ELSEVIER

Food Chemistry 68 (2000) 359–367

Food Chemistry

www.elsevier.com/locate/foodchem

Analytical, Nutritional and Clinical Methods Section

Nutritive evaluation on chemical components of leaves, stalks and stems of sweet potatoes (*Ipomoea batatas poir*)

Hiroshi Ishida [a,*], Hiroko Suzuno [a], Noriko Sugiyama [a], Satoshi Innami [b], Tadahiro Tadokoro [c], Akio Maekawa [c]

[a] *Department of Nutrition, Junior College of Tokyo University of Agriculture, 1-1-1, Sakuragaoka, Setagayaku, Tokyo, Japan*
[b] *Department of Nutritional Science, Faculty of Applied Bio-Science, Tokyo University of Agriculture, 1-1-1, Sakuragaoka, Setagayaku, Tokyo, Japan*
[c] *Department of Applied Biology and Chemistry, Faculty of Applied Bio-science, Tokyo University of Agriculture, 1-1-1, Sakuragaoka, Setagayaku, Tokyo, Japan*

Received 4 January 1999; received in revised form 8 August 1999; accepted 8 August 1999

Abstract

For the effective use of leaves, stalks and stems of two kinds of sweet potatoes, we determined their chemical components and evaluated their nutritive values. Some parts of this plant, which are not usually used, were found to be rich in nutritive and functional components. In particular, leaves contain a large amount of protein, showing high amino acid score. Any part of sweet potatoes was rich in dietary fiber and in particular, leaves were soluble dietary fiber and stems were insoluble dietary fiber, respectively. Mineral content, particularly iron, and vitamin content such as carotene, vitamin B_2, vitamin C and vitamin E were high in leaves in comparison with other vegetables. Furthermore, polyphenol content in leaves was comparatively high. These results suggest that the whole parts of sweet potatoes should be utilized as valuable foodstuffs to cope with future changes in food supply and demand, particularly in developing countries.

1. Introduction

At present in advanced countries, overeating or an unbalanced diet rather than shortage of food is a major concern as a health hazard. However, from a global perspective, there is a shortage of food production and supply because of the population increase in developing countries and the decrease in cultivated field due to desertization. From these points of view, revaluation of the crops, which are tolerant to environmental changes such as drought, storms and floods, and which can be cultivated in waste land and tropical areas, is necessary. One such crop is sweet potatoes (*Ipomea batatas poir*) which originated from Central America. China is the leading country of sweet potato production, and the global yield was 134, 244t in 1996 [Food and Agriculture Organization (FAO), 1997], which was about 1/2 of that of potatoes (*Solanum tuberosum* L.) and 1/4 of that of wheat, meaning that sweet potatoes are one of the major food crops. In Japan, sweet potatoes have been cultivated as a hardy plant since the early 1700's, not only its tubers but also leaves, stalks and stems are edible. However, at present, other parts than tubers of sweet potatoes are not used as a food material in any areas except southeast Asia including Okinawa and Formosa, and detailed reports on the effective components in the leaves, stalks and stems are scarce. Therefore, an attempt to use other parts than the tubers would be meaningful to insure future food resources. In particular, leaves of sweet potatoes are dark green and expected to have nutritive components like the dark green and yellow vegetables. Generally, vegetable leaves such as spinach or alfalfa are considered to be a notable protein source (Standard Tables of Food Composition in Japan, 1995; Sun, Tseng, Leu & Chang, 1979) and studies on the nutritive value of the leaf proteins and the technics for food use are gradually in progress. Then we examined various nutritive components of each part of sweet potatoes and revaluated the characteristics of them.

2. Materials and methods

2.1. Materials

Two varieties of sweet potatoes, Koganesengan (KS) and Beniazuma (BA) cultivated at the experimental

* Corresponding author.

0308-8146/99/$ - see front matter
PII: S0308-8146(99)00206-X

farm in the university campus, were used. KS is widely cultivated in mainly southern areas of Japan, and BA in Japan except Hokkaido. Both varieties were planted late in May, harvested early in October, and separated into leaves (10–15 cm from the base to the tip), stalks (15–25 cm), stems and tubers (150–200 g with the skins on) as shown in Fig. 1.

For reference, Table 1 shows the character of the soil used for the cultivation of sweet potatoes. The levels of exchangeable potassium and electric conductivity (approximate indicator of inorganic nitrogen) were proper, but the level of exchangeable calcium was high and available phosphate was low.

2.2. Analysis

The materials for the determinations of all components except vitamins and polyphenols were freeze-dried, powdered and passed through 30 mesh sieves (500 μm). These were stored at −30°C until analysis. Analytical methods of chemical components in each part of sweet potatoes are described in the following sections and data were expressed as means of triplicate determinations.

Certified reference material [CRM 383:Haricots Verts (Beans)] purchased from the Institute for Reference Materials and Measurements:IRMM (Geel, Belgium) was examined to ensure the accuracy of following analytical methods used in this experiment.

2.3. General composition

The components of leaves, stalks, stems and tubers were measured based on the methods described in Standard Tables of Food Composition in Japan (1995). Moisture content was determined by atmospheric pressure drying method (at 70°C). Protein content ($N \times 6.25$) was estimated by the copper catalyst Kjeldahl method and fat content by the Soxhlet method after treating with an activated carbon column. Ash content was measured by the dry ashing method (at 550°C).

2.4. Amino acid composition

Hydrolysis conditions of protein for the determination of amino acid composition in samples were followed by the method described in Handbook of Food Analysis (1996). The hydrolysis was carried out at 110°C for 22 h in a sealed tube under vacuum. Samples were hydrolyzed by 6 N hydrochloric acid solution containing 0.02% mercaptoethanol for determinations of other amino acids except tryptophan, cystine and methionine. The 4 N barium hydroxide solution was used in hydrolysis for tryptophan analysis. For determinations of cystine and methionine, samples were oxidized by performic acid and then hydrolyzed by 6N hydrochloric acid solution. Each amino acid was measured by amino acid autoanalyzer (Hitachi AA835, Hitachi LTD., Tokyo, Japan) applied with ninhydrin colorimetry. Reagents used for the amino acid analysis were purchased from Wako Pure Chemical Industries, LTD., Tokyo.

2.5. Dietary fiber

The method proposed by Prosky, Asp, Schweizer, Devries and Furda (1988) was used for determinations of total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). Samples were hydrolyzed by the following enzymes: heat-stable α-amylase solution (Termamyl 120L, Novo Nordisk, Aktie Selskab, Bagsvaerd, Denmark) for starch, protease (Sigma P-3910, Sigma Chemical Co., St. Louis, USA) for protein and amyloglucosidase (Sigma A-9913, Sigma Chemical Co.) for dextrin.

2.6. Mineral contents

The ashed preparation was dissolved in diluted hydrochloric acid and then diluted with an ion-exchanged water. Based on the Association of Official Analytical Chemists (AOAC), 1990a), measurements were carried out by potassium permanganate volumetric method for

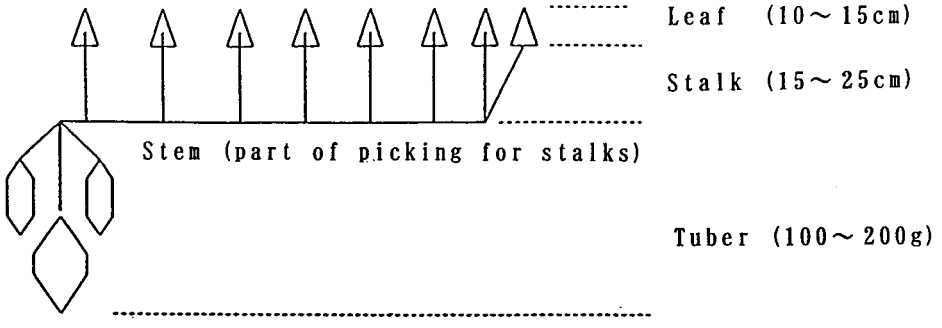

Fig. 1. The parts of sweet potato.

Table 1
Character of soil used for cultivation of sweet potatoes

Soil type	Andosol	Electric conductivity mS/cm	0.13
Soil texture	Loam	Exchangeable-CaO mg/100g	856
Apparant density g/ml	0.93	Exchangeable-MgO mg/100g	55.9
Total carbon (T·C)%	2.46	Exchangeable-K_2O mg/100g	46.6
Humus %	4.24	Cation exchange capacity meq/100g	26.5
Total nitrogen (T-N) %	0.18	Base saturation degree %	129
C/N ratio	13.4	Available phosphoric acid P_2O_5 mg/100g	1.3

calcium, by molybdenum-blue colorimetry for phosphorus and by *o*-phenanthroline colorimetry for iron, respectively. Guaranteed reagents were purchased from Kanto Chemical Co. Inc. Tokyo and used for determinations of the above three minerals. After wet ashing samples with hydroperoxide, nitric acid and sulfuric acid based on the procedures described in AOAC (1990a), sodium, potassium, magnesium, zinc and copper were determined by an atomic absorption photometric method described in AOAC (1990a). The atomic absorption analyzer of Shimadzu AA-630-12 (Shimadzu Co., Kyoto, Japan) with holocathode lamp L-233 (Hamamatsu Photonics Co., Shizuoka, Japan) was used. Reagents prepared for atomic absorption photometry were all purchased from Kanto Chemical Co. All of the glass implements for analysis were used after dipping in 1% nitric acid solution and rinsing with demineralized water.

2.7. Vitamins

β-Carotene was determined by high performance liquid chromatography (HPLC) on a Hitachi L6000 chromatograph (Hitachi LTD, Tokyo) with Mightysil RP-18 (5 μm) packed column (ID 4.6 mm×250 mm, Kanto Chemical Co.) and a visual spectrophotometric detector (454 nm). Twenty per cent (v/v) chloroform in methanol as a mobile phase was used at a flow rate of 1.0 ml min^{-1}. Preparation of samples for HPLC was followed by the method described in Standard Method of Analysis for Hygienic Chemist (SMAHC), (1990). Reagents used for the analysis were guaranteed and purchased from Kanto Chemical Co. All trans β-carotene and α-carotene as standard materials were purchased from Wako Pure Chemical Ltd. and Sigma Chemical Co., respectively.

Vitamin B_1 and B_2 were measured fluorometrically according to the Association of Analytical Chemists (AOAC, 1990b) and SMAHC (1990), respectively. The fluorescence was read on a Hitachi F204R spectrofluorophotometer (Hitachi Ltd., Tokyo) at 375 nm excitation and 430 nm emission for thiochrome, and at 430 nm excitation and 530 nm emission for lumiflavin. The standard vitamin B_1 and B_2 were obtained from National Institute of Hygienic Sciences. The other reagents were all guaranteed and purchased from Kanto Chemical Co.

A microbiological assay (turbidimetry) was carried out by the method described in SMAHC (1990). Microorganisms used in the assay were: *Saccharomyces uvarm* ATCC No. 9080 for vitamin B_6 and *Lactobacillus plantarum* ATCC No.8014 for niacin, pantothenic acid and biotin, respectively. The basic culture media and stock culture media used for the assay were purchased from Nissui Pharmaceutical Co., Tokyo. Standard materials of all vitamins for bioassay use were USP grade and were purchased from Sigma Chemical Co.

Vitamin C (total ascorbic acid) was determined by HPLC on a Hitachi L6000 chromatograph (Hitachi LTD.) with a Inertsil ODS-2 packed column (ID 4 mm×250 mm, GL Science Inc., Tokyo) and ultraviolet (UV) spectrophotometric detector (Hitachi L4200, 254 nm). As a solvent, 1.5% ammonium dihydrogenphosphate solution adjusted to pH 3.8 with phosphoric acid was used at a flow rate of 1 ml min^{-1}. An extraction procedure of vitamin C from samples was carried out as described by Masuda, Hayakawa, Kakiuchi and Iwamoto (1988). Samples were homogenized with 5% metaphosphoric acid and diluted with ion exchanged water. The homogenate was centrifuged and filtered with a membrane filter (0.45 μm). The supernatant was reduced by dithiothreitol after adjusting to pH 7.2. Standard material of vitamin C was USP grade and was purchased from Sigma Chemical Co.

Vitamin E was determined by HPLC on a Hitachi L6000 chromatograph (Hitachi Ltd.) with a Hiber Lichrosorb Si 60 (5 μm) packed column (ID 4 mm×250 mm, Kanto Chemical Co.) and the UV spectrophotometric detector (Hitachi L4200, 280 nm). The extraction procedure of vitamin E was followed by the method described in SMAHC (1990). Samples were hydrolyzed in potassium hydroxide ethanol solution containing pyrogallol as an antioxidant. Then, the hydrolyzate was extracted by petroleum ether and the organic phase was rinsed with water and dehydrated by anhydrous sodium sulfate. The resulting extract was evaporated and dissolved by *n*-hexane. An aliqot of *n*-hexane solution was supplied for HPLC analysis. The apparatus was operated by 0.75% (v/v) iso-propanol in *n*-hexane as mobile phase and flow rate of 1 ml min^{-1}.

Vitamin E homologue set (α, β, γ, δ-tocopherol) as standard material was purchased from Eizai Co. Ltd., Tokyo.

2.8. Polyphenols

The amount of total polyphenols was measured by the spectrophotometric method described in Association of Official Analytical Chemists (AOAC, 1984) and was expressed as chlorogenic acid content. Chlorogenic acid was directly measured quantitatively by UV absorption method (327 nm) after obtaining an extract from samples with the following procedures (Aoki, Yahagi & Tamura, 1984). An extraction of chlorogenic acid from homogenized samples was performed with hot methanol. After diluting with methanol, 4 volumes of extract were mixed with 4 volumes of iso-propanol and 2 volumes of benzene. The mixtures were charged with polyvinylpolypyrrolidone column (ID 21×65 mm) and eluted with methanol after rinsing twice with benzene and methanol mixture (9:1 and 3:1,v/v). Standard materials of chlorogenic acid and polyvinylpolypyrrolidone were purchased from Sigma Chemical Co.

3. Results and discussion

3.1. Analysis of CRM 383: Haricots Verts (Beans)

Certified components in CRM 383 samples were analyzed by various analytical methods used in the present experiment.

The results are shown in Table 2. The data are expressed as the mean of four trials. All the values obtained by our analytical methods coincided well with the certified values and also not certified ones. Thus, the accuracy of our analytical methods in this study was ensured by these results.

3.2. General composition

Table 3 shows the general composition. The amount of protein in 100 g of leaves (numerals in parentheses are the values on a dry weight basis) was 3.8 g (29.5 g) in KS and 3.7 g (24.5 g) in BA. The protein content in dry matter of leaves was higher than those of other vegetables listed in Standard Tables of Food Composition in Japan (1995), showing that the leaves of sweet potatoes can be used as a protein source. The content per 100 g dry weight in other parts was less than 10 g, which was lower than that in leaves. In southeast Asia, both leaves and stalks are usually used for cooking such as sauteed vegetables and soup. Sugar content was high in tubers and low in leaves and stalks. The sugar content in stems was positioned between that in leaves and stalks. The content of dietary fiber was more than 10 g in stems of both varieties, and was about 6 g in leaves. The ranges of ash content in each part were 1.3–1.9 g in KS and 0.8–1.5 g in BA.

3.3. Amino acid composition

To examine the utility of the leaves as a protein source other than animal resources, we measured amino acid components and estimated the amino acid score in comparison with the standard amino acid pattern (age: 2–5 years old) of FAO/WHO/UNU (1985). Table 4 shows the amino acid composition after hydrolysis and the amino acid score. In both the KS and BA, the first limiting amino acid was lysine, and the amino acid score was 76.1 and 83.9%, respectively. Thus, the leaf protein was clearly found to be good quality in amino acid composition, and its usefulness as a protein resource was suggested. Sun et al. (1979) measured protein content and amino acid composition in the mixture of leaves and stalks of sweet potatoes, and they showed that protein content was 1.9%, limiting amino acid was lysine and amino acid score was 69%. Our results were similar to their report except for protein content. It is considered that the protein content was different due to the samples being with or without stalks.

3.4. Dietary fiber

Table 5 shows the dietary fiber (DF) content. The leaves, stalks and stems showed a high content, which is

Table 2
Confirmation of accuracy of our analytical method by CRM 383-Haricots Verts (Beans)[a]

	Kjeldahl-N	Ash	DF	Na	K	Ca	Mg	P	Vitamin C	Thiamin	Niacin	α-Tocopherol
Certified or not certified values	1.05[b] ±0.02	2.4[b] ±0.1	11.9[b] ±0.2	0.075[b] ±0.004	7.8[b] ±0.2	2.9[b] ±0.2	0.9[c]	1.8[c]	15.1[c]	0.22[c]	1.7[c]	0.34[c]
Mean values ($n=4$)	1.07	2.3	11.6	0.079	7.8	2.9	0.85	1.69	14.8	0.22	1.8	0.32
SD	0.01	0	0.32	0.07	0.14	0.08	0.05	0.02	0.44	0.01	0.05	0.20
CV	1.32	0	2.79	8.85	1.81	2.88	5.88	1.40	2.98	4.39	2.85	6.39

[a] Unit is expressed as g/100 g for Kjeldahl-N, ash and dietary fiber (DF); mg/g for sodium, potassium, calcium, magnesium and phosphorus; mg/100 g for vitamin C, thiamin, niacin and α-tocopherol.
[b] Certified values.
[c] Not certified values.

Table 3
Compositions in each part of the two kinds of sweet potatoes (gram per 100 g)[a]

Kinds	Parts	Moisture	Protein[b]	Lipid	Sugar[c]	Dietary fiber[d]	Ash
Koganesengan	Leaf	87.1	3.80	0.33	0.95	5.94	1.88
	Stalk	94.4	0.50	0.10	0.93	2.42	1.65
	Stem	83.7	0.85	0.53	3.22	10.4	1.30
	Tuber	70.9	2.13	0.20	21.9	3.42	1.43
Beniazuma	Leaf	84.9	3.68	1.03	1.96	6.90	1.53
	Stalk	88.9	0.70	0.33	4.52	4.61	0.94
	Stem	79.2	1.43	0.58	6.65	11.3	0.84
	Tuber	69.9	1.28	0.33	25.1	2.30	1.08

[a] Values are means of tripricate determinations.
[b] 6.25×N gram per 100 g.
[c] Calculated by the following equation: 100−(moisture + protein + lipid + dietary fiber + ash).
[d] Total dietary fiber.

comparable to the values in burdock (8.5 g/100 g) and spinach (3.5 g/100 g), being known as vegetables with a high dietary fiber content. In the advanced countries where DF intake is insufficient in common dietary life, the importance of DF is pointed out in connection with diabetes (Anderson, Gustafson, Bryant & Lietyon-Clark, 1987), hyperlipidemia (Stasse-Wolthuis et al., 1979), and colon cancer (Burkitt, 1971; Greenwald, Lanza & Eddy, 1987). Thus, the leaves, stalks and stems of sweet potato are suggested to be valuable as sources of DF. The leaves were characterized to contain the highest amount of soluble dietary fiber (SDF) among each part of sweet potato. The amount of SDF in leaves was 6.83% on dry matter basis in KS and 5.77% in BA. The leaves have a specific viscosity like Okra (*Abelmoschus esculentus*) when thinly cut (Ishida, Suzuno, Sugiyama, Innami, Wada & Matsumoto, 1995). Since most of the mucilaginous dietary fibers have been known to have lowering effects on postprandial blood glucose (Jenkins, Leeds, Gassull, Cochet & Alberti, 1977), serum and hepatic cholesterol (Innami, Nakamura, Tabata, Wada & Takita, 1995; Keys, Grande & Anderson, 1961; Kiriyama, Morisaki & Yosida, 1970), much interest is focusing on viscous SDF of sweet potato leaves. Innami et al. (1998) reported that the freeze-dried powder of the green leaves of sweet potatoes showed a hepatic cholesterol lowering effect in rats. They suggest that this lowering effect might be greatly attributed to the viscous SDF. Thus sweet potato leaves should be also evaluated from the aspect of physiological action of DF.

3.5. Mineral contents

Table 6 shows the mineral contents. The leaves of sweet potatoes contain a large amount of minerals except for sodium, and are situated on a useful foodstuff for mineral supply. Calcium content was about 70 mg/100 g in the tuber and 150–200 mg/100 g in the other parts.

Iron content was high especially in leaves, both in KS and BA. The value of iron in foods should not be evaluated with the content alone (Bjorn, Rasmussen, Halberg & Isaksson, 1974), because the intestinal absorption rates of heme-iron and non-heme-iron are different, the former being 37% and the latter 5%. Hallberg, Bjorn-Rasmussen, Howard and Rossander (1979) reported that about 90% of the iron taken as food is non-heme-iron.

Further, Bothwell, Baynes, MacFarland and Macphail (1989) reported that 1 mg/day of iron is suitable for adult humans to maintain the daily balance of intake and excretion and iron absorption rate increases with vitamin C intake. From the above, the intake of iron from dark green and yellow vegetables is also meaningful. Thus, we consider that the leaves of sweet potatoes are useful foodstuffs as an iron source.

Sodium content in both the samples was less than in stalk (1.38 mg or 1.80 mg/100 g) and stems (2.36 mg or 5.24 mg/100 g), and was much in tubers (22.3 mg or 26.6 mg/100 g). On the contrary, potassium content ranged from 188 mg/100 g in stalk of BA to 637 mg/100 g in leaves of KS, showing that these values are comparable to those of leaf vegetables (Standard Tables of Food Composition in Japan, 1995). Therefore, it is considered that leaves and other parts of sweet potatoes are very useful as potassium sources. Yoshimura, Takahashi and Nakanishi (1991) described that the increase of K/Na ratio in diet might be important for prevention of hypertension and arteriosclerosis. However, potassium in leaf vegetable is known to be easily lost during cooking in boiling water (Ego, Tsutsumi & Nagahara, 1976; Ishida et al., 1974). So that, careful consideration and handling are necessary for taking potassium effectively from these parts of sweet potatoes.

The magnesium content in 100 g leaves was 79 mg in KS and 107 mg in BA, and that in 100 g stalks was 41 mg in KS and 62 mg in BA. The magnesium content in stems was 30 and 35 mg in KS and BA, respectively, and that in tubers was 27 mg in the both varieties.

Table 4
Amino acid contents and amino acid score of sweet potato leaf protein[a]

	ILeu	Leu	Lys	Met	Cys	Phe	Tyr	Thr	Try	Val	His	Arg	Ala	Asp	Glu	Gly	Pro	Ser	Protein-N[b]	Amino acid score
Amino acid pattern[c] (A)	180	410	360	160		390		210	70	220	120	–	–	–	–	–	–		–	100
Kogane-sengan																				
Amino acid contents[d]	1.062	2.037	1.292	0.405	0.413	1.336	0.810	1.139	0.361	1.336	0.537	1.248	1.478	2.880	2.727	1.247	1.084	1.062	–	–
AA-N/P-N[e] (B-1)	225	432	274	86	88	283	172	242	77	283	225	–	–	–	–	–	–	–	4 714	–
B-1/A(%)	125	105	76.1	109		117		115	110	129	188	–	–	–	–	–	–	–	–	76.1 (Lys)[f]
Beni-azuma																				
Amino acid contents[d]	0.960	1.834	1.187	0.367	0.469	1.208	0.723	1.036	0.291	1.230	0.486	1.111	1.295	2.805	2.676	1.241	0.993	0.993	–	–
AA-N/P-N[e] (B-2)	244	467	302	93	119	307	184	264	74	313	204	–	–	–	–	–	–	–	3 030	–
B-2/A(%)	136	114	83.9	133		126		126	106	142	170	–	–	–	–	–	–	–	–	83.9 (Lys)[f]

[a] Values are means of triplicates.
[b] Miligram per gram of nitrogen in protein.
[c] Standard amino acid pattern (age 2–5 years old) of FAO/WHO/UNU in 1985, (mg/gN)(A).
[d] Gram per 100 g of dry matter.
[e] Ratio of nitrogen in amino acid to nitrogen in protein (mg/g) (B-1 or 2).
[f] First limiting amino acid.

Table 5
Dietary fiber contents in each part of the two kinds of sweet potatoes (gram per 100 g)[a]

Kinds	Parts	SDF[b]	IDF[c]	TDF[d]
Koganesengan	Leaf	0.88 (6.83)[e]	5.06 (39.1)	5.94 (45.9)
	Stalk	0.24 (4.23)	2.19 (39.0)	2.43 (43.2)
	Stem	0.66 (4.03)	9.72 (59.6)	10.4 (63.6)
	Tuber	0.79 (2.73)	2.62 (9.00)	3.41 (11.7)
Beniazuma	Leaf	0.87 (5.77)	6.03 (39.9)	6.90 (45.7)
	Stalk	0.37 (3.30)	4.25 (38.3)	4.62 (41.6)
	Stem	0.69 (3.33)	10.6 (51.1)	11.3 (54.4)
	Tuber	0.43 (1.43)	1.85 (6.13)	2.28 (7.56)

[a] Values are means of triplicate determinations.
[b] SDF = soluble dietary fiber.
[c] IDF = insoluble dietary fiber.
[d] TDF = total dietary fiber.
[e] Calculated by dry matter.

Table 6
Mineral contents in each part of the two kinds of sweet potatoes (mg or μg per 100 g)[a]

Kinds	Parts	Ca	P	Fe	Na	K	Mg	Zn[b]	Cu[b]
Koganesengan	Leaf	187	68.0	5.43	3.77	639	79.0	885	431
	Stalk	193	14.7	1.18	1.80	467	41.0	549	152
	Stem	179	21.7	2.40	5.24	574	30.0	683	298
	Tuber	73.3	40.0	1.64	22.3	502	27.0	389	304
Beniazuma	Leaf	174	36.7	5.54	2.12	357	107	596	550
	Stalk	162	8.33	2.82	1.38	188	62.0	213	193
	Stem	155	18.7	3.89	2.36	247	35.3	283	373
	Tuber	68.0	42.7	2.27	26.6	235	26.7	249	152

[a] Values are means of triplicate determinations.
[b] Zn znd Cu contents are expressed as microgram per 100 g.

Magnesium is an important mineral in connection with circulatory diseases such as ischemic heart diseases and calcium metabolism in bone (Ouchi, Tabata, Stergiopoulos, Sato, Hattori & Orimo, 1990).

Zinc and copper contents were also higher in leaves than in the other parts. Physiological effect of each mineral should be evaluated in connection with the minerals daily taken from other foods. At any rate, it is considered that leaves, stalks and stems of the sweet potatoes are also useful mineral sources.

3.6. Vitamin contents

Vitamin contents in the samples are shown in Table 7. Most of vitamins (β-carotene, vitamin B_2, vitamin C and vitamin E) tended to be high in leaves. The β-carotene content in 100 g leaves of KS and BA was 400 mg and 273 mg, respectively, and these values were close to those in dark green and yellow vegetables. The vitamin B_2 content in leaves was 0.254 and 0.248 mg in KS and BA, respectively, and was close to the values in broccoli (0.27 mg) and spinach (0.23 mg) which are known to have high vitamin B_2 content. The vitamin C content in leaves was 62.7 and 81.0 mg in KS and BA, respectively, and similar to the 65 mg in spinach. The vitamin E content was also high in leaves, and was 2.81 and 1.39 mg in KS and BA, respectively. Those values are close to the 2.8 mg in parsley, 2.5 mg in spinach and 2.2 mg in leek. Recently, much attention is focused on β-carotene, vitamin C and vitamin E as physiological bioactive substances. For instance, there are many reports that carotene reveals antitumor activity (Peto, Doll, Buckley & Sporn, 1981; Murakosi et al., 1992) and antioxidant activity (Di Mascio, Kaiser & Sies, 1989; Foote, Chang & Dew, 1970), and vitamin C does also show antioxidant activity (Frei, 1991; Rojas, Cadenas, Perez-Campo, Lopez-Torres & Ba-rja, 1994). Vitamin E is related to promote the improvement of lipid metabolism, to have bioprotecting activity against lipid peroxide, and to prevent cell aging (Ikeda & Sugano, 1983), atherosclerosis and coronary heart disease (Hermann, Ward & Faucett, 1979). Thus the efficient utilization of leaves should be considered.

3.7. Total polyphenol and chlorogenic acid contents

The amount of total polyphenol in 100 g was 90.0, 45.0, 90.0 and 180 mg, in leaves, stalks, stems and tubers

Table 7
Vitamin contents in each part of the two kinds of sweet potatoes (μg and mg per 100 g)[a]

Kinds	Parts	Carotene	B_1	B_2	B_6	Niacin	Pantotenic acid	Biotin	C[b]	E[b]
Koganesengan	Leaf	400	128	254	329	856	320	8	62.7	2.81
	Stalk	22	23	31	19	443	123	Trace	9.00	0.47
	Stem	291	55	64	32	679	303	2	13.0	0.19
	Tuber	8	52	37	36	627	333	3	32.3	0.34
Beniazuma	Leaf	273	53	248	120	1498	660	3	81.0	1.39
	Stalk	191	72	62	23	144	218	Trace	17.3	0.16
	Stem	159	47	47	69	410	267	Trace	19.3	0.39
	Tuber	236	126	58	105	913	695	Trace	35.0	0.18

[a] Values are means of triplicate determinations.
[b] Vitamin C and E contents are expressed as miligram per 100 g.

in KS, respectively. It was 356, 126, 197 and 154 mg, in leaves, stalks, stems and tubers in BA, respectively. The content in BA tended to be higher than that in KS. The chlorogenic acid content (in 100 g) was 30.1, 2.07, 4.52 and 21.2 mg, in leaves, stalks, stems and tubers in KS, respectively. It was 47.6, 24.3, 129 and 15.8 mg in BA, respectively. These values were corrected based on the results from recovery test of standard chlorogenic acid. From the above results, difference between the total polyphenol content and chlorogenic acid content may be due to the presence of some polyphenols other than chlorogenic acid.

Polyphenol has a strong reducing activity. In particular, plant polyphenols having esterified carboxylic acid, such as caffeic acid ester with catechol structure, are reported to have an inhibitory effect on the cell damage caused by active oxygen species (Nakayama, Niimi, Osawa & Kawakisi, 1992), and suppress harmful bacterial growth (Toda, Okubo, Hiyoshi & Shimamura, 1989). Further detailed examination on polyphenols in the whole parts of sweet potatoes is necessary. In conclusion, the chemical composition of the leaves of sweet potatoes, both in KS and BA, is similar to that in dark green and yellow vegetables. The composition of the stalks of sweet potatoes was similar to that in the other vegetables, and that in stems was positioned between that in tubers and in stalks. Not only tubers but also leaves and other parts of sweet potatoes have nutritionally and functionally valuable components and are highly useful. From a global perspective, whole parts of sweet potatoes are suggested to be an important foodstuff to cope with future changes in food supply and demand, particularly in developing countries.

References

Anderson, J. W., Gustafson, M. S., Bryant, C. A., & Lietyen-Clark, J. (1987). Dietary fiber and diabetes: a comprehensive review and practical application. *Journal of American Dietetic Association, 87*, 1189–1197.

Association of Official Analytical Chemists. (1990a). *Official method of analysis* (Vol. 1, 15th ed.). Washington, DC: Association of Official Analytical Chemists.

Association of Official Analytical Chemists (1990b). *Official method of analysis* (Vol. 2, 15th ed.) Washington, DC: Association of Official Analytical Chemists.

Association of Official Analytical Chemists (1984). *Official method of analysis* (14th ed.). Washington, DC: Association of Official Analytical Chemists.

Aoki, S., Yahagi, Y., & Tamura, T. (1984). The use of polyvinylpyrrolidonecolumn for the quantitative determination of chlorogenic acid in apple fruit. *Journal of Japanese Society for Food Science and Technology, 31*, 110–113.

Bjorn-Rasmussen, E., Halberg, L., & Isaksson, B. (1974). Food iron adsorptionin man (Applications of the two pool extrinsic tag method to measure heme and nonheme iron absorption from the whole diet). *Journal of Clinical Investigation, 53*, 247–255.

Bothwell, T. H., Baynes, R. D., MacFarland, B. J., & Macphail, A. P. (1989). Nutritional requirement and food iron adsorption. *Journal of International Medicines, 226*, 357–365.

Burkitt, D. P. (1971). Epidemiology of cancer of the colon and rectum. *Cancer, 28*, 3–13.

Di Mascio, P., Kaiser, S., & Sies, H. (1989). Lycopene as the most efficient biological carotenoid singlet oxygen quencher. *Archives of Biochemistry and Biophysics, 274*, 532–538.

Ego, M., Tsutsumi, C., & Nagahara, T. (1976). Behavior of minerals in cooking. *Journal of Home Economics of Japan, 27*, 511–514.

Food and Agriculture Organization. (1997). Regional offer for Asia and the Pacific. Bangkok: Food and Agriculture Organization of the United Nations.

FAO/WHO/UNU (1985). Standard amino acid pattern. WHO Technical report series No.724, 1985 (Energy and protein requirements. Report of a Joint FAO/WHO/UNU Expert Consulting).

Foote, C. S., Chang, Y., & Denny, R. W. (1970). Chemistry of singlet oxygen. X. Carotenoid quenching parallels biological protection. *Journal of the American Chemical Society, 92*, 5216–5218.

Frei, B. (1991). Ascorbic acid protects lipid in human plasma and low density lipoprotein against oxidative damage. *American Journal of Clinical Nutrition, 54*, 1113s–1118s.

Greenwald, P., Lanza, E., & Eddy, G. A. (1987). Dietary fiber in the reduction of colon cancer risk. *Journal of American Dietetic Association, 87*, 1178–1188.

Hallberg, L., Bjorn-Rasmussen, E., Howard, L., & Rossander, L. (1979). Dietary heme iron adsorption (a discussion of possible mechanisms for the adsorption promoting effect of meet and for the regulation of iron). *Scandinavia Journal of Gastroenterology, 14*, 769–779.

Handbook of food analysis (1996). Physical characterization and nutrient analysis. New York: Marcel Dekker.

Hermann, W. J., Ward, K., & Faucett, J. (1979). The effect of tocopherol on high-density lipoprotein cholesterol. *American Society of Clinical Pathologists, 72*, 848–852.

Ikeda, I., & Sugano, M. (1983). Vitamin E and lipid metabolism. *Vitamins (Japan), 57*, 119–132.

Innami, S., Nakamura, K., Tabata, K., Wada, M., & Takita, T. (1995). Water-soluble viscous substance of Jews Mellow leaves lowers serum and liver cholesterol concentrations and increases fecal steroid extractionin rats fed a high cholesterol diet. *Journal of Nutritional Science and Vitaminology, 41*, 465–475.

Innami, S., Tabata, K., Simizu, J., Kusunoki, K., Ishida, H., Matsukuma, M., Wada, M., Sugiyama, N., & Kondo, M. (1998). Dried green leaf powders of Jews mellow (*Corchorus olitorius*), Persimmons (*Diophyros kaki*) and Sweetpotato (*Ipomoea batatas poia*) lower hepatic cholesterol concentration and increase fecal bile acid excretion in rats fed cholesterol-free diet. *Journal of Plant Food for Human Nutrition, 52*, 55–65.

Ishida, H., Daimatsu, T., & Ono, F. (1974). Effect of cooking on sodium and potassium content in Foods. *Japanese Journal of Nutrition, 32*, 103–106.

Ishida, H., Suzuno, H., Sugiyama, N., Innami, S., Wada, M., & Matsumoto, S. (1995) Studies on chemical structure and physiological function of edible green leaf vegetables. *Report project of Tokyo University of Agriculture*, 241–245.

Jenkins, D. J. A., Leeds, A. R., Gassull, M. A., Cochet, B., & Alberti, K. G. M. M. (1977). Decrease postprandial insulin and glucose concentrations by guar and pectin. *American Internal Medicine, 86*, 20–25.

Keys, A., Grande, F., & Anderson, J. T. (1961). Fiber and pectin in the diet and serum cholesterol concentration in man. *Proceedings of the Society Experimental Biology and Medicine, 106*, 555–558.

Kiriyama, S., Morisaki, H., & Yosida, A. (1970). Changes in hypocholesterolemic activity in rats by various Konnyaku powder treatments. *Agricultural and Biological Chemistry, 34*, 641–643.

Masuda, R., Hayakawa, A., Kakiuchi, N., & Iwamoto, M. (1988). HPLC determination of total ascorbic acid in fruits and vegetables. *Report of National Food Research Institute Japan, 52*, 30–35.

Murakosi, M., Nisino, H., Satomi, Y., Takayasu, J., Hasegawa, T., Tokuda, H., Iwasima, A., Okuzumi, J., Okabe, H., Kitano, H., & Iwasaki, R. (1992). Potentpreventive action of α-carotene against carcinogenesis: Spontaneous liver carcinogenesis and promoting stage of lung and skin carcinogenesis in mice are suppressed more effectively by α-carotene than by β-carotene. *Cancer Research, 52*, 6583–6587.

Nakayama, T., Niimi, T., Osawa, T., & Kawakisi, S. (1992). The protective role of polyphenols cytotoxity of hydrogen peroxide. *Mutation Research, 281*, 77–80.

Ouchi, Y., Tabata, E. R., Stergiopoulos, K., Sato, F., Hattori, A., & Orimo, H. (1990). Effect of dietary magnesium on development of atherosclerosis in cholesterol-fed rabbits. *Arteriosclerosis, 10*, 732–737.

Prosky, L., Asp, N. G., Schweizer, T. F., Devries, J. W., & Furda, I. (1988). Determination of insoluble, soluble, and total dietary fiber in foods and food products, interlaboratory study. *Journal of the Association Official Analytical Chemists, 71*, 1017–1023.

Peto, R., Doll, R., Buckley, J. D., & Sporn, M. B. (1981). Can dietary beta-carotene materially reduce human cancer rates? *Nature, 290*, 201–208.

Rojas, C., Cadenas, S., Perez-Campo, R., Lopez-Torres, M., & Ba-rja, G. (1994). Effect of vitamin C on antioxidation, lipid peroxidation and GSH system in the normal guinea pig heart. *Journal of Nutritional Science and Vitaminology, 40*, 411–420.

Standard Methods of Analysis for Hygienic Chemists (1990). Authorized by the Pharmaceutical Society of Japan, Kinbara, Tokyo.

Standard tables of food composition in Japan (1995). (4th ed.). Japan: Resources Council, Science and Technology Agency.

Stasse-Wolthuis, M., Hautvast, J. G. A. J., Hermus, R. J. J., Katan, M. B., Bausch, J. E., Rietberg-Brussaard, J. H., Velema, J. P., Zondrvan, J. H., Eastwood, M. A., & Brydon, W. G. (1979). The effect of a natural high fiber diet on serum lipids, fecal lipids and colonic function. *American Journal of the Clinical Nutrition, 32*, 1881–1888.

Sun, C. T., Tseng, S. Y., Leu, J. J., & Chang, W.ri. (1979). Leaf protein concentrates from some sources available in Taiwan. *Journal of the Chinese Agricultural Chemical Society, 17*, 78–92.

Toda, M., Okubo, S., Hiyoshi, R., & Shimamura, T. (1989). The bactericidal activity of tea and coffee. *Letters in Applied Microbiology, 8*, 123–125.

Yoshimura, M., Takahashi, H., & Nakanishi, T. (1991). Role of sodium, potassium, calcium, magnesium on blood pressure regulation and antihypertensive dietary therapy. *Japanese Journal of Nutrition, 49*, 53–62.