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Nutritional Evaluation of Korean Yam (*Dioscorea batatas* DECNE.)

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Abstract : The aim of this study was conducted to investigate the proximate and nutritional compositions including mineral, vitamin, amino acids and fatty acids in Korean yam (*Dioscorea batatas* DECNE.). Carbohydrate (68.1%) possessed the large single constituent of yam. Small amounts of crude protein (16.9%), crude ash (5.8%) and crude fat (2.0%) contents were found. Yam was found to be good sources of essential minerals such as K (1295.5 mg/100 g), Mg (115.3 mg/100 g), Na (99.0 mg/100 g) and Ca (56.5 mg/100 g) but Zn (0.3 mg/100 g) content was low. Relatively abundant vitamin B_1 (11.5 mg/100g) could be observed while vitamin A, B_3 and B_6 were not found. The amino acid analysis revealed that the yam was superior with respect to glutamic acid (1770.6 mg%), lysine (1210.6 mg%) and urea (550.9 mg%). Essential amino acids were calculated to be 2954.5 mg%. The amino acid profiles showed that yam to be limiting in valine and leusine. Palmitic acid and linoleic acid were the most predominant fatty acids with the value of 31.5% and 41.5%, respectively. And the polyunsaturated fatty acids including linoleic acid and linolenic acid were present in a large quantities in yam. And it also contained higher amounts of unsaturated fatty acids compared saturated fatty acids.

Keywords : yam (Dioscorea batatas DECNE.), proximate composition, mineral, amino acids, fatty acids

1. Introduction

Yam (*Dioscorea batatas* DECNE.) is widely produced throughout East Asia such as Korea, China and Japan, which is the perennial trailing herb and belongs to the *Dioscoreaceae* family [1]. Due to its component characteristics, yam is usually served as the crucial staple food as well as traditional medicine ingredient to treat asthma, abscesses, chronic diarrhea and ulcers in many parts of world [2, 3]. Yam is mainly composed of starch (75.6-84.3%) with small amounts of crude protein, crude fat, crude fiber and crude ash, whose contents are in the range of 6.7-7.9%, 1.0-1.2%, 1.2-1.8%, 2.8-3.8%, respectively.

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Furthermore, yam tubers also contain vitamin C (13.0–24.7 mg/100 g dry weight), minerals (K, Na, P, Ca, Mg, Cu, Fe, Mn, Zn) [4] and organic acids (succinic acid, citric acid, malic acid, oxalic acid) [5].

In plants, the scavenging of peroxide was accomplished by means of the ascorbic acid (AsA)-glutathione pathway. This is a coupled series of redox reactions involving four enzymes: AsA-specific peroxidase, mono-dehydroascorbate reductase, dehydroascorbate reductase and glutathione reductase. Numerous studies have conclusively conducted that dioscorins are the storage proteins of yam tubers, which exhibit dehydroascorbate (DHA) reductase and monodehydroascorbate (MDA) reductase activities as well as antioxidant activities against both DPPH and hydroxyl radicals [6, 7]. Steroidal saponins, furostanol and spirostanol glycosides are the remarkable functional compounds in yams [1]. For the past few years, some relevant biological studies on the steroid saponins of *Dioscorea* species described in the literature are related to cytotoxic (anti-tumor) and antifungal properties that will be used as drug formulas to treat some diseases. And other biological functions about active steroidal saponins from *Dioscorea* species are summarized in the follows: immunomodulating, antimicrobial, hormonal, anti-osteoporotic, anti-inflammatory, and anti-allergic activities [8].

In this study, in order to investigate the nutritional compounds in yam, the proximate composition, mineral, vitamin, amino acid and fatty acid compositions will be determined and analyzed.

2. Materials and Methods

2.1. Materials and chemicals

Yam (*Dioscorea batatas* Decne.) was purchased from Andong (Korea), which was seeded in March or April and harvested in the end of October or December. The fresh yam was washed, sliced (thickness, 0.4–0.6 cm) and dried in the hot air for 18–24 h at 60–70℃. Then the dried chips were smashed (150-mesh) into raw yam meals (RY, commonly called white yam).

2.2. Proximate and nutritional analysis

Moisture, crude protein, crude fat and crude ash contents of raw yam meals and thermal treatment yam meals were analyzed according to AOAC 934.01, 984.13, 954.02 and 942.05, respectively [9]. Total sugar content was assayed by anthrone-sulphuric acid colorimetry according to the method of Loewus [10]. Cholesterol content determination was assayed by gas chromatography using flame ionization detection. And sample preparation and gas chromatography operating conditions was performed according to the method of KFDA (Korea Food and Drug Association) [11].

2.3. Mineral analysis

Mineral analysis was determined by atomic absorption spectrophotometry (Perkin-Elmer, Model Aanalyst 400, USA) at different wavelength for each mineral element (Zn-213.9, Ca-422.7, Fe-248.3, Mg-285.2, Na-589 and K-766.5 nm) according to the method of Novozamsky et al. [12].

2.4. Vitamin analysis

The analyses of vitamin A, B_1, B_2, B_6 and E were according to the method of KFDA (Korea Food and Drug Association) [13] with some modification by a high performance liquid chromatographic (HPLC) system with fluorescence detection (F1080, Hitachi, Japan). Vitamin C content determination was according to by Kubola, Siriamornpun and Meeso [14]. HPLC was performed on a C18 column (2504.6 mm, 5 μm) using a mobile phase of 0.05 M KH_2PO_4/methanol at a flow rate of 1 mL/min as follows: KH_2PO_4/methanol (97:3). Column temperature was maintained. UV detection was performed at 254 nm. Niacin content was assayed according to Maria et al.

[15] and a high performance liquid chromatograph coupled with a Photo Diode Array (PDA, Waters 996) detector was used.

2.5. Protein bound amino acid analysis

Protein bound amino acid analysis was conducted according to the method of Kim [16]. The sample (0.5 g) was hydrolysed by 6 N HCl at 150℃ for 1 h in the Waters Pico-tag system (Pico-Tag workstation, Waters). After the sample cooling to the room temperature, NaOH was added in order to neutralize the sample. The mixture was diluted with 0.2 N sodium citrate loading buffer (pH 2.2), then filtered with 0.22 μm membrane filter. The filtrate was injected into the Amino Acid Analyzer (Biochrom 20, Pharmacia Biotech. Ltd, UK) equipped with sodium type of ion exchange resin column.

2.6. Free amino acid analysis

Free amino acid analysis was performed by the method of Kim [16]. Samples were mixed with 0.2 N lithium citrate loading buffer (pH 2.2) in a ratio of 1:10, and then homogenized at 300 rpm for 10 min. After the mixture filtering with 0.22 μm membrane filter, the filtrate was injected into the Amino Acid Analyzer (Biochrom 20, Pharmacia Biotech. Ltd, UK) equipped with lithium type of ion exchange resin column.

2.7. Fatty acid analysis

Fatty acid compositions were determined by using the method of Kim [16]. Lipids were extracted from raw yam meals and thermal treatment yam meals with the mixture chloroform-methanol (C:M=2:1, v/v). Extracted lipid or oil was converted to methyl ester by using 14% BF_3-MeOH. And the fatty acid methyl esters were analyzed using a gas chromatography (Hewlett Packard HP 6890 series, GC, USA) fitted with ultra 2 column (cross linked 5% Ph Me silicone, 25 m×0.32 mm×0.52 μm) and a flame ionization detector. Nitrogen was used as the carrier gas and its flow rate was 1.4 mL/min. The column initial temperature was 160℃ rising to a final temperature of 250℃ while the injection port and the detector were maintained at 210 and 250℃, respectively. The contents of fatty acid were expressed as peak area to relative percentage (%).

3. Results and discussion

3.1. Proximate and nutritional composition

The proximate and nutritional compositions of yam available for this study were presented in Table 1. Carbohydrate possessed the large single constituent of yam meals, which was determined to be 68.1%. The most abundant carbohydrate content obtained in yam (68.1%) was in accordance with previous study [17]. Crude protein content (16.9%) was the second abundant. This value was high compared with crude protein-rich food such as legume [18]. Low crude fat content (2.0%) were found. The similar results were also reported by Hsu et al. [19]. Crude ash contents were found to be 5.8%, which reflected the mineral contents of the yam meals. Yam flours manufactured by hot air-drying are reported to contain low level of moisture [19]. And the cholesterol was not found in this assay. However, total caloric value and sugar content were determined to be 358 kcal and 10.8%, respectively.

3.2. Mineral composition

The result of mineral estimation of yam was presented in Table 2. The results revealed that potassium was the most abundant yam-contained minerals and calculated to be 1295.5 mg/100 g. These levels would appear to be similar to values reported for yam species by other researchers [4]. And the magnesium content (115.3 mg/100 g) was greater than the reported values for several cultivated yam species [20, 21]. These followed by Na (99.0 mg/100 g) and Ca (56.5 mg/100 g). A little amount of Zn (0.3 mg/100 g) was found, but ion was not detected.

Table 1. Proximate and nutritional compositions of raw yam (*Dioscorea batatas* DECNE.)

Composition	Content
Moisture (%)	7.2
Crude protein (%)	16.9
Crude fat (%)	2.0
Crude ash (%)	5.8
Carbohydrate (%)	68.1
Saturated fat (%)	0.7
Unsaturated fat (%)	1.2
Cholesterol (mg/100 g)	ND[1)]
Sugar (%)	10.8
Total caloric value (kcal)	358

[1)]ND: not detected.

Table 2. Mineral compositions of raw yam (*Dioscorea batatas* DECNE.)

Composition	Content (mg/100 g)
Na	99.0
Ca	56.5
Mg	115.3
K	1295.5
Fe	ND[1)]
Zn	0.3

[1)]ND: not detected.

3.3. Vitamin composition

A summary of the vitamin content of yam was shown in Table 3. In the previous study, yam was conducted to possess high content of vitamin C, ranging from 13.0 to 24.7 mg/100 g [4]. The vitamin C content of yam appeared to be little (2.2 mg/100 g) as the hot air drying, which was consistent with the values reported for tropical yam species from the Sri Lanka [22]. The vitamin A, vitamin B_3 and vitamin B_6 were not found. On the contrary, yam was relatively rich in vitamin B_1 (11.5 mg/100 g), which was higher than the reported values for *Dioscorea species* [22]. Small concentration of vitamin B_2 (0.01 mg/100 g) could be found in this study, which appeared to be similar to the corresponding value reported elsewhere for other yam species [22].

Table 3. Vitamin compositions of raw yam (*Dioscorea batatas* DECNE.)

Composition	Content
Vitamin A (μg RE[1)]/100 g)	ND[2)]
Vitamin E (mg/100 g)	1.2
Vitamin C (mg/100 g)	2.2
Vitamin B_1 (mg/100 g)	11.5
Vitamin B_2 (mg/100 g)	0.01
Vitamin B_3 (mg/100 g)	ND
Vitamin B_6 (mg/100 g)	ND

[1)]μg RE: micrograms of retinol equivalent.
[2)]ND: not detected.

3.4. Protein bound amino acid composition

The result for the protein bound amino acid composition of yam was presented in Table 4. Yam contained a considerable diversity of protein bound amino acids, whose total amino acid contents were 8530.4 mg%. Amongst the protein bound amino acids analyzed herein, the content of L-glutamic acid (1770.6 mg%), L-aspartic acid (958.0 mg%) and L-lysine (1210.6 mg%) tended to predominate in RY. The present results were in line with the results in yam tubers where aspartic acid and glutamic acid are the major abundant amino acids [23]. Essential amino acids apart from L-tryptophan in RY were of 2954.5 mg%, which accounted for 34.6% of total amino acids. The limiting amino acids were found to be L-valine and L-leusine. The sulfur-containing amino acid level (261.1 mg%) was lower than the reported values for Nigerian yam varieties [24].

3.5. Free amino acid composition

A summary of the free amino acid composition in yam was presented in Table 5.

Table 4. Protein bound amino acid compositions of raw yam (*Dioscorea batatas* DECNE.)

Amino Acids (AA)	Composition (mg%)	% to Total AA
Monoamino acid & monocarboxylic AA		
Glycine	577.5	6.8
L-Alanine	330.4	3.9
L-Valine	86.9	1.0
L-Leucine	233.6	2.7
L-Isoleucine	490.1	5.7
Monoamino-dicarboxylic AA		
L-Aspartic acid	958.0	11.2
L-Glutamic acid	1770.6	20.8
Hydroxy-AA		
L-Serine	753.5	8.8
L-Threonine	310.7	3.6
Thio(sulfur)-containing AA		
L-Cysteine	ND[1)]	-
L-Methionine	261.1	3.1
Diamino-monocarboxylic AA		
L-Lysine	1210.6	14.2
L-Arginine	294.9	3.5
L-Histidine	142.3	1.7
Aromatic AA		
L-Phenylalanine	361.5	4.2
L-Tyrosine	356.8	4.2
Imino acid		
L-Proline	391.9	4.6
Total AA (TAA)	8530.4	100.0
EAA[2)]	2954.5	
EAA/TAA (%)	34.6	

1)ND: not detected.
2)EAA: essential amino acids (valine, leucine, isoleucine, threonine, methionine, lysine, phenylalanine).

Yam contained a small amount of free amino acids, whose total amino acid contents were 688.0 mg%. Amongst the free amino acids analyzed herein, urea as a major amino acid accounted for about 80.1% of the total free amino acids. The results showed that L-serine (30.4 mg%) was the second abundant followed by L-alanine (29.3 mg%), L-arginine (16.2 mg%) and L-ornithine (15.1 mg%) in RY. The results showed that L-threonine (6.9 mg%) in yam was less than soybean (0.35-0.90 nmol/mg) [25]. The relatively higher content of β-alanine (0.4 mg%) could be observed in RY compared with roots from alfalfa plants [26].

3.6. Fatty acid composition

The fatty acid composition for yam was showed in Table 6. The saturated fatty acids (SFA) content was of 37.0% of total fatty acids for RY. Saturated fatty acids were found to be mainly composed of palmitic acid,

Table 5. Free amino acid compositions of raw yam (*Dioscorea batatas* DECNE.)

Sequential Peak	Amino Acids (AA)	Composition (mg%)	% to Total AA (%)
1	*O*-Phospho-L-Serine	ND[1)]	-
2	Taurine	ND	-
3	*O*-Phosphoethanolamine	ND	-
4	Urea	550.9	80.1
5	L-Aspartic acid	ND	-
6	Hydroxy-L-proline	1.8	0.3
7	L-Threonine	6.9	1.0
8	L-Serine	30.4	4.4
9	L-Asparagine	ND	-
10	L-Glutamic acid	ND	-
11	L-Sarcosine	ND	-
12	L-α-Aminoadipic acid	ND	-
13	L-Proline	ND	-
14	Glycine	4.2	0.6
15	L-Alanine	29.3	4.3
16	L-Citrulline	1.8	0.3
17	L-α-Amino-*n*-butyric acid	ND	-
18	L-Valine	4.8	0.7
19	L-Cystine	ND	-
20	L-Methionine	ND	-
21	Cystathionine	ND	-
22	L-Isoleucine	3.7	0.5
23	L-Leucine	3.3	0.5
24	L-Tyrosine	1.6	0.2
25	β-Alanine	0.4	0.1
26	L-Phenylalnine	2.6	0.4
27	DL-β-Aminobutyric acid	1.3	0.2
28	L-Homocystine	ND	-
29	γ-Amino-*n*-butyric acid	13.7	2.0
30	L-Tryptophan	ND	-
31	Ethanolamine	ND	-
32	Ammonium chloride[2)]	ND	-
33	δ-Hydroxylysine	ND	-
34	L-Ornithine	15.1	2.2
35	L-Lysine	ND	-

Table 5. Continued

Sequential Peak	Amino Acids (AA)	Composition (mg%)	% to Total AA (%)
36	1-Methyl-L-histidine	ND	-
37	L-Histidine	ND	-
38	3-Methyl-L-histidine	ND	-
39	Anserine	ND	-
40	α-Aminoguanidinopropionic acid	ND	-
41	L-Carnosine	ND	-
42	L-Arginine	16.2	2.4
Total AA		688.0	100.0

1)ND: not detected.

2)not calculation.

Table 6. Fatty acid compositions of raw yam (*Dioscorea batatas* DECNE.)

Fatty Acid	Peak Area (%)
Myristic acid (C14:0)	0.3
Palmitic acid (C16:0)	31.5
Heptadecanoic acid (C17:0)	0.4
Stearic acid (C18:0)	1.5
Arachidic acid (C20:0)	0.3
Behenic acid (C22:0)	0.6
Tricosanoic acid (C23:0)	0.7
Lignoceric acid (C24:0)	1.7
Saturates	37.0
Palmitoleic acid (C16:1)	0.7
Elaidic acid (C18:1t, *n*-9)	0.4
Oleic acid (C18:1c, *n*-9)	13.9
Nervonic acid (C24:1)	0.7
Monoenes	15.7
Linolelaidic acid (C18:2t, *n*-6)	1.0
Linoleic acid (C18:2c, *n*-6)	41.5
Linolenic acid (C18:3, *n*-3)	4.9
Polyenes	47.4

accounting for 31.5%. Monounsaturated fatty acids (MUFA) represented approximately 15.7% of total fatty acids. And the major MUFA in RY were oleic acid (13.9%), which appeared to be higher than the African yam bean [27]. Linoleic acid was the most abundant among the fatty acids analyzed in this study, which was determined to be 41.5%. This value compared favourably with common bean (43.1%) reported by Grela and Günter

[28], however higher than the reported value for cashew nut (2.5%) reported by [29]. Yam contained enough essential fatty acids such as linoleic acid (41.5%) and linolenic acid (4.9%). Our results differed from those of African yam beans, the composition of fatty acids were: 53.4%-60.2% SFA, 1.29%-3.60% MUFA and 28.3%-38.9% PUFA [27].

4. Conclusions

The proximate and nutritional compositions including mineral, vitamin, amino acids and fatty acids in Korean yam (*Dioscorea batatas* DECNE.). Carbohydrate (68.1%) possessed the large single constituent of yam. Small amounts of crude protein (16.9%), crude ash (5.8%) and crude fat (2.0%) contents were found. Yam was found to be good sources of essential minerals such as K (1295.5 mg/100 g), Mg (115.3 mg/100 g), Na (99.0 mg/100 g) and Ca (56.5 mg/100 g) but Zn (0.3 mg/100 g) content was low. Relatively abundant vitamin B_1 (11.5 mg/100g) could be observed while vitamin A, B_3 and B_6 were not found. The amino acid analysis revealed that the yam was superior with respect to glutamic acid (1770.6 mg%), lysine (1210.6 mg%) and urea (550.9 mg%). Essential amino acids were calculated to be 2954.5 mg%. The amino acid profiles showed that yam to be limiting in valine and leusine. Palmitic acid and linoleic acid were the most predominant fatty acids with the value of 31.5% and 41.5%, respectively. And the polyunsaturated fatty acids including linoleic acid and linolenic acid were present in a large quantities in yam.

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