0.6 ± 0.0	5.7 ± 0.2	0.4 ± 0.0	24.9 ± 1.1
134	IT142561	13.4 ± 0.1	7.4 ± 0.4	2.0 ± 0.1	6.9 ± 0.3	0.9 ± 0.1	16.8 ± 0.7
135	IT142562	18.6 ± 0.3	12.3 ± 0.1	3.1 ± 0.2	7.9 ± 0.3	0.8 ± 0.0	11.4 ± 0.1
136	IT142563	25.0 ± 1.1	12.2 ± 0.4	1.8 ± 0.1	9.4 ± 0.5	0.8 ± 0.0	19.7 ± 0.2
137	IT142565	50.5 ± 3.8	11.8 ± 0.3	2.9 ± 0.1	6.9 ± 0.4	0.7 ± 0.1	17.2 ± 0.6
138	IT142567	32.9 ± 1.0	11.2 ± 0.5	4.3 ± 0.4	9.9 ± 0.5	1.0 ± 0.1	19.3 ± 1.5
139	IT142568	31.6 ± 1.1	12.1 ± 0.1	3.0 ± 0.3	8.8 ± 0.6	1.0 ± 0.1	14.8 ± 0.7
140	IT142570	42.2 ± 3.0	12.1 ± 0.3	3.9 ± 0.1	9.9 ± 0.9	0.8 ± 0.0	19.6 ± 1.0
141	IT142573	71.0 ± 10.8	11.1 ± 0.5	5.9 ± 0.2	9.3 ± 0.5	0.9 ± 0.1	15.4 ± 1.5
142	IT142575	93.1 ± 8.7	10.2 ± 1.1	1.7 ± 0.1	11.1 ± 0.3	0.9 ± 0.0	15.9 ± 1.2
143	IT142577	23.6 ± 0.5	12.4 ± 0.1	2.5 ± 0.2	9.7 ± 0.7	0.9 ± 0.0	27.8 ± 3.5
144	IT142580	20.0 ± 1.2	11.6 ± 0.4	2.8 ± 0.2	8.8 ± 0.7	0.8 ± 0.1	10.8 ± 0.1
145	IT142584	15.7 ± 0.7	8.7 ± 0.9	4.3 ± 0.3	8.9 ± 0.4	1.0 ± 0.1	11.0 ± 0.4
146	IT142588	14.4 ± 0.2	11.5 ± 0.6	5.6 ± 0.1	9.1 ± 0.7	1.1 ± 0.0	15.0 ± 1.4
147	IT142590	13.9 ± 0.3	12.3 ± 0.2	3.5 ± 0.2	7.9 ± 0.4	1.1 ± 0.1	10.9 ± 0.1
148	IT142591	14.6 ± 0.2	12.5 ± 0.1	5.3 ± 0.1	14.0 ± 0.5	0.8 ± 0.0	16.5 ± 0.5
149	IT142592	15.6 ± 0.5	11.5 ± 0.2	3.0 ± 0.2	6.7 ± 0.3	1.0 ± 0.1	13.2 ± 0.5
150	IT142593	23.4 ± 1.0	11.5 ± 0.2	2.3 ± 0.1	5.5 ± 0.1	0.8 ± 0.0	16.7 ± 0.3
151	IT142594	16.7 ± 0.8	11.1 ± 0.6	3.5 ± 0.0	11.3 ± 0.6	1.0 ± 0.0	17.5 ± 1.1
152	IT142595	42.6 ± 2.7	11.8 ± 0.2	5.1 ± 0.2	7.3 ± 0.2	1.4 ± 0.0	14.2 ± 0.9
153	IT142598	16.0 ± 0.6	12.0 ± 0.2	2.9 ± 0.2	10.2 ± 0.4	1.1 ± 0.0	14.3 ± 0.5
154	IT142604	19.0 ± 1.5	11.9 ± 0.2	4.8 ± 0.3	6.6 ± 0.5	0.9 ± 0.0	8.3 ± 0.1
155	IT142609	18.4 ± 1.2	10.5 ± 0.6	2.8 ± 0.1	9.5 ± 0.2	0.8 ± 0.0	8.0 ± 0.3
156	IT142610	20.8 ± 0.9	10.4 ± 0.4	2.9 ± 0.2	4.0 ± 0.2	1.1 ± 0.0	14.0 ± 1.0

Table S1. Continued

#	IT	DPPH(ul, IC50)	ABTS (mgASC/g)	FRAP (mgASC/g)	TPC (mgGAE/g)	RP (mgASC/g)	SOD (ul, IC50)
157	IT142612	123.3 ± 7.5	11.9 ± 0.3	4.9 ± 0.4	5.3 ± 0.1	1.1 ± 0.1	10.6 ± 0.3
158	IT142613	25.8 ± 2.4	12.0 ± 0.2	3.2 ± 0.1	5.2 ± 0.4	2.1 ± 0.1	10.7 ± 0.9
159	IT142615	14.9 ± 0.6	11.2 ± 0.6	4.4 ± 0.3	6.7 ± 0.1	1.0 ± 0.0	10.6 ± 0.5
160	IT142619	60.5 ± 6.9	12.0 ± 0.2	3.7 ± 0.1	5.7 ± 0.3	0.8 ± 0.1	10.5 ± 0.5
161	IT142625	16.4 ± 0.3	11.8 ± 0.3	6.0 ± 0.3	4.9 ± 0.2	0.8 ± 0.1	14.1 ± 1.0
162	IT142635	64.8 ± 2.7	12.0 ± 0.2	3.9 ± 0.1	5.9 ± 0.2	1.1 ± 0.1	12.8 ± 0.6
163	IT142640	17.9 ± 0.5	11.8 ± 0.2	3.8 ± 0.2	6.9 ± 0.1	0.9 ± 0.0	14.5 ± 1.1
164	IT142642	38.3 ± 3.8	11.8 ± 0.3	3.7 ± 0.2	10.0 ± 0.4	0.9 ± 0.0	11.8 ± 0.5
165	IT142646	19.5 ± 1.4	12.0 ± 0.2	3.9 ± 0.0	8.0 ± 0.2	1.0 ± 0.0	14.6 ± 1.3
166	IT142650	17.4 ± 0.5	12.1 ± 0.2	5.5 ± 0.3	6.5 ± 0.2	1.0 ± 0.1	12.0 ± 0.6
167	IT025806	14.5 ± 0.4	11.9 ± 0.1	4.2 ± 0.4	6.5 ± 0.3	0.9 ± 0.1	11.3 ± 0.6
168	IT025842	12.6 ± 0.0	12.0 ± 0.1	3.7 ± 0.1	9.7 ± 0.5	0.8 ± 0.0	16.3 ± 0.9
169	IT025785	36.4 ± 2.5	11.8 ± 0.2	2.3 ± 0.1	7.9 ± 0.2	0.8 ± 0.0	16.2 ± 1.6
170	IT025789	21.9 ± 1.0	11.6 ± 0.6	0.4 ± 0.0	6.3 ± 0.2	0.4 ± 0.0	24.0 ± 2.5
171	IT025790	73.6 ± 3.0	11.0 ± 0.3	1.5 ± 0.1	9.8 ± 0.3	0.7 ± 0.1	42.4 ± 3.2
172	IT025791	18.6 ± 0.3	11.2 ± 0.4	3.0 ± 0.2	11.7 ± 0.5	0.8 ± 0.1	11.9 ± 0.3
173	IT025805	17.0 ± 1.2	11.4 ± 0.3	2.8 ± 0.3	8.1 ± 0.5	0.8 ± 0.0	12.0 ± 0.4
174	IT025808	13.3 ± 0.2	11.9 ± 0.1	2.1 ± 0.1	10.0 ± 0.4	0.8 ± 0.1	12.1 ± 0.6
175	IT025875	22.1 ± 1.5	11.5 ± 0.5	3.1 ± 0.2	8.8 ± 0.2	0.8 ± 0.0	18.8 ± 2.1
176	IT025879	58.0 ± 5.5	12.0 ± 0.2	3.9 ± 0.2	10.3 ± 0.3	1.0 ± 0.1	12.8 ± 1.4
177	IT025885	15.6 ± 0.3	11.6 ± 0.4	2.0 ± 0.2	9.1 ± 0.4	1.2 ± 0.1	33.5 ± 1.6
178	IT025943	15.6 ± 0.8	12.1 ± 0.2	1.4 ± 0.1	8.6 ± 0.9	0.8 ± 0.0	13.4 ± 0.4
179	IT025945	15.5 ± 0.3	12.1 ± 0.2	1.2 ± 0.1	12.0 ± 1.0	0.7 ± 0.1	15.5 ± 1.0
180	IT025947	59.5 ± 5.7	10.9 ± 0.8	2.0 ± 0.2	9.7 ± 0.9	0.8 ± 0.0	10.7 ± 0.5
181	IT025948	15.5 ± 0.2	10.7 ± 0.5	1.5 ± 0.1	10.6 ± 1.0	0.7 ± 0.0	10.5 ± 0.3
182	IT025962	30.1 ± 2.5	9.9 ± 0.3	2.1 ± 0.1	7.0 ± 0.5	0.6 ± 0.0	16.0 ± 0.9
183	IT025970	18.7 ± 0.7	11.6 ± 0.3	1.4 ± 0.1	9.1 ± 0.3	0.8 ± 0.0	13.5 ± 0.9
184	IT100903	12.7 ± 0.1	11.9 ± 0.4	3.8 ± 0.1	10.1 ± 0.2	1.1 ± 0.0	10.6 ± 0.5
185	IT100916	17.0 ± 0.7	10.6 ± 0.7	2.6 ± 0.0	10.5 ± 0.4	1.1 ± 0.0	10.3 ± 0.4
186	IT100923	13.9 ± 0.4	11.5 ± 0.2	5.0 ± 0.2	5.0 ± 0.3	1.1 ± 0.0	8.9 ± 0.2
187	IT101078	13.6 ± 0.1	11.1 ± 0.3	3.0 ± 0.1	5.9 ± 0.1	1.0 ± 0.1	10.5 ± 0.2
188	IT105276	13.5 ± 0.1	11.6 ± 0.2	4.0 ± 0.2	4.5 ± 0.0	1.1 ± 0.0	13.2 ± 0.5
189	IT112745	28.2 ± 1.9	11.5 ± 0.1	4.3 ± 0.3	6.5 ± 0.1	1.2 ± 0.0	9.7 ± 0.2
190	IT115176	13.8 ± 0.5	11.7 ± 0.1	3.8 ± 0.2	7.3 ± 0.6	1.0 ± 0.1	8.8 ± 0.3
191	IT118986	13.5 ± 0.3	11.7 ± 0.2	5.0 ± 0.2	7.2 ± 1.0	1.2 ± 0.1	12.1 ± 0.5
192	IT138096	22.2 ± 0.9	11.9 ± 0.1	4.6 ± 0.4	5.5 ± 0.6	1.2 ± 0.1	14.1 ± 0.4
193	IT160598	13.7 ± 0.1	12.0 ± 0.1	2.7 ± 0.2	4.1 ± 0.3	0.7 ± 0.1	13.7 ± 0.5
194	IT160606	30.0 ± 2.3	12.1 ± 0.2	5.6 ± 0.4	8.8 ± 0.1	1.2 ± 0.1	25.3 ± 1.1
195	IT162895	14.3 ± 0.3	12.1 ± 0.2	3.3 ± 0.2	6.6 ± 0.2	0.9 ± 0.1	19.8 ± 1.0
196	IT167996	43.2 ± 4.0	11.9 ± 0.2	4.3 ± 0.2	4.5 ± 0.3	1.0 ± 0.1	9.5 ± 0.2
197	IT175828	14.1 ± 0.2	12.0 ± 0.1	2.9 ± 0.1	6.6 ± 0.2	1.0 ± 0.1	10.8 ± 0.4
198	IT175831	15.1 ± 0.8	12.0 ± 0.2	2.8 ± 0.2	8.7 ± 0.6	1.1 ± 0.1	10.7 ± 0.1
199	IT175879	32.3 ± 2.8	11.4 ± 0.5	1.6 ± 0.1	8.5 ± 0.4	0.7 ± 0.0	13.7 ± 1.1
200	IT175886	22.3 ± 0.6	11.6 ± 0.4	2.1 ± 0.1	8.8 ± 0.3	0.9 ± 0.1	23.7 ± 0.7
201	IT175981	43.6 ± 2.8	11.9 ± 0.3	3.2 ± 0.2	8.1 ± 0.3	1.2 ± 0.1	14.1 ± 0.3
202	IT178384	70.7 ± 7.0	11.8 ± 0.2	3.8 ± 0.2	8.9 ± 0.4	1.3 ± 0.1	9.8 ± 0.2
203	IT178390	56.5 ± 0.8	12.0 ± 0.1	2.3 ± 0.2	7.6 ± 0.4	0.9 ± 0.1	17.6 ± 1.2
204	IT180464	70.0 ± 7.9	11.6 ± 0.3	2.3 ± 0.2	7.2 ± 0.3	0.9 ± 0.0	14.2 ± 1.1
205	IT180478	18.3 ± 0.5	11.6 ± 0.3	1.9 ± 0.2	6.8 ± 0.1	0.7 ± 0.1	20.8 ± 0.6
206	IT180583	51.1 ± 2.1	11.8 ± 0.1	3.2 ± 0.2	4.8 ± 0.0	1.0 ± 0.1	13.2 ± 0.9
207	IT180585	14.8 ± 0.3	12.1 ± 0.1	3.3 ± 0.2	5.5 ± 0.2	1.0 ± 0.1	11.2 ± 0.6
208	IT180615	26.3 ± 2.3	12.2 ± 0.1	2.9 ± 0.1	8.9 ± 0.6	1.1 ± 0.1	10.1 ± 0.3

Table S1. Continued

#	IT	DPPH(ul, IC50)	ABTS (mgASC/g)	FRAP (mgASC/g)	TPC (mgGAE/g)	RP (mgASC/g)	SOD (ul, IC50)
209	IT180655	15.3 ± 0.7	12.0 ± 0.2	3.5 ± 0.2	10.1 ± 0.4	0.9 ± 0.1	13.2 ± 0.8
210	IT180892	14.5 ± 0.3	12.0 ± 0.1	3.6 ± 0.2	11.9 ± 0.3	1.0 ± 0.1	9.7 ± 0.3
211	IT180894	16.2 ± 1.0	12.0 ± 0.2	3.8 ± 0.0	9.4 ± 0.3	1.1 ± 0.1	14.4 ± 0.3
212	IT181957	14.4 ± 0.5	11.7 ± 0.3	3.9 ± 0.2	4.5 ± 0.1	1.0 ± 0.0	10.9 ± 0.2
213	IT181958	16.6 ± 0.9	12.1 ± 0.1	3.5 ± 0.3	3.7 ± 0.1	0.8 ± 0.0	12.9 ± 0.3
214	IT186256	15.1 ± 0.6	12.1 ± 0.1	3.5 ± 0.1	6.8 ± 0.3	0.9 ± 0.0	13.1 ± 0.4
215	IT186259	18.2 ± 0.8	12.3 ± 0.1	3.3 ± 0.1	10.6 ± 0.3	1.0 ± 0.1	17.3 ± 1.3
216	IT186269	23.1 ± 1.4	12.1 ± 0.2	3.8 ± 0.3	10.1 ± 0.9	1.0 ± 0.0	24.0 ± 2.0
217	IT186276	17.6 ± 1.6	12.1 ± 0.1	3.1 ± 0.1	8.7 ± 0.4	1.5 ± 0.0	20.6 ± 1.0
218	IT186277	15.8 ± 0.5	12.1 ± 0.1	3.4 ± 0.2	6.2 ± 0.2	0.9 ± 0.1	24.3 ± 2.9
219	IT186288	17.2 ± 2.1	12.0 ± 0.1	2.8 ± 0.2	5.5 ± 0.1	0.8 ± 0.0	23.3 ± 2.2
220	IT186305	23.9 ± 6.6	11.4 ± 0.4	3.8 ± 0.2	9.2 ± 0.1	0.9 ± 0.1	11.7 ± 0.4
221	IT186308	15.0 ± 0.4	12.0 ± 0.2	4.0 ± 0.3	10.9 ± 0.6	1.0 ± 0.1	11.4 ± 0.3
222	IT189394	18.0 ± 1.2	12.2 ± 0.1	3.7 ± 0.3	10.7 ± 0.4	1.0 ± 0.0	11.5 ± 0.5
223	IT189406	34.2 ± 2.0	12.2 ± 0.1	3.0 ± 0.1	11.9 ± 0.2	1.1 ± 0.0	16.4 ± 0.4
	LSD	4.2	0.5	0.3	0.7	0.1	1.0

Table S2. Antioxidant activity, a-glucosidase inhibition activity, tyrosinase inhibition activity, and phytochemical content of leaf extracts of ten selected Korean adzuki bean landraces

	IT	DPPH (ul, IC50)	ABTS (mgASC/g)	FRAP (mgASC/g)	TPC (mgGAE/g)	RP (mgASC/g)	SOD (ul, IC50)	AGC[a] (ul, IC50)
	IT142500	14.9 ± 0.4	12.5 ± 0.1	5.7 ± 0.4	14.7 ± 1.0	1.0 ± 0.1	9.7 ± 0.3	27.9 ± 1.2
	IT142476	13.4 ± 0.3	12.5 ± 0.1	5.4 ± 0.2	12.7 ± 0.5	1.1 ± 0.1	11.6 ± 0.5	28.5 ± 2
HG	IT142507	13.0 ± 0.2	12.5 ± 0.2	4.9 ± 0.2	12.0 ± 0.6	1.0 ± 0.0	11.6 ± 0.1	46 ± 4.6
	IT120265	13.6 ± 0.6	11.3 ± 0.3	3.7 ± 0.2	11.0 ± 0.7	1.2 ± 0.0	8.6 ± 0	29.8 ± 1.2
	IT120225	17.5 ± 0.8	12 ± 0.2	4.1 ± 0.0	9.1 ± 1.7	1.2 ± 0.1	8 ± 0.2	35 ± 1.6
	IT142560	42.3 ± 2.2	9.0 ± 1.0	0.6 ± 0.0	5.7 ± 0.2	0.4 ± 0.0	24.9 ± 1.1	37.4 ± 2.2
	IT025789	21.9 ± 1.0	11.6 ± 0.6	0.4 ± 0.0	6.3 ± 0.2	0.4 ± 0.0	24 ± 2.5	39 ± 2.4
LG	IT025962	30.1 ± 2.5	9.9 ± 0.3	2.1 ± 0.1	7.0 ± 0.5	0.6 ± 0.0	16 ± 0.9	40.1 ± 2.4
	IT142561	13.4 ± 0.1	7.4 ± 0.4	2.0 ± 0.1	6.9 ± 0.3	0.9 ± 0.1	16.8 ± 0.7	32.9 ± 2.1
	IT142559	50.4 ± 11.0	12.4 ± 0.1	1.1 ± 0.1	5.0 ± 0.4	0.6 ± 0.0	14.2 ± 0.4	35.2 ± 1.9
	LSD	3.9	0.6	0.3	1.1	0.1	1.4	3.3
	IT	TIA (ul, IC50)	Kaempferol (ug/100g)	Myricetin (ug/100g)	Quercetin (ug/100g)	Daidzein (ug/100g)	Genesteiin (ug/100g)	Glycitein (ug/100g)
	IT142500	45.6 ± 0.5	235.8 ± 21.2	605.6 ± 2	473.3 ± 43	3450.6 ± 147.1	294 ± 68.4	1068 ± 60.8
	IT142476	44.4 ± 0.6	259.4 ± 21.3	333.7 ± 5.7	304.3 ± 16.2	2211.5 ± 116.4	270.5 ± 49	468.6 ± 39.2
HG	IT142507	68.5 ± 1.6	64.5 ± 2.7	200.5 ± 25.1	641.9 ± 29.5	533.2 ± 37.8	113 ± 5.7	407.3 ± 8.9
	IT120265	47.5 ± 0.2	237.2 ± 41.4	559.1 ± 9.7	371.6 ± 59.6	2576.5 ± 387.8	246.7 ± 6	1003.7 ± 190
	IT120225	53.2 ± 0.9	97 ± 4.6	247.2 ± 39.6	503.8 ± 15.4	981 ± 68.4	92.8 ± 19.6	379.6 ± 38.8
	IT142560	52.5 ± 0.5	136.5 ± 24.4	55 ± 13.6	746.8 ± 53.8	1712.8 ± 326.6	143.6 ± 29.4	157.6 ± 51.9
	IT025789	54.4 ± 0.9	103.1 ± 3.4	61.4 ± 0.6	373.7 ± 25.7	1297.3 ± 102.5	104.6 ± 18.5	137.7 ± 47.8
LG	IT025962	57.5 ± 0.8	42.4 ± 1.7	227.1 ± 10.4	378.7 ± 27.2	640.2 ± 82.2	94.5 ± 2.8	391.8 ± 11.8
	IT142561	47.9 ± 1	90.3 ± 7.3	216 ± 17.1	793.1 ± 50.6	3959.7 ± 103.6	379.1 ± 68.7	446.4 ± 40.3
	IT142559	51.5 ± 0.9	106.3 ± 11.8	134.3 ± 18.2	691 ± 99.2	2172.7 ± 102.6	213.7 ± 29	278 ± 21.5
	LSD	1.2	33.6	32.7	87.8	332.6	68.6	128.3

[a] AGC, α-glucosidase inhibition activity; TIA, tyrosinase inhibition activity

Table S3. Antioxidant activity, a-glucosidase inhibition activity, tyrosinase inhibition activity, and phytochemical content of seed extracts of ten selected Korean adzuki bean landraces

	IT	DPPH (ul, IC50)	ABTS (mgASC/g)	FRAP (mgASC/g)	TPC (mgGAE/g)	RP (mgASC/g)	SOD (ul, IC50)	AGC[a] (ul, IC50)
HG	IT142500	38.8 ± 1.9	2.6 ± 0.0	3.4 ± 0.1	4.9 ± 0.2	1.5 ± 0.1	65.8 ± 1.4	41.2 ± 2.3
	IT142476	51.0 ± 0.8	2.7 ± 0.0	2.5 ± 0.1	3.3 ± 0.1	1.5 ± 0.0	65.5 ± 1.4	92.8 ± 8.5
	IT142507	14.7 ± 0.1	2.6 ± 0.2	1.5 ± 0.0	4.9 ± 0.2	1.6 ± 0.1	72.9 ± 0.9	120.4 ± 19.8
	IT120265	20.7 ± 0.6	2.6 ± 0.0	2.1 ± 0.0	3.2 ± 0.1	1.5 ± 0.1	60.7 ± 0.9	56.7 ± 3.1
	IT120225	25.9 ± 0.9	2.7 ± 0.0	2.6 ± 0.0	5.3 ± 0.1	1.6 ± 0.1	63.3 ± 2.1	139.7 ± 40.4
LG	IT142560	12.6 ± 0.2	2.7 ± 0.1	3.0 ± 0.2	3.7 ± 0.0	1.6 ± 0.0	79.5 ± 4.1	71.1 ± 5.0
	IT025789	25.7 ± 0.7	2.2 ± 0.2	1.8 ± 0.1	2.8 ± 0.1	0.6 ± 0.1	72.2 ± 2.8	52.8 ± 1.0
	IT025962	14.4 ± 0.6	2.4 ± 0.1	1.0 ± 0.0	1.4 ± 0.0	0.9 ± 0.1	88.3 ± 3.0	64.6 ± 3.7
	IT142561	17.3 ± 1.0	2.5 ± 0.0	3.2 ± 0.2	3.2 ± 0.1	1.5 ± 0.0	67.8 ± 0.9	66.9 ± 7.0
	IT142559	15.0 ± 1.1	2.7 ± 0.0	2.4 ± 0.0	2.8 ± 0.0	1.4 ± 0.1	70.2 ± 1.5	100.1 ± 27.7
	LSD	5.9	0.1	0.5	0.1	0.1	3.1	19.8

	IT	TIA (ul, IC50)	Kaempferol (ug/100g)	Myricetin (ug/100g)	Quercetin (ug/100g)	Daidzein (ug/100g)	Genesteiin (ug/100g)	Glycitein (ug/100g)
HG	IT142500	84.1 ± 4.3	3.5 ± 0.6	8.9 ± 1.7	12.0 ± 3.0	17.9 ± 5.1	3.2 ± 1.7	24.2 ± 7.3
	IT142476	794 ± 540.2	2.0 ± 0.0	3.2 ± 1.1	6.0 ± 0.7	9.2 ± 1.0	2.8 ± 0.3	24.6 ± 1.9
	IT142507	510.8 ± 56.7	2.8 ± 1.3	5.6 ± 1.9	15.1 ± 3.5	13.5 ± 0.5	1.5 ± 0.1	27.5 ± 3.0
	IT120265	105.1 ± 1.1	1.7 ± 0.3	8.1 ± 1.4	6.5 ± 1.6	9.0 ± 3.1	1.3 ± 0.9	43.6 ± 7.7
	IT120225	158.9 ± 17.3	2.4 ± 1.7	6.5 ± 6.4	3.9 ± 0.1	14.8 ± 7.8	8.6 ± 8.3	35.2 ± 9.6
LG	IT142560	102.6 ± 1.8	2.7 ± 0.4	12.2 ± 1.2	10.3 ± 0.7	13.7 ± 0.4	6.5 ± 0.1	42.9 ± 0.4
	IT025789	345.6 ± 94.0	2.0 ± 0.2	15.0 ± 8.4	22.9 ± 5.2	19.9 ± 1.1	10.8 ± 0.4	46.3 ± 7.8
	IT025962	154.7 ± 13.9	4.6 ± 0.4	55.8 ± 13.6	24.8 ± 11.4	15.9 ± 0.8	10.1 ± 0.6	104.9 ± 4.6
	IT142561	279.6 ± 73.5	1.4 ± 0.3	7.8 ± 1.6	7.0 ± 0.7	14.5 ± 1.5	15.2 ± 5.7	32.8 ± 1.6
	IT142559	280.4 ± 21.9	3.4 ± 2.8	22.4 ± 6.4	13.2 ± 3.3	18.1 ± 5.1	12.1 ± 0.8	62.3 ± 7.2
	LSD	198.8	ns	8.8	6.5	ns	4.8	8.8

[a] AGC, α-glucosidase inhibition activity; TIA, tyrosinase inhibition activity