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Original Research Article

Antioxidant Activity of Several Cabbage (*Brassica oleracea* L.) Cultivars

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Abstract - Total phenol, flavonoid and antioxidant components of cabbage leaf samples derived from different cultivar were determined. Total phenol compound content showed the highest amount in methanol extracts from '*YR Howol*' cultivar (11.72 ㎎/g), followed by '*Harutame*' (10.66㎎/g), '*Winstar*' (10.34 ㎎/g) and *YR Hero* (10.20 ㎎/g). The highest amount of total flavonoid content was observed from the methanol extracts of *Harutame* (5.39 ㎎/g), followed by *Winstar* (4.28 ㎎/g), *Wialhowol* (4.10 ㎎/g). The SOD enzyme activity showed a high activity of '*YR Hogeo*' cultivar, and the cultivar of '*YR Howol*' cultivar showed the lowest activity of SOD. The activity of CAT and APX showed higher values '*Ogane*' and '*YR Hogeol*' cultivars than the other cultivars. The POD activities showed relatively high values '*Ogane*' and '*YR Howol*' cultivars compared with other cultivars. The free radical (DPPH) scavenging activity showed lower IC_{50} values of '*Harutame*' (15.71) and '*YR Howol*' cultivar (16.88), however methanol extract of '*YR Hero*' cultivar (22.49) being the highest. The extracts of all cabbage cultivars in the reaction solution of pH 1.2 could be decomposed nitrite more than 50%. Especially, the cultivar '*YR Hogeol*' and '*Ogane*' showed a relatively high nitrite scavenging activity for each 60.13% and 57.20% respectively. The IC_{50} values of antioxidant activity determined by ABTS were lower in '*Harutame*' (17.04) and '*YR Howol*' cultivar (17.97), and its results observed similar with values obtained from the same extracts by DPPH method. The result of this study suggests that the methanol extract of *Brassica oleracea* L. contains the high amount of phenolic and higher radical scavenging activities.

Key words - *Brassica oleracea* L., Phenolic compounds, Antioxidant enzyme, DPPH, ABTS, Nitrite scavenging

Introduction

Brassica oleracea L. belongs to the Brassicaceae (formerly called Cruciferae) family and are consumed in enormous quantities throughout the world and are important in human nutrition (Ferreres *et al.,* 2006). They are reported to reduce the risks of some cancers, especially due to its content of glucosinolates and their derived products (Chun *et al.,* 2004), although phenolic compounds are also considered to contribute to this capacity (Galati and O'Brien, 2004; Hollman, 1996). The phenolic compounds which occur in food of plant origin and natural health products possess such common biological properties as antioxidant activity, the ability to scavenge active oxygen species, the ability to scavenge electrophiles, the ability to inhibit nitrosation, the ability to chelate metals, the potential to produce hydrogen peroxide in the presence of certain metals, and the capability to modulate certain cellular enzyme activities (Shahidi and Ho, 2005). Currently, consumers are aware of the need for a constant supply of phytochemical-containing plants to get the most complete antioxidant support for disease prevention. Recently, plant and plant-derived products are treated a part of the health care system by applying the bioactive phytochemicals. Antioxidant compounds in food play an important role as a health-protecting factor. Most of the antioxidant compounds in a typical diet are derived from plant sources and belong to various classes of compounds with a wide variety of physical and chemical properties. The main characteristic of an antioxidant is its ability to eliminate free radicals. Highly reactive free radicals and oxygen species are present in biological systems from a wide variety of sources. The role of antioxidants in foods is to inhibit or control oxidation. The plant has antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), peroxidase (POD), and ascorbate peroxidase (APX) against ROS (reactive oxygen species) (Zhou *et al.,* 2005). The production of activated oxygen

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species occurs when plants are subjected to stress conditions (Dionisio-Sese and Tobita, 1998). Both enzymatic and nonenzymatic antioxidant systems are present in plants. Superoxide radicals are detoxified by SOD and hydrogen peroxide is destroyed by CAT and different kinds of peroxidases (Kang and Saltveit, 2002). A major hydrogen peroxide-detoxifying system in plant is the ascorbate-glutathione cycle that includes APX and glutathione reductase (GR) (Asada, 1994). Ascorbate peroxidase, catalase and peroxidase, together with low-molecular mass scavengers such as ascorbate, glutathione and proline, act as the main defense against ROS produced in various parts of plant cells (Apel and Hirt, 2004). The induction of ROS-scavenging enzymes, such as SOD, POXs and CAT, is the most common mechanism for detoxifying ROS synthesized during stress responses (Wojtaszek, 1997; Mittler, 2002). In response to the increased production of oxygen radicals the capacity of the antioxidant defense system is increased, but in most situations the response is moderate (Foyer *et al.,* 1994). The objective of this study was conducted to evaluate the phenolics and the antioxidant potential of cabbage leaves according to the cultivars.

Materials and Methods

Plant material

Seven cultivars of cabbage such as *Ogane, YR Howol, Harutama, Winster, YR Hero, YR Hogeol, Daebakna* grown in the open field in Jeju Island were used. The cabbage samples were directly freeze-dried and then ground into a fine powder. Each sample powder was stored at -20˚C for experiments. Methanol extracts were prepared by soaking the sample powder into 100% methanol for 24 hours at room temperature. The crude extracts were filtered through a Whatman filter paper No. 3. The collected filtrate was evaporated to dryness under vacuum at -45˚C using a rotary evaporator (IKA RV 10, Germany). The concentrated methanol extract was stored at -20˚C until required.

Determination of total phenol compound content

Total phenols were determined by the modified method of the Folin- Ciocalteu assay (Singleton and Rossi, 1965). Freeze-dried samples were extracted with methanol, and then the extract was concentrated under reduced pressure, and freeze-dried in powder. 1 ㎎ freeze-dried powder dissolved in 95% methanol, and 500 ㎕ of Folin- Ciocalteu reagent were added to a 25 ㎖ volumetric flask, and were mixed for 5 minute at 30℃ in water bath. 500 ㎕ saturated solution of 7.5% Na_2CO_3 was added to the mixture, and then was incubated for 1 hour at room temperature, and the absorbance was read at 725 ㎚ using a spectrophotometer (Biochrom Co., England). Total phenolic of the sample was expressed as mg chlorogenic acid equivalent in 1 g dry weight of sample extract.

Determination of total flavonoid compound content

Total flavonoid was measured using the modified method that previously described (Zhishen *et al*., 1999). Briefly, 1 ㎎ freeze-dried samples dissolved in 95% methanol, and 1 ㎖ of extract solution, 10 ㎖ diethylene glycol and 0.1 ㎖ 1N NaOH were added to a 25 ㎖ volumetric flask. The mixture was incubated for 1 hour at 37℃ in water bath. The absorbance was measured at 420 ㎚ using a spectrophotometer (Biochrom Co., England). Total flavonoid of the samples was expressed as mg narincin equivalent in 1 g dry weight of sample extract.

Assay of antioxidant enzyme

- SOD activity

The superoxide dismutase (SOD) activity was measured using SOD assay Kit-WST purchased from Sigma-Aldrich (Sigma-Aldrich Co., Japan). This assay is based on the colorimetric assay for the measurement of total antioxidant capacity of crude aqueous fractions. The 60 ㎕ of sample solution (sample and blank2) or double distilled water (blank1 and blank3) was mixed with 600 ㎕ of WST working solution. For Blank2 and Blank3, 60 ㎕ of dilution buffer was added. Then, 60 ㎕ of enzyme working solution was added to each sample and blank1. The plate was incubated at 37℃ for 20 min, and the OD (Optical density) was determined at 450 ㎚ using a spectrophotometer (Biochrom Co., England). SOD activity (inhibition rate percent) was calculated using the following equation:

SOD activity=
{[(Ablank1 − Ablank3) − (Asample − Ablank2)] / (Ablank 1 − Ablank 3)} × 100.

- CAT activity

Catalase (CAT) activity was assayed by the method of Mishra *et al*. (1993). The reaction mixture contained 50 mM potassium phosphate buffer (pH 7.0), 11 mM H_2O_2, and the crude enzyme extract. The reaction was initiated by addition of H_2O_2 to the mixture, and enzyme activity was determined by monitoring the decline in absorbance at 240 ㎚ (ε=36 M^{-1} cm^{-1}), because of H_2O_2 consumption.

- APX activity

Ascorbate peroxidase (APX) activity was determined by monitoring the decline of absorbance at 290 ㎚ as ascorbate (ε=2.8 mM^{-1} cm^{-1}) was oxidized, by the method of Chen and Asada (1989). The reaction mixture contained 100 mM potassium phosphate buffer (pH 7.5), 0.5 mM ascorbate, and 0.2 mM H_2O_2.

- POX activity

Peroxidase (POX) activity was determined specifically with guaiacol at 470 ㎚ (ε=26.6mM^{-1} cm^{-1}), following the method of Egley *et al*. (1983). The reaction mixture contained 40 mM potassium phosphate buffer (pH 6.9), 1.5 mM guaiacol, and 6.5 mM H_2O_2 in 1 ㎖ with crude enzyme extract. Control assays in which the enzyme extracts or substrates were replaced by buffer were performed.

Assay of DPPH radical scavenging rate

100 ㎕ of various concentrations (100, 250, 500, 1000, 2500, 5000 and 10000 ㎎ L^{-1}) of extracts of cabbage were added to 900 ㎕ of 100% methanol containing 100 ㎛ DPPH, and the reaction mixture was shaken for 5 min in the slight vortex. Leaving room temperature for 30 min under darkness, the absorbance of DPPH was determined by spectrophotometer at 517 ㎚. The DPPH radical scavenging activity was calculated according to the following equation: Scavenging effect on DPPH radical (%) = [(A-B)/A] × 100, Where A is the absorbance at 517 ㎚ without pigment compositions and B is the change in absorbance at 517 ㎚ with pigment compositions incubation (Brand-Williams *et al*., 1995).

Assay of Nitrite scavenging rate

The nitrite scavenging activity (NSA) was determined according to a method using Griess reagent (Kato *et al*., 1987). First, 40 ㎕ of each sample was mixed with 20 ㎕ of 1 mM nitrite sodium. Then the mixture was added to 140 ㎕ of 0.2 M citrate buffer (pH 3.0, 4.2, or 6.0). The final volume of each sample wad adjusted to 200 ㎕. After, the mixtures had been incubated for 1 h at 37℃, and added to 1000 ㎕ of 2% acetic acid and 80 ㎕ of Griess reagent (1% sulfanilic acid and 1% naphthylamine in a methanol solution containing 30% acetic acid). After vigorous mixing with a vortex, the mixture was placed at room temperature for 15 min, and absorbance was measured at 520 ㎚. The nitrite scavenging activity was determined based on the following formula:

NSA (%) = ((1-A-C)/B) × 100

Where A is the absorbance of the mixture sample during a reation with 1 mM $NaNO_2$ after a 1 h reaction, B is the absorbance of a mixture of distilled water and 1 mM $NaNO_2$ after a 1 h reaction and C is the absorbance of the sample.

Assay of ABTS radical scavenging rate

The spectrophotomeric analysis of ABTS (2,2'-azinbis-(3-ethyl-benzothiazoline-6-sulfonic acid) radical cation ($ABTS^{\bullet+}$) scavenging activity of *Lactuca indica* was determined according to the method described previously (Re *et al*., 1999). 7 mM ABTS solution with 2.45 mM potassium persulfate was mixed, and the mixture was incubated in the dark at room temperature for 15 hours, and then was diluted to the absorbance 0.7 at 734 ㎚. 50 ㎕ of each sample prepared in different concentrations with 950 ㎕ diluted solution was added, and was shaken for 10 seconds by vortex mixer, and then was reacted for 5 min at room temperature, and the absorbance was read at 734 ㎚ using a spectrophotometer (Biochrom Co., England). The $ABTS^{\bullet+}$ scavenging activity showed as RAEAC (relative ascorbic acid equivalent antioxidant capacity), was calculated by the following equation:

$$RAEAC = \frac{Caa}{\Delta Aaa} \times \frac{\Delta As}{Cs}$$

ΔAaa: change of the absorbance after addition of ascorbic acid

Caa: concentration of ascorbic acid

ΔAs: change of the absorbance after addition of sample solution

Cs: concentration of sample

Data analysis

All experiments were conducted for three to five independent replicates. The data are expressed in terms of mean and standard error. Data were performed using the procedures of the Statistical Analysis System (SAS version 9.1). ANOVA procedure followed by Duncan Multiple Range Test was used to determine the significant difference at the $P < 0.05$ level.

Results and Discussion

Total phenol and flavonoid compounds content

Total phenol compound content showed the highest amount in methanol extracts from *YR Howol* cultivar (11.72 ㎎/g), and followed by *Harutame* (10.66 ㎎/g), *Winstar* (10.34 ㎎/g) and *YR Hero* (10.20 ㎎/g). However, *Ogan*e cultivar showed a relatively low content (6.96 ㎎/g) compared to other cultivars (Table 1). The result was found that the polyphenol content differ between cabbage cultivars and considerably consistent with the finding of DPPH radical scavenging activity (Ismail *et al.*, 2004; Ahmed *et al.*, 2012). Total flavonoid compound content showed the highest amount in methanol extracts from *Harutame* (5.39 ㎎/g), and followed by *Winstar* (4.28 ㎎/g), *YR Howol* (4.10 ㎎/g). On the other hand, *Ogan*e (2.77 ㎎/g) and *YR Hogeol* (2.93 ㎎/g) cultivars showed a relatively low content of total phenol (Table 1). In this study, we assume that DPPH radical scavenging and ABTS radical scavenging activities are related to the presence of bioactive compounds such as phenolic substances. Plant tissues contain a wide variety of compounds with antioxidant activity. Flavonoids and phenolic compounds are the main antioxidative compounds of fruits and vegetables (Huang *et al.,* 1998). Total phenolic compounds can play a major role in the antioxidant activity of plant materials.

Antioxidant enzyme activity

The antioxidant enzyme activity of different cabbage cultivars was investigated (Fig. 1). The SOD enzyme activity showed the highest activity '*YR Hogeo*', followed by '*Daebakna*', '*Winstar*', and '*YR Howo*' showed the lowest activity of SOD. The activity of CAT and APX showed higher values in '*Ogane*' and '*YR Hogeo*' than the other cultivars. The POD activities according to cabbage cultivar showed relatively high values in cultivar '*Ogane*' and '*YR Howol*' compared with other cultivars, and the POD activity showed a slightly different aspect in comparison with SOD, CAT and APX. Significant roles of POD have been suggested in plant development processes (Gaspar *et al.,* 1985), which was involved in scavenging of H_2O_2 produced in chloroplasts (Asish and Anath, 2005). The SOD is one of the enzymes, *in vivo*, to catalyze the reaction that converts the harmful reduced oxygen formed in a cell due to rancidity into hydrogen peroxide; is generated in most aerobic or anaerobic biological organisms; is switched to water and oxygen by the CAT and APX, and loses then its toxicity. In other words, the SOD and APX enzymes of the cellular antioxidative system involved in

Table 1. Total polyphenol and flavonoid contents in various cultivars of cabbage

Cultivar	Total polyphenol (㎎/g extract D.W)[z]	Total flavonoid (㎎/g extract D.W)[z]
Ogane	6.96 ± 0.24[e]	2.77 ± 0.03[d]
YR Hogeol	9.72 ± 0.13[cd]	2.93 ± 0.02[d]
Harutama	10.66 ± 0.24[b]	5.39 ± 0.19[a]
YR Hero	10.20 ± 0.28[bc]	3.35 ± 0.08[c]
Daebakna	9.22 ± 0.12[d]	3.23 ± 0.03[c]
YR Howol	11.72 ± 0.14[a]	4.10 ± 0.05[b]
Winster	10.34 ± 0.44[bc]	4.28 ± 0.05[b]

[z]Data represent the mean values ± SE of three independent experiments. Mean separation within columns by Duncan's Multiple range test at $p < 0.05$.

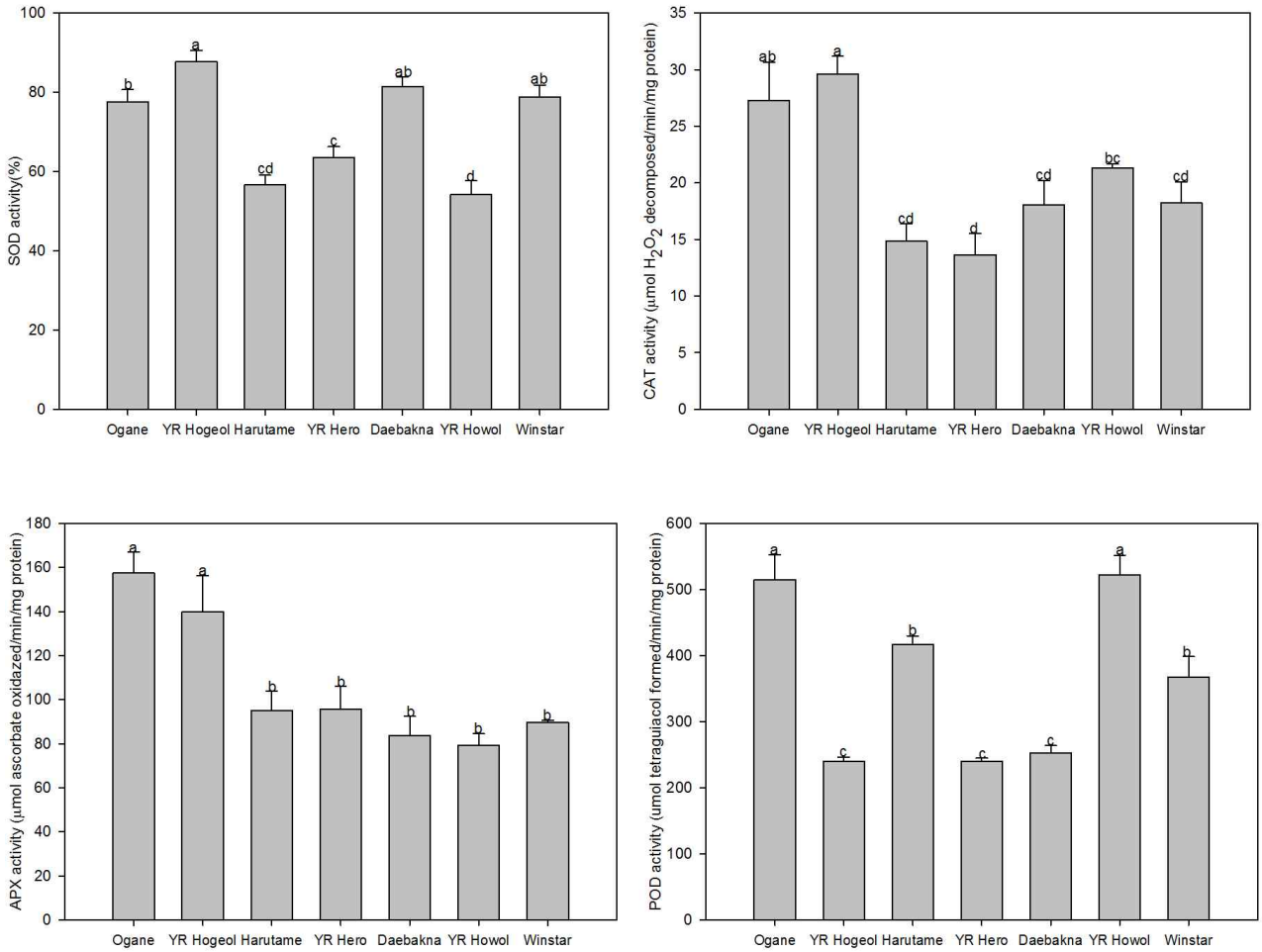

Fig.1. Antioxidant enzyme (SOD, CAT, APX and POD) activities in various cultivars of cabbage. Mean separation within columns by Duncan's Multiple range test at $p < 0.05$. Bars represent the standard error of the mean (n = 3).

H_2O_2 metabolism; SOD, which catalyses the disproportionation of O_2^- radicals into H_2O_2 and molecular oxygen, and APX, an enzyme that scavenges H_2O_2 (Bonnet *et al.,* 2000). Typically, the APX plays the most important scavenger role in the cytoplasm and chloroplasts of plants, and ascorbic acid is used as a reduction substrate (Wheeler *et al.,* 1998). APX activity, which is important component of the antioxidant system, plays a key role in eliminating H_2O_2 molecules and in the modulation of its steady-state levels in various plant subcellular compartments (Najami *et al.,* 2008). The CAT is also an antioxidant enzyme that protects cells by dispatching of *in vivo* harmful oxygen and is a typical enzyme that acts to decompose and scavenge the H_2O_2 together with APX. The antioxidant enzymes, indicating a high activity to remove harmful free radicals, have the effect of prevention and inhibition of various diseases and aging. The results obtained in this study indicate that certain cultivar of cabbage may constitute a good source of healthy functional foods, as they showed higher antioxidant enzyme activity.

DPPH radical scavenging activity

The measurement results of free radical (DPPH) scavenging activity at seven different concentrations, 0.1, 0.25, 0.5, 1, 2.5, 5 and 10 ㎎/㎖ are shown in Table 2. Lower IC_{50} value indicated a greater antioxidant activity. IC_{50} value is defined as the concentration of substrate that causes 50% loss of the DPPH activity. Results showed lower IC_{50} values of '*Harutame*' (15.71) and '*YR Howol*' (16.88) cultivar, however methanol extract of '*YR Hero*' cultivar (22.49) being the highest. The DPPH radical scavenging activity showed that the gradually

Table 2. DPPH radical scavenging activities in various cultivars of cabbage

Cultivar	DPPH radical scavenging activity (% of control)							
	Concentration (㎎/㎖)[z]							
	0.1	0.25	0.5	1	2.5	5	10	IC_{50}
Ogane	ND[w]	10.29 ± 0.57[a]	10.43 ± 0.54[a]	10.85 ± 0.17[ab]	11.07 ± 0.27[b]	14.24 ± 0.43[bc]	31.59 ± 0.80[d]	> 19.95
YRHogeol	ND	9.96 ± 0.03[a]	10.17 ± 0.03[a]	10.36 ± 0.14[b]	11.47 ± 0.13[b]	13.10 ± 0.39[c]	27.55 ± 0.31e	> 24.58
Harutama	ND	10.02 ± 0.17[a]	10.43 ± 0.14[a]	11.05 ± 0.07[a]	12.82 ± 0.21[a]	15.87 ± 0.34[a]	37.59 ± 0.59[a]	> 15.71
YR Hero	ND	8.85 ± 0.03[b]	9.06 ± 0.29[b]	9.69 ± 0.44[c]	11.08 ± 0.47[b]	13.09 ± 0.47[c]	27.74 ± 0.54e	> 22.49
Daebakna	ND	ND[c]	9.95 ± 0.18[ab]	10.65 ± 0.03[ab]	11.74 ± 0.15[b]	14.37 ± 0.26[bc]	30.63 ± 0.45[d]	> 20.02
YR Howol	ND	10.21 ± 0.10[a]	10.28 ± 0.29[a]	10.88 ± 0.06[ab]	12.43 ± 0.10[a]	15.29 ± 0.24[ab]	34.89 ± 0.30[b]	> 16.88
Winster	ND	8.40 ± 0.17[b]	9.52 ± 0.33[ab]	9.74 ± 0.17[c]	11.40 ± 0.26[b]	14.22 ± 0.74[bc]	32.25 ± 0.74[c]	> 18.78
Vit. C[y]	96.97 ± 0.03	97.22 ± 0.03	97.36 ± 0.08	97.49 ± 0.03	97.52 ± 0.00	97.55 ± 0.03	97.61 ± 0.03	< 1
BHA[x]	57.20 ± 0.04	88.92 ± 0.03	96.47 ± 0.08	97.35 ± 0.03	97.39 ± 0.03	97.55 ± 0.03	97.67 ± 0.03	< 1

[z]Data represent the mean values ± SE of three independent experiments. Mean separation within columns by Duncan's Multiple range test at $p < 0.05$.
[y]Vit. C: Ascorbic acid, [x]BHA: Butylated hydroxyanisole. [w]ND: not detected.

increasing activity was proportional to the concentration. The investigation of the antioxidant activity of natural substances is based on the measuring of the electron donor capacity of DPPH with the ability to inhibit the oxidation by donating electrons in free radicals causing this lipid peroxidation (Boo *et al.,* 2012), that is, free radical are known to be a major factor in biological damages, and DPPH has been used to evaluate the free radical-scavenging activity of natural antioxidants (Yokozawa *et al.,* 1998; Zhu *et al.,* 2001). Active oxygen caused by *in vivo* metabolism removed by the body's antioxidant system, but excessive free radicals induced stress, causing the lipid peroxidation by combining with unsaturated fatty acids in the cell membrane, and brought intracellular structural and functional damage. Cells are oxidized and damaged by the free radical, depending on the growth of cells. In this study, the DPPH radical scavenging activity appeared to concentration dependent, and there were significant differences between cabbage cultivar.

Nitrite scavenging activity

The nitrite scavenging activity of methanol extracts for cabbage cultivars was investigated at various acidic conditions (Table 4). The extracts of all cabbage cultivars in the reaction solution of pH 1.2 could be decomposed nitrite more than 50%. Especially, the cultivar '*YR Hogeo*' and '*Ogane*' showed a relatively high nitrite scavenging activity for each 60.13% and 57.20% respectively. The nitrite scavenging activity in the reaction solution of pH 4.2 showed the values lower than 10% in all the extracts. However, the nitrite scavenging activity at pH of 6.0 was not almost detected. Nitrite ions in the acidic environment of the stomach induce mutagenic and cell-damaging reactions (Kato and Puck, 1971). Exposure to excess nitrite from the diet is implicated as a potential etiological factor in the development of stomach and colorectal cancers (Lee *et al.,* 2006). Nitrite reacts with second and third grade amines to form nitrosamine in protein-rich foods, medicines, and residual pesticides. It is also present in large quantities in meat and both leafy and root vegetables. Nitrosamine is converted to diazoalkane (alkane nucleic acid), proteins, and intracellular components, which can increase the risk for cancer (Choi *et al.,* 2008). In this study, the nitrite scavenging activities were affected by changes in pH, and the values showed differences depending on the cabbage cultivars. These results were consistent with other findings that had the highest the nitrite scavenging at pH of 1.2 in fermented pine extract (Hong *et al.,* 2004) and extracts from different parts of citron (Shin *et al.,* 2005).

ABTS radical scavenging activity

The results of the determinations of ABTS radical scavenging activity of cabbage samples examined showed in Table 3, and the ABTS values were measured at five different

Table 3. ABTS radical scavenging activities in various cultivars of cabbage

Cultivar	ABTS radical scavenging activity (% of control)					
	Concentration (㎎/㎖)[z]					
	1	2.5	5	10	20	IC_{50}
Ogane	8.80 ± 0.37[b]	10.46 ± 0.58[abc]	17.02 ± 0.62[bcd]	29.34 ± 0.74[b]	48.43 ± 1.27[b]	20.78
YRHogeol	7.43 ± 0.21[c]	10.22 ± 0.13[d]	16.17 ± 0.13[de]	25.86 ± 0.56[d]	42.88 ± 0.78[c]	23.09
Harutama	10.17 ± 0.34[a]	12.51 ± 0.26[a]	20.35 ± 0.34[a]	34.30 ± 0.48[a]	57.67 ± 0.54[a]	17.04
YR Hero	8.53 ± 0.26[b]	11.21 ± 0.38[bcd]	16.93 ± 0.29[cd]	26.80 ± 0.57[cd]	47.64 ± 1.29[b]	20.79
Daebakna	8.19 ± 0.05[b]	11.06 ± 0.26[bcd]	15.21 ± 0.29[e]	24.83 ± 0.63[d]	44.01 ± 0.86[c]	23.09
YR Howol	10.29 ± 0.09[a]	12.04 ± 0.43[ab]	18.17 ± 0.46[b]	32.55 ± 0.84[a]	55.52 ± 0.052[a]	17.97
Winster	8.77 ± 0.13[b]	11.45 ± 0.10[cd]	18.12 ± 0.33[bc]	28.17 ± 0.60[bc]	49.07 ± 0.28[b]	20.59
Vit. C[y]	98.43 ± 0.00	98.59 ± 0.03	98.53 ± 0.00	98.59 ± 0.03	98.45 ± 0.03	< 1
BHA[x]	98.09 ± 0.00	98.38 ± 0.03	98.23 ± 0.00	98.87 ± 0.03	98.66 ± 0.03	< 1

[z]Data represent the mean values ± SE of three independent experiments. Mean separation within columns by Duncan's Multiple range test at $p < 0.05$.
[y]Vit. C: Ascorbic acid, [x]BHA: Butylated hydroxyanisole.

Table 4. Nitrite scavenging activities in various cultivars of cabbage

Cultivar	Nitrite scavenging activity (%)[z]		
	pH 1.2	pH 4.2	pH 6.0
Ogane	57.20 ± 1.42[b]	10.52 ± 1.03[a]	ND[y]
YR Hogeol	60.13 ± 0.25[a]	8.65 ± 0.73[a]	ND
Harutama	52.18 ± 0.66[c]	9.18 ± 0.24[a]	ND
YR Hero	51.42 ± 0.59[cd]	4.28 ± 0.41[c]	ND
Daebakna	51.14 ± 1.18[cd]	6.60 ± 0.76[b]	ND
YR Howol	55.21 ± 0.90[b]	6.60 ± 0.32[b]	ND
Winster	49.15 ± 0.49[d]	4.72 ± 0.09[cd]	ND

[z]Data represent the mean values ± SE of three independent experiments. [y]ND : not detected. Mean separation within columns by Duncan's Multiple range test at $p < 0.05$.

concentrations, 1, 2.5, 5, 10 and 20 ㎎/㎖. The IC_{50} values of antioxidant activity determined by ABTS were lower in '*Harutame*' (17.04) and '*YR Howol*' cultivar (17.97), and its results showed similar with values obtained for the same extracts by DPPH method. Methanol extract at 20 ㎎ $㎖^{-1}$ from cultivar '*Harutame*' exhibited strongest antioxidant activity by 57.67%. ABTS radical scavenging activity in cabbage was studied by other authors (Stratil *et al.,* 2006; Kusznierewicz *et al.,* 2008), they are indicated similar result between the ABTS and the DPPH activity. Also, according to our data (Table 2 and 3), the correlation between results obtained by the ABTS and DPPH assays is highly significant.

References

Ahmed, M.F., A.S. Rao, S.R. Ahemad and M. Ibrahim. 2012. Phytochemical studies and antioxidant activities of *Brassica Oleracea* L. var. Capitata. Int. J. Pharm. Sci. 4(3):374-378.

Apel, K. and H. Hirt. 2004. Reactive oxygen species: Metabolism, oxidative stress, and signal transduction. Annu. Rev. Plant Biol. 5:373-99.

Asada, K. 1994. Production and action of active oxygen species in photosynthetic tissues: *In* Foyer, C.H. and P.M. Mullineaux (eds.), Causes of Photooxidative Stress and Amelioration of Defense Systems in Plants. CRC Press, London, England. pp. 77-105.

Asish, K.P. and B.D. Anath. 2005. Salt tolerance and salinity

effects on plants. A review Ecotoxicol. Environ. Saf. 60:324-349.

Bonnet, M., O. Camares and P. Veisseire. 2000. Effects of zinc and influence of *Acremonium lolii* on growth parameters, chlorophyll a fluorescence and antioxidant enzyme activities of ryegrass (*Lolium perenne* L. cv Apollo). J. Exp. Bot. 51(346):945-953.

Boo, H.O., J.H. Shin, J.S. Shin, E.S. Choung, M.A. Bang, K.M. Choi and W.S. Song. 2012. Assessment on antioxidant potential and enzyme activity of some economic resource plants. Korean J. Plant Res. 25(3):349-356.

Choi, D.B., K.A. Cho, M.S. Na, H.S. Choi, Y.O. Kim, D.H. Lim, S.J. Cho and H. Cho. 2008. Effect of bamboo oil on antioxidative activity and nitrite scavenging activity. J. Ind. Eng. Chem. 14:765-770.

Chun, O.K., N. Smith, A. Sakagawa and C.Y. Lee. 2004. Antioxidant properties of raw and processed cabbage. Int. J. Food Sci. Nutr. 55(3):191-199.

Dionisio-Sese, M.L. and S. Tobita. 1998. Antioxidant responses of rice seedlings to salinity stress. Plant Sci. 135:1-9.

Ferreres, F., C. Sousa, V. Vrchovska, P. Valentao, J.A. Pereira, R.M. Seabra and P.B. Andrade. 2006. Chemical composition and antioxidant activity of tronchuda cabbage internal leaves. Eur. Food Res. Technol. 222:88-98.

Foyer, C.H., P. Descourvières and K.J. Kunert. 1994. Protection against oxygen radicals: an important defence mechanism studied in transgenic plants. Plant Cell Env. 17:507-523.

Galati, G. and P.J. O'Brien. 2004. Potential toxicity of flavonoids and other dietary phenolics: significance for their chemopreventive and anticancer properties. Free Radic. Biol. Med. 37(3):287-303.

Gaspar, T., C. Penel, F.J. Castillo and H. Greppin. 1985. A two step control of basic and acid peroxidases and its significance for growth and development. Plant Physiol. 64:418-423.

Hollman, P.C., M.G. Hertog and M.B. Katan. 1996. Role of dietary flavonoids in protection against cancer and coronary heart disease. Biochem. Soc. Trans. 24(3):785-789.

Hong, T.G., Y.R. Lee, M.H. Yim and C.N. Hyun. 2004. Physiological functionality and nitrite scavenging ability of fermentation extracts from pine needles. Korean J. Food Preserv. 11:94-99.

Huang, Y., A. Tan, Y. Shen and J. Lu. 1998. Scavenging effect of total flavonoids of *Lycium barbarum* L. on active oxygen radicals and inhibitory effects on heat output from L 1210 cells. Wei Sheng Yen Chiu. 27:109-111.

Ismail, A., Z.M. Marjan and C.W. Foong. 2004. Total antioxidant activity and phenolic content in selected vegetables. Food Chem. 87:581-586.

Kang, H.M. and M.E. Saltveit. 2002. Chilling tolerance of maize, cucumber and rice seedling leaves and roots are differentially affected by salicylic acid. Physiol. Plant. 115:571-576.

Kato, F.T. and T.T. Puck. 1971. Mutagenesis by carcinogenic nitroso compounds. J. Cell Physiol. 78:139-144.

Kusznierewicz, B., A. Bartoszek, L. Wolska, J. Drzewiecki, S. Gorinstein and J. Namiesnik. 2008. Partial characterization of white cabbage (*Brassica oleracea* var. *capitata* f. *alba*) from different regions by glucosinolates, bioactive compounds, total antioxidant activities and proteins. LWT. 41:1-9.

Lee, S.C., S.Y. Kim, S.M. Jeong and J.H. Park. 2006. Effect of far-infrared irradiation on catechins and nitrite scavenging activity of green tea. J. Agric. Food Chem. 54:399-403.

Mittler, R. 2002. Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci. 7:405-410.

Najami, N., J. Tibor, W. Barriah, G. Kayam, T. Moshe, M. Guy and M. Volokita. 2008. Ascorbate peroxidase gene family in tomato: its identification and characterization. Mol. Genet. Genom. 279:171-182.

Shahidi, F. and C.T. Ho. 2005. Phenolics in food and natural health products: an overview: *In* Shahidi, F. and C.T. Ho (eds.), Phenolic Compounds in Foods and Natural Health Products, ACS, Washington DC. (USA). pp. 1-8.

Shin, J.H., J.Y. Lee, J.C. Ju, S.J. Lee, H.S. Cho and N.J. Sung. 2005. Chemical properties and nitrite scavenging ability of citron (*Citrus junos*). J. Korean Soc. Food Sci. Nutr. 34:496-502.

Stratil, P., B. Klejdus and V. Kuban. 2006. Determination of total content of phenolic compounds and their antioxidant activity in vegetables—evaluation of spectrophotometric methods. J. Agri. Food Chem. 54:607-616.

Wheeler, G.L., M.A. Jones and N. Smirnoff. 1998. The biosynthetic pathway of vitamin C in higher plants. Nature 393:363-369.

Wojtaszek, P. 1997. Oxidative burst: an early plant response to pathogen infection. Biochem. J. 322:681-692.

Yokozawa, T., C. P. Chen, E. Dong, T. Tanaka, G.I. Nonaka and I. Nishioka. 1998. Study on the inhibitory effect of tannins and flavonoids against the 1,1-diphenyl-2-picrylhydrazyl radical. Biochemical Phamacology 56:213-222.

Zhou, B.Y., Z.F. Guo and Z.L. Liu. 2005. Effects of abscisic

acid on antioxidant systems of *Stylosanthes guianensis* (Aublet) Sw. under chilling stress. Crop Sci. 45:599-605.

Zhu, N., M. Wang, G.J. Wei, J.K. Lin, C.S. Yang and C.T. Ho. 2001. Identification of reaction products of (-)-epigallocatechin, (-)-epigallocatechin gallate and pyrogallol with 2,2-diphenyl-1-picrylhydrazyl radical. Food Chemistry 73:345-349.

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