

# Agricultural Characters, Phenolic and Nutritional Contents, and Antioxidant Activities of Pigeon Pea (*Cajanus cajan*) Germplasms Cultivated in the Republic of Korea

Yu-Mi Choi<sup>1</sup>, Do Yoon Hyun<sup>1</sup>, Sukyeung Lee<sup>1</sup>, Hyemyeong Yoon<sup>1</sup>, Myung-Chul Lee<sup>2</sup>, Sejong Oh<sup>2</sup>,  
Ho-Cheol Ko<sup>3</sup>, Myoung-Jae Shin<sup>1</sup>, Onsook Hur<sup>1</sup>, Jung Yoon Yi<sup>1</sup> and Kebede Taye Desta<sup>4,5\*</sup>

<sup>1</sup>Junior Researcher, <sup>2</sup>Senior Researcher and <sup>4</sup>Post-doctoral Researcher, National Agrobiodiversity Center, National Institute of Agricultural Sciences, Rural Development Administration, Jeonju 54874, Korea

<sup>3</sup>Junior Researcher, Rural Development Administration, Jeonju 54875, Korea

<sup>5</sup>Assistant Professor, Department of Applied Chemistry, Adama Science and Technology University, Adama 1888, Ethiopia

**Abstract** - Pigeon pea (*Cajanus cajan*) is an important legume species that produces seeds that are rich in phenolic compounds and dietary nutrients. The aim of the present study was to evaluate the agricultural characters, phenolic and nutritional contents, and antioxidant capacities of seeds from 82 pigeon pea germplasms cultivated in the Republic of Korea. The accessions exhibited compact (24.39%), semi-spreading (74.39%), or spreading (1.22%) growth habits and determinate (89.02%), indeterminate (8.54%), or semi-determinate (2.44%) flowering patterns. Days to 75% maturity ranged from 30 to 72 d, and yield per plant ranged from 6.00 to 148.60 g. Meanwhile, total phenolic, crude protein, crude fiber, and dietary fiber contents ranged from  $16.42 \pm 0.62$  to  $29.67 \pm 0.43$  mg gallic acid equivalent per g of dried extract, from  $16.76 \pm 6.74\%$  to  $22.61 \pm 0.05\%$ , from  $4.70 \pm 0.24$  to  $8.63 \pm 0.02\%$ , and from  $12.98 \pm 0.71$  to  $33.19 \pm 1.50\%$ , respectively. In addition, DPPH radical-scavenging capacity ranged from  $1.61 \pm 0.10$  to  $16.04 \pm 2.30$  mg ascorbic acid equivalent per g of dried extract, and Trolox equivalent antioxidant capacity ranged from  $3.03 \pm 0.86$  to  $42.24 \pm 0.72$  mg Trolox equivalent per g of dried extract. Phenolic content was correlated with both DPPH radical-scavenging capacity ( $r = 0.63$ ) and Trolox equivalent antioxidant capacity ( $r = 0.29$ ). Nine accessions (IT170290, IT170291, IT170270, IT170276, IT170379, IT170386, IT170388, IT170418, and IT170340) exhibited early maturity, compact and erect growth habits, and above average antioxidant activities and phenolic and protein contents. In addition, accessions IT170290 and IT170291 were especially promising pigeon pea germplasms to grow, owing to various favorable characteristics (e.g., high yield and dietary fiber content). Hence, these accessions could be useful cultivars to the Republic of Korea if considered in future agricultural systems.

**Key words** – Antioxidant, *Cajanus cajan*, Dietary nutrient, Phenolic compound, Pigeon pea

## Introduction

Pigeon pea (*Cajanus cajan* (L.) Millsp.; Fabaceae) is a perennial crop and the only cultivated *Cajanus* spp. known for drought resistance (Kassa *et al.*, 2012; Rathinam *et al.*, 2019). Recent archaeobotanical evidence has indicated that pigeon pea was originally domesticated in India (Fuller *et al.*, 2019). However, the crop is ubiquitous in many tropical and

subtropical regions, including Africa, Latin America, the Caribbean, and various parts of Asia (Kassa *et al.*, 2012; Saxena *et al.*, 2010). The plant has been used in traditional medicine to treat a variety of ailments, including coughs, measles, diabetes, and ischemic necrosis (Fuller *et al.*, 2019; Wei *et al.*, 2013a). Furthermore, a number of studies have also reported that the plant possesses anticancer, antidiabetic, and antimicrobial properties (Pal *et al.*, 2011; Wei *et al.*, 2013a; Zu *et al.*, 2010).

For most people in many countries, pigeon pea is the main source of proteins and dietary minerals. In addition, the plant is known for its fiber, carbohydrate, and fat contents (Adenekan

\*Corresponding author. E-mail : kebedetdesta@korea.kr,  
kebetila@gmail.com  
Tel. +82-63-238-4864

*et al.*, 2018; Kaur *et al.*, 2007; Oloyo, 2004; Saxena *et al.*, 2010; Tekale *et al.*, 2016), and legume proteins, in general, are recognized as sources of essential amino acids and as precursors of bioactive peptides with important physiological functions (Duranti, 2006). As such, pigeon pea seeds are increasingly used to augment the nutritive values of low-protein cereals (Akoja *et al.*, 2017; Saxena *et al.*, 2002; Torres *et al.*, 2006). Legume-derived dietary fibers are also important components of food formulations and play major roles in the prevention of cardiovascular disease (Benítez *et al.*, 2013).

In addition to dietary nutrients, pigeon pea has also been reported to contain a number of phenolic compounds with antioxidant properties (Liu *et al.*, 2014; Nix *et al.*, 2015; Wu *et al.*, 2009). A variety of biochemical reactions in animal bodies generate reactive oxygen species (ROS) and reactive nitrogen species (RNS), and the overproduction of these radical species can degrade cellular components and, hence, cause a variety of physiological disorders and ailments (Jang and Park, 2018). In contrast, plant-derived phenolic compounds can neutralize ROS and RNS through a process known as radical scavenging (Nimse and Pal, 2015). Anthocyanins, isoflavones, and flavones are among the most important phenolic compounds reported from pigeon pea (Nix *et al.*, 2015; Wei *et al.*, 2013a; 2013b). For instance, cajanol is a specific isoflavone found in pigeon pea which has a promising anticancer property (Luo *et al.*, 2010; Zhao *et al.*, 2013). Furthermore, pinostrobin, vitexin, and orientin are known to be the species' main flavonoid components (Liu *et al.*, 2010; Wu *et al.*, 2009).

Despite the health and nutritional benefits of pigeon pea, the crop remains underutilized. As the global population increases and food production is challenged by climate factors, orphan legume crops, such as pigeon pea, should be considered as important resources when developing future agricultural systems. As in other legumes (e.g., chickpea, lentil, and guar), there is growing interest in pigeon pea in the Republic of Korea (Choi *et al.*, 2018). However, studies of pigeon pea germplasm collections grown in the Republic of Korea are lacking. Thus, to maximize the crop's future use, utilization, and conservation, its morphological and biochemical properties must be fully evaluated. Accordingly, the aim of the present study was to evaluate the agricultural characters, phenolic and nutritional contents, and antioxidant capacities of seeds from 82 pigeon

pea germplasm grown in the Republic of Korea. In addition to improving the crop's utilization, the present study will provide a basis for the domestic adaptation of pigeon pea in future agricultural systems.

## Materials and Methods

### Plant Materials and Sampling

Seeds of 82 pigeon pea germplasm were obtained from the gene bank of the National Agrobiodiversity Center (<http://genebank.rda.go.kr>), Rural Development Administration, Republic of Korea, and were cultivated during the cropping season. More specifically, the seeds were sown in plug trays having 50 cells (one seed per cell) on April 4<sup>th</sup>, 2018, and after 23 d, they were planted in rows at spacing of 90 x 30 cm on an experimental field in Jeonju City. Agricultural characters related to growth habit, flower characters, pod characters, seed characters, and days to flowering and maturity were recorded from field observations during the growth period and laboratory experiments. Mature seeds were hand-harvested, oven-dried (25 °C for 3 d), pulverized, and stored at -20 °C for subsequent analysis.

### Chemicals and Materials

Diatomaceous earth, ethanol, acetone, sulfuric acid and petroleum ether were purchased from Fisher Scientific (Pittsburgh, PA, USA). Gallic acid, Folin-Ciocalteu phenol reagent, *L*-ascorbic acid, diammonium salt of 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), 1,1-diphenyl-2-picrylhydrazyl radical (DPPH•), 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox),  $\alpha$ -amylase, protease, and amyloglucosidase were purchased from Sigma-Aldrich (St. Louis, MO, USA). All reagents and chemicals used in the present study were of analytical grade, with  $\geq 98\%$  purity.

### Phenolic Compounds Extraction and Preparation

Phenolic compounds extraction was achieved using Dionex accelerated solvent extractor-200 (Thermo Scientific, Waltham, MA, USA), which was equipped with a solvent reservoir, extraction cell, and collection vial, and a previously reported method (Assefa *et al.*, 2018), with some modifications. Briefly, a circular cellulose filter (i.d. 19.88 mm) was placed at the bottom of each stainless-steel extraction cell, after which 7 g

seed powder was placed between two layers of diatomaceous earth, and each extraction cell was tightly closed. Ethanol (75%) was used as an extraction solvent for 3 cycles of 15 min each under nitrogen at 1500 psi and 70 °C. The extractants were collected in 50 mL conical plastic tubes and dried using a HT-4X vacuum concentrator (Genevac, Ipswich, UK) at 40 °C. Dried extracts were stored at -20 °C and later used for the measurement of total phenolic contents (TPCs) and antioxidant activities.

#### Determination of Total Phenolic Contents (TPCs)

The TPCs of the dried seed extracts were determined using the Folin-Ciocalteu method (Assefa *et al.*, 2018). Specifically, 100 µL of Folin-Ciocalteu reagent was added to 100 µL of sample extract (200 ppm in 75% ethanol). The mixture was allowed to react in the dark for 3 min at room temperature (~25 °C), supplemented with 100 µL sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>, 2%), and then incubated for an additional 30 min. Finally, the absorbance ( $\lambda_{\max}$  750 nm) of the mixtures was evaluated using an Eon Microplate Spectrophotometer (Bio-Tek, Winooski, VT, USA) and 75% ethanol as a negative. Measurements were performed in triplicate and were expressed as gallic acid equivalent (mg) per g dried sample extract (mg GAE g<sup>-1</sup> DE).

#### Determination of Crude Fiber Content (CFC)

The CFCs of the seed extracts were measured using the methods of the AOAC (1990). Briefly, 0.7 g of pulverized seed samples sealed in filter bags and defatted in petroleum ether for 10 min, after which the solvent was poured off. The filter bags were then air-dried, and agitated in H<sub>2</sub>SO<sub>4</sub> using a Fiber Analyzer (FOSS, Hillerod, Denmark) to extract crude fiber by eliminating non-fibrous components. After 40 min, the bags were removed, and then immersed in acetone for 10 min. The filter bags were then recovered, dried at 105 °C for 2 h, and cooled for 30 min in a desiccator. The filter bags were weighed, incinerated in an electric furnace (550 °C for 2 h), cooled for 40 min in a desiccator, and then re-weighed. Finally, percent crude fiber content was calculated as the loss in weight after incineration.

#### Determination of Dietary Fiber Content (DFC)

The DFC of the seeds samples were analyzed using Analytical

Fibertec E-1023 System (FOSS, Hillerod, Denmark), as described previously (AOAC, 1990). Briefly, 1 g of each pulverized seed sample was individually suspended in 50 mL phosphate buffer (0.08 M), digested using  $\alpha$ -amylase (0.1 mL), and incubated at 100 °C for 15 min. The samples were then subjected to successive digestion (i.e., hydrolysis) using protease and amyloglucosidase (0.1 mL each) at 60 °C for 30 min each, with proper pH adjustment between successive digestion steps. The mixtures were treated with four volumes of 95% ethanol, stirred, and then incubated overnight at room temperature (~25 °C). The resulting precipitates were filtered through a crucible with Celite, successively washed with 78% ethanol, 95% ethanol, and pure acetone, dried at 60 °C overnight, and then weighed to determine percent DFC.

#### Determination of Crude Protein Content (CPC)

The CPCs of the seed samples were measured using the automatic Kjeldahl method (Horax *et al.*, 2010) and protein digestion with an Auto-digester (FOSS, Hoganas, Sweden) that was preheated to 420 °C. More specifically, 0.5 g of each pulverized seed sample was put into digestion tube and hydrolyzed using 12 mL concentrated H<sub>2</sub>SO<sub>4</sub> and two selenium catalyst pellets for 1 h. The digestion tube was then removed, cooled to room temperature (~25 °C), and processed using an automatic Kjeltel analyzer (FOSS, Hoganas, Sweden) that was capable of distillation and colorimetric titration. Finally, percent CPC was auto-computed as percent nitrogen content multiplied by 6.25 (standard Kjeldahl factor).

#### Determination of DPPH Radical-Scavenging Activity (DPPH-RSA)

The DPPH-RSAs of the seed extracts were measured following a previously reported procedure (Piao *et al.*, 2013) with some modifications. Briefly, 100 µL of each sample extract (200 ppm, 75% ethanol) was individually mixed with 100 µL DPPH (150 µM), protected from sunlight, and incubated at room temperature. After 30 min, the absorbance ( $\lambda_{\max}$  517 nm) of each sample was measured, and percent DPPH-RSA was calculated as follows:

$$\left( 1 - \left( \frac{A_{\text{Sample}} - A_{\text{Blank sample}}}{A_{\text{Control}} - A_{\text{Blank control}}} \right) \times 100 \right) \quad (1)$$

where *A* represents absorbance. The values were calculated in triplicate and then compared with the DPPH-RSA of ascorbic acid and calculated as ascorbic acid equivalent (mg) per g dried extract (mg AAE g<sup>-1</sup> DE).

### Determination of Trolox Equivalent Antioxidant Capacity (TEAC)

The TEACs of the sample extracts were evaluated using a previously reported method (Piao *et al.*, 2013) with some modifications. Before analysis, a stock solution of ABTS radical was prepared in the dark by dissolving ABTS (7 mM) in potassium persulfate (K<sub>2</sub>S<sub>2</sub>O<sub>8</sub>, 2.45 mM), incubating the mixture at room temperature (~25°C) for 16 h, and then diluting the mixture with water until reaching an absorbance ( $\lambda_{\text{max}}$  734 nm) of 0.700 ± 0.02. Then, 10 µL of each sample extract (200 ppm in 75% ethanol) was individually mixed with 150 µL of the ABTS radical stock solution, and incubated in the dark at room temperature. After 3 min, the absorbance ( $\lambda_{\text{max}}$  734 nm) of each sample was measured in triplicate. The percent ABTS-scavenging activity was calculated using equation (1) and compared to the ABTS-scavenging activity of Trolox and calculated as Trolox equivalent (mg) per g dried extract (mg TE g<sup>-1</sup> DE).

### Statistical Analysis

All measurements were performed in triplicate, and data were expressed as mean ± standard deviation (SD) values. Measurements were compared using one-way analysis of variance (ANOVA), and *p*-values of <0.05 were considered statistically significant. Percent coefficient of variance (%CV) was used to evaluate the variability of the measured variables, and Pearson's correlation coefficient was used to identify associations among the quantitative variables. Principal component analysis (PCA) was used to evaluate variations among accessions based on quantitative data files. All statistical analyses were conducted using XLSTAT ver. 2016 (Addinsoft, Long Island, NY, USA).

## Results and Discussion

### Plant Characteristics

The pigeon pea accessions exhibited erect and compact (24.39%),

semi-spreading (74.39%), or spreading (1.22%) growth habits and determinate (89.02%), semi-determinate (2.44%), or indeterminate (8.54%) flowering patterns (Table 1). Most accessions produced yellow (93.9%), medium-streaked (90.24%), and red-accented (97.56%) flowers, and around half (52.44%) of the accessions produced flat pods, whereas the others (47.56%) produced cylindrical pods, which is the dominant form among pigeon pea accessions grown in India and Benin (Uphadhyaya

Table 1. Summary of qualitative agricultural characters in 82 pigeon pea germplasms grown in the Republic of Korea

Trait	Observation	<i>f</i> <sup>z</sup>	<i>%</i> <sup>y</sup>
<i>Growth habit</i>	Erect and compact	20	24.39
	Semi-spread	61	74.39
	Spread	1	1.22
<i>Flower pattern</i>	Determinate	73	89.02
	Semi-determinate	2	2.44
	Indeterminate	7	8.54
<i>Streak pattern</i>	Spares	4	4.88
	Medium	74	90.24
	Dense	4	4.88
<i>Base flower color</i>	Yellow	77	93.90
	Yellowish orange	5	6.10
<i>Secondary flower color</i>	Red	80	97.56
	Purple	2	2.44
	Green	78	95.12
<i>Stem color</i>	Purple	3	3.66
	Sun-red	1	1.22
<i>Pod form</i>	Flat	43	52.44
	Cylindrical	39	47.56
<i>Pod color</i>	Green	82	100.00
<i>Pod hairiness</i>	Pubescent	82	100.00
<i>Seed shape</i>	Oval	3	3.66
	Globular	15	18.29
	Square	64	78.05
<i>Base seed color</i>	Cream	3	3.66
	Orange	79	96.34
<i>Secondary seed color</i>	Orange	81	98.78
	Purple	1	1.22
	Plain	78	95.12
<i>Seed color pattern</i>	Mottled	3	3.66
	Speckled	1	1.22

<sup>z</sup>*f*: Frequency; <sup>y</sup>*%*: Percent of total.

*et al.*, 2007; Zavinon *et al.*, 2019). All accessions produced green and pubescent pods, and most accessions (95.12%) produced green stems. Seed shape was oval (3.66%), globular (18.29%), or square (78.05%), and most accessions produced seeds with orange (96.34%) and orange-accented (98.78%) coloration, usually with a plain pattern (95.12%; Table 1). Overall, the accessions exhibited considerable variation, as reported previously (Uphadhyaya *et al.*, 2007; Zavinon *et al.*, 2019).

Variations were also observed in days to 50% flowering (D50F), duration of flowering (DoF), days to 75% maturity (D75M), seeds per pod, 100-seed weight, and yield per plant (YPP) (Table 2). D50F ranged from 64 (IT170382) to 116 d (IT170340), and most of the accessions could be considered early flowering when compared to previous reports (Kumara *et al.*, 2013; Uphadhyaya *et al.*, 2007). The duration of flowering ranged from 20 (IT170443) to 72 d (IT170306). Meanwhile, days to 75% maturity ranged from 30 (IT170350 and IT170340) to 72 d (IT170306). Seeds per pod ranged from 3.00 to 5.70, with a mean of 3.82, and the greatest 100-seed weight was 12.60 g (IT170366), whereas the lowest was 6.00 g (IT170383). Accession IT170419 exhibited the greatest yield per plant (148.60 g), whereas accession IT170379 exhibited the lowest (6.00 g). Finally, the %CV values ranged from 10.51% (seeds per pod) to 57.15% (yield per plant),

thereby indicating a high degree of variation (Table 2). Overall, the observations of the present study were comparable to those of previous reports (Kumara *et al.*, 2013; Uphadhyaya *et al.*, 2007; Zavinon *et al.*, 2019).

Among all the agricultural characters evaluated in the present study, growth habit, flowering pattern, DoF, D75M, and YPP were considered most important, owing to their polymorphic nature and high variability (Tables 1 and 2). Legumes with erect and compact growth habits are usually preferred in agricultural systems since they are convenient for field management and large-scale harvest (Schlautman *et al.*, 2018). Such cultivars are also less susceptible to pod rots, which are caused by contact between pods and the soil. In the present study, 20 accessions exhibited compact and erect growth habit, whereas 60 were semi-spreading, and a single accession (IT170419) exhibited a spreading growth habit. Meanwhile, 73 accessions exhibited determinate flowering patterns, whereas seven were indeterminate, and two (IT170350 and IT170356) were semi-determinate. Based on D75M, the determinate-flowering accessions matured earlier (July 26 to August 30, 2018) than indeterminate-flowering accessions (September 11–14, 2018). Overall, 14 accessions (IT170270, IT170276, IT170291, IT170290, IT170355, IT170449, IT170292, IT170312, IT170379, IT170386, IT170388, IT170418, IT170443, and IT170340) exhibited early maturity, compact and erect growth

Table 2. Variation in the quantitative agricultural characters, phenolic and nutritional contents, and antioxidant activities of 82 pigeon pea accessions

Character (units)	Abbreviation	Maximum	Minimum	Mean	SD	%CV
Days to 50% flowering (d)	D50F	116.00	64.00	77.13	8.76	11.36
Duration of flowering (d)	DoF	72.00	20.00	43.54	16.30	37.34
Days to 75% maturity(d)	D75M	72.00	30.00	45.56	8.44	18.52
Seeds per pod (g)	SPP	5.70	3.00	3.82	0.40	10.51
100-seed weight (g)	HSW	12.60	6.00	8.06	1.32	16.35
Yield per plant (g)	YPP	148.60	6.00	42.07	24.04	57.15
Total phenolic content (mg GAE <sup>z</sup> g <sup>-1</sup> DE <sup>y</sup> )	TPC	29.67	16.42	24.48	3.11	12.72
Crude protein content (%)	CPC	22.61	16.76	20.22	1.51	7.44
Crude fiber content (%)	CFC	8.63	4.70	6.83	0.71	10.45
Dietary fiber content (%)	DFC	33.19	12.98	21.84	3.35	13.36
DPPH radical-scavenging activity (mg AAE <sup>x</sup> g <sup>-1</sup> of DE)	DPPH-RSA	16.04	1.61	6.57	2.63	40.06
Trolox equivalent antioxidant capacity (mg TE <sup>w</sup> g <sup>-1</sup> of DE)	TEAC	42.24	3.03	15.61	7.15	45.80

<sup>z</sup>GAE: Gallic acid equivalent; <sup>y</sup>DE: dried seed extract; <sup>x</sup>AAE: Ascorbic acid equivalent; <sup>w</sup>TE: Trolox equivalent.

habits, and determinate flowering patterns, with the six (IT170379, IT170386, IT170388, IT170418, IT170443, and IT170) exhibiting above-average YPP values (Table 3).

### Total Phenolic Content and Nutritional Composition

The study accessions showed variation in the total phenolic (TPC), crude protein (CPC), crude fiber (CFC), and dietary fiber (DFC) contents. TPC ranged from  $16.42 \pm 0.62$  (IT170346) to  $29.67 \pm 0.43$  mg GAE g<sup>-1</sup> DE (IT170446), with a mean of  $24.48 \pm 3.11$  mg GAE g<sup>-1</sup> DE (Table 2, Appendix 1), which is greater than the TPC previously reported for a Nigerian cultivar ( $22.8 \mu\text{g}/100$  g; Oloyo, 2004) and two pigeon pea cultivars from India (4.8 and 13.5 mg/g; Singh, 1993). CPC ranged from  $16.76 \pm 6.74\%$  (IT170286) to  $22.61 \pm 0.05\%$  (IT170309), with a mean of 20.22% and with all values falling within the previously reported range for the mature seeds of commonly grown pigeon pea cultivars (15.5–26.8%; Salunkhe *et al.*, 1986; Table 2). The CFC ranged from  $4.70 \pm 0.24$  (IT170291) to  $8.63 \pm 0.02\%$  (IT170355), with a mean of 6.83%, whereas DFC ranged from  $12.98 \pm 0.71$  (IT170336) to  $33.19 \pm 1.50\%$  (IT170444), with a mean of and 21.84%.

Previous studies have reported CFCs as high as 8.30% (Oloyo, 2004) and ranging from 9.8 to 11.9 % in Botswana (Amarteifio *et al.*, 2002). In general, the phenolic and nutritional contents of the study accessions from the Republic of Korea were comparable to those of pigeon pea seed samples grown in other countries. Among the 14 accessions that exhibited early maturity, determinate flowering, and compact and erect growth habits, only two accessions (IT170312 and IT170449) yielded below-average TPCs, and only IT170355, IT170449, and IT170443 failed to yield above-average CPCs. Furthermore, accessions IT170270, IT170291, IT170290, IT170355, IT170449, IT170292, and IT170312 yielded high DFCs (Table 3).

### Antioxidant Activities

The antioxidant activity assays indicated that the pigeon pea accessions varied in their DPPH-RSA and TEAC. DPPH-RSA ranged from  $1.61 \pm 0.10$  to  $16.04 \pm 2.30$  mg AAS g<sup>-1</sup> DE, whereas TEAC ranged from  $3.03 \pm 0.86$  to  $42.24 \pm 0.72$  mg TE g<sup>-1</sup> DE (Table 2, Appendix 1), and accession IT170415 yielded the greatest values for both, whereas accessions IT170346 and IT170419 yielded the lowest DPPH-RSA and TEAC

Table 3. Phenolic and nutritional contents, antioxidant activities, and yield of selected early-maturing pigeon pea germplasms grown in the Republic of Korea

Accession	YPP <sup>z</sup> (g)	Nutritional content (Mean $\pm$ SD)			TPC <sup>u</sup> (mg GAE g <sup>-1</sup> )	Antioxidant activity (Mean $\pm$ SD)	
		CFC <sup>y</sup> (%)	DFC <sup>x</sup> (%)	CPC <sup>w</sup> (%)		DPPH-RSA <sup>t</sup> (mg AAE g <sup>-1</sup> )	TEAC <sup>s</sup> (mg TE g <sup>-1</sup> )
IT170270	35.00	6.76 $\pm$ 0.15	23.00 $\pm$ 0.49	20.647 $\pm$ 0.11	25.13 $\pm$ 0.63	8.61 $\pm$ 1.26	15.21 $\pm$ 0.67
IT170276	18.30	7.17 $\pm$ 0.14	21.83 $\pm$ 0.57	20.738 $\pm$ 0.19	29.63 $\pm$ 1.76	11.46 $\pm$ 0.90	22.64 $\pm$ 0.92
IT170290	53.30	6.64 $\pm$ 0.11	24.75 $\pm$ 0.04	21.442 $\pm$ 0.06	26.08 $\pm$ 1.62	11.03 $\pm$ 0.79	25.23 $\pm$ 1.64
IT170291	49.70	4.70 $\pm$ 0.24	22.74 $\pm$ 1.00	22.217 $\pm$ 0.08	28.52 $\pm$ 0.52	8.12 $\pm$ 0.39	12.59 $\pm$ 1.40
IT170292	16.30	6.47 $\pm$ 0.04	24.49 $\pm$ 0.62	21.809 $\pm$ 0.09	28.52 $\pm$ 0.52	7.83 $\pm$ 0.10	13.94 $\pm$ 1.63
IT170312	49.50	7.69 $\pm$ 0.11	25.95 $\pm$ 0.27	21.637 $\pm$ 0.19	17.60 $\pm$ 0.92	2.51 $\pm$ 0.38	11.56 $\pm$ 1.78
IT170340	137.70	7.15 $\pm$ 0.22	19.68 $\pm$ 0.59	20.336 $\pm$ 0.14	27.28 $\pm$ 0.95	6.46 $\pm$ 0.60	14.55 $\pm$ 1.36
IT170355	34.60	8.63 $\pm$ 0.02	25.25 $\pm$ 1.04	17.716 $\pm$ 0.04	24.94 $\pm$ 1.51	8.83 $\pm$ 0.86	22.16 $\pm$ 1.54
IT170379	6.00	6.58 $\pm$ 0.06	21.47 $\pm$ 0.26	21.531 $\pm$ 0.18	25.93 $\pm$ 1.20	9.10 $\pm$ 1.05	21.75 $\pm$ 1.41
IT170386	23.40	7.20 $\pm$ 0.01	19.30 $\pm$ 0.21	21.301 $\pm$ 0.29	24.52 $\pm$ 1.39	8.85 $\pm$ 1.08	19.60 $\pm$ 1.15
IT170388	30.10	6.61 $\pm$ 0.07	16.55 $\pm$ 0.14	20.916 $\pm$ 0.29	24.14 $\pm$ 0.14	8.99 $\pm$ 0.35	15.35 $\pm$ 0.39
IT170418	24.60	6.37 $\pm$ 0.08	19.51 $\pm$ 0.04	21.812 $\pm$ 0.12	27.28 $\pm$ 0.12	8.18 $\pm$ 0.5	17.01 $\pm$ 1.45
IT170443	65.40	6.59 $\pm$ 0.06	18.18 $\pm$ 0.06	17.822 $\pm$ 0.10	24.88 $\pm$ 1.17	3.93 $\pm$ 0.21	16.97 $\pm$ 2.33
IT170449	53.50	6.46 $\pm$ 0.11	26.87 $\pm$ 0.14	18.637 $\pm$ 0.11	24.19 $\pm$ 0.89	8.89 $\pm$ 0.04	8.09 $\pm$ 1.35

<sup>z</sup>YPP: Yield per plant; <sup>y</sup>FC: Crude fiber content; <sup>x</sup>DFC: Dietary fiber content; <sup>w</sup>PC: Crude protein content; <sup>u</sup>TPC: Total phenolic content; <sup>t</sup>DPPH-RSA; <sup>t</sup>DPPH radical-scavenging activity; <sup>s</sup>TEAC: Trolox equivalent antioxidant capacity.

values, respectively. Differences in chemical composition and concentration may have contributed to the observed variation in antioxidant capacity (Pal *et al.*, 2011). Among the 14 accessions that exhibited early maturity, determinate flowering, and compact and erect growth habits, only three (IT170312, IT170443, and IT170443) yielded below-average DPPH-RSAs, and IT170276, IT170290, IT170355, IT170379, IT170386, IT170418, and IT170443 yielded above-average TEACs (Table 3).

### Correlation and Principal Component Analysis

Pearson correlation analysis showed ranges of associations between measured variables (Table 4). YPP was negatively correlated with D75M ( $r = -0.22$ ) and DoF ( $r = -0.33$ ) and positively correlated with D50F ( $r = 0.59$ ) and SPP ( $r = 0.32$ ), as previously reported (Upadhyaya *et al.*, 2007). However, CPC was weakly correlated with TEAC ( $r = 0.05$ ) and negatively correlated with DPPH-RSA ( $r = -0.09$ ), and fiber contents were weakly correlated with antioxidant capacities (Table 4). TPC was positively correlated with both DPPH-RSA ( $r = 0.63$ ) and TEAC ( $r = 0.29$ ). Positive correlations between phenolic contents and antioxidant activities are important factors in cultivar utilization. However, previous studies have

failed to identify correlations between the phenolic contents and antioxidant activities of some legumes and cereals (Djordjevic *et al.*, 2011; Jin-wei *et al.*, 2005; Othman *et al.*, 2007). Thus, the findings of the present study suggest that phenolic contents were major contributors to the antioxidant activities of the pigeon pea accessions.

The principal component analysis (PCA) indicated that five components explained 74.66% of the total variance among the accessions (Table 5), and that 42.53% could be attributed to the first two components alone. YPP, DoF, D75M, and D50F were the greatest contributors to PC1 scores, whereas DPPH-RSA, TPC, TEAC, and CPC were the greatest contributors to PC2 scores (Table 5). The PCA biplot also confirmed the positive correlations among TPC, DPPH-RSA, and TEAC, as well as the opposite trends of CPC and antioxidant activities along the PC2 axis, thereby confirming the variables' negative or poor associations (Fig. 1).

In conclusion, the results of the present study indicated clear variation in the phenolic, crude protein, crude fiber, and dietary fiber contents of pigeon pea accessions grown in the Republic of Korea, as well as in their agricultural characters and antioxidant capacities. More specifically, IT170270, IT170276, IT170291, IT170290, IT170379, IT170386, IT170388, IT170418,

Table 4. Correlations among quantitative agricultural characters, phenolic and nutritional contents, and antioxidant activities of 82 pigeon pea germplasm grown in the Republic of Korea

Variables	D50F <sup>z</sup>	DoF <sup>y</sup>	D75M <sup>x</sup>	SPP <sup>w</sup>	HSW <sup>v</sup>	YPP <sup>u</sup>	CFC <sup>t</sup>	DFC <sup>s</sup>	CPC <sup>r</sup>	TPC <sup>q</sup>	DPPH-RSA <sup>p</sup>	TEAC <sup>o</sup>
D50F	1											
DoF	-0.10	1										
D75M	-0.04	0.745* <sup>ni</sup>	1									
SPP	0.42*	-0.17	-0.10	1								
HSW	0.16	-0.20	-0.15	0.10	1							
YPP	0.59*	-0.33*	-0.22*	0.32*	0.41*	1						
CFC	0.33*	0.02	-0.02	0.05	-0.33*	0.0	1					
DFC	-0.02	-0.20	-0.12	-0.06	-0.05	-0.03	-0.01	1				
CPC	-0.39*	0.30*	0.14	-0.28*	-0.04	-0.37*	-0.28*	-0.04	1			
TPC	-0.01	-0.12	0.12	0.21	-0.21	0.01	-0.15	0.06	-0.21	1		
DPPH-RSA	-0.08	0.10	0.32*	0.14	-0.29*	-0.27*	0.02	0.16	-0.09	0.63*	1	
TEAC	0.04	0.16	0.29*	0.14	-0.12	-0.21	0.11	0.05	0.05	0.29*	0.53*	1

<sup>z</sup>D50F: Days to 50% flowering; <sup>y</sup>DoF: Duration of flowering; <sup>x</sup>D75M: Days to 75% maturity; <sup>w</sup>SPP: Seeds per pod; <sup>v</sup>HSW: 100-seed weight; <sup>u</sup>YPP: Yield per plant; <sup>t</sup>CFC: Crude fiber content; <sup>s</sup>DFC: Dietary fiber content; <sup>r</sup>CPC: Crude protein content; <sup>q</sup>TPC: Total phenolic content; <sup>p</sup>DPPH-RSA: DPPH radical-scavenging activity; <sup>o</sup>TEAC: Trolox equivalent antioxidant capacity.

<sup>n</sup>\*Significant at  $p < 0.05$  level.

Table 5. Quantitative variables and eigenvectors of principal components in 82 pigeon pea germplasms grown in the Republic of Korea

Variable	Component (variance contribution)				
	PC1 (23.57%)	PC2 (18.96%)	PC3 (13.11%)	PC4 (11.29%)	PC5 (7.72%)
D50F <sup>z</sup>	0.3298	0.2991	0.3940	0.0036	0.2080
DoF <sup>y</sup>	-0.3875	-0.0753	0.4915	-0.1419	0.1092
D75M <sup>x</sup>	-0.3815	0.1066	0.4125	-0.2461	0.1848
SPP <sup>w</sup>	0.2138	0.3673	0.0958	-0.2084	-0.1462
HSW <sup>v</sup>	0.2958	-0.1481	0.0088	-0.5248	0.2758
YPP <sup>u</sup>	0.4573	0.1284	0.1567	-0.2254	0.1020
CFC <sup>t</sup>	0.0477	0.1882	0.3442	0.6477	0.0187
DFC <sup>s</sup>	0.0060	0.0864	-0.3673	0.2122	0.8219
CPC <sup>r</sup>	-0.2814	-0.3516	-0.0517	-0.1749	0.1035
TPC <sup>q</sup>	-0.1232	0.4539	-0.3191	-0.1990	-0.2617
DPPH-RSA <sup>p</sup>	-0.3021	0.4642	-0.2020	-0.0715	0.0204
TEAC <sup>o</sup>	-0.2556	0.3635	0.0236	-0.0990	0.2173

<sup>z</sup>D50F: Days to 50% flowering; <sup>y</sup>DoF: Duration of flowering; <sup>x</sup>D75M: Days to 75% maturity; <sup>w</sup>SPP: Seeds per pod; <sup>v</sup>HSW: 100-seed weight; <sup>u</sup>YPP: Yield per plant; <sup>t</sup>CFC: Crude fiber content; <sup>s</sup>DFC: Dietary fiber content; <sup>r</sup>CPC: Crude protein content; <sup>q</sup>TPC: Total phenolic content; <sup>p</sup>DPPH-RSA: DPPH radical-scavenging activity; <sup>o</sup>TEAC: Trolox equivalent antioxidant capacity.

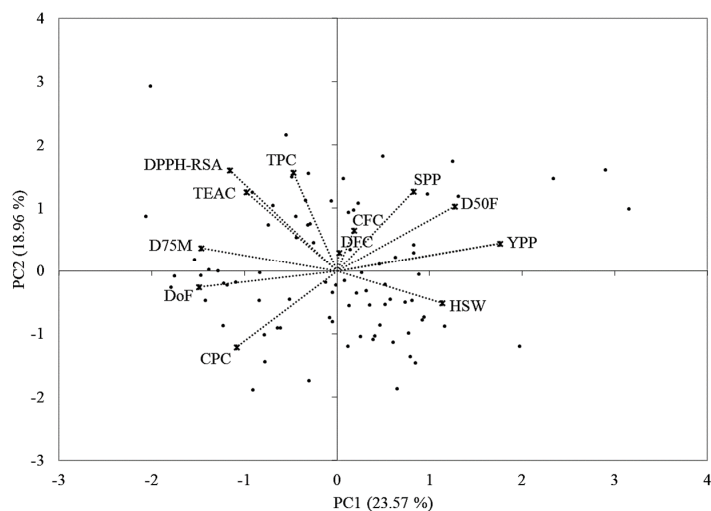


Fig. 1. Principal components analysis bi-plot of quantitative variable data from 82 pigeon pea germplasms. The first two principal components accounted for 42.53% of the total variance. CFC: Crude fiber content; CPC: Crude protein content; DFC: Dietary fiber content; DoF: Duration of flowering; DPPH-RSA: DPPH radical-scavenging activity; D50F: Days to 50% flowering; D75M: Days to 75% maturity; HSW: 100-seed weight; SPP: Seeds per pod; TEAC: Trolox equivalent antioxidant capacity; TPC: Total phenolic content; YPP: Yield per plant.

and IT170340 are, here, considered excellent accessions, owing to their relatively high antioxidant activities and phenolic and protein contents. These accessions exhibited early maturity, determinate flowering, and compact and erect growth habits. In addition, accessions IT170270, IT170291, IT170290, and

IT170392 yielded above-average DFC. Other accessions, including IT170355, IT170449, and IT170312 provided high DFCs, and accessions IT170291 and IT170290 are typically excellent, owing to their high YPP, DFC, CPC, TPC, and DPPH-RSA. The accessions considered as excellent could be



useful cultivars to be adapted and grown in future agricultural systems of the Republic of Korea.

## Acknowledgement

This work was supported by the Research Program for Agricultural Science & Technology Development (Project No. PJ012478) of the National Institute of Agricultural Sciences, Rural Development Administration (Jeonju, Republic of Korea).

## Conflict of Interest

The authors declare no conflict of interest.

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(Received 4 December 2019 ; Revised 14 January 2020 ; Accepted 14 January 2020)

Appendix 1. Phenolic and nutritional contents and antioxidant activities of 82 pigeon pea accessions grown in the Republic of Korea

Sample No.	Accession (IT No.)	Chemical composition (Mean $\pm$ SD)			TPC <sup>w</sup> (mg GAE g <sup>-1</sup> )	Antioxidant capacity (Mean $\pm$ SD)	
		CFC <sup>z</sup> (%)	DFC <sup>y</sup> (%)	CPC <sup>x</sup> (%)		DPPH-RSA <sup>v</sup> (mg AAE g <sup>-1</sup> )	TEAC <sup>u</sup> (mg TE g <sup>-1</sup> )
1	IT170263	6.76 $\pm$ 0.04	16.06 $\pm$ 0.58	20.692 $\pm$ 2.81	24.08 $\pm$ 0.62	5.20 $\pm$ 0.31	19.41 $\pm$ 2.57
2	IT170264	6.49 $\pm$ 0.20	16.24 $\pm$ 0.26	19.297 $\pm$ 0.15	24.90 $\pm$ 1.21	4.66 $\pm$ 0.67	8.23 $\pm$ 1.14
3	IT170267	6.78 $\pm$ 0.03	14.81 $\pm$ 0.47	20.809 $\pm$ 0.29	21.91 $\pm$ 0.70	4.46 $\pm$ 0.80	7.66 $\pm$ 1.50
4	IT170268	7.64 $\pm$ 0.06	22.43 $\pm$ 0.82	20.676 $\pm$ 0.18	24.53 $\pm$ 0.87	6.14 $\pm$ 1.12	12.94 $\pm$ 1.62
5	IT170269	7.53 $\pm$ 0.05	19.40 $\pm$ 0.01	20.625 $\pm$ 0.80	27.24 $\pm$ 1.44	9.87 $\pm$ 0.50	24.01 $\pm$ 0.21
6	IT170270	6.76 $\pm$ 0.15	23.00 $\pm$ 0.49	20.647 $\pm$ 0.11	25.13 $\pm$ 0.63	8.61 $\pm$ 1.26	15.21 $\pm$ 0.67
7	IT170273	7.41 $\pm$ 0.18	20.75 $\pm$ 0.65	21.352 $\pm$ 0.07	26.20 $\pm$ 0.67	9.51 $\pm$ 1.56	17.88 $\pm$ 0.67
8	IT170274	7.20 $\pm$ 0.02	25.40 $\pm$ 1.11	19.069 $\pm$ 0.04	22.10 $\pm$ 1.74	6.70 $\pm$ 1.16	10.33 $\pm$ 1.99
9	IT170275	6.66 $\pm$ 0.04	22.35 $\pm$ 0.11	20.364 $\pm$ 0.14	27.65 $\pm$ 1.02	10.40 $\pm$ 1.30	11.96 $\pm$ 1.92
10	IT170276	7.17 $\pm$ 0.14	21.83 $\pm$ 0.57	20.738 $\pm$ 0.19	29.63 $\pm$ 1.76	11.46 $\pm$ 0.90	22.64 $\pm$ 0.92
11	IT170278	7.31 $\pm$ 0.04	25.81 $\pm$ 0.51	19.622 $\pm$ 0.17	28.75 $\pm$ 1.40	8.82 $\pm$ 0.94	11.23 $\pm$ 1.56
12	IT170279	7.52 $\pm$ 0.11	25.13 $\pm$ 0.89	20.313 $\pm$ 0.21	28.36 $\pm$ 1.63	8.69 $\pm$ 0.58	13.82 $\pm$ 1.13
13	IT170280	7.24 $\pm$ 0.22	19.68 $\pm$ 0.25	21.779 $\pm$ 0.26	24.14 $\pm$ 1.18	4.13 $\pm$ 0.21	8.24 $\pm$ 1.21
14	IT170281	6.40 $\pm$ 0.31	21.70 $\pm$ 12.3	22.268 $\pm$ 0.20	21.71 $\pm$ 0.81	4.51 $\pm$ 0.32	7.29 $\pm$ 0.92
15	IT170283	6.13 $\pm$ 0.07	22.09 $\pm$ 0.98	21.367 $\pm$ 0.09	21.19 $\pm$ 1.68	4.93 $\pm$ 0.19	8.12 $\pm$ 0.97
16	IT170284	6.37 $\pm$ 0.21	20.76 $\pm$ 1.29	21.121 $\pm$ 0.10	22.03 $\pm$ 0.56	6.02 $\pm$ 0.56	9.52 $\pm$ 1.55
17	IT170285	7.29 $\pm$ 0.23	17.77 $\pm$ 0.29	20.662 $\pm$ 0.15	23.48 $\pm$ 1.47	8.49 $\pm$ 1.42	12.14 $\pm$ 1.43
18	IT170286	6.88 $\pm$ 0.12	20.80 $\pm$ 0.78	16.755 $\pm$ 6.74	26.94 $\pm$ 0.39	8.42 $\pm$ 0.41	6.76 $\pm$ 0.66
19	IT170289	6.10 $\pm$ 0.02	24.61 $\pm$ 0.38	22.432 $\pm$ 0.08	25.84 $\pm$ 1.23	9.81 $\pm$ 1.79	17.11 $\pm$ 1.39
20	IT170290	6.64 $\pm$ 0.11	24.75 $\pm$ 0.04	21.442 $\pm$ 0.06	26.08 $\pm$ 1.62	11.03 $\pm$ 0.79	25.23 $\pm$ 1.64
21	IT170291	4.70 $\pm$ 0.24	22.74 $\pm$ 1.00	22.217 $\pm$ 0.08	28.52 $\pm$ 0.52	8.12 $\pm$ 0.39	12.59 $\pm$ 1.40
22	IT170292	6.47 $\pm$ 0.04	24.49 $\pm$ 0.62	21.809 $\pm$ 0.09	28.52 $\pm$ 0.52	7.83 $\pm$ 0.10	13.94 $\pm$ 1.63
23	IT170293	5.14 $\pm$ 0.02	29.39 $\pm$ 0.90	22.334 $\pm$ 0.15	24.06 $\pm$ 0.87	5.49 $\pm$ 0.49	12.5 $\pm$ 0.57
24	IT170295	6.23 $\pm$ 0.25	21.82 $\pm$ 0.76	19.253 $\pm$ 0.11	25.97 $\pm$ 0.45	5.63 $\pm$ 0.49	9.96 $\pm$ 0.78
25	IT170297	5.30 $\pm$ 0.14	26.05 $\pm$ 0.30	18.433 $\pm$ 0.20	28.65 $\pm$ 1.57	11.48 $\pm$ 0.63	23.52 $\pm$ 1.30
26	IT170298	5.95 $\pm$ 0.31	22.47 $\pm$ 1.03	19.712 $\pm$ 0.10	24.65 $\pm$ 0.76	5.14 $\pm$ 0.71	22.15 $\pm$ 1.49
27	IT170299	5.54 $\pm$ 0.08	20.78 $\pm$ 0.01	18.994 $\pm$ 0.09	24.87 $\pm$ 0.62	6.73 $\pm$ 0.17	11.99 $\pm$ 0.71
28	IT170300	5.73 $\pm$ 0.13	20.64 $\pm$ 0.14	20.162 $\pm$ 0.04	26.57 $\pm$ 1.51	6.41 $\pm$ 0.92	18.42 $\pm$ 1.98
29	IT170301	6.13 $\pm$ 0.23	22.80 $\pm$ 1.02	21.538 $\pm$ 0.08	23.80 $\pm$ 0.11	5.32 $\pm$ 1.05	22.52 $\pm$ 1.32
30	IT170302	6.76 $\pm$ 0.02	23.29 $\pm$ 0.49	22.125 $\pm$ 0.11	27.07 $\pm$ 1.74	5.55 $\pm$ 0.14	13.13 $\pm$ 1.50
31	IT170303	7.38 $\pm$ 0.16	23.44 $\pm$ 1.20	22.449 $\pm$ 0.11	24.39 $\pm$ 0.27	5.30 $\pm$ 0.83	21.67 $\pm$ 1.41
32	IT170304	6.53 $\pm$ 0.12	20.77 $\pm$ 0.96	21.033 $\pm$ 0.02	26.08 $\pm$ 1.73	6.75 $\pm$ 0.79	23.09 $\pm$ 1.93
33	IT170305	6.49 $\pm$ 0.22	22.39 $\pm$ 0.08	21.713 $\pm$ 0.05	19.86 $\pm$ 1.76	6.02 $\pm$ 1.04	24.62 $\pm$ 1.61
34	IT170306	6.04 $\pm$ 0.00	21.78 $\pm$ 0.53	19.980 $\pm$ 0.06	24.99 $\pm$ 1.45	6.88 $\pm$ 0.64	33.41 $\pm$ 1.32
35	IT170309	7.05 $\pm$ 0.01	18.94 $\pm$ 0.16	22.614 $\pm$ 0.05	18.68 $\pm$ 1.40	5.32 $\pm$ 1.40	12.78 $\pm$ 1.78
36	IT170310	6.27 $\pm$ 0.21	22.63 $\pm$ 0.04	21.796 $\pm$ 0.22	17.75 $\pm$ 0.35	3.87 $\pm$ 0.55	10.03 $\pm$ 0.46
37	IT170312	7.69 $\pm$ 0.11	25.95 $\pm$ 0.27	21.637 $\pm$ 0.19	17.60 $\pm$ 0.92	2.51 $\pm$ 0.38	11.56 $\pm$ 1.78
38	IT170313	8.04 $\pm$ 0.05	20.70 $\pm$ 0.48	22.004 $\pm$ 0.03	21.69 $\pm$ 0.80	3.26 $\pm$ 0.35	20.3 $\pm$ 0.99
39	IT170316	7.01 $\pm$ 0.14	24.67 $\pm$ 0.87	21.279 $\pm$ 0.07	19.48 $\pm$ 0.94	2.70 $\pm$ 0.27	19.41 $\pm$ 1.70
40	IT170317	7.51 $\pm$ 0.13	21.05 $\pm$ 0.81	19.516 $\pm$ 0.08	23.38 $\pm$ 0.23	3.10 $\pm$ 0.00	17.55 $\pm$ 2.04
41	IT170319	6.39 $\pm$ 0.04	20.58 $\pm$ 0.77	19.144 $\pm$ 0.05	26.79 $\pm$ 1.74	5.06 $\pm$ 0.77	21.04 $\pm$ 1.15
42	IT170320	7.80 $\pm$ 0.12	20.78 $\pm$ 0.14	19.658 $\pm$ 0.05	24.03 $\pm$ 0.68	5.05 $\pm$ 0.70	14.39 $\pm$ 0.85

Appendix 1. Continued

Sample No.	Accession (IT No.)	Chemical composition (Mean $\pm$ SD)			TPC <sup>w</sup> (mg GAE g <sup>-1</sup> )	Antioxidant capacity (Mean $\pm$ SD)	
		CFC <sup>z</sup> (%)	DFC <sup>y</sup> (%)	CPC <sup>x</sup> (%)		DPPH-RSA <sup>v</sup> (mg AAE g <sup>-1</sup> )	TEAC <sup>u</sup> (mg TE g <sup>-1</sup> )
43	IT170321	6.93 $\pm$ 0.06	24.62 $\pm$ 1.34	20.298 $\pm$ 0.11	21.59 $\pm$ 1.60	3.78 $\pm$ 0.41	12.81 $\pm$ 1.35
44	IT170336	5.62 $\pm$ 0.09	12.98 $\pm$ 0.71	21.750 $\pm$ 0.23	25.44 $\pm$ 1.11	4.50 $\pm$ 0.49	11.97 $\pm$ 1.15
45	IT170340	7.15 $\pm$ 0.22	19.68 $\pm$ 0.59	20.336 $\pm$ 0.14	27.28 $\pm$ 0.95	6.46 $\pm$ 0.60	14.55 $\pm$ 1.36
46	IT170344	7.33 $\pm$ 0.02	19.60 $\pm$ 0.33	18.769 $\pm$ 0.16	26.06 $\pm$ 1.67	5.60 $\pm$ 0.44	10.01 $\pm$ 0.98
47	IT170346	6.87 $\pm$ 0.10	22.90 $\pm$ 0.06	21.160 $\pm$ 0.11	16.42 $\pm$ 0.62	1.61 $\pm$ 0.10	10.77 $\pm$ 1.22
48	IT170350	8.31 $\pm$ 0.16	26.11 $\pm$ 1.36	16.826 $\pm$ 0.04	24.43 $\pm$ 0.47	7.79 $\pm$ 0.48	25.01 $\pm$ 1.05
49	IT170353	8.36 $\pm$ 0.08	23.30 $\pm$ 0.06	19.004 $\pm$ 0.06	22.57 $\pm$ 1.17	6.63 $\pm$ 0.94	14.81 $\pm$ 0.80
50	IT170354	7.28 $\pm$ 0.09	20.59 $\pm$ 0.64	18.798 $\pm$ 0.01	17.90 $\pm$ 1.27	4.80 $\pm$ 0.39	10.34 $\pm$ 1.56
51	IT170355	8.63 $\pm$ 0.02	25.25 $\pm$ 1.04	17.716 $\pm$ 0.04	24.94 $\pm$ 1.51	8.83 $\pm$ 0.86	22.16 $\pm$ 1.54
52	IT170356	7.41 $\pm$ 0.02	25.42 $\pm$ 0.87	18.633 $\pm$ 0.03	24.42 $\pm$ 0.76	5.62 $\pm$ 0.28	16.04 $\pm$ 1.28
53	IT170360	7.44 $\pm$ 0.17	21.75 $\pm$ 0.90	22.108 $\pm$ 0.14	18.53 $\pm$ 0.41	2.45 $\pm$ 0.30	9.86 $\pm$ 1.65
54	IT170362	7.42 $\pm$ 0.21	19.79 $\pm$ 0.28	20.485 $\pm$ 0.26	21.31 $\pm$ 1.64	2.54 $\pm$ 0.32	7.2 $\pm$ 1.78
55	IT170365	7.54 $\pm$ 0.09	19.58 $\pm$ 0.29	18.407 $\pm$ 0.14	21.72 $\pm$ 1.18	5.24 $\pm$ 0.39	5.97 $\pm$ 0.83
56	IT170366	6.62 $\pm$ 0.24	16.61 $\pm$ 0.21	18.302 $\pm$ 0.09	18.67 $\pm$ 1.70	1.84 $\pm$ 0.26	7.68 $\pm$ 1.02
57	IT170371	6.92 $\pm$ 0.03	19.71 $\pm$ 0.32	17.887 $\pm$ 0.09	25.20 $\pm$ 1.61	4.72 $\pm$ 0.43	15.62 $\pm$ 0.69
58	IT170372	7.33 $\pm$ 0.17	18.72 $\pm$ 0.59	18.554 $\pm$ 0.02	22.72 $\pm$ 0.79	4.06 $\pm$ 0.26	18.13 $\pm$ 1.66
59	IT170378	6.64 $\pm$ 0.03	22.20 $\pm$ 0.24	21.583 $\pm$ 0.07	16.70 $\pm$ 1.55	4.56 $\pm$ 0.25	9.81 $\pm$ 1.44
60	IT170379	6.58 $\pm$ 0.06	21.47 $\pm$ 0.26	21.531 $\pm$ 0.18	25.93 $\pm$ 1.20	9.10 $\pm$ 1.05	21.75 $\pm$ 1.41
61	IT170382	5.98 $\pm$ 0.05	21.72 $\pm$ 0.33	22.565 $\pm$ 0.10	26.55 $\pm$ 0.34	6.81 $\pm$ 0.82	22.68 $\pm$ 0.97
62	IT170383	6.37 $\pm$ 0.10	20.85 $\pm$ 0.34	20.657 $\pm$ 0.10	27.45 $\pm$ 1.35	10.89 $\pm$ 0.39	30.08 $\pm$ 2.05
63	IT170384	6.76 $\pm$ 0.01	20.41 $\pm$ 1.03	20.560 $\pm$ 0.10	25.53 $\pm$ 1.38	6.87 $\pm$ 0.61	15.78 $\pm$ 0.81
64	IT170385	6.82 $\pm$ 0.17	17.53 $\pm$ 0.37	20.683 $\pm$ 0.06	28.41 $\pm$ 1.34	5.80 $\pm$ 0.55	15.92 $\pm$ 0.72
65	IT170386	7.20 $\pm$ 0.01	19.30 $\pm$ 0.21	21.301 $\pm$ 0.29	24.52 $\pm$ 1.39	8.85 $\pm$ 1.08	19.60 $\pm$ 1.15
66	IT170388	6.61 $\pm$ 0.07	16.55 $\pm$ 0.14	20.916 $\pm$ 0.29	24.14 $\pm$ 0.14	8.99 $\pm$ 0.35	15.35 $\pm$ 0.39
67	IT170410	7.37 $\pm$ 0.15	20.62 $\pm$ 0.49	18.014 $\pm$ 0.09	24.00 $\pm$ 1.73	9.09 $\pm$ 0.75	13.27 $\pm$ 0.69
68	IT170411	7.37 $\pm$ 0.11	20.58 $\pm$ 0.27	17.793 $\pm$ 0.12	27.64 $\pm$ 0.12	12.15 $\pm$ 0.89	29.19 $\pm$ 1.32
69	IT170412	7.31 $\pm$ 0.06	20.60 $\pm$ 0.84	18.394 $\pm$ 0.13	26.00 $\pm$ 0.85	7.26 $\pm$ 1.14	21.71 $\pm$ 0.97
70	IT170413	6.97 $\pm$ 0.02	19.90 $\pm$ 0.09	19.091 $\pm$ 0.18	29.09 $\pm$ 1.72	5.33 $\pm$ 0.90	19.06 $\pm$ 1.82
71	IT170415	7.74 $\pm$ 0.30	18.03 $\pm$ 0.86	20.446 $\pm$ 0.19	28.06 $\pm$ 1.66	16.04 $\pm$ 2.30	42.24 $\pm$ 0.72
72	IT170418	6.37 $\pm$ 0.08	19.51 $\pm$ 0.04	21.812 $\pm$ 0.12	27.28 $\pm$ 0.12	8.18 $\pm$ 0.5	17.01 $\pm$ 1.45
73	IT170419	6.33 $\pm$ 0.16	23.15 $\pm$ 0.41	16.759 $\pm$ 0.04	27.54 $\pm$ 1.05	3.97 $\pm$ 0.23	3.03 $\pm$ 0.85
74	IT170420	6.64 $\pm$ 0.24	19.01 $\pm$ 0.94	20.217 $\pm$ 0.06	24.33 $\pm$ 0.81	6.53 $\pm$ 0.83	10.62 $\pm$ 1.30
75	IT170421	7.54 $\pm$ 0.04	22.81 $\pm$ 0.01	20.394 $\pm$ 0.09	25.30 $\pm$ 1.21	7.65 $\pm$ 0.81	10.42 $\pm$ 0.70
76	IT170425	5.95 $\pm$ 0.19	29.37 $\pm$ 1.35	20.121 $\pm$ 0.16	26.20 $\pm$ 1.35	8.37 $\pm$ 1.55	7.37 $\pm$ 0.65
77	IT170438	5.97 $\pm$ 0.02	23.36 $\pm$ 0.31	21.107 $\pm$ 0.12	25.88 $\pm$ 1.63	5.54 $\pm$ 0.58	5.23 $\pm$ 0.49
78	IT170439	6.84 $\pm$ 0.07	29.00 $\pm$ 0.43	20.054 $\pm$ 0.13	24.78 $\pm$ 0.22	4.45 $\pm$ 0.41	11.51 $\pm$ 1.15
79	IT170443	6.59 $\pm$ 0.06	18.18 $\pm$ 0.06	17.822 $\pm$ 0.10	24.88 $\pm$ 1.17	3.93 $\pm$ 0.21	16.97 $\pm$ 2.33
80	IT170444	7.20 $\pm$ 0.16	33.19 $\pm$ 1.50	19.689 $\pm$ 0.19	24.94 $\pm$ 0.23	10.27 $\pm$ 0.48	32.35 $\pm$ 1.74
81	IT170446	7.34 $\pm$ 0.09	26.50 $\pm$ 1.32	17.400 $\pm$ 0.04	29.67 $\pm$ 0.43	7.55 $\pm$ 0.77	7.46 $\pm$ 0.42
82	IT170449	6.46 $\pm$ 0.11	26.87 $\pm$ 0.14	18.637 $\pm$ 0.11	24.19 $\pm$ 0.89	8.89 $\pm$ 0.04	8.09 $\pm$ 1.35

<sup>z</sup>CFC: Crude fiber content; <sup>y</sup>DFC: Dietary fiber content; <sup>x</sup>CPC: Crude protein content; <sup>w</sup>TPC: Total phenolic content; <sup>v</sup>DPPH-RSA: DPPH radical-scavenging activity; <sup>u</sup>TEAC: Trolox equivalent antioxidant capacity.