Food Sci. Biotechnol. 26(1): 97-103 (2017)
DOI 10.1007/s10068-017-0013-6

Food Science
and
Biotechnology

Comparison of functional components in various sweet potato leaves and stalks

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Received September 8, 2016
Revised November 11, 2016
Accepted November 15, 2016
Published online February 28, 2017

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pISSN 1226-7708
eISSN 2092-6456

Abstract The functional components of leaves and stalks from 14 sweet potato cultivars were investigated by determining lutein, β-carotene, chlorophyll, tannin and phenolic acid contents. It was found that the contents of the functional components in different cultivars differ significantly (p<0.05). Lutein, β-carotene and total chlorophyll contents were high in leaves and ranged from 19.01–28.85, 35.21–52.01 and 440.9–712.2 mg/100 g, respectively. The tannin and total phenolic acid contents of sweet potato leaves ranged from 2,280–4,460 and 2,640.2–4,200.9 mg/100 g, respectively. Significant correlations have been observed among cultivar, lutein, β-carotene, chlorophyll, and other antioxidants. The leaves of Healthymi cultivar contained the highest level of lutein, β-carotene and total chlorophyll, and Geonpungmi cultivar contained the highest level of the other antioxidant, among the all cultivars examined. Sweet potato leaves and stalks contain abundant functional components that make them potentially useful as fresh vegetables or processed foods.

Keywords: sweet potato leaves and stalks, lutein, β-carotene, chlorophyll, phenolic acid

Introduction

Sweet potato (*Ipomoea batatas* L.) is one of the most economically important crops and is widely grown around the world (1). Sweet potato leaves and stalks are the aboveground parts of the sweet potato, can be harvested several times in a year, their yield is ultimately higher than that of many other leafy vegetables. Sweet potato leaves have long been known to contain functional compounds with antioxidant activities such as carotenoids, flavonoids, chlorogenic acids, and several caffeoylquinic derivatives, all of which contribute to significant decreases in risks associated with chronic diseases (2). Color and variety can influence levels and profiles of phenolics as well as of carotenoids, anthocyanins and chlorophylls (3,4).

Aside from their well-known role as vitamin A precursors, carotenoids are among the phytochemicals most cited as responsible for a reduced risk of developing diseases such as cancer, cardiovascular diseases, cataracts, and macular degeneration. In addition to lutein and β-carotene, carotenoids also play an important role in the human body's antioxidant defense system (5). The biological functions of lutein in the eye include antioxidant activity against various pro-oxidants behavior (6,7). β-Carotene is the most abundant carotenoid found in plant-derived foods (mainly fruits and vegetables) consumed by humans and exhibits the highest biological activity of all pro-vitamin A carotenoids. Recent evaluations of its biological importance emphasized β-carotene function as potent singlet oxygen scavenger and antioxidant. Chlorophylls are a group of naturally occurring pigments produced in all photosynthetic plants as well as algae and some bacteria. The major portions of chlorophyll colorants are in water-soluble forms and they are used in dairy products, soups, oils, sugar confections, drinks, and cosmetics (8,9). Tannins have beneficial effects on human and animal health (10). The biochemical activities of tannins range from beneficial antioxidants to damaging toxins and prooxidants. If tannins scavenged free radicals, or reduce other oxidized compounds, and form relatively stable semiquinone radicals they can act as antioxidants (11,12). Both leaves and stalks are also good sources of phenolic compounds. Sweet potato leaves are a rich source of caffeoylquinic acid (CQA) derivatives (esters of caffeic acid and quinic acid) (13), which are known to exhibit antioxidative potential and have many beneficial effects on human health (14). Sweet potato leaves contain significantly more isochlorogenic acid than other commercial vegetables, including sweet potato roots and potato tubers (15).

Sweet potato leaves possess a variety of chemical compounds that are relevant to human health, and its leaves and stalks have value as

very nutritious and tasty vegetables. Although Asian and African regions have used this plant as food, there is little information about its nutritional characteristics. In addition, other parts of sweet potatoes have limited use compared to the tuber and to date have been used only for animal feed and fertilizer. Since the functional components of sweet potato parts and cultivars have not previously been reported, the objective of the present study was to evaluate the functional component of leaves and stalks from different cultivars and better assess their potential as sources of functional foods in the food industries.

Materials and Methods

Materials Sweet potato leaves and stalks of 14 varieties (Geonpungmi, Daeyumi, Yulmi, Jinhongmi, Healthymi, Manami, Sinchunmi, Gunmi, Yeonhwangmi, Yeonmi, Andong, Singeonmi, Gogeonmi, and Jeungmi) were obtained from Cheongwon-Gun in Chungbuk, South Korea. They were rinsed with tap water and dried in hot-air drying equipment (WFO-459PD; EYELA, Tokyo, Japan) at 40°C for 48 h and then ground into powder by an ultrafine grinder (Micro hammer cutter mill type-3; Culatti AG, Zurich, Swiss) and filtered through a 0.18-mm screen. Powdered samples were stored in well-labeled polyethylene films placed in a freezer at –20°C until analyzed.

Chemicals The reference substances lutein, β-carotene, chlorogenic acid, caffeic acid, ferulic acid, three caffeoylquinic acid (4,5-diCQA, 3,5-diCQA, and 3,4-diCQA), butylated hydroxyl toluene (BHT), tannic acid and Folin-Ciocalteu's phenol reagent were purchased from Sigma Chemicals Co. (St. Louis, MO, USA). Sodium chloride (NaCl), sodium sulfate (Na_2SO_4), and potassium hydroxide (KOH) were purchased from Samchun (Samchun Co., Ltd., Seoul, Korea). HPLC-grade acetone, water, and ethyl acetate were purchased from J.T. Baker Inc. (Phillipsburg, NJ, USA).

Analysis of lutein and β-carotene contents According to the slightly modified protocol of Wang *et al*. (16), 1 g of sample was extracted three times with 10 mL acetone (containing 0.1% BHT) for 10 min using an ultrasonic water bath (frequency 50Hz, power 872 W; WUC-D22H; Wonju, Korea), then centrifuged at 3,800×*g* for 15 min. The supernatants were combined and concentrated using a rotary evaporator (EYELA N-1000; EYELA) under vacuum at 35°C. The residue was dissolved with 20 mL ether (containing 0.1% BHT) and saponified by the 10% methanolic KOH. This was followed by standing for 3 h at 4°C in the dark, and then 20 mL of NaCl (10%, w/v) was added. After phase separation, the lower phase was extracted twice with 40 mL ether (containing 0.1% BHT). The combined ether phases were dried over anhydrous sodium sulfate and reduced using a rotary evaporator at 35°C. The residue was dissolved in 5-mL of methanol/ethyl acetate (50:50, v/v) containing 0.1% BHT and filtered through a 0.20-μm PVDF membrane filter before further analysis.

Separation and analysis of lutein and β-carotene were determined by high performance liquid chromatography (HPLC; Younglin Inc., Anyang, Korea). The analytical column was a Mightysil RP-18 GP column (4.6×250 mm, 5 μm, Kanto Chemical, Tokyo, Japan). Acetone-water was used at a flow rate of 0.6 mL/min. The injection volume was 20 μL, and the UV detector was set at 450 nm. Figure 1A shows the chromatograms of the reference mixture and a sample, respectively. Standard curves were linear in the concentration range studied, and the fitted lines showed very good correlations coefficients of R^2=0.999 and R^2= 0.999 for lutein and β-carotene, respectively. All samples were analyzed in triplicate.

Analysis of chlorophyll a and b contents Chlorophyll a and b contents were evaluated according to the method of Shin *et al*. (17). In brief, 0.3 g of sample was extracted with 80% (v/v) acetone-water solution. The extract was sonicated in an ultrasonic water bath, then centrifuged at 3,800×*g* for 30 min. The residue was dissolved in 20 mL ether (containing 0.1% BHT) and then 10 mL of NaCl (2%, w/v) was added. After phase separation, the lower phase was extracted twice with 40 mL ether (containing 0.1% BHT) then added to a 50-mL volumetric flask. The absorbance was determined at 660 and 642 nm with a UV-Vis spectrophotometer (UV-1650PC; Shimadzu, Kyoto, Japan).

Content was calculated by the following equations:

Chlorophyll a (mg/L)=9.93 OD (660 nm)–0.777 OD (642 nm)

Chlorophyll b (mg/L)=17.6 OD (642 nm)–2.81 OD (660 nm)

Analysis of tannin content Tannin contents were measured according to a modification of the method of Duval and Shetty (18). 1 g of sample was extracted with 20 mL of 80% (v/v) ethanol for 30 min at room temperature and subjected to ultrasonic wave treatment, then centrifuged at 3,800×*g* for 30 min. Three replicate extracts were combined and the solvent was evaporated using a rotary evaporator under vacuum at 40°C. In a 10-mL test tube, 1 mL of 95% ethanol and 1 mL of distilled water were mixed with 1 mL of the sample. Then, the 5% Na_2CO_3 solution and 500 μL of 2 N Folin-Ciocalteu's phenol reagent were added and mixed. After exactly 60 min, the absorbance was determined at 725 nm with a UV-Vis Spectrophotometer (UV-1650PC; Shimadzu). Tannin content of the extracts was expressed as mg of tannic acid equivalents (TAE) per 100 g of dry weight. All extracts were analyzed in triplicate.

Analysis of phenolic acid Leaves and stalks (0.5 g) were extracted with 20 mL of 80% (v/v) ethanol for 30 min and subjected to ultrasonic wave treatment. Following centrifugation at 3,800×*g* for 30 min at 4°C, the residue was again extracted twice with 20 mL of 80% (v/v) ethanol and centrifuged. The combined supernatants were diluted to 50 mL with ethanol.

The phenolic acid extracts were filtered through a 0.20-μm PVDF membrane filter before further analysis. Quantitative analysis of phenolic acid were determined by HPLC system (Younglin Inc.)

equipped with a UV detector and the monitoring wavelength was 280 nm. Figure 1B shows the chromatograms of the reference mixture and a sample, respectively. The separation was achieved on a XDB-C18 column (5 μm, 4.6×250 mm, Agilent Technologies). The mobile phase consisted of 0.1% (v/v) acetic acid in water (solvent A) and 0.1% (v/v) acetic acid in acetonitrile (solvent B). The gradient used is as follows: 0–2 min, 8% B; 2–27 min, 10% B; 27–50 min, 30% B; 50–51 min, 90% B; 51–60 min, 100% B; 60–70 min, 8% B. The flow rate was 1.0 mL/min and the injection volume was 20 μL.

Statistical analysis Data were expressed as mean±standard deviation (SD). The significance of differences among treatment means was determined using one-way analysis of variance (ANOVA) with SPSS software (SPSS Institute, Chicago, IL, USA) and a significance level of $p<0.05$.

Results and Discussion

Lutein The results obtained for the lutein content of the leaves and stalks from different sweet potato cultivars are shown in Table 1. There were significant differences among the sweet potato cultivars. Lutein contents ranged from 19.01 (Gunmi) to 28.85 mg/100 g (Healthymi) with an average of 24.67 mg/100 g in different sweet potato leaves. The values in stalks ranged from 1.88 (Yulmi) to 3.77 mg/100 g (Gogeonmi) ($p<0.05$), with an average of 2.70 mg/100 g. Lutein content of leaves was more than 10-fold higher than in stalks. Lee and Kim (19) reported that lutein contents of other commercial vegetables were lower than in this study, ranging from 10,115 to 13,718 μg/100 g. In other reports for other vegetables or leaves, lutein values based on HPLC ranged from 2.0 μg/g (lettuce) to 53.8 μg/g (India mustard) (20). In contrast, the leaves and stalks of sweet potato had slightly higher carotenoid levels than those of the other vegetables.

β-Carotene The β-carotene content of leaves and stalks from different sweet potato cultivars are shown in Table 1. There were significant differences among sweet potato cultivars and the leaves had higher content than did the stalks. The data showed that β-carotene content of the leaves ranged from 35.21 to 52.01 mg/100 g and was highest in Healthymi and Manami, with the values of 52.01 and 49.94 mg/100 g, respectively, which are not significantly different at $p>0.05$, followed by Yulmi (44.83 mg/100 g) ($p<0.05$). β-Carotene content of the stalks ranged from 0.48 to 2.57 mg/100 g and was the highest in Singeonmi at 2.57 mg/100 g ($p<0.05$), followed by Jinhongmi, Gunmi, and Gogeonmi with the values of 2.06, 2.04, and 2.07 mg/100 g, which are not significantly different at $p>0.05$. On the other hand, the lowest value for Yeonmi was 0.48 mg/100 g, which was significantly different at $p<0.05$. These values were corrected based on the results from a recovery test of standard β-carotene. The average β-carotene content of leaves was 41.36 mg/100 g dry weight, which was similar to the findings reported by Ishida *et al*. (21). They reported that leaves have a lot of vitamins, such as riboflavin, β-carotene, vitamin C, vitamin E and so on. The β-carotene content in leaves of Koganesengan (KS) and Beniazuma (BA) was 400 and 273 μg/100 g wet basis, respectively, and stalks of KS and BA had 22 and 191 μg/100 g wet basis, respectively. In addition, β-carotene content of sweet potato leaves and stalks was higher than that in spinach (31.5 mg/kg wet basis) and other vegetables (2–1,700 μg/100 g wet basis) (22,23).

Table 1. Lutein and β-carotene contents (mg/100 g dry basis) on leaves and stalks of different sweet potato cultivars

No.	Cultivars	Lutein		β-Carotene	
		Leaf	Stalk	Leaf	Stalk
1	Geonpungmi	21.71±0.62$^{f1)}$	2.03±0.05^{hi}	38.93±1.21^{e}	1.00±0.01^{g}
2	Daeyumi	26.60±0.63^{cd}	2.14±0.09^{hi}	43.97±1.52^{bc}	1.38±0.04^{d}
3	Yulmi	25.79±0.29^{d}	1.88±0.06^{j}	44.83±1.13^{b}	0.93±0.01^{h}
4	Jinhongmi	28.28±0.31^{ab}	3.26±0.11^{d}	37.76±1.22^{e}	2.06±0.04^{b}
5	Healthymi	28.85±0.35^{a}	2.54±0.07^{f}	52.01±1.06^{a}	1.42±0.01^{d}
6	Manami	27.32±0.77^{bc}	2.15±0.01^{h}	49.94±1.18^{a}	1.01±0.02^{fg}
7	Sinchunmi	21.15±1.04^{f}	2.02±0.07^{i}	37.18±1.37^{ef}	1.09±0.05^{e}
8	Yeonhwangmi	25.84±0.93^{d}	3.71±0.01^{a}	42.63±1.92^{bcd}	1.48±0.05^{c}
9	Yeonmi	25.55±0.68^{d}	2.77±0.11^{e}	38.24±1.67^{e}	0.48±0.01^{i}
10	Andong	24.16±0.40^{e}	2.11±0.04^{hi}	36.86±0.19^{ef}	1.00±0.02^{g}
11	Singeonmi	24.20±0.21^{e}	3.44±0.08^{c}	41.85±1.01^{cd}	2.57±0.02^{a}
12	Gunmi	19.01±0.83^{g}	3.58±0.04^{b}	35.21±1.60^{f}	2.04±0.03^{b}
13	Gogeonmi	26.14±0.79^{d}	3.77±0.06^{a}	41.18±1.15^{d}	2.07±0.05^{b}
14	Jeungmi	20.83±0.20^{f}	2.39±0.02^{g}	38.41±0.28^{e}	1.06±0.03^{ef}
Mean±SD		24.67±2.98	2.70±0.71	41.36±4.97	1.40±0.58
CV (%)		12.1	26.3	12.0	41.4

[1)]Data are mean±SD of 3 replicates. Values within columns with different letters are significantly different ($p<0.05$).

Chlorophyll a and b The chlorophyll a and b content of leaves from different sweet potato cultivars are shown in Table 2. There were significant differences among sweet potato cultivars, and leaves had 7.6–14.7 times higher content than did stalks. The data showed that the chlorophyll a content of the leaves ranged from 329.0 to 518.6 mg/100 g, with significant differences among varieties. Chlorophyll a predominated over chlorophyll b in partially colored leaves and stalks. Chlorophyll a and b contents were the highest (518.6 and 193.6 mg/100 g, respectively) in the Healthymi cultivar and the lowest in the Gunmi variety (329.0 and 111.5 mg/100 g, respectively) (p<0.05). Total chlorophyll contents of sweet potato leaves are close to the 740 mg/100 g found in mustard leaves and to the 92.34 mg/100 g wet basis in Dolsan leaf mustard (24,25). In this study, different cultivars of sweet potato leaves had higher chlorophyll content than in other leaves of Chinese sweet potato varieties (26). The chlorophyll contents of stalks from different sweet potato cultivars are shown in Table 2. Chlorophyll a and b contents were the highest in the Yeonhwangmi cultivar (56.6 and 24.6 mg/100 g, respectively) and the lowest in the Andong cultivar (27.3 and 9.5 mg/100 g, respectively) (p<0.05). These results are in disagreement with those of Peng *et al*. (27). The authors reported that the chlorophyll contents of the sweet potato leaf stalks ranged from 20 to 48 mg/g wet basis. It is determined that the difference is likely due to the varieties, cultivation areas, and growing conditions.

Tannin The reactivity of tannins with molecules of biological significance has important physiologi-cal and nutritional consequences that naturally occur in leaf, fruits, beverages, and cereals. Their multiple phenolic hydroxyl groups the form complexes with proteins, with metal ions, and with other macromolecules such as polysaccharides (28,29). The tannin contents of leaves and stalks from different sweet potato cultivars are shown in Table 3. There were significant differences among sweet potato cultivars. The data showed that tannin content of the leaves ranged from 2,280 to 4,460 mg/100 g and was highest in the Geonpungmi cultivar (p<0.05), followed by the Daeyumi and Jeungmi varieties with values of 3,800 and 3,780 mg/100 g (p>0.05), respectively. On the other hand, the Yulmi variety had the lowest value, which was significantly different at p<0.05. Tannin content of the stalks ranged from 680 to 1,390 mg/100 g and was the highest in the Sinchunnmi cultivar, followed by the

Table 3. Tannin content on the leaves and stalks of different sweet potato cultivars

No.	Cultivars	Tannin content (mg/100 g dry basis)	
		Leaf	Stalk
1	Geonpungmi	4,460±120$^{a1)}$	930±10^{g}
2	Daeyumi	3,800±70^{b}	1,040±20^{e}
3	Yulmi	2,280±10^{j}	680±10^{j}
4	Jinhongmi	2,560±40^{i}	970±20^{f}
5	Healthymi	3,230±40^{f}	1,120±20^{d}
6	Manami	2,940±60^{h}	1,150±20^{cd}
7	Sinchunmi	3,370±90^{d}	1,390±30^{a}
8	Yeonhwangmi	3,670±50^{c}	730±30^{i}
9	Yeonmi	3,360±70de	840±30^{h}
10	Andong	3,390±40^{d}	690±20^{j}
11	Singeonmi	3,090±30^{g}	910±20^{g}
12	Gunmi	3,240±90^{ef}	820±20^{h}
13	Gogeonmi	3,280±40^{def}	1,170±10^{c}
14	Jeungmi	3,780±60^{b}	1,210±10^{b}
Mean±SD		3,320±540	980±220
CV (%)		16.3	22.4

$^{1)}$Data are mean±SD of 3 replicates. Values within columns with different letters are significantly different (p<0.05).

Table 2. Chlorophyll contents (mg/100 g dry basis) on leaves and stalks of different sweet potato cultivars

No.	Cultivars	Chlorophyll a		Chlorophyll b	
		Leaf	Stalk	Leaf	Stalk
1	Geonpungmi	344.5±4.9$^{i(1)}$	33.4±0.4^{g}	116.8±1.6^{g}	14.2±0.2^{f}
2	Daeyumi	454.3±1.9^{c}	30.7±0.4^{j}	163.9±0.3^{c}	11.5±0.1^{g}
3	Yulmi	439.7±2.2^{d}	30.0±0.2^{ij}	158.1±7.0^{d}	11.1±0.2^{g}
4	Jinhongmi	450.3±4.0^{c}	44.1±0.2^{e}	166.9±1.6^{bc}	17.7±0.3^{d}
5	Healthymi	518.6±2.1^{a}	49.4±0.2^{b}	193.6±3.1^{a}	22.2±0.5^{b}
6	Manami	478.3±3.5^{b}	32.2±0.5^{h}	164.5±1.5^{bc}	13.8±0.3^{f}
7	Sinchunmi	418.5±3.3^{f}	47.3±0.3^{c}	145.3±2.3^{f}	21.1±0.4^{c}
8	Yeonhwangmi	454.2±3.1^{c}	56.6±0.2^{a}	164.1±1.1^{c}	24.6±0.2^{a}
9	Yeonmi	449.4±4.0^{c}	45.5±0.5^{d}	168.7±1.8^{b}	21.9±0.4^{b}
10	Andong	363.6±2.9^{h}	27.3±0.7^{k}	118.0±0.5^{g}	9.5±0.3^{h}
11	Singeonmi	425.6±6.9^{e}	44.3±0.5^{e}	150.1±3.8^{e}	17.6±0.1^{d}
12	Gunmi	329.0±5.7^{j}	38.1±0.4^{f}	111.5±2.4^{h}	17.0±0.5^{e}
13	Gogeonmi	380.0±5.7^{g}	45.4±0.7^{d}	142.0±2.4^{f}	20.9±0.9^{c}
14	Jeungmi	359.7±10.6^{h}	29.9±0.4^{j}	115.4±4.3^{gh}	10.9±0.0^{g}
Mean±SD		419.0±55.5	39.6±9.1	148.5±24.9	16.7±4.9
CV (%)		13.2	23.0	16.8	29.3

$^{1)}$Data are mean±SD of 3 replicates. Values within columns with different letters are significantly different (p<0.05).

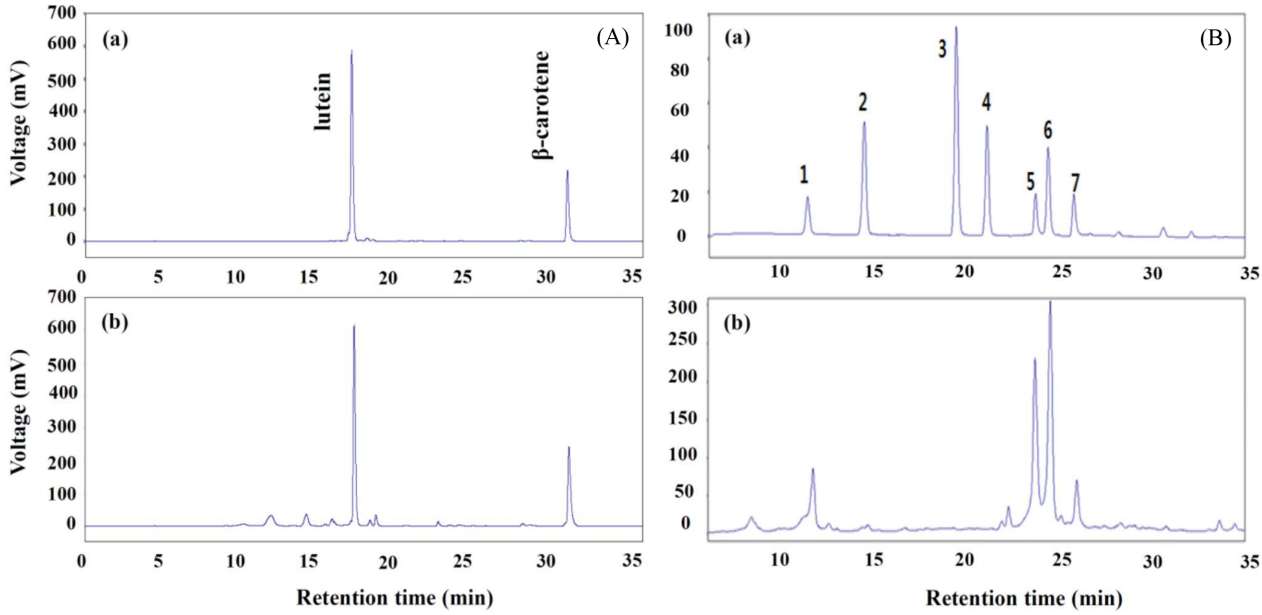

Fig. 1. Representative chromatograms of standard mixture (a) and sample (b). (A) Lutein and β-carotene (B) phenolic acid peak (1) chlorogenic acid; (2) caffeic acid; (3) ρ-coumaric acid; (4) ferulic acid; (5) 4,5-dicaffeoylquinic acid (4,5-diCQA); (6) 3,5-dicaffeoylquinic acid (3,5-diCQA); (7) 3,4-dicaffeoylquinic acid (3,4-diCQA).

Jeungmi cultivar at 1,210 mg/100 g, which was significantly different at $p<0.05$. On the other hand, the lowest values were for the Yulmi and Jeungmi cultivars at 680 and 690 mg/100 g, respectively. These values were corrected based on the results from the recovery test of standard tannic acid. Park *et al*. (30) reported that the tannin contents of green tea and Chungtaejeon tea were 12.4 and 11.80 g/100 g, respectively. The average tannin content of leaves was 3,320 mg/100 g dry weight, which was similar to the findings reported by Almazan *et al*. (31). The authors reported that the tannin contents of three cultivar sweet potato leaves ranged from 2.8 to 3.6 g/100 g.

Phenolic acid Sweet potato roots, leaves, and stalks are good sources of nutrients and micronutrients for animals and humans. Recent studies demonstrated that the leaves and stalks of the sweet potato contained high levels of phenolic acids compared to other commercial vegetables (32). The following phenolic acids were found in leaves and stalks of the sweet potato and all the varieties. Individual phenolic compound contents of leaves and stalks from different sweet potato cultivars are shown in Fig. 2. The contents of these 6 phenolic acids were significantly different ($p<0.05$) among the leaves and stalks samples of the 14 cultivars. In fourteen varieties, either 3,5-diCQA or 4,5-diCQA were most abundant. In the stalk tissues, the quantities of the identified phenolic compounds in all cultivars were much lower than those of the respective compounds in the leaves.

Apparently, 4,5-diCQA was the main phenolic acid (25 to 48% of total phenolics) followed by either 3,5-diCQA or chlorogenic acid in leaves, whereas chlorogenic acid and 4,5- diCQA were the main phenolic acid (23–51 and 23–42% of total phenolics, respectively) followed by 3,5-diCQA in stalks, which was in accordance with the previous reports (33,34). Chlorogenic acid contents of leaves levels ranged from 330.5 mg/100 g for Sinchunmi to 1,023.8 mg/100 g for Gogeonmi. The stalks of the Jeungmi variety (601.7 mg/100 g) have the highest levels of chlorogenic acid. Average chlorogenic acid levels for all of varieties in the current study are higher than those determined for the leaves and stalks of 3 cultivars by Jung *et al*. (35). Caffeic acid and ferulic acid contents of the leaves were 13.7–32.5 and 29.0–87.5 mg/100 g, respectively. The average caffeic acid and ferulic acid contents were 22.8 and 49.4 mg/100 g, respectively. Caffeic acid and ferulic acid contents of the stalks were the highest in Singeonmi (9.3 and 6.2 mg/100 g). 4,5-diCQA, 3,5-diCQA, and 3,4-diCQA of leaves ranged from 691.2 to 2,011.1 mg/100 g (Jeungmi), 677.7 to 1,091.1 mg/100 g (Gogeonmi), 123.0 to 395.3 mg/100 g (Healthymi), respectively. The stalks of the Sinchunmi varieties have the highest levels of 4,5-diCQA, 3,5-diCQA, and 3,4-diCQA (871.4, 427.5, and 291.6 mg/100 g, respectively). Islam (34) quantified individual phenolic compounds (ChA, CA, 3,5-diCQA, 4,5-diCQA, 3,4-diCQA, and 3,4,5-triCQA) in the leaves of sweet potato genotypes, and also concluded that 4,5-diCQA and 3,5-diCQA (315.38–1,183.0 and 952.9–3,503.6 mg/100 g dry weight, respectively) was the main component of CQA derivatives.

The leaves contain the largest amount of phenolic acids, with an amount significantly ($p<0.05$) greater than in stalks. There were significant differences among sweet potato cultivars. The data showed that total phenolic acid contents of the leaves ranged from 2,640.2 to 4,200.9 mg/100 g and was highest in the Gogeonmi cultivar ($p<0.05$), followed by the Geonpungmi and Jeungmi varieties with values of 4,122.0 and 4,163.2 mg/100 g ($p>0.05$), respectively.

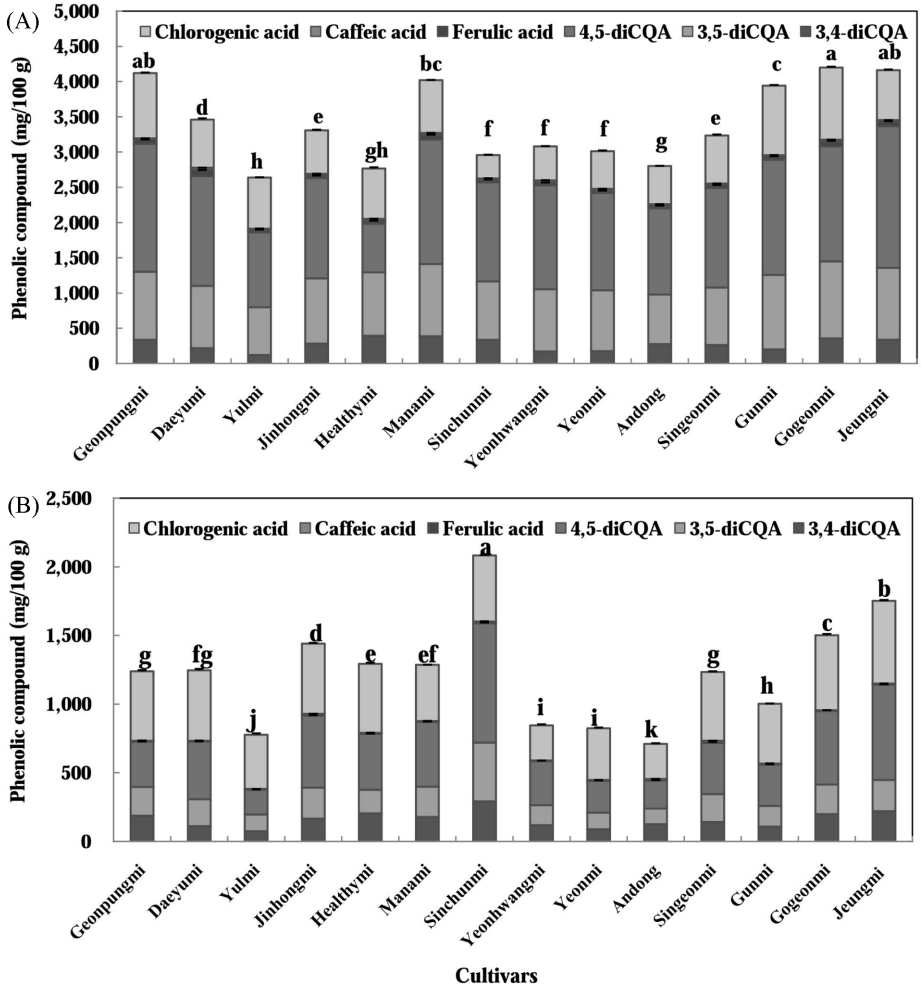

Fig. 2. Phenolic acid contents on leaves (A) and stalks (B) of different sweet potato cultivars. Values within columns with different letters are significantly different (p<0.05).

Table 4. Matrix correlation for all the samples

	Lutein	β-Carotene	Total chlorophyll	Tannin	Total phenolic acid
Lutein	1	0.680***[1)]	0.821***	-0.421**	-0.353*
β-Carotene		1	0.733***	-0.214	-0.151
Total chlorophyll			1	-0.400**	-0.505**
Tannin				1	0.419**
Total phenolic acid					1

[1)]*p<0.05, **p<0.01, ***p<0.001

On the other hand, the Yulmi variety had the lowest value, which was significantly different at p<0.05. The stalks of the Sinchunmi varieties have the highest levels of total phenolic acids (2,083.0 mg/100 g) and followed by the Jeungmi varieties with values of 1,751.9 mg/100 g (p<0.05).

Multivariate analysis A statistical study of the correlation analyses between the tested carotenoid, chlorophyll, tannin and the levels of phenolic compounds, across all the plant tissues, support these findings (Table 4). Negative and statistically significant correlations were found between lutein, chlorophyll, and phenolic compounds, and a positive significant correlation (at p<0.001) between chlorophyll and carotenoid (lutein and β-carotene).

The functional components, such as lutein, β-carotene, chlorophyll, tannin and phenolic acid on leaves and stalks differed significantly among the sweet potato cultivars. Lutein and the other carotenoid pigments found in mature leaves are often not obvious because of being masked by the presence of chlorophyll. Lutein, β-carotene and chlorophyll contents of leaves were high in the Healthymi cultivar. The leaves of Geonpungmi cultivar contained the highest level of tannin and total phenolic acid among the all cultivars examined. These results suggested that sweet potato leaves and stalks, which

contain abundant functional components, can be useful as fresh vegetables or processed foods.

Disclosure The authors declare no conflict of interest.

References

1. Bovell-Benjamin AC. Sweet potato: A review of its past, present, and future role in human nutrition. Adv. Food Nutr. Res. 52: 1–59 (2007)
2. Ishiguro K, Kumagai T, Kai Y, Nakazawa Y, Yamakawa O. Genetic resources and breeding of sweet potato in Japan. pp. 57–61. In: Exploring the complementarities of *in situ* and *ex situ* conservation strategies for Asian sweet potato genetic resources, proceeding of the 3rd international workshop of the Asian Network for sweet potato genetic resources. October 2–4, Bali, Indonesia. Asian Network for sweet potato genetic resources, Bali, Indonesia (2002)
3. Steed LE, Truong VD. Anthocyanin content, antioxidant activity, and selected physical properties of flow able purple-fleshed sweetpotato purees. J. Food Sci. 73: S215–S221 (2008)
4. Van H, Faulks R, Granado HF, Hirschberg J, Olmedilla B, Sandmann G, Southon S, Stahl W. The potential for the improvement of carotenoid levels in foods and the likely systemic effects. J. Sci. Food Agr. 80: 880–912 (2000)
5. Riso P, Brusamolino A, Scalfi L, Porrini M. Bioavailability of carotenoids from spinach and tomatoes. Nutr. Metab. Cardiovas. 14: 150–156 (2004)
6. Amar I, Aserin A, Garti N. Solubilization patterns of lutein and lutein esters in food grade nonionic micro emulsions. J. Agr. Food Chem. 51: 4775–4781 (2003)
7. Johnson EJ. A biological role of lutein. Food Rev. Int. 20: 1–16 (2004)
8. MacDougall DB. Color measurement of food: Principles and practice. pp. 33–63. In: Color in Food: Improving Quality. MacDougall DB (ed). Woodhead Publishing Limited, Cambridge, UK (2002)
9. Mortensen A. Carotenoids and other pigments as natural colorants. Pure Appl. Chem. 78: 1477–1491 (2006)
10. Veloz-Garcia RA, Marin-Martinez R, Veloz-Rodriguez R, Munoz-Sanchez CI, Guevara-Olvera L, Miranda-Lopez R. Antimutagenic and antioxidant activities of cascalote (*Caesalpinia cacalaco*) phenolics. J. Sci. Food Agr. 84: 1632–1638 (2004)
11. Hagerman AE, Riedl-Jones GA, Sovik KN, Ritchard NT, Hartzfeld PW, Riechel TL. High molecular weight plant polyphenolics (tannins) as biological antioxidants. J. Agr. Food Chem. 46: 1887–1892 (1998)
12. Halliwell B, Gutteridge JMC. Free radicals in biology and medicine. Oxford University Press, Oxford, UK. pp. 22–85 (1999)
13. Zheng W, Clifford, MN. Profiling the chlorogenic acids of sweet potato (*Ipomoea batatas*) from China. Food Chem. 106: 147–152 (2008)
14. Truong VD, McFeeters RF, Thompson RT, Dean LL, Shofran B. Phenolic acid content and composition in leaves and roots of common commercial sweet potato (*Ipomea batatas* L.) cultivars in the United States. J. Food Sci. 72: 343–349 (2007)
15. Sondheimer E. On the distribution of caffeic acid and the chlorogenic acid isomers in plants. Arch. Biochem. Biophys. 74: 131–138 (1958)
16. Wang XC, Chen L, Ma CL, Yao MZ, Yang YJ. Genotypic variation of beta-carotene and lutein contents in tea germplasms, *Camellia sinensis* (L.) O. Kuntze. J. Food Compos. Anal. 23: 9–14 (2010)
17. Shin MK, Chang MK, Seo ES. Chemical properties on the quality of marketed roasting green teas. Korean J. Food Cook. Sci. 11: 356–361 (1995)
18. Duval B, Shetty K. The stimulation of phenolics and antioxidant activity in pea (*Pisum Sativam*) elicited by genetically transformed anise root extract. J. Food Biochem. 25: 361–377 (2001)
19. Lee HS, Kim YN. Beta-carotene and lutein contents in green leafy vegetables. J. East Asian Soc. Diet. Life. 7: 175–179 (1997)
20. Murillo E, Melendez-Martinez AJ, Portugal F. Screening of vegetables and fruits from panama for rich sources of lutein and zeaxanthin. Food Chem. 122: 167–172 (2010)
21. Ishida H, Suzuno H, Sugiyama N, Innami S, Tadokoro T, Maekawa A. Nutritive evaluation on chemical components of leaves, stalks and stems of sweet potatoes (*Ipomoea batatas poir*). Food Chem. 68: 359–367 (2000)
22. Bunea A, Andjelkovic M, Socaciu C, Bobis O, Neacsu M, Verhe R, Camp JV. Total and individual carotenoids and phenolic acids content in fresh, refrigerated and processed spinach (*Spinacia oleracea* L.). Food Chem. 108: 649–656 (2008)
23. Kandlakunta B, Rajendran A, Thingnganing L. Carotene content of some common (cereals, pulses, vegetables, spices, and condiments) and unconventional sources of plant origin. Food Chem. 106: 85–89 (2008)
24. Song ES, Jeon YS, Cheigh HS. Isolation of chlorophyll derivatives and β-carotene from mustard leaf and their antioxidative activities on the lipid autoxidation. J. Korean Soc. Food Sci. Nutr. 30: 377–381 (2001)
25. Cho YS, Ha BS, Park SK, Chun SS. Contents of carotenoids and chlorophylls in dolsan leaf mustard (*Brassica juncea*). J. Korean Soc. Food Cult. 8: 153–157 (1993)
26. Chen XX, Cai BQ, Huang MJ, Zhang FD, Kong XX. Extraction and stability of chlorophyll from sweet potato leaves. Ghuangzhou Chem. Ind. 41: 72–75 (2013)
27. Peng Y, Xu YQ, Duan DF, Mao LC. Postharvest quality and physiological behavior of sweet potato (*Ipomoea batatas* Lam.) leaf stalks under three temperatures. Agr. Sci. China. 8: 244–248 (2009)
28. Van Acker SABE, Plemper van Balen GP, van den Berg DJ, Bast A, van der Vijgh WJF. Influence of iron chelation on the antioxidant activity of flavonoids. Biochem. Pharmacol. 56: 935–943 (1998)
29. Hagerman AE, Rice ME, Ritchard NT. Mechanisms of protein precipitation for two tannins, pentagalloyl glucose and epicatechin$_{16}$ (48) catechin. J. Agr. Food Chem. 46: 2590–2595 (1998)
30. Park YS, Lee MK, Ryu HH, Heo BG. Content analysis of chungtaejeon tea and green tea produced in jangheung district. Korean J. Commun. Living Sci. 19: 55–61 (2008)
31. Almazan AM, Begum F, Johnson C. Nutritional quality of sweet potato greens from greenhouse plants. J. Food Compos. Anal. 10: 246–253 (1997)
32. Liao WC, Lai YC, Yuan MC, Hsu YL, Chan CF. Antioxidative activity of water extract of sweet potato leaves in Taiwan. Food Chem. 127: 1224–1228 (2001)
33. Islam MS, Yoshimoto M, Yahara S, Yamakawa O. Identification and characterization of foliar polyphenolic composition in sweetpotato genotypes. J. Agr. Food Chem. 50: 3718–3722 (2002)
34. Islam S. Sweetpotato (*Ipomeabatatas* L.) leaf: Its potential effect on human health and nutrition. J. Food Sci. 71: R13–R121 (2006)
35. Jung JK, Lee SU, Kozukue N, Levin CE, Friedman M. Distribution of phenolic compounds and antioxidative activities in parts of sweet potato (*Ipomoea batata* L.) plants and in home processed roots. J. Food Compos. Anal. 24: 29–37 (2011)