Food Chemistry 156 (2014) 380–389

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Sweet potato (*Ipomoea batatas* L.) leaves as nutritional and functional foods

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ARTICLE INFO

Article history:
Received 9 October 2013
Received in revised form 20 January 2014
Accepted 23 January 2014
Available online 5 February 2014

Keywords:
Sweet potato leaves
Proximate composition
Mineral content
Index of nutritional quality
Polyphenols
Antioxidant activity

ABSTRACT

In this study, the nutritional compositions of leaves from 40 sweet potato (*Ipomoea batatas* L.) cultivars were assessed. The correlations between antioxidant activity and crude protein, crude fat, crude fiber, carbohydrate, and polyphenol contents were determined. The crude protein, crude fiber, crude fat, carbohydrate and ash contents ranged between 16.69–31.08, 9.15–14.26, 2.08–5.28, 42.03–61.36, and 7.39–14.66 g/100 g dry weight (DW), respectively. According to the index of nutritional quality, sweet potato leaves are good sources of protein, fiber, and minerals, especially K, P, Ca, Mg, Fe, Mn, and Cu. The correlation coefficient between antioxidant activity and total polyphenol content was the highest (0.76032, $p < 0.0001$), indicating that polyphenols are important antioxidants in sweet potato leaves. Sweet potato leaves, which contain several nutrients and bioactive compounds, should be consumed as leafy vegetables in an attempt to reduce malnutrition, especially in developing countries.

1. Introduction

In developing countries, desertification has contributed to a reduction in cultivated land and thus to an increase in food shortage. Crops that are resistant to different environmental, soil, and temperature conditions are required. Sweet potato (*Ipomoea batatas* L.) is a highly resistant crop that originated from Central America. China, the leading producer of sweet potato, had an annual production of 75,567,929 tons in 2011 (76.07% of the world's production) (FAO (Food, 2011). In Japan, where sweet potato is considered to be a hardy plant, both roots and leaves are consumed (Ishida et al., 2000). However, in China, sweet potato leaves are only used in livestock feed. Furthermore, studies focusing on the bioactive components of sweet potato leaves are scarce.

Sweet potato leaves can be harvested several times during the year, and their yields are much higher than those of green leafy vegetables (An, Frankow-Lindberg, & Lindberg, 2003). Furthermore, compared to green leafy vegetables, sweet potato leaves are more tolerant of diseases, pests, and high moisture conditions. Sweet potato leaves constitute an alternative source of green leafy vegetables during their off-season and could potentially alleviate food shortage due to natural disasters, e.g., tsunamis, floods, or typhoons (Taira, Taira, Ohmine, & Nagata, 2013). Several studies have reported that antioxidants play important roles in the prevention of aging and age-related diseases. Due to the safety concerns associated with supplemental forms of antioxidants, consumers are paying more attention to fruits and vegetables as natural sources of antioxidants. Therefore, the objective of this study was to assess the nutritional quality of proximate composition and antioxidant activity of polyphenols in sweet potato leaves, and provide data support for utilization of sweet potato leaves as nutritional and functional foods.

2. Materials and methods

2.1. Plant materials

Leaves from 40 sweet potato cultivars were obtained from the Research Institute of Sweet Potato of the Chinese Academy of Agricultural Sciences (Xuzhou, China), and were chosen according to sweet potato uses in food processing, i.e., Nongda No. 6-2, Miyuan No. 6, Jishu No. 04150, Xushu No. 22-1 and Shangshu No. 19 are used for starch processing, and the rest are used for other food processing, e.g. dried fruit, juice and chips. All cultivars were planted with standard production practices at the experimental farm of the Research Institute of Sweet Potato of the Chinese Academy of Agricultural Sciences in the middle of March, 2012. The average temperatures during the growth period of 2012 were as follows: March 8 °C, April 16 °C, May 22 °C, June 27 °C, July 26 °C, and

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http://dx.doi.org/10.1016/j.foodchem.2014.01.079
0308-8146/

August 26 °C. Prior to harvest, i.e., at the end of August, the leaves were collected, washed, and freeze-dried. All samples were ground in a commercial grinder and stored at 20 °C in sealed aluminum bags.

2.2. Proximate composition

Moisture content was measured following ASAE standards (ASAE, 1983). Briefly, triplicates of sweet potato leaf samples were oven-dried at 103 °C for 72 h, transferred to a desiccator, and allowed to cool at room temperature. The sample weights were recorded on a digital balance (Denver Instruments, Denver, Colorado, USA).

Ash, crude fat, and crude protein contents were determined by AOAC methods (AOAC (Association of Analytical Chemists), 2000). Ash content was determined by weighing leaf samples before and after heat treatment (550 °C for 12 h). Crude fat content was determined according to AOAC method 960.39. Crude protein was assessed by the micro-Kjeldahl method, with nitrogen to protein conversion factor of 6.25 (AOAC method 976.05).

Crude fiber was determined by ISO method 5498:1981. First, a sample of leaf powder was boiled in 0.255 M sulfuric acid for 30 min. The resulting insoluble residue was filtered, washed, and boiled in 0.313 M sodium hydroxide. After filtering and washing the sample, it was dried at 130 ± 2 °C for 2 h. Weight loss was determined at 350 ± 25 °C. Crude fiber content was expressed relative to the dry weight (DW) of leaf powder. Carbohydrate content (g/100 g DW) was calculated by subtracting the sum of percent ash, crude fat, crude protein, and crude fiber contents from 100. Gross energy was determined using a bomb calorimeter according to ISO method 9831 (ISO (International Standards Organization), 1998).

2.3. Mineral content

Leaf samples were digested in concentrated HNO_3 (AOAC (Association of Analytical Chemists), 1995). The digest was transferred to a 25-ml volumetric flask, and the volume was adjusted to 25 ml with deionized water. A blank digest was prepared in a similar manner. Mineral content, expressed as mg mineral/kg DW, was determined by inductively coupled plasma atomic emission spectrometry (ICAP6000, Thermo Fisher Scientific).

2.4. Index of nutritional quality

The index of nutritional quality (INQ) was calculated according to the following formula (Venom, 2013):

$$\text{INQ} = (\text{Nutrient amount in 100 g DW sweet potato leaves}/\text{Chinese NRV})/(\text{Calories in 100 g DW sweet potato leaves}/\text{Average energy intake}),$$

where the Chinese nutrient reference value (NRV) for protein, fat, carbohydrate, and fiber are 60 g, ⩽60 g, 300 g, and 25 g, respectively; the NRV for calcium (Ca), phosphorus (P), potassium (K), sodium (Na), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) are 800 mg, 700 mg, 2000 mg, 2000 mg, 300 mg, 15 mg, 15 mg, 1.5 mg, and 3 mg, respectively; and the average energy intake is 2000 kcal (Chinese Nutrient Reference Value).

2.5. Total polyphenol content

Total polyphenol content (TPC) was measured by the Folin–Ciocalteu method (Yoshimoto et al., 2002). Briefly, 1 g of leaf powder was extracted with 20 ml of 70% (v/v) ethanol for 30 min at 50 °C and subjected to ultrasonic wave treatment. Following centrifugation at 5000g for 10 min at 4 °C, the residue was re-extracted twice with 70% ethanol as described above. The supernatants were pooled, concentrated in a rotary evaporator, and freeze-dried, thereby obtaining a crude extract. The crude extract was dissolved in 100 ml distilled water; an aliquot (0.5 ml) was mixed with 1.0 ml of Folin–Ciocalteu reagent (Sigma–Aldrich, Inc., St. Louis, MO, USA), previously diluted 10 times, and allowed to react at 30 °C for 30 min. Subsequently, 2.0 ml of saturated Na_2CO_3 (10%, w/v) was added to the mixture. Following 30 min, absorbance was measured at 736 nm in a UV1101 spectrophotometer (Hitachi, Japan). A calibration curve consisting of chlorogenic acid (CHA) standards (Sigma–Aldrich, Inc., St. Louis, MO, USA), ranging from 0.02 to 0.10 mg/ml, was prepared. TPC was expressed as CHA equivalents (CHAE) on a DW basis.

2.6. Antioxidant activity

Antioxidant activity in leaf powder samples was determined in triplicate using an automated photochemiluminescent system (Photochem, Analytik Jena AG, Germany), which measures the capacity of a sample to quench free radicals. This system is based on a controlled photochemical generation of radicals, part of which are quenched by antioxidants present in the sample. The remaining radicals in the sample are quantified by a sensitive chemiluminescence-detection method as reported by Cofrades et al. (2011). Briefly, 1 g of leaf powder sample was extracted with 20 ml of 70% (v/v) ethanol for 30 min at 50 °C and subjected to ultrasonic wave treatment. Following centrifugation at 5000g for 10 min at 4 °C, the residue was re-extracted twice with 70% ethanol as described above. The supernatants were pooled, concentrated in a rotary evaporator, and freeze-dried, thereby obtaining a crude extract. The crude extract was dissolved in 100 ml distilled water; a 20-μl aliquot was used in a commercial kit for antioxidant capacity determination. Ascorbic acid (Sigma–Aldrich, Inc., St. Louis, MO, USA) was used as the standard. The results were expressed as ascorbic acid equivalents (ACE) relative to sample weight (mg ACE/mg DW).

2.7. Statistical analyses

Experiments were performed in triplicate. The results were expressed as mean ± SD (standard deviation). Statistical analyses were performed using SAS version 8.1 software (SAS Institute Inc., Cary, NC, USA). Statistical significance was set at $p < 0.05$.

3. Results and discussion

3.1. Proximate composition

Table 1 shows the proximate composition of sweet potato leaves. The moisture content ranged between 84.09 and 88.92 g/100 g FW. Xushu No. 053601 had the highest moisture content (88.92 ± 0.34 g/100 g FW), while Sushu No. 16 had the lowest moisture content (84.09 ± 0.81 g/100 g FW). The moisture contents obtained in this study were similar to those reported by Ishida et al. (2000). The maturity of sweet potato leaves could have an influence on moisture content.

Shi No. 5 had the highest crude protein content (31.08 ± 0.09 g/100 g DW), whereas Shangshu No. 19 (spring) had the lowest crude protein content (16.69 ± 0.09 g/100 g DW). There were significant differences in protein content among the cultivars ($p \leqslant 0.05$). Our results were similar to those reported by Ishida et al. (2000), who analyzed the crude protein content of two sweet potato cultivar leaves in Japan: Koganesengan (KS) and Beniazuma (BA). The authors reported that the crude protein content was 29.5 g/

Table 1
(A) Moisture, crude protein, crude fiber, and crude fat contents of leaves of 40 sweet potato cultivars (g/100 g DW). (B) Carbohydrate, ash, and gross energy contents of leaves of 40 sweet potato cultivars (g/100 g DW).

A

No.	Cultivar	Moisture[a]	Crude protein	Crude fiber	Crude fat
1	Ximeng No. 1	88.70 ± 1.81a	25.66 ± 0.63hi	12.76 ± 0.05abcd	3.06 ± 0.15qr
2	Jinyu No. 1	88.10 ± 2.03a	27.53 ± 0.33f	11.28 ± 0.02 cdefghijklm	3.43 ± 0.06lmn
3	Jishu	87.60 ± 0.23a	29.27 ± 0.02c	11.26 ± 0.06 cdefghijklmn	3.99 ± 0.11gh
4	Shi No. 5	87.95 ± 1.85a	31.08 ± 0.09a	11.06 ± 0.07 cdefghijklmn	5.13 ± 0.09ab
5	Xushu No. 55-2	87.85 ± 0.12a	29.08 ± 0.35 cd	10.62 ± 0.05 efghijklmn	4.88 ± 0.12c
6	Jishu No. 22	87.57 ± 0.58a	27.15 ± 0.13 fg	12.98 ± 0.07abc	4.90 ± 0.04c
7	Yanshu No. 25	87.33 ± 0.93ab	23.46 ± 0.21mn	11.26 ± 0.05 cdefghijklmn	4.08 ± 0.06 fg
8	Xushu No. 23	84.54 ± 0.66bc	30.53 ± 0.32b	11.36 ± 0.00cdefghijklm	4.95 ± 0.06bc
9	Sushu No. 14	87.63 ± 0.16a	26.75 ± 0.16 g	11.03 ± 0.10 cdefghijklmn	4.47 ± 0.15d
10	Wanshu No. 5	86.79 ± 0.19abc	27.20 ± 0.12 fg	12.45 ± 0.17abcdefg	5.23 ± 0.18a
11	Longshu No. 9	86.25 ± 0.69abc	25.71 ± 0.04hi	13.00 ± 0.02abc	4.90 ± 0.12c
12	Hongxinwang	87.52 ± 0.31a	24.72 ± 0.17j	10.55 ± 0.54 fghijklmn	3.71 ± 0.08ijk
13	Xushu No. 053601	88.92 ± 0.34a	23.43 ± 0.11mno	10.04 ± 0.50 jklmn	3.75 ± 0.01ij
14	Nongda No. 6-2	88.84 ± 1.02a	24.21 ± 0.17kl	9.86 ± 0.35 klmn	3.84 ± 0.16hi
15	Miyuan No. 6	88.59 ± 0.53a	23.49 ± 0.43mn	9.25 ± 0.38mn	3.97 ± 0.04gh
16	Yuzi No. 7	87.52 ± 0.20a	21.12 ± 0.25w	10.68 ± 1.15 defghijklmn	2.24 ± 0.08uv
17	Beijing No. 553	86.75 ± 0.87abc	22.03 ± 0.01tu	9.71 ± 1.50lmn	5.17 ± 0.10a
18	Xinong No.1	87.78 ± 0.62a	18.35 ± 0.01xy	10.19 ± 0.85 ijklmn	5.28 ± 0.15a
19	Jishu No.04150	87.82 ± 1.16a	23.18 ± 0.13nop	10.24 ± 0.69 hijklmn	4.22 ± 0.04ef
20	Pushu No.53	88.28 ± 1.02a	24.04 ± 0.11 l	11.33 ± 0.46 cdefghijklm	4.39 ± 0.16de
21	Xushu No. 22-1	86.81 ± 0.22abc	22.96 ± 0.25opq	11.88 ± 0.93bcdefghijk	2.08 ± 0.06v
22	Shangshu No. 19 (spring)	88.56 ± 0.14a	16.69 ± 0.09A	10.01 ± 0.75 jklmn	2.94 ± 0.10rs
23	Shangshu No. 19 (summer)	87.85 ± 0.65a	17.92 ± 0.11yz	9.15 ± 0.49n	2.85 ± 0.16s
24	Sushu No. 16	84.09 ± 0.81c	27.55 ± 0.35f	12.70 ± 0.35abcde	2.37 ± 0.08tu
25	Chuanshu No. 294	87.76 ± 0.14a	28.57 ± 0.04e	12.32 ± 0.74abcdefgh	2.53 ± 0.01t
26	Xinxiang No. 1	86.33 ± 0.90abc	28.62 ± 0.08de	13.11 ± 0.72abc	2.42 ± 0.03tu
27	Xushu No. 038008	86.75 ± 3.31abc	25.94 ± 0.06 h	11.54 ± 0.68bcdefghijkl	3.17 ± 0.04pq
28	Yanzi No. 337	88.65 ± 2.56a	23.77 ± 0.19 lm	10.33 ± 0.79 ghijklmn	3.57 ± 0.12jkl
29	Shanchuanzi	88.76 ± 1.44a	21.46 ± 0.13vw	11.26 ± 1.19 cdefghijklmn	3.25 ± 0.06nop
30	Pushu No. 17	88.89 ± 1.69a	18.62 ± 0.11x	14.26 ± 0.38a	3.16 ± 0.01pq
31	Jinong No. 2694	86.20 ± 1.44abc	25.26 ± 0.26i	10.82 ± 1.28 defghijklmn	3.31 ± 0.08nop
32	Fushu No. 2	88.53 ± 2.36a	24.59 ± 0.33jk	12.10 ± 1.02bcdefghij	3.81 ± 0.08hi
33	Ningzi No. 23-1	88.45 ± 2.19a	22.76 ± 0.35pqr	13.00 ± 1.02abc	3.54 ± 0.01klm
34	Langshu No. 7-12	88.42 ± 1.90a	22.25 ± 0.01stu	12.40 ± 0.58abcdefg	3.89 ± 0.02hi
35	Jingshu No. 6	87.24 ± 2.64ab	23.76 ± 0.07 lm	12.70 ± 0.49abcde	3.27 ± 0.06nop
36	Ningzi No. 1	87.53 ± 2.55a	22.45 ± 0.26rst	13.59 ± 1.00ab	3.37 ± 0.07mno
37	Yuzi No. 263	87.93 ± 0.37a	22.76 ± 0.01pqr	13.13 ± 0.67abc	3.22 ± 0.02opq
38	Xushu No. 26	88.15 ± 2.14a	22.63 ± 0.07qrs	12.20 ± 1.80abcdefghi	2.93 ± 0.16rs
39	Jishu No. 65	87.58 ± 1.53a	21.80 ± 0.56uv	11.81 ± 1.29bcdefghijkl	3.30 ± 0.00nop
40	Xushu No. 22 (spring)	87.68 ± 1.39a	17.53 ± 0.29z	12.62 ± 0.23abcdef	3.04 ± 0.01qrs

B

No.	Cultivar	Carbohydrate	Gross energy[b]	Ash
1	Ximeng No. 1	46.43 ± 0.53lmn	386.84 ± 0.42v	12.11 ± 0.04bc
2	Jinyu No. 1	47.05 ± 0.27 lm	398.64 ± 0.88st	10.72 ± 0.01cdef
3	Jishu	42.03 ± 0.03q	404.68 ± 1.05q	13.46 ± 0.08ab
4	Shi No. 5	43.16 ± 0.08opq	418.80 ± 0.81i	9.59 ± 0.01defgh
5	Xushu No. 55-2	44.01 ± 0.21nopq	400.71 ± 1.38rs	11.42 ± 0.00 cd
6	Jishu No. 22	44.55 ± 0.02mnopq	412.51 ± 0.13 m	10.43 ± 0.03cdefg
7	Yanshu No. 25	47.50 ± 0.16kl	390.20 ± 0.41u	13.72 ± 0.02ab
8	Xushu No. 23	42.82 ± 0.22pq	407.08 ± 0.60op	10.35 ± 0.05cdefg
9	Sushu No. 14	43.10 ± 0.12opq	375.40 ± 1.16w	14.66 ± 0.00a
10	Wanshu No. 5	44.51 ± 0.43mnopq	404.61 ± 1.37q	10.63 ± 0.07cdef
11	Longshu No. 9	45.73 ± 0.10lmno	401.49 ± 0.64r	10.67 ± 0.03cdef
12	Hongxinwang	51.71 ± 0.93ij	413.09 ± 0.58 m	9.31 ± 0.46efgh
13	Xushu No. 053601	54.69 ± 1.27cdefgh	426.51 ± 3.28def	8.10 ± 1.20hi
14	Nongda No. 6-2	53.00 ± 0.57efghi	416.46 ± 2.06ijk	9.09 ± 0.64fghi
15	Miyuan No. 6	54.32 ± 0.47defghi	423.37 ± 2.16gh	8.98 ± 0.79fghi
16	Yuzi No. 7	57.30 ± 1.34bc	427.66 ± 1.53cde	8.67 ± 0.59ghi
17	Beijing No. 553	55.26 ± 2.34bcdefg	422.01 ± 0.01 h	7.83 ± 1.30hi
18	Xinong No. 1	57.69 ± 1.99b	417.56 ± 0.75ijk	8.50 ± 1.45hi
19	Jishu No. 04150	53.57 ± 0.41defghi	424.97 ± 0.35 fg	8.79 ± 1.38ghi
20	Pushu No. 53	51.84 ± 1.61hij	418.30 ± 0.19ij	8.41 ± 1.68hi
21	Xushu No. 22-1	53.97 ± 0.01defghi	415.56 ± 0.74kl	9.11 ± 1.13fghi
22	Shangshu No. 19 (spring)	61.36 ± 0.90a	405.34 ± 0.14pq	9.01 ± 2.33fghi
23	Shangshu No. 19 (summer)	58.02 ± 1.30b	398.28 ± 1.01t	12.07 ± 0.89bc
24	Sushu No. 16	46.97 ± 0.82 lm	409.15 ± 0.99no	10.42 ± 1.38cdefg
25	Chuanshu No. 294	45.52 ± 1.30lmnop	409.81 ± 0.36n	11.06 ± 0.76cde
26	Xinxiang No. 1	44.34 ± 0.31mnopq	398.58 ± 1.81st	11.51 ± 0.69c
27	Xushu No. 038008	50.13 ± 1.60jk	428.31 ± 1.33 cd	9.22 ± 1.41efghi
28	Yanzi No. 337	54.28 ± 0.20defghi	437.86 ± 0.92a	8.05 ± 1.33hi

Table 1 (*continued*)

B				
No.	Cultivar	Carbohydrate	Gross energy[b]	Ash
29	Shanchuanzi	55.59 ± 0.79bcdef	425.88 ± 0.10ef	8.45 ± 0.64hi
30	Pushu No. 17	56.04 ± 0.99bcd	417.98 ± 0.31ij	7.92 ± 0.95hi
31	Jinong No. 2694	52.80 ± 1.84fghij	434.71 ± 0.45b	7.81 ± 0.97hi
32	Fushu No. 2	51.72 ± 0.71ij	438.48 ± 0.09a	7.79 ± 0.86hi
33	Ningzi No. 23-1	52.43 ± 1.15ghij	414.54 ± 2.77 lm	8.28 ± 0.53hi
34	Langshu No. 7-12	54.04 ± 0.72defghi	428.40 ± 0.67 cd	7.43 ± 0.19i
35	Jingshu No. 6	51.59 ± 0.09ij	428.50 ± 0.74 cd	8.68 ± 0.68ghi
36	Ningzi No. 1	51.63 ± 1.30ij	429.65 ± 0.90c	8.97 ± 0.61fghi
37	Yuzi No. 263	52.18 ± 1.24hij	419.32 ± 0.56i	8.72 ± 0.81ghi
38	Xushu No. 26	54.10 ± 1.32defghi	435.16 ± 0.41b	8.15 ± 0.78hi
39	Jishu No. 65	55.70 ± 1.50bcde	434.20 ± 0.14b	7.39 ± 0.86i
40	Xushu No. 22 (spring)	57.23 ± 0.73bc	412.99 ± 0.18 m	9.59 ± 1.01defgh

Data are means ± SD ($n \geqslant 2$). Values within columns with different letters are significantly different ($p < 0.05$).
[a] Moisture content was expressed in g/100 g FW.
[b] Gross energy was expressed in kcal/100 g DW.

100 g DW in KS and 24.5 g/100 g DW in BA. Additionally, the authors reported that the average crude protein content in fresh sweet potato leaves (2.99 g/100 g FW) was higher than that of sweet potato roots (1.28–2.13 g/100 g FW) and of fresh vegetables (1.9 g/100 g FW) (FAIS Food Composition Table, 2013), but similar to that of milk (3.3 g/100 g FW).

Crude fiber content varied among the sweet potato cultivars (9.15 ± 0.49 to 14.26 ± 0.38 g/100 g DW; Table 1A). Pushu No. 17 had the highest crude fiber content (14.26 ± 0.38 g/100 g DW), while Shangshu No. 19 (summer) had the lowest crude fiber content (9.15 ± 0.49 g/100 g DW). The average crude fiber content was 11.55 ± 1.26 g/100 g DW (1.43 g/100 g FW), which is lower

Table 2
(A) Macroelement composition of leaves of 40 sweet potato cultivars (mg/100 g DW). (B) Microelement composition of leaves of 40 sweet potato cultivars (mg/100 g DW).

A						
No.	Cultivar	Ca	K	P	Mg	Na
1	Ximeng No. 1	1135.5 ± 43.8	4195.5 ± 100.5	688.0 ± 67.8	258.5 ± 8.6	8.06 ± 0.55
2	Jinyu No. 1	1110.1 ± 5.6	3423.0 ± 24.0	131.1 ± 3.3	336.7 ± 2.3	50.97 ± 2.04
3	Jishu	1520.1 ± 175.5	4280.6 ± 37.0	296.0 ± 72.1	299.3 ± 4.3	832.31 ± 68.84
4	Shi No. 5	892.7 ± 46.2	3065.7 ± 86.7	450.2 ± 11.4	329.8 ± 6.1	56.10 ± 2.58
5	Xushu No. 55-2	1389.7 ± 7.6	2881.8 ± 71.6	538.3 ± 26.6	426.6 ± 1.8	54.66 ± 1.18
6	Jishu No. 22	972.7 ± 24.4	3506.2 ± 112.1	728.9 ± 9.9	271.0 ± 6.2	101.79 ± 0.58
7	Yanshu No. 25	1468.2 ± 7.0	3863.3 ± 3.0	598.5 ± 18.9	295.3 ± 0.7	197.17 ± 0.27
8	Xushu No. 23	922.0 ± 1.3	3071.1 ± 10.2	888.4 ± 28.2	303.2 ± 0.6	16.19 ± 0.24
9	Sushu No. 14	1958.1 ± 24.1	3970.5 ± 76.2	736.5 ± 24.0	361.2 ± 2.2	82.96 ± 1.51
10	Wanshu No. 5	921.1 ± 8.3	3466.9 ± 15.3	1007.8 ± 27.2	220.2 ± 2.4	137.53 ± 0.11
11	Longshu No. 9	945.9 ± 28.9	3514.4 ± 18.9	993.9 ± 49.4	311.7 ± 10.4	43.25 ± 0.29
12	Hongxinwang	284.5 ± 0.6	913.3 ± 2.0	975.3 ± 0.3	438.3 ± 2.9	391.30 ± 1.10
13	Xushu No. 053601	364.7 ± 0.4	1077.9 ± 0.3	1150.2 ± 1.7	468.4 ± 0.3	91.60 ± 0.10
14	Nongda No. 6-2	573.8 ± 1.4	914.4 ± 0.8	906.4 ± 0.9	675.3 ± 4.0	14.00 ± 0.00
15	Miyuan No. 6	319.8 ± 0.1	1043.0 ± 0.2	1296.5 ± 2.2	457.7 ± 1.9	51.95 ± 0.05
16	Yuzi No. 7	294.3 ± 0.4	983.6 ± 1.4	1137.0 ± 0.7	422.2 ± 1.0	240.80 ± 0.50
17	Beijing No. 553	976.4 ± 1.3	479.3 ± 1.0	763.7 ± 0.4	692.0 ± 0.9	243.65 ± 0.05
18	Xinong No. 1	1071.0 ± 5.6	639.2 ± 0.2	880.9 ± 0.6	716.0 ± 1.1	164.65 ± 0.35
19	Jishu No. 04150	258.5 ± 0.5	1059.8 ± 1.3	1580.4 ± 2.5	471.7 ± 1.6	76.75 ± 0.05
20	Pushu No. 53	491.2 ± 0.8	929.5 ± 2.5	1142.3 ± 1.1	234.6 ± 0.1	156.05 ± 0.05
21	Xushu No. 22-1	229.7 ± 0.4	978.7 ± 0.8	1666.6 ± 1.2	418.6 ± 0.1	308.20 ± 0.50
22	Shangshu No. 19 (spring)	881.5 ± 1.9	794.9 ± 0.4	927.4 ± 0.3	712.0 ± 0.8	47.20 ± 0.00
23	Shangshu No. 19 (summer)	736.6 ± 4.1	1395.5 ± 4.8	990.9 ± 1.0	608.6 ± 0.6	39.45 ± 0.05
24	Sushu No. 16	510.0 ± 0.9	1292.9 ± 1.8	1808.7 ± 0.2	518.8 ± 0.0	37.60 ± 0.10
25	Chuanshu No. 294	1043.6 ± 1.3	1042.4 ± 0.4	1704.0 ± 2.2	598.3 ± 0.3	56.40 ± 0.00
26	Xinxiang No. 1	807.3 ± 1.5	978.7 ± 2.8	1693.9 ± 1.5	910.5 ± 1.3	420.35 ± 1.95
27	Xushu No. 038008	404.7 ± 3.4	962.5 ± 3.4	1072.7 ± 0.6	280.8 ± 0.8	19.30 ± 0.40
28	Yanzi No. 337	456.4 ± 2.8	760.3 ± 1.5	1060.7 ± 1.1	293.3 ± 4.6	140.37 ± 1.67
29	Shanchuanzi	588.4 ± 4.1	709.6 ± 2.1	1169.9 ± 0.3	298.2 ± 2.9	396.25 ± 3.75
30	Pushu No. 17	503.1 ± 3.6	768.9 ± 0.4	1273.8 ± 0.7	299.5 ± 0.9	322.79 ± 4.29
31	Jinong No. 2694	598.9 ± 0.8	790.0 ± 1.5	1494.3 ± 4.8	303.6 ± 2.6	115.26 ± 3.16
32	Fushu No. 2	517.9 ± 4.1	820.6 ± 0.8	1573.7 ± 4.6	314.1 ± 4.1	34.20 ± 0.80
33	Ningzi No. 23-1	505.0 ± 1.7	810.2 ± 1.1	1853.8 ± 6.9	277.1 ± 2.7	213.65 ± 7.55
34	Langshu No. 7-12	408.8 ± 2.3	772.0 ± 2.1	1759.4 ± 2.8	273.7 ± 2.6	16.04 ± 0.14
35	Jingshu No. 6	423.3 ± 0.6	1060.0 ± 1.2	2292.7 ± 5.2	290.2 ± 1.3	154.06 ± 2.44
36	Ningzi No. 1	429.7 ± 6.6	720.3 ± 1.7	2206.3 ± 3.9	321.6 ± 1.9	548.05 ± 4.55
37	Yuzi No. 263	483.8 ± 5.3	839.3 ± 3.9	2186.8 ± 5.5	276.7 ± 2.2	317.54 ± 0.54
38	Xushu No. 26	379.0 ± 2.0	859.1 ± 3.0	2639.8 ± 1.3	267.5 ± 2.4	83.74 ± 0.64
39	Jishu No. 65	508.0 ± 4.6	789.9 ± 4.3	2169.7 ± 3.9	279.8 ± 0.3	20.99 ± 0.22
40	Xushu No. 22 (spring)	1509.0 ± 3.1	580.2 ± 2.2	1493.4 ± 4.7	676.8 ± 5.4	96.13 ± 0.33

(*continued on next page*)

B

No.	Cultivar	Fe	Mn	Zn	Cu
1	Ximeng No. 1	10.06 ± 0.25	3.11 ± 0.01	2.74 ± 0.09	1.62 ± 0.09
2	Jinyu No. 1	8.39 ± 0.18	5.53 ± 0.23	2.51 ± 0.03	1.61 ± 0.02
3	Jishu	10.09 ± 1.06	4.03 ± 0.33	2.58 ± 0.19	1.86 ± 0.25
4	Shi No. 5	8.45 ± 0.33	3.12 ± 0.12	2.76 ± 0.10	1.58 ± 0.05
5	Xushu No. 55-2	9.51 ± 1.18	4.04 ± 0.08	2.72 ± 0.00	1.70 ± 0.01
6	Jishu No. 22	10.26 ± 0.21	3.20 ± 0.09	2.51 ± 0.08	1.59 ± 0.06
7	Yanshu No. 25	14.52 ± 0.26	5.00 ± 0.03	2.00 ± 0.03	1.41 ± 0.01
8	Xushu No. 23	9.08 ± 0.29	3.29 ± 0.01	3.23 ± 0.04	1.62 ± 0.01
9	Sushu No. 14	11.09 ± 0.28	3.98 ± 0.06	2.27 ± 0.10	1.54 ± 0.04
10	Wanshu No. 5	8.93 ± 1.00	2.30 ± 0.01	2.55 ± 0.02	1.62 ± 0.00
11	Longshu No. 9	6.90 ± 0.25	3.69 ± 0.03	2.46 ± 0.00	1.67 ± 0.01
12	Hongxinwang	2.45 ± 0.02	2.14 ± 0.00	1.98 ± 0.00	1.03 ± 0.00
13	Xushu No. 053601	3.71 ± 0.00	2.76 ± 0.00	2.28 ± 0.00	0.97 ± 0.00
14	Nongda No. 6-2	4.59 ± 0.02	3.03 ± 0.01	1.85 ± 0.00	1.14 ± 0.00
15	Miyuan No. 6	4.15 ± 0.01	2.53 ± 0.01	2.05 ± 0.00	1.05 ± 0.00
16	Yuzi No. 7	4.39 ± 0.01	2.94 ± 0.00	1.72 ± 0.00	0.85 ± 0.00
17	Beijing No. 553	8.47 ± 0.00	6.23 ± 0.00	1.43 ± 0.00	0.80 ± 0.00
18	Xinong No. 1	8.53 ± 0.00	5.10 ± 0.01	1.45 ± 0.00	0.84 ± 0.00
19	Jishu No. 04150	3.96 ± 0.01	2.11 ± 0.01	2.04 ± 0.00	0.95 ± 0.01
20	Pushu No. 53	4.72 ± 0.01	2.70 ± 0.00	1.84 ± 0.00	0.89 ± 0.00
21	Xushu No. 22-1	1.92 ± 0.00	1.71 ± 0.00	2.04 ± 0.00	0.90 ± 0.00
22	Shangshu No. 19 (spring)	9.81 ± 0.01	4.85 ± 0.00	1.20 ± 0.00	0.67 ± 0.00
23	Shangshu No. 19 (summer)	19.64 ± 0.03	4.45 ± 0.00	1.48 ± 0.00	0.77 ± 0.00
24	Sushu No. 16	4.96 ± 0.01	2.14 ± 0.01	2.08 ± 0.00	1.09 ± 0.00
25	Chuanshu No. 294	4.39 ± 0.00	2.55 ± 0.00	2.00 ± 0.00	0.99 ± 0.00
26	Xinxiang No. 1	5.95 ± 0.01	2.90 ± 0.00	1.99 ± 0.00	1.09 ± 0.00
27	Xushu No. 038008	6.90 ± 0.02	3.76 ± 0.04	2.81 ± 0.02	1.38 ± 0.03
28	Yanzi No. 337	6.29 ± 0.02	3.79 ± 0.02	2.49 ± 0.03	1.18 ± 0.01
29	Shanchuanzi	9.76 ± 0.03	5.04 ± 0.02	2.21 ± 0.02	1.28 ± 0.02
30	Pushu No. 17	6.26 ± 0.03	4.17 ± 0.02	2.11 ± 0.05	1.30 ± 0.02
31	Jinong No. 2694	9.50 ± 0.01	6.29 ± 0.01	2.53 ± 0.04	1.35 ± 0.04
32	Fushu No. 2	8.80 ± 0.02	5.73 ± 0.01	2.81 ± 0.03	1.59 ± 0.02
33	Ningzi No. 23-1	8.44 ± 0.02	4.63 ± 0.04	2.97 ± 0.01	1.31 ± 0.03
34	Langshu No. 7-12	7.38 ± 0.03	4.82 ± 0.01	2.46 ± 0.04	1.20 ± 0.01
35	Jingshu No. 6	8.51 ± 0.01	4.86 ± 0.01	2.74 ± 0.03	1.45 ± 0.03
36	Ningzi No. 1	8.28 ± 0.02	5.97 ± 0.05	2.43 ± 0.00	1.53 ± 0.02
37	Yuzi No. 263	9.10 ± 0.04	6.21 ± 0.02	2.36 ± 0.03	1.25 ± 0.03
38	Xushu No. 26	7.93 ± 0.02	4.12 ± 0.04	2.70 ± 0.02	1.37 ± 0.02
39	Jishu No. 65	8.08 ± 0.04	4.33 ± 0.02	2.43 ± 0.01	1.52 ± 0.04
40	Xushu No. 22 (spring)	21.77 ± 0.33	10.92 ± 0.18	1.84 ± 0.01	1.48 ± 0.03

Data are means ± SD ($n \geqslant 2$).

than the NRV for fiber (25 g). Several factors contribute to the differences in crude fiber content including genotype, maturity and nutritional composition.

The crude fat content was the highest in Xinong No. 1 (5.28 ± 0.15 g/100 g DW) and lowest in Xushu No. 22-1 (2.08 ± 0.06 g/100 g DW), with an average of 3.69 ± 0.88 g/100 g DW. There were significant differences in crude fat content among the sweet potato cultivars ($p \leqslant 0.05$; Table 1A). The average crude fat content (3.69 ± 0.88 g/100 g DW; 0.46 g/100 g FW) was higher than that of sweet potato roots (0.33 g/100 g FW), but lower than sweet potato stems (0.53 g/100 g FW) (Ishida et al., 2000). Fat is involved in the insulation of body organs and in the maintenance of body temperature and cell function. Additionally, fats are sources of omega-3 and omega-6 fatty acids and are required for the digestion, absorption, and transport of vitamins A, D, E, and K.

The carbohydrate and ash contents were 42.03–61.36 g/100 g DW and 7.39–14.66 g/100 g DW, respectively. The average carbohydrate content was 51.00 ± 5.05 g/100 g DW and the average ash content was 9.63 ± 1.78 g/100 g DW. Gross energy ranged from 375.40 ± 1.16 kcal/100 g DW to 438.48 ± 0.09 kcal/100 g DW, with an average of 415.34 ± 14.59 kcal/g DW (Table 1B).

3.2. Mineral content

Table 2 shows the mineral content of the sweet potato leaves. Minerals are classified into two groups: macroelements (Ca, K, P, Mg, and Na) and microelements (Fe, Mn, Zn, and Cu). In this study, Ca ranged from 229.7 ± 0.4 (Xushu No. 22-1) to 1958.1 ± 24.1 (Sushu No. 14) mg/100 g DW; K ranged from 479.3 ± 1.0 (Beijing No. 553) to 4280.6 ± 37.0 (Jishu) mg/100 g DW; P ranged from 131.1 ± 3.3 (Jinyu No. 1) to 2639.8 ± 1.3 (Xushu No. 26) mg/100 g DW; Mg ranged from 220.2 ± 2.4 (Wanshu No. 5) to 910.5 ± 1.3 (Xinxiang No. 1) mg/100 g DW; and Na ranged from 8.06 ± 0.55 (Ximeng No. 1) to 832.31 ± 68.84 (Jishu) mg/100 g DW (Table 2A).

The most abundant macroelement was K (average content of 1625.1 mg/100 g DW), followed by P (average content of 1248.2 mg/100 g DW), Ca (average content of 744.9 mg/100 g DW), Mg (average content of 405.2 mg/100 g DW), and Na (average content of 159.98 mg/100 g DW). In this study, the K/Na ratios determined in Ximeng No. 1 (520.39), Xushu No. 23 (189.73), Longshu No. 9 (81.26), Jinyu No. 1 (67.16), Nongda No. 6-2 (65.31), Shi No. 5 (54.64), Xushu No. 55-2 (52.73), Xushu No. 038008 (49.88), Langshu No. 7-12 (48.12), Sushu No. 14 (47.86), Jishu No. 65 (37.64), Shangshu No. 19 (summer) (35.37), Jishu No. 22 (34.45), Sushu No. 16 (34.39), Wanshu No. 5 (25.21), Fushu No. 2 (23.99), Miyuan No. 6 (20.08), Yanshu No. 25 (19.59), and Chuanshu No. 294 (18.48) were higher than those of spinach (18.10) and water-spinach (11.56) (Taira et al., 2013). K is important for the maintenance of fluid and electrolyte balance in body cells. Insufficient intake of K from the diet leads to hypokalemia, which contributes to life-threatening conditions such as cardiac arrhythmias and acute respiratory failure.

Table 3
(A) Index of nutritional quality (INQ) of leaves of 40 sweet potato cultivars: crude protein, crude fat, carbohydrate, crude fiber, K, and P. (B) Index of nutritional quality (INQ) of leaves of 40 sweet potato cultivars: Ca, Mg, Na, Fe, Mn, Zn, and Cu.

A

No.	Cultivar	Crude protein	Crude fat	Carbohydrate	Crude fiber	K	P
1	Ximeng No. 1	2	<1	<1	2	10	5
2	Jinyu No. 1	2	<1	<1	2	8	1
3	Jishu	2	<1	<1	2	10	2
4	Shi No. 5	3	<1	<1	2	7	3
5	Xushu No. 55-2	2	<1	<1	2	7	4
6	Jishu No. 22	2	<1	<1	3	8	5
7	Yanshu No. 25	2	<1	<1	2	9	4
8	Xushu No. 23	2	<1	<1	2	7	6
9	Sushu No. 14	2	<1	<1	2	9	5
10	Wanshu No. 5	2	<1	<1	2	8	7
11	Longshu No. 9	2	<1	<1	3	8	7
12	Hongxinwang	2	<1	<1	2	2	7
13	Xushu No. 053601	2	<1	<1	2	3	8
14	Nongda No. 6-2	2	<1	<1	2	2	6
15	Miyuan No. 6	2	<1	<1	2	2	9
16	Yuzi No. 7	2	<1	<1	2	2	8
17	Beijing No. 553	2	<1	<1	2	1	5
18	Xinong No. 1	2	<1	<1	2	2	6
19	Jishu No. 04150	2	<1	<1	2	3	11
20	Pushu No. 53	2	<1	<1	2	2	8
21	Xushu No. 22-1	2	<1	<1	2	2	11
22	Shangshu No. 19 (spring)	1	<1	1	2	2	6
23	Shangshu No. 19 (summer)	1	<1	<1	2	3	7
24	Sushu No. 16	2	<1	<1	2	3	12
25	Chuanshu No. 294	2	<1	<1	2	2	12
26	Xinxiang No. 1	2	<1	<1	3	2	12
27	Xushu No. 038008	2	<1	<1	2	2	7
28	Yanzi No. 337	2	<1	<1	2	2	7
29	Shanchuanzi	2	<1	<1	2	2	8
30	Pushu No. 17	2	<1	<1	3	2	9
31	Jinong No. 2694	2	<1	<1	2	2	10
32	Fushu No. 2	2	<1	<1	2	2	11
33	Ningzi No. 23-1	2	<1	<1	2	2	13
34	Langshu No. 7-12	2	<1	<1	2	2	12
35	Jingshu No. 6	2	<1	<1	2	3	16
36	Ningzi No. 1	2	<1	<1	3	2	15
37	Yuzi No. 263	2	<1	<1	3	2	15
38	Xushu No. 26	2	<1	<1	2	2	18
39	Jishu No. 65	2	<1	<1	2	2	15
40	Xushu No. 22 (spring)	1	<1	<1	2	1	10

B

No.	Cultivar	Ca	Mg	Na	Fe	Mn	Zn	Cu
1	Ximeng No. 1	7	4	<1	3	5	<1	5
2	Jinyu No. 1	7	5	<1	3	9	<1	5
3	Jishu	9	5	2	3	6	<1	6
4	Shi No. 5	5	5	<1	3	5	<1	5
5	Xushu No. 55-2	8	7	<1	3	6	<1	5
6	Jishu No. 22	6	4	<1	3	5	<1	5
7	Yanshu No. 25	9	5	<1	5	8	<1	4
8	Xushu No. 23	5	5	<1	3	5	1	5
9	Sushu No. 14	12	6	<1	4	6	<1	5
10	Wanshu No. 5	5	3	<1	3	4	<1	5
11	Longshu No. 9	6	5	<1	2	6	<1	5
12	Hongxinwang	2	7	<1	<1	3	<1	3
13	Xushu No. 053601	2	7	<1	1	4	<1	3
14	Nongda No. 6-2	3	11	<1	2	5	<1	4
15	Miyuan No. 6	2	7	<1	1	4	<1	3
16	Yuzi No. 7	2	7	<1	1	5	<1	3
17	Beijing No. 553	6	11	<1	3	10	<1	3
18	Xinong No. 1	6	11	<1	3	8	<1	3
19	Jishu No. 04150	2	7	<1	1	3	<1	3
20	Pushu No. 53	3	4	<1	2	4	<1	3
21	Xushu No. 22-1	1	7	<1	<1	3	<1	3
22	Shangshu No. 19 (spring)	5	11	<1	3	8	<1	2
23	Shangshu No. 19 (summer)	4	10	<1	6	7	<1	2
24	Sushu No. 16	3	8	<1	2	3	<1	3
25	Chuanshu No. 294	6	9	<1	1	4	<1	3
26	Xinxiang No. 1	5	14	1	2	5	<1	3
27	Xushu No. 038008	2	4	<1	2	6	<1	4
28	Yanzi No. 337	3	5	<1	2	6	<1	4

(continued on next page)

Table 3 (*continued*)

B								
No.	Cultivar	Ca	Mg	Na	Fe	Mn	Zn	Cu
29	Shanchuanzi	4	5	<1	3	8	<1	4
30	Pushu No. 17	3	5	<1	2	7	<1	4
31	Jinong No. 2694	4	5	<1	3	10	<1	4
32	Fushu No. 2	3	5	<1	3	9	<1	5
33	Ningzi No. 23-1	3	4	<1	3	7	<1	4
34	Langshu No. 7-12	2	4	<1	2	8	<1	4
35	Jingshu No. 6	3	5	<1	3	8	<1	5
36	Ningzi No. 1	3	5	1	3	9	<1	5
37	Yuzi No. 263	3	4	<1	3	10	<1	4
38	Xushu No. 26	2	4	<1	3	7	<1	4
39	Jishu No. 65	3	4	<1	3	7	<1	5
40	Xushu No. 22 (spring)	9	11	<1	7	17	<1	5

A food between 2 and 6 in the INQ ranking system is considered good, and above this is viewed as an excellent source.

In this study, the Mg content (average content of 405.2 mg/100 g DW; 50.2 mg/100 g FW) was similar to that reported by Ishida et al. (2000): 79 mg/100 g FW. As a result of its interaction with phosphate, Mg is essential in nucleic acid synthesis. Low levels of Mg have been associated with several diseases including asthma, diabetes, and osteoporosis.

Fe ranged from 1.92 ± 0.00 (Xushu No. 22–1) to 21.77 ± 0.33 (Xushu No. 22, spring) mg/100 g DW; Mn ranged from 1.71 ± 0.00 (Xushu No. 22-1) to 10.92 ± 0.18 (Xushu No. 22, spring) mg/100 g DW; Zn ranged from 1.20 ± 0.00 (Shangshu No. 19, spring) to 3.23 ± 0.04 (Xushu No. 23) mg/100 g DW; and Cu ranged from 0.67 ± 0.00 (Shangshu No. 19, spring) to 1.86 ± 0.25 (Jishu) mg/100 g DW (Table 2B).

The most abundant microelement was Fe (average content of 8.15 mg/100 g DW), followed by Mn (average content of 4.10 mg/100 g DW), Zn (average content of 2.27 mg/100 g DW), and Cu (average content of 1.28 mg/100 g DW). Even though heme iron from meat is more bioavailable than non-heme iron from

Table 4
Total polyphenol content (TPC) and antioxidant activity of leaves of 40 sweet potato cultivars.

No.	Cultivar	Total polyphenols (g CHAE/100 g DW)	Antioxidant activity (mg ACE/mg DW)
1	Ximeng No. 1	7.67 ± 0.31h	0.57 ± 0.01gh
2	Jinyu No. 1	4.03 ± 0.05m	0.26 ± 0.01o
3	Jishu	3.49 ± 0.04op	0.11 ± 0.01st
4	Shi No. 5	2.73 ± 0.02q	0.08 ± 0.01u
5	Xushu No. 55-2	3.41 ± 0.04op	0.10 ± 0.01tu
6	Jishu No. 22	5.36 ± 0.55k	0.22 ± 0.00p
7	Yanshu No. 25	6.91 ± 0.10i	0.12 ± 0.01s
8	Xushu No. 23	7.09 ± 0.12i	0.19 ± 0.00qr
9	Sushu No. 14	2.74 ± 0.03q	0.31 ± 0.01n
10	Wanshu No. 5	6.00 ± 0.03j	0.08 ± 0.01u
11	Longshu No. 9	5.07 ± 0.00kl	0.23 ± 0.01p
12	Hongxinwang	8.45 ± 0.05g	0.60 ± 0.00ef
13	Xushu No. 053601	11.36 ± 0.07b	0.66 ± 0.01d
14	Nongda No. 6-2	8.74 ± 0.14fg	0.47 ± 0.01j
15	Miyuan No. 6	11.66 ± 0.07b	0.58 ± 0.00fgh
16	Yuzi No. 7	12.30 ± 0.65a	0.82 ± 0.01a
17	Beijing No. 553	6.01 ± 0.02j	0.54 ± 0.00i
18	Xinong No. 1	6.70 ± 0.07i	0.69 ± 0.01c
19	Jishu No. 04150	12.46 ± 0.62a	0.73 ± 0.01b
20	Pushu No. 53	6.76 ± 0.07i	0.59 ± 0.01fg
21	Xushu No. 22-1	8.82 ± 0.10efg	0.62 ± 0.01e
22	Shangshu No. 19 (spring)	4.73 ± 0.12l	0.30 ± 0.00n
23	Shangshu No. 19 (summer)	6.76 ± 0.09i	0.40 ± 0.00k
24	Sushu No. 16	9.71 ± 0.36d	0.56 ± 0.01h
25	Chuanshu No. 294	5.44 ± 0.65k	0.29 ± 0.00n
26	Xinxiang No. 1	3.25 ± 0.04op	0.09 ± 0.01tu
27	Xushu No. 038008	3.62 ± 0.02no	0.39 ± 0.00kl
28	Yanzi No. 337	5.06 ± 0.14kl	0.21 ± 0.00pq
29	Shanchuanzi	6.92 ± 0.27i	0.35 ± 0.01m
30	Pushu No. 17	11.45 ± 0.13b	0.39 ± 0.00kl
31	Jinong No. 2694	10.17 ± 0.21c	0.39 ± 0.01kl
32	Fushu No. 2	5.31 ± 0.03k	0.22 ± 0.00p
33	Ningzi No. 23-1	4.02 ± 0.22mn	0.19 ± 0.02r
34	Langshu No. 7-12	8.97 ± 0.12ef	0.36 ± 0.00m
35	Jingshu No. 6	11.57 ± 0.21b	0.73 ± 0.01b
36	Ningzi No. 1	6.26 ± 0.07j	0.40 ± 0.02k
37	Yuzi No. 263	9.75 ± 0.29d	0.39 ± 0.00kl
38	Xushu No. 26	9.19 ± 0.50e	0.57 ± 0.01gh
39	Jishu No. 65	5.88 ± 0.16j	0.37 ± 0.01lm
40	Xushu No. 22 (spring)	3.13 ± 0.21pq	0.19 ± 0.01r

Data are means ± SD ($n \geqslant 2$). Values within columns with different letters are significantly different ($p < 0.05$).

vegetables, the intake of heme Fe/hemoglobin from red meat may increases the risk of colorectal cancer.

Mn is involved in the body antioxidant system, in glucose homeostasis, and in Ca mobilization (Mason, 2001). The NRV for Mn is 3 mg (GB28050-2011); therefore, 100 g DW of sweet potato leaves (i.e., 807.10 g FW of sweet potato leaves) supply 136.67% of the NRV of Mn for adults. Zn and Cu contents of sweet potato leaves were higher than that those of sweet potato roots (Ishida et al., 2000) and similar to that of spinach (Taira et al., 2013). Zn, which is a component of several metalloenzymes, is involved in DNA and RNA metabolism, signal transduction, and gene expression. Cu is involved in Fe absorption, enzymatic reactions, and collagen synthesis. Cu is important in preventing premature aging, increasing energy production, regulating heart rhythm, balancing

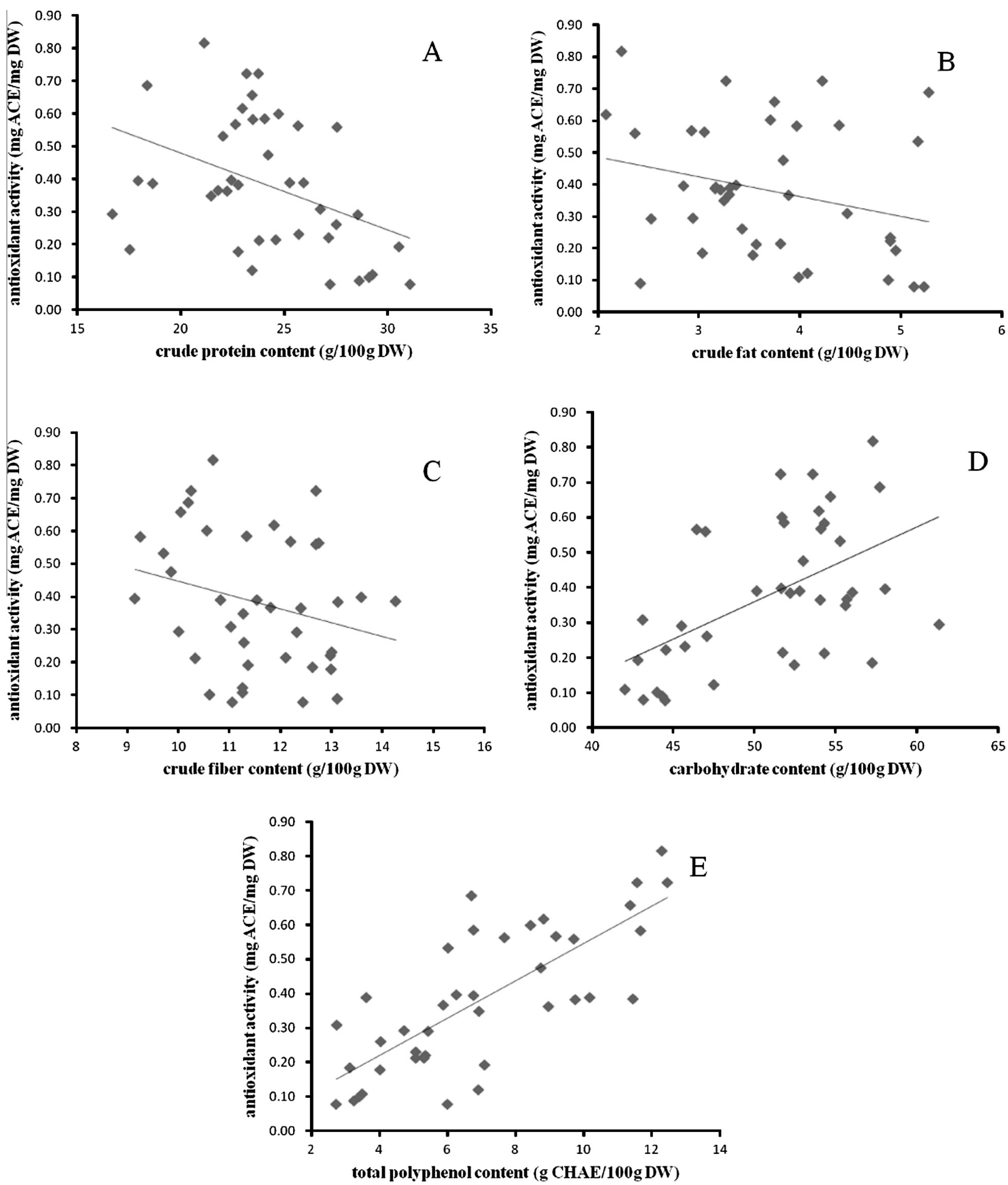

Fig. 1. (A) Correlation coefficient between crude protein content and antioxidant activity of sweet potato leaves ($R = -0.47896$; $p = 0.0020$). (B) Correlation coefficient between crude fat content and antioxidant activity of sweet potato leaves ($R = -0.26587$; $p = 0.0973$). (C) Correlation coefficient between crude fiber content and antioxidant activity of sweet potato leaves ($R = -0.26038$; $p = 0.1046$). (D) Correlation coefficient between carbohydrate content and antioxidant activity of sweet potato leaves ($R = 0.52816$; $p = 0.0005$). (E) Correlation coefficient between total polyphenol content and antioxidant activity of sweet potato leaves ($R = 0.76032$; $p < 0.0001$).

thyroid glands, reducing symptoms of arthritis, promoting wound healing, increasing red blood cell formation, and reducing cholesterol.

3.3. INQ

INQ is a measure of the relationship between the amount of a nutrient in single foods, meals and diets and the NRV. A food item with an INQ of 2–6 is considered to be a good source of a nutrient; a food item with an INQ > 6 is considered to be an excellent source of that particular nutrient (Venom, 2013). With the exception of Shangshu No. 19 (spring), Shangshu No. 19 (summer), and Xushu No. 22 (spring), all sweet potato cultivars were good sources of protein (Table 3A). Therefore, sweet potato leaves could be useful in populations with protein energy malnutrition. INQ of fiber was 2–6 (Table 3A). The mineral INQs revealed that leaves of most sweet potato cultivars were good sources of K, P, Ca, Mg, Fe, Mn, and Cu. Ximeng No. 1 was an excellent source of K (INQ = 10) and Ca (INQ = 7); Yuzi No. 7 was an excellent source of P (INQ = 8) and Mg (INQ = 7) (Table 3A and B).

3.4. TPC and antioxidant activity

TPC was determined by the Folin–Ciocalteu colorimetric method. The regression equation of the chlorogenic acid standard curve was $y = 8.7671x + 0.0068$ ($R^2 = 0.9994$). The TPC results are shown in Table 4. Jishu No. 04150 and Yuzi No. 7 had the highest TPC (12.46 ± 0.62 and 12.30 ± 0.65 g/100 g DW, respectively, without significant differences), whereas Shi No. 5 had the lowest TPC (2.73 ± 0.02 g/100 g DW). The average TPC was 7.08 g/100 g DW, which was similar to the findings reported by Islam et al. (2002) (1.42–17.1 g/100 g DW). There were significant differences ($p \leqslant 0.05$) in TPC among sweet potato cultivars probably attributed to differences in polyphenol oxidase activity, maturity, post-harvest processing methods, genotype, storage conditions, and nutrient composition, among others. In order of decreasing content, the polyphenols in sweet potato leaves are 3,5-di-*O*-caffeoylquinic, 4,5-di-*O*-caffeoylquinic acid, chlorogenic acid (3-*O*-caffeoylquinic acid), 3,4-di-*O*-caffeoylquinic acid, 3,4,5-tri-*O*-caffeoylquinic acid, and caffeic acid (Islam et al., 2002). The 3,4,5-tri-*O*-caffeoylquinic acid and 4,5-di-*O*-caffeoylquinic acid contents are 221 and 1183.30 mg/100 g DW, respectively (Islam et al., 2002). Sweet potato leaves contain bioactive polyphenols, which may have significant health promoting and medicinal effects in human health.

Antioxidant activity was determined by the photochemiluminescent method. The results are shown in Table 4. Yuzi No. 7 had the highest antioxidant activity (0.82 ± 0.01 mg ACE/mg DW), whereas Wanshu No. 5 and Shi No. 5 had the lowest antioxidant activity (0.08 ± 0.01 mg ACE/mg DW). There was no significant difference in TPC between Jishu No. 04150 and Yuzi No. 7; however, antioxidant activity was significantly different between these two cultivars. It suggested that the polyphenols of sweet potato leaves from the two cultivars mentioned above might contain different phenolic constituents, and even if the phenolic constituents were similar, the proportions of different phenolic constituents might be different between the two cultivars. In addition, sweet potato leaves from the two cultivars mentioned above might contain different contents of proximate composition which possess synergistic effect or antagonistic effect on the antioxidant activity of polyphenols. Additionally, there were significant differences in antioxidant activity among the sweet potato cultivars, probably attributed to TPC, polyphenol types, and nutrient composition.

The correlations between antioxidant activity and crude protein, crude fat, crude fiber, carbohydrate, and TPC are shown in Fig. 1A–E, respectively. The correlation coefficient between antioxidant activity and TPC ($R = 0.76032$; $p < 0.0001$) was the highest, followed by the correlation coefficient between antioxidant activity and carbohydrate content ($R = 0.52816$; $p = 0.0005$). There were negative correlation coefficients between antioxidant activity and crude protein, crude fat, and crude fiber contents. Therefore, polyphenols are considered to be the most important antioxidants in sweet potato leaves. Because of their diversity and wide distribution, plant polyphenols are the most important natural antioxidants, which play significant roles in the organoleptic and nutritional qualities of fruits and vegetables. Interestingly, there was a positive correlation between antioxidant activity and carbohydrate content. This result could be attributed to the protective role that carbohydrates have on polyphenols, i.e., carbohydrates prevent polyphenol oxidation.

4. Conclusion

There were significant differences in proximate composition among the sweet potato cultivars. Shi No. 5 had the highest crude protein content (31.08 ± 0.09 g/100 g DW), Pushu No. 17 had the highest crude fiber content (14.26 ± 0.38 g/100 g DW), and Xinong No. 1 had the highest crude fat content (5.28 ± 0.15 g/100 g DW). Ximeng No. 1 had a high K/Na ratio (520.39), followed by Xushu No. 23 (189.73), and Longshu No. 9 (81.26). High K/Na ratios are important in the prevention of hypertension and atherosclerosis. Xinxiang No. 1 had the highest Mg content and Yuzi No. 7 constituted an excellent source of polyphenols. Sweet potato leaves, which contain several nutrients and bioactive compounds, should be consumed as leafy vegetables in an attempt to reduce malnutrition, especially in developing countries.

Acknowledgements

The authors gratefully acknowledge the earmarked funds for the China Agriculture Research System (CARS-11-B-19) and the Fundamental Research Funds for Incremental Project Budget of Chinese Academy of Agricultural Sciences (No. 2013ZL014). The results obtained in this study reflect only the authors' view. The authors and corresponding affiliations are not liable for any damages resulting from the use of the information contained herein. The authors are grateful to the Crop Nutrition and Processing Characteristics Research Project of the Chinese Academy of Agricultural Sciences, the Support Plan of National Science and Technology (2012BAD29B03-03), and the Research Institute of Sweet Potato for providing the sweet potato cultivars used in this study.

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