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Effect of collection time on the chemical composition and levels of thiobarbituric acid reactive substance of *Godulbaegi* (*Youngia sonchifolia* M.)

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채취시기에 따른 고들빼기의 성분 조성과 산화방지활성

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Abstract

This study analyzes the chemical composition and thiobarbituric acid reactive substance levels of *Godulbaegi* (*Youngia sonchifolia* M.) depending on collection time. The moisture and crude fat content in leaf and root decreased, while crude fiber, crude protein, carbohydrate, and ash increased with increases in collection time. The mineral elements tended to increase in each sample with increases in collection time. The content of vitamin B increased as collection time increased. Vitamin C content was approximately five times higher in the leaves than that in the roots. Total amino acids in leaf and root increased considerably as collection time increased content of phenolic compounds in root were higher than that in the leaf and these contents increased. Antioxidant activity of *Godulbaegi* was higher in the root than in the leaf and increased as collection time increased.

Key words : Godulbaegi, harvesting time, functionality, nutritional components, phenolic compound, thiobarbituric acid reactive substances (TBARS)

Introduction

As living standards have improved and eating habits have changed with economic growth, consumer interest in health is increasing. Consumption of functional foods is increasing to maintain health, prevent diseases, and slow aging (1). The consumption of plant foods rich in vitamins and minerals such as fruits and vegetables, especially wild herbs and vegetables, rather than meat, is expanding gradually (2).

Godulbaegi (*Youngia sonchifolia* M., YSM) is currently the sixth most widely cultivated herb in South Korea. It is being grown to meet the demand of big cities; large quantities of the herb are supplied to regions including Seoul, and the supply is gradually expanding throughout South Korea. YSM, an annual or biennial plant belonging to the composite family, is native to the fields and mountains of South Korea (3). YSM has long been eaten as herbs in spring or made into a kimchi in autumn in South Korea, and nowadays, in some regions of the southern part of the country, it is made into kimchi and eaten all year round. YSM possesses blood circulation improvement and anti-inflammatory effects (4-8). Park (9) reported the amino acid composition, identification of chlorogenic acid, and the results of an anti-cancer effect test for Korean lettuce extract. Bae et al. (10) found that YSM inhibited the generation of lipid peroxides in a murine model, and Young et al. (11) reported that the serum cholesterol level was lowered by YSM extract in mice. Hwang et al. (12) reported that godulbaegi kimchi had an effect on

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protein digestibility. The functional components and activities of the plants may differ by harvest time or weather conditions at harvest time even if the products belong to the same variety (13). However, research on the changes in the chemical composition of the YSM has not been reported in international journals. For domestic studies, although a comparison of the physiologic and chemical properties of wild and cultivated *Lactu caindica* was conducted by Kim et al. (14), research on the effect of weather conditions at harvest time on functional components and antioxidant activities has not been conducted.

Although its utilization range as a food is gradually expanding in South Korea, research on YSM processing methods is insufficient. We analyze the components that affect the quality, palatability, and functionality of YSM parts by collection time, and describe YSM antioxidant properties.

Materials and Methods

Plant materials

YSM (leaf and root) is godulbaegi (*Youngia sonchifolia* M.) cultivated in open field after spraying seeds at early June in the Suncheon, South Jeolla Province, Korea. Samples were collected in the same area in early October and early December (Suncheon area weather (Data of Korea Meteorological Administration). : mean temperature/days; October→16.13℃ /days, December→0℃/days, precipitation/month; October→ 13.8 mm/month, December→10.6 mm/month). The samples used for the experiments were 25-30 cm length samples. The samples were washed and the roots and leaves were separated and stored at -54℃ deep freezer (FDA5508; Ilsinbiobase, Dongducheon, Korea).

Chemicals

Methanol, acetonitrile (HPLC grade), glacial acetic acid (analytical grade), monopotassium phosphate, and phosphoric acid were purchased from Merck (Germany). Sodium 1-hexanesulfonate (98% purity), anhydrous sodium carbonate (99% purity), and 2,4,6-trichloroanisole and 2,4,6-tribromoanisole were from Sigma-Aldrich (St. Louis, MO, USA). Standards of phenolic acids (arbutin, catechin, chlorogenic acid, p-coumaric acid), and standards of vitamins, organic acids, amino acids and free sugars were purchased from Sigma-Aldrich. To determine mineral and trace element contents, calibration standards were prepared by appropriate dilution from 1,000 ug/mL pure single element standard solutions (PerkinElmer, Shelton, CT, USA) while nitric acid (70%, Fluka 84380), hydrochloric acid (37%, Riedel-de-Haen30721), and hydrogen peroxide (30%, Fluka 95302) were of analytical purity.

Preparation of YSM extracts by water

A water extract of YSM was homogenized to a fine powder, followed by maceration of 100 g with 3 L of water at room temperature for 24 h. The extracts were filtered and stored at 4℃.

Preparation of oil emulsion

After the pH level of 0.1 M maleic acid buffer was adjusted to pH 6.5, 8 mL of the solution was put into a vessel. In addition, 50 Ul of Tween-20 and 0.5 mL of fish oil were added and the mixture was stirred for 15 minutes. Two or three pieces of KOH were added, and while the mixture was being stirred, an oil emulsion at pH 6.5 was prepared with 0.1 N HCl (15).

Sample preparation for thiobarbituric acid reactive substances (TBARS) assay

For oxygen species samples, 4 mM KO_2 was prepared for KO_2, 4 mM H_2O_2, for H_2O_2, 4 mM $FeCl_2$, for Fe^{2+}, 4 mM H_2O^{2+} 4 mM $FeCl_2$, for OH, and 4 mM $CuSO_4$, for Cu^{2+} (16). 0.1 mL of the oxygen species sample and 0.1 mL of YSM water extract were added to 0.5 mL of oil emulsion, and the mixture was adjusted by adding distilled water until the total amount of the mixture was 1 mL before it was used for experiments.

Proximate composition assay

The moisture, crude protein, crude fat, crude ash, and crude fiber contents were determined by the AOAC official method (17). Moisture content was obtained by calculating the weight loss after powdered samples were oven-dried at 105℃ to a constant weight. Crude protein and crude fat were analyzed using the Kjeldahl and the Soxhlet extraction methods. Ash content was determined gravimetrically after the samples were ignited in a furnace at 600℃. Estimation of crude fiber was based on the loss upon ignition of the dried residue after samples were digested with 1.25% each of sulfuric acid and sodium hydroxide solutions. The following equation was used for calculation of carbohydrate contents: % carbohydrates= 100%-(% crude protein+% crude fat+% crude ash).

Minerals assay

In the mineral analysis, all glassware was soaked overnight in a solution of 10% HCl in distilled water (v/v) prior to use. Ashed YSM samples (550℃, 6 h) were dissolved in 2 mL of 70% nitric acid. The acidified samples were neutralized in 5 mL of ddH_2O, filtered through Whatman No. 1 paper and diluted to volume with ddH_2O in a 50 mL volumetric flask. Major minerals: magnesium (Mg), potassium (K), calcium (Ca), iron (Fe), sodium (Na), and cooper (Cu) were determined using inductively coupled plasma optical emission spectrometry (ELEMENT 2*ICPMS, Thermo Fisher Scientific Inc., MA, USA).

Vitamin assay

The vitamin B group and vitamin C in YSM were assayed by the methods from Wimalasiri and Wills (18), and Hefferan et al. (19) with a slight modification. Concentrations of vitamin B group (Niacin, Vit. B_6, Vit. B_2, Vit. B_1) and vitamin C were analyzed using a high performance liquid chromatography system (Waters M510, Waters Co., Milford, MA, USA) with a Radial Pak C18 column (ID 0.8×300 mm, Waters Co., Milford, MA, USA) operated at 25℃ and UV 486 detector (Waters Co.) at 280 nm. The mobile phase was composed of 75% methanol with 5 mM sodium 1-hexanesulfonate (Pic B_6, Fluka), and the flow rate was set to 1.0 mL/min.

Organic acids assay

One hundred grams of YSM was homogenized in 3 L of water. The solution was then incubated for 20 min in a 35℃ water bath and centrifuged at 10,000 ×*g* for 10 min.. The supernatants were collected and filtered through membrane filters (Millipore Co., Billerica, MA, USA) with a pore size of 0.45 μm for the organic acid tests. Concentrations of the six main organic acids (lactic, citric, maleic, succinic, acetic and tartaric acids) were analyzed using a high performance liquid chromatography system (Waters M510, Waters Co.) with a Rspak KC-811 column (ID 0.8×300 mm, Waters Co.,) operated at 25℃ and UV 486 detector (Waters Co.,) at 220 nm. The mobile phase was composed of 95% (v/v) 3.3 mM KH_2PO_4 and 5% methanol with the pH adjusted to 2.5 with phosphoric acid, and the flow rate was set to 1.0 mL/min.

Total amino acids assay

In the amino acid analysis, the YSM was hydrolyzed in 6 N HCl for 24 h. Amino acids were quantified using the amino acid auto analyzer (S433, Sykam Co., Eresing, Germany) employing sodium citrate buffers as step gradients with the cation exchange post column ninhydrin derivatization method. The data were described as grams of amino acid per 100 g.

Free sugars assay

Free sugar contents in YSM were identified by methods from Damon and Pettitt (20) with a slight modification. Concentrations of the four main free sugars (fructose, glucose, sucrose and maltose) were analyzed using a high performance liquid chromatography system (Waters M510, Waters Co.,) with a carbohydrate analysis column (ID 4.6×250 mm, Grace Co., Deerfield, IL, USA) operated at 30℃ and ELSD 2000ES detector (ELSD 2000ES detector, Alltech Co., Vienna, VA, USA). The mobile phase was composed of 75% acetonitrile, and the flow rate was set to 1.0 mL/min.

Polyphenol compounds assay

The polyphenol compounds in YSM were identified by the methods from Liu et al. (21) with a slight modification. The high performance liquid chromatography (HPLC) system is composed of a Waters M510 pump system (Waters M510, Waters Co.,) pump system and a 486 detector (Waters Co.). A u-Bondpak C_{18} column (ID 3.9×250 mm, Waters Co.) and a gradient solvent system consisting of methanol (solvent A) and water with 2% glacial acetic acid (solvent B) (conditions: 5-17% A from 0 to 5 min and kept at 17% A from 5 to 25 min; 17-31% A from 25 to 40 min and kept at 31% A from 40 to 76 min; 31-40 % A from 76 to 80 min and kept at 40% A from 80 to 120 min; flow rate=1 mL/min) were used for separation of components whose UV spectra were recorded from 280 nm. Polyphenol compounds included arbutin, catechin, chlorogenic acid, p-coumaric acid.

Thiobarbituric acid reactive substances (TBARS) assay

The TBARS method was conducted by allowing the test tube filled with 1 mL of the reaction mixture to react in 37℃ water bath for one hour following the method of Buege and Aust (22). Immediately after the reaction was terminated, 50 Ul of 7.2% BHT was added to the sample to stop the oxidation reaction, and 2 mL of the TCA/TBA reagent was added. The mixture was heated in boiling water for 15 minutes, cooled in cold water, and centrifuged at a rate of 2,000 ×*g* for 15 min. The supernatant was measured at 531 nm, and the blank sample was measured in the same manner

after distilled water was added to them in place of the sample. The TBARS values were represented as the malondialdehyde (MDA) values for the reaction mixture.

Statistical methods

Data were expressed as mean±SD and statistical analysis for single comparisons was performed using Duncan's multiple range test. Each experiment was repeated at least three times to yield comparable results. Null hypotheses of no difference were rejected if p-values were less than 0.05.

Results and Discussion

Proximate

The results of dividing the roots and leaves of YSM and analysis of the changes in the contents of general components by collection periods are shown in Table 1. The moisture contents of leaves and roots were 86.12% and 84.12%, respectively, in the October test plot (hereafter, October) and decreased slightly to 85.32% and 82.44%, respectively, in the December test plot (hereafter, December). The crude ash content increased from 0.70% in October to 0.61% in December in the leaves and increased from 0.64% to 1.12% in the roots. Like the crude ash content, the crude protein content increased from 1.83% in October to 2.10% in December in the leaves and increased from 1.83% to 2.74% in the roots. The crude fat content decreased in both the leaves and roots in December compared to that of October, but the crude fiber increased in the leaves and roots from 4.34% and 4.63% in October to 4.93% and 4.81% in December. The carbohydrate contents of both the leaves and roots increased slightly from 6.21% and 8.42% in October and to 7.03% and 8.70% in December. In the content analysis of the general components of *Lactuca indica* from June to August, Kim et al. (14) reported that the moisture content decreased and the crude protein content increased, while no significant difference was observed in the contents of the crude fat, crude ash, and crude fiber. The results of this research were similar in regard to the changes in the moisture and crude protein contents, but different from those of Kim et al. (14) in the contents of crude fat, crude ash, and crude fiber. These results may be because this research differed from Kim et al. (14) in the varieties used and harvesting periods, from June to August versus from October to December.

Minerals

The presence of minerals in plants is largely dependent on growing conditions including cultivation techniques, abiotic or biotic stress and nutrient status. The changes in the mineral content of YSM (leaf and root) by collection time are presented in Table 1. The main minerals of the leaves and roots were K (potassium), Na (sodium), Mg (magnesium), and Ca (calcium), in descending order of contents. Fe (iron) and Cu (copper) were minimal. The Na content decreased in the leaves from 44.43 mg% in October to 34.82 mg% in December, while it increased in the roots from 23.84 mg% in October to 30.23 mg% in December. Thus, Na changed the most. Nour V et al. (23) analyzed the mineral contents of the leaves of blackcurrants (*Ribes nigrum* L.) by harvest time and reported delayed harvest decreased Na. The results of this study are consistent with their research. In addition, Kim et al. (14) reported that potassium was high irrespective of the growth conditions, as a result of analyzing minerals of wild and cultivated *Lactuca indica*.

Table 1. Proximate composition and minerals contents of *Godulbaegi* (*Youngia sonchifolia* M.)

Composition	Samples			
	Leaf		Root	
	October	December	October	December
Proximate (%)				
Moisture	86.12±1.89[1)a2)]	85.32±1.53[a]	84.12±1.88[b]	82.44±1.76[c]
Crude ash	0.70±0.04[b]	0.61±0.03[b]	0.64±0.03[b]	1.12±0.12[a]
Crude protein	1.83±0.15[c]	2.10±0.28[b]	1.83±0.16[c]	2.74±0.53[a]
Crude fat	0.60±0.03[a]	0.41±0.02[b]	0.51±0.02[ab]	0.34±0.02[c]
Crude fiber	4.34±0.89[b]	4.93±1.03[a]	4.63±0.81[a]	4.81±0.79[a]
Carbohydrate	6.21±1.23[b]	7.03±1.33[b]	8.42±1.62[a]	8.70±1.33[a]
Minerals[3)] (mg%)				
Ca	10.72±0.96[c]	12.10±1.89[b]	12.93±1.93[ab]	14.23±2.16[a]
K	309.59±6.34[a]	308.47±7.23[a]	310.09±8.08[a]	312.33±8.39[a]
Mg	11.82±1.33[b]	10.23±1.26[c]	12.33±1.77[ab]	13.44±1.97[a]
Na	44.43±2.39[a]	34.82±2.01[b]	23.84±1.33[c]	30.23±1.09[b]
Fe	t[4)]	t	t	t
Cu	t	t	t	t

[1)]Each value is expressed as mean±SD, n=3.
[2)]Mean±SD with different superscript within a row are significantly different ($p<0.05$) by Duncan's multiple range test.
[3)]Detection limits of minerals analysis (mg/L): Ca, 0.3213; K, 0.1316; Mg, 0.2639; Na, 0.0265; Fe, 0.0027; Cu, 0.0011.
[4)]t, trace.

Vitamins

The changes in vitamin contents of YSM (leaf and root)

by collection time are in Table 2. Vitamin C in the leaves and roots was 87.12 mg% and 15.87 mg% in October, and 78.68 mg% and 13.56 mg% in December, respectively, so decreasing slightly in December compared to October. The vitamin C content was approximately five times higher in the leaves than in the roots, and the amount of reduction was higher in the leaves. The content of vitamin C varies greatly depending on the growth age and climate conditions of the plant. Choi and Han (24) reported that vitamin C content of perilla leaves by leaf age was high in young leaves. In this study, samples collected at early October were higher. The niacin contents of the leaves and roots was 4.63 mg% and 3.78 mg% in October, and 3.29 mg% and 3.33 mg% in December, respectively, so decreased slightly in December compared to October and the niacin content was higher in the leaves. The vitamin B group was slightly higher in December than in October in the leaves, but B_2 and B_1 tended to decrease slightly in the roots. Content differences by the parts of YSM were generally not seen, except that the B_6 content was nearly double in the leaves than in the roots.

Table 2. Contents of vitamins and organic acids in *Godulbaegi* (*Youngia sonchifolia* M.)

Composition	Samples			
	Leaf		Root	
	October	December	October	December
Vitamins (mg%)				
Vit. C	87.12±2.36[1)a2)]	78.68±2.51[b]	15.87±0.96[c]	13.56±0.81[c]
Niacin	4.63±0.61[a]	3.29±0.53[c]	3.78±0.52[b]	3.33±0.55[bc]
Vit. B_6	0.23±0.06[a]	0.25±0.09[a]	0.12±0.03[b]	0.15±0.03[b]
Vit. B_2	0.11±0.02[a]	0.12±0.03[a]	0.12±0.03[a]	0.13±0.03[a]
Vit. B_1	0.12±0.01[b]	0.17±0.04[a]	0.18±0.05[a]	0.19±0.04[a]
Organic acids (mg%)				
Maleic acid	1.86±0.38[a]	1.97±0.22[a]	0.56±0.09[b]	0.36±0.06[b]
Citric acid	0.90±0.12[b]	1.21±0.23[a]	1.20±0.30[a]	1.12±0.36[ab]
Tartaric acid	0.82±0.16[a]	0.51±0.08[b]	t	t
Succinic acid	t[3)]	t	t	t

[1)]Each value is expressed as mean±SD, n=3.
[2)]Mean±SD with different superscript within a row are significantly different ($p<0.05$) by Duncan's multiple range test.
[3)]t, trace.

Organic acids

The changes in the organic acid contents of YSM (leaf and root) by collection time are presented in Table 2. The main organic acids of the leaves and roots of YSM were citric, maleic and tartaric acid. For the leaves, the maleic acid content was the highest with 1.86 mg% in October and 1.97 mg% in December, and for the roots, the citric acid content was highest with 1.20 mg% in October and 1.12 mg% in December. Tartaric acid was detected in the leaves, but a very small amount was detected in the roots. For the leaves, an overall increase in the contents was observed in December, the later harvest time, compared to the measurements of October. However, root content tended to decrease overall. The total content of organic acids of YSM was higher in the leaves than in the roots. Kim et al. (14) measured the organic acid contents of *Lactuca indica* and reported that they were higher in the leaves than in the roots.

Total amino acids

The changes in the contents of component amino acids of YSM (leaf and root) by collection time are in Table 3. Sixteen kinds of component amino acids of YSM were identified, including aspartic acid, and they contained all the eight essential amino acids. In the leaves, total component amino acids increased significantly from 94.87 mg% in October to 145.97 mg% in December, and increased in the roots from 127.91 mg% in October to 171.79 mg% in December. Thus, amino acid levels were higher in the roots than in the leaves. The main amino acids of the YSM leaves in December detected were Ile at 64.01 mg%, Leu at 52.03 mg%, Glu at 3.62 mg%, Ser at 3.52 mg%, and Pro at 3.36 mg%, and the isoleucine content was the highest. For the YSM roots in October, the main amino acids were Ile, Leu, Arg, Thr, Phe, and Glu from the highest to the lowest, and following those, other amino acids detected were Ser, Ala, Asp, Val, and Lys.

Free sugars

The changes in the free sugar contents of the YSM (leaf and root) by collection time are in Table 4. Four kinds of free sugars contained in the leaves and roots of YSM were identified: fructose, glucose, sucrose, and maltose. The fructose content of the YSM leaves was 0.23% in October and 0.33% in December, while the fructose content of the roots was 0.43% in October and 0.73% in December, so the fructose content was higher in December. The glucose content was higher in the leaves than in the roots, and while there were no differences in the content by collection time in the roots, the glucose content increased five times in the leaves from 0.20% in October to 1.04% in December, a significant difference. Liu S et al. (25) measured the free sugar content of *Arundo donax* L. by harvest time and reported that the

Table 3. Contents of total amino acids in *Godulbaegi* (*Youngia sonchifolia* M.)

Components	Samples (mg%)			
	Leaf		Root	
	October	December	October	December
Aspartic acid	3.23±0.42[1)a2)]	2.83±0.33[b]	2.32±0.35[c]	2.22±0.17[c]
Threonine	3.79±0.64[a]	2.12±0.28[b]	3.94±0.58[a]	1.98±0.22[b]
Serine	1.23±0.13[d]	3.52±0.44[b]	2.60±0.36[c]	4.88±0.68[a]
Glutamic acid	3.12±0.30[b]	3.62±0.38[a]	3.15±0.29[b]	2.41±0.33[c]
Proline	0.77±0.12[d]	3.36±0.35[b]	1.77±0.23[c]	5.23±0.84[a]
Glycine	0.40±0.09[c]	0.60±0.12[a]	0.55±0.09[b]	0.53±0.13[b]
Alanine	1.70±0.13[c]	2.45±0.22[b]	2.58±0.23[a]	2.01±0.14[bc]
Cystine	-	-	-	-
Valine	1.83±0.15[d]	2.78±0.23[b]	2.29±0.26[c]	2.92±0.24[a]
Methionine	0.15±0.02[c]	0.55±0.05[b]	0.85±0.08[a]	0.72±0.06[ab]
Isoleucine	42.07±3.36[c]	64.01±5.02[b]	77.96±6.16[a]	72.84±6.30[a]
Leucine	31.19±3.67[c]	52.03±5.34[b]	21.94±3.62[d]	62.39±4.27[a]
Tyrosine	0.73±0.08[b]	0.59±0.07[c]	0.23±0.02[d]	1.47±0.11[a]
Phenylalanine	1.31±0.12[c]	2.07±0.23[b]	3.17±0.30[a]	3.10±0.33[a]
Histidine	0.18±0.03[d]	2.13±0.21[b]	1.60±0.32[c]	2.89±0.40[a]
Tryptophan	0.82±0.09[c]	1.03±0.34[b]	0.87±0.31[c]	3.12±0.43[a]
Lysine	2.35±0.23[b]	2.28±0.22[b]	2.09±0.30[c]	3.08±0.36[a]
Arginine	1.24±0.14[c]	2.55±0.42[b]	4.71±0.61[a]	4.67±0.62[a]
Total	94.87	145.97	127.91	171.79

[1)]Each value is expressed as mean±SD, n=3.
[2)]Mean±SD with different superscript within a row are significantly different ($p<0.05$) by Duncan's multiple range test.

Table 4. Contents of free sugars in *Godulbaegi* (*Youngia sonchifolia* M.)

Components	Samples (%)			
	Leaf		Root	
	October	December	October	December
Fructose	0.23±0.02[1)b2)]	0.33±0.02[b]	0.43±0.03[ab]	0.73±0.06[a]
Glucose	0.20±0.01[b]	1.04±0.13[a]	0.12±0.01[a]	0.10±0.01[a]
Sucrose	1.51±0.38[c]	2.53±0.37[ab]	2.12±0.29[ab]	3.33±0.41[a]
Maltose	t[3)]	t	0.24±0.09	0.34±0.04
Total	1.94	3.90	2.91	4.40

[1)]Each value is expressed as mean±SD, n=3.
[2)]Mean±SD with different superscript within a row are significantly different ($p<0.05$) by Duncan's multiple range test.
[3)]t, trace.

glucose content increased in all samples as the harvest time was delayed. Thus, their research is consistent with this study. Sucrose comprises most of the free sugars contained in the YSM, and its content was higher in the samples collected in December in both the leaves and roots. Maltose was higher in the roots.

Polyphenol compounds

Among the polyphenolic compounds, flavonoid reacts with $1O^2$ or O^{2-}, forms a stable complex, and prevents lipid peroxidation by scavenging them. Consequently, the phenolic content and antioxidant activity are associated (26). The changes in the content of polyphenol compounds of YSM (leaf and root) by collection time are in Table 5. For the YSM samples collected in October, polyphenol was 1.02 mg% in the leaves and 2.04 mg% in the roots. For the samples collected in December, it was 1.81 mg% in the leaves and 3.80 mg% in the roots, so the contents were higher in the samples collected in December. In addition, the root contents were more than twice as high as the leaves. The main components of both roots and leaves were arbutin and p-coumaric acid. The arbutin content was more than 2.5 times higher in the samples collected in December than those collected in October, a significant difference. The catechin content tended to decrease in the samples collected in December in comparison to those collected in October in the leaves, but increased by more than 35 times in the roots of samples collected in December. Chlorogenic acid was detected only in the roots collected in December, and the p-coumaric acid content was higher in the samples collected in October, tending to decrease as the collection time is delayed.

Table 5. Contents of polyphenol compounds in *Godulbaegi* (*Youngia sonchifolia* M.)

Components	Samples (mg%)			
	Leaf		Root	
	October	December	October	December
Arbutin	0.62±0.12[1)b2)]	1.65±0.20[a]	0.79±0.09[b]	1.60±0.31[a]
Catechin	0.05±0.01[b]	0.02±0.00[b]	0.02±0.01[b]	0.76±0.14[a]
Chlorogenic acid	t[3)]	t	t	0.83±0.15
p-Coumaric acid	0.35±0.07[bc]	0.14±0.03[c]	1.23±0.45[a]	0.61±0.11[b]
Total	1.02	1.81	2.04	3.80

[1)]Each value is expressed as mean±SD, n=3.
[2)]Mean±SD with different superscript within a row are significantly different ($p<0.05$) by Duncan's multiple range test.
[3)]t, trace.

Effects of water extracts of YSM (leaf and root) on the lipid oxidation of oil emulsion

The effect of the addition of 0.05% YSM (leaf and root) water extracts on reactive oxygen species that reacted in the

oil emulsion was measured by thiobarbituric acid reactive substances (TBARS) (Table 6). Adding KO_2 resulted in a measurement of 0.15 mg MDA/L in the YSM root extract, excellent antioxidative activity. Other samples did not differ significantly. For the effect on H_2O_2, the TBARS values of the YSM root extract were lower than those of the YSM leaf extract, strongly antioxidative. The TBARS values did not differ by collection time. The YSM root extract possessed higher capture capacity for hydroxyl radical (·OH, which causes fat oxidation and accelerates the aging process) compared with the YSM leaf extract and exhibited antioxidative activity. As to Fe^{2+} and Cu^{2+}, the YSM root extract showed better antioxidative activity than the YSM leaf extract. The December samples showed stronger antioxidative activity than those of October. Lee and Han (27) measured TBARS values of the butanol extract of *Ulmus devidiana* and reported that the measured values were 0.14 -0.44 mg MDA/L, indicating the highest antioxidative activity. In this study, TBARS measurements ranged from 0.13 to 0.25 mg MDA/L, so YSM extracts showed similar antioxidant activity to *Ulmus devidiana* butanol extracts.

Table 6. Effects of *Godulbaegi* (*Youngia sonchifolia* M.) water extract reacted with active oxygen species and metal iron on lipid oxidation in oil emulsion

Element[1)]	Samples (TBARS (mg MDA/L reaction mixture))			
	Leaf		Root	
	October	December	October	December
KO_2	0.25±0.03[2)a3)]	0.20±0.02[a]	0.21±0.02[a]	0.15±0.01[b]
H_2O_2	0.24±0.02[a]	0.25±0.02[a]	0.15±0.01[a]	0.12±0.01[a]
·OH	0.24±0.03[a]	0.25±0.03[a]	0.15±0.02[b]	0.14±0.02[b]
Fe^{2+}	0.21±0.03[a]	0.15±0.01[b]	0.16±0.02[b]	0.15±0.02[b]
Cu^{2+}	0.25±0.03[a]	0.21±0.02[a]	0.13±0.01[b]	0.15±0.01[b]

[1)]KO_2, 4 mM KO_2; H_2O_2, 4 mM H_2O_2; Fe^{2+}, 4 mM $FeCl_2$; ·OH, 4 mM H_2O_2+4 mM $FeCl_2$; Cu^{2+}, 4 mM $CuSO_4$.
[2)]Each value is expressed as mean±SD, n=3.
[3)]Mean±SD with different superscript within a row are significantly different ($p<0.05$) by Duncan's multiple range test.

Conclusion

We analyze the components that affect the quality, palatability, and functionality of YSM parts by collection time, and describe YSM antioxidant properties. Until now, we have taken the collection time of field cultivation *Godulbaegi* (*Youngia sonchifolia* M.) to the end of October. However, there was no significant difference in the components of the samples collected at the early October and at the early December. Therefore, it has been confirmed that the food value of godulbaegi collected in early December (10 days before) is sufficient. And the possibility of delaying the collection time was confirmed.

요 약

본 연구에서는 식품으로서 활용범위가 점차 증가되고 있는 고들빼기 식품의 품질에 영향을 미칠 수 있는 여러 화학 성분과 기호성에 관계되는 특수성분을 조사하기 위하여 10월(A)과 12월(B) 2회에 걸쳐 채취시기별로 나누어 분석하였으며, 고들빼기에 함유된 항산화물질을 분석하여 가공식품으로 정착시키는데 필요한 기초 자료를 얻고자 하였다. 고들빼기의 채취 시기별 일반성분의 변화를 조사한 결과, 잎과 뿌리에서 채취 시기가 경과할수록 수분 함량과 조지방 함량은 공통적으로 감소하였으나, 섬유질, 단백질, 가용성무질소물 및 회분 함량은 증가하는 경향을 나타냈다. 무기질은 채취 시기가 경과할수록 잎의 Mg과 Na를 제외하고는 모든 시료에서 공통적으로 증가하는 경향이었다. Vit. C와 Niacin은 채취 시기가 경과할수록 잎과 뿌리 모두에서 공통적으로 감소하는 경향이었으나, Vit. B_1, B_2는 소량 증가하는 경향을 보였다. 고들빼기 잎과 뿌리의 주된 유기산은 구연산, 사과산 및 주석산이 검출되었고, 시기별로 성분함량의 차이는 보이지 않았다. 주요 구성아미노산은 잎과 뿌리 모두에서 isoleucine과 leucine이었고, 채취시기가 늦을수록 구성아미노산 함량은 증가하였다. 고들빼기의 잎과 뿌리에 함유된 유리당은 fructose, glucose, sucrose, maltose 등 4개의 당이 확인되었고 총 유리당 함량은 채취시기가 늦을수록 증가하였다. Phenol화합물은 arbutin, catechin, chlorogenic acid, p-coumaric acid 등 4개의 성분이 확인 되었으며, 잎보다 뿌리 함량이 높은 것으로 나타났으며, 채취시기가 늦을수록 그 함량이 증가하는 것으로 나타났다. 고들빼기 항산화력은 잎보다 뿌리의 항산화력이 더 강한 것으로 나타났으며, 채취 시기가 늦을 수 록 더 강한 것으로 나타났다.

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References

1. Lee YM, Bae JH, Jung HY, Kim JH, Park DS (2011)

Antioxidant activity in water and methanol extracts from Korean edible wild plants. J Korean Soc Food Sci Nutr, 40, 29-36
2. Ahn SY, Kim JH, Choi SJ, Kim YJ (2009) Current status and prospect of cultivation of wild vegetable crops. Paper presented at 90th Annual Meeting of Korean J Hort Sci Technol, May 22~23, Gyeongsangnamdo, Korea
3. Kim HR, Lee IS (2008) Quality changes of *Godulbaegi* (*Youngia sonchifolia* Maxim) kimchi during storage at different temperatures. Korean J Food Cookery Sci, 24, 617-625
4. Yee SB, Lee JH, Chung HY, Im KS, Bae SJ, Choi JS, Kim ND (2003) Inhibitory effects of luteolin isolated from *Ixeris sonchifolia* Hance on the proliferation of HepG2 human hepatocellular carcinoma cells. Arch Pharm Res, 26, 151-156
5. Chen CG, Jia HL, Lv SX, Xu CQ (2012) Protective effect of Kudiezi on acute cerebral ischemic reperfusion injury in rats. Chin J Clin Pharmacol, 28, 196-199
6. Lu J, Feng X, Sun Q, Lu HW, Manabe M, Sugahara K, Ma D, Sagara Y, Kodama H (2002) Effect of six flavonoid compounds from *Ixeris sonchifolia* on stimulus-induced superoxide generation and tyrosyl phosphorylation in human neutrophils. Clin Chim Acta, 316, 95-99
7. Zhai YR, Huang XN, Yu XF, Qu SC, Sai DY (2008) Effect of *Ixeris sonchifolia* extracts (KDZ) for injection on myocardial enzymes and blood viscosities of myocardial ischemia reperfusion injury rats. Pharmacol Clin Chin Mater Med, 24, 53-55
8. Zhai YR, Yu XF, Qu SC, Xu HL, Sui DY (2010) Protective effects of total flavonoids of sowthistle-leaf *Ixeris* sedling on myocardial ischemia reperfusion injury in rats. Chin Pharmacol Bull, 26, 276-277
9. Park SS (1977) Studies on the constituents and their biological activities of *Ixeris sonchifolia* Hance (Ⅰ). Korean Biochem J, 10, 241-252
10. Bae SJ, Kim NH, Ha BJ, Jung BM, Roh SB (1997) Effects of *Godulbaegi* leaf extracts on CCl_4-induced hepatotoxicity in rats. J Korean Soc Food Sci Nutr, 26, 137-143
11. Young HS, Im KS, Choi JS (1992) The pharmacochemical study on the plant of Ixeris spp.:2. Flavonoids and free amino acid composition of *Ixeris sonchifolia*. J Korean Soc Food Nutr, 21, 296-301
12. Hwang EY, Ryu HS, Chun SS, Park KY, Rhee SH (1995) Effect of *Godulbaegi* (Korean lettuce, *Ixeris sonchifolia* H.) kimchi on the *in vitro* digestibility of proteins. J Korean Soc Food Nutr, 24, 1010-1015
13. Yao L, Caffin N, D'Arcy B, Jiang Y, Shi J, Singanusong R, Liu X, Datta N, Kakuda Y, Xu Y (2005) Seasonal variations of phenolic compounds in Australia-grown tea (*Camellia sinensis*). J Agric Food Chem, 53, 6477-6483
14. Kim JM, Kim JN, Lee KS, Shin SR, Yoon KY (2012) Comparison of physicochemical properties of wild and cultivated *Lactuca indica*. J Korean Soc Food Sci Nutr, 41, 526-532
15. Blois MS (1958) Antioxidant determinations by the use of a stable free radical. Nature 181, 1199-1200
16. Lee YJ, Han JP (2000) Antioxidative activities and nitrite scavenging abilities of extracts from *Ulmus devidiana*. J Korean Soc Food Sci Nutr, 29, 893-899
17. AOAC (2000) Official Methods of Analysis. 17th ed, Association of Official Analytical Chemists, Gaithersburg, MD, USA, p 1-26
18. Wimalasiri P, Wills RBH (1985) Simultaneous analysis of thiamin and riboflavin in foods by high-performance liquid chromatography. J Chromatogr A, 318, 412-416
19. Hefferan TE, Chrisley BM, Driskell JA (1986) Quantitation of B_6 vitamins in rat plasma by high performance liquid chromatography. J Chromatogr A, 374, 155-161
20. Damon CE, Pettitt BC Jr (1980) High performance liquid chromatographic determination of fructose, glucose, and sucrose in molasses. J Assoc Off Anal Chem, 63, 476-480
21. Liu CW, Yang DJ, Chang YY, Hsu CL, Tseng JK, Chang MH, Wang M, Chen YC (2012) Polyphenol-rich longan (*Dimocarpus longan* Lour.)-flower- water-extract attenuates nonalcoholic fatty liver via decreasing lipid peroxidation and downregulating matrix metalloproteinases-2 and -9. Food Res Int, 45, 444-449
22. Buege JA, Aust SD (1978) Microsomal lipid peroxidation. Methods Enzymol, 52, 302-310
23. Nour V, Trandafir I, Cosmulescu S (2014) Antioxidant capacity, phenolic compounds and minerals content of blackcurrant (*Ribes nigrum* L.) leaves as influenced by harvesting date and extraction method. Ind Crops Prod, 53, 133-139
24. Choi YH, Han JS (2001) Vitamin C and mineral contents in perilla leaves by leaf age and storage conditions. Korean J Soc Food Cookery Sci, 17, 583-588
25. Liu S, Ge X, Liu Z, Li Y (2016) Effect of harvest date on *Arundo donax* L.(giant reed) composition, ensilage performance, and enzymatic digestibility. Bioresour

Technol, 205, 97-103
26. Boudet AM (2007) Evalution and current status of research in phenolic compounds. Phytochemistry, 68, 2722-2735
27. Lee YJ, Han JP (2000) Antioxidative activities and nitrite scavenging abilities of extracts from *Ulmus devidiana*. J Korean Soc Food Sci Nutr, 29, 893-899