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ARTICLE

Antioxidant compounds and activities of edible roses (*Rosa hybrida spp.*) from different cultivars grown in Korea

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Abstract Edible roses have been identified as a potential source of antioxidant compounds promoting human health. In order to assess this potential, nine cultivars of edible roses harvested in Jincheon, Chungbuk, were examined in this study. Extracts of flower petals of edible roses were prepared, and the constituent antioxidant compounds and their antioxidant activity were analyzed. Total anthocyanin concentrations and total flavonoid concentrations were significantly higher in the Mister Lincoln cultivar than those in others. Total phenolic compounds and total antioxidant activity in the cultivars Mister Lincoln and Orange Meillandina were significantly higher than those in other cultivars ($p < 0.05$). Total anthocyanin content was highly correlated with flavonoid content ($R = 0.927$), and the relationship between total phenolics and DPPH radical scavenging activity was also strongly correlated ($R = 0.915$). Overall, antioxidant compounds and antioxidant activity of edible roses were found to be greater than those of fruits and leafy vegetables. Thus, edible roses are a natural source of antioxidant compounds, and they are expected to have great potential for application in the production of functional foods and in the cosmetic industry.

Keywords Antioxidant · Correlation · Cultivar · Edible rose · Phenolic

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Introduction

Phenolic compounds including phenolic acids, flavonoids, anthocyanins, and carotenoids are natural antioxidants that are present throughout all parts of a plant (tree, bark, stem, leaf, fruit, root, flower, and seed), which help to reduce the risk of various plant diseases by delaying or inhibiting oxidation [13, 14, 17]. Among plant tissues, flower petals have especially high flavonoid compound content (including anthocyanins) and are known as a potential natural antioxidant source [9].

Anthocyanin pigment is a known antioxidant that plays an important role in the prevention of cardiovascular disease and diabetes in humans; it is also known to have anticancer and anti-inflammatory activities [4]. This component draws much attention in the food industry as a non-toxic natural plant pigment and functional food material [27]. It imparts attractive and diverse red-to-purple coloration to flowers and fruits [30]. Accordingly, studies on finding antioxidant compounds with various components are being pursued actively [37].

Taxonomically, roses belong to the family Rosaceae and the genus *Rosa*. They are perennial woody plants known as an important commercial crop used in gardens and parks. They are also used as an important ingredient in the production of spices and functional foods, owing to their brilliant color, rich aroma, and high nutritional value [12, 20]. Historically, roses have been used as herbal folk remedies for alleviating menstrual problems and treating blood circulation disorders, and more recently, some applications for regulating cancer cell growth have been found. Vanderjagt et al. [31] found that rose had second highest antioxidant level among 30 medicinal plants including hibiscus. However, only few have been studied

on the antioxidant activity of roses with various cultivars. According to a recent study, roses possess a high level of antioxidant activity due to high level of phenolic compounds [6].

Edible roses are produced by selecting cultivars with minimally sour flavor and/or pest resistance and then cultivating them using organic farming or hydroponic cultivation. Consuming various teas and functional beverages made with phenolic compounds extracted from edible roses provides beneficial effects to human health [6, 29, 32]. Traditionally, roses placed in flower rice pancakes were eaten, but in recent years, roses are being consumed in increasing quantities as they are used in various preparations such as flower rice, salads, rice wraps, and breads in various places such as restaurants and cafes [24]. Edible roses are also known to have efficacy for inhibiting histamine release, leading to their development as a therapeutic option for patients with allergy [5, 18]. There is a worldwide trend of using edible roses as not only an ingredient in various foods, but also as raw material for anti-inflammatory drugs and antioxidants [34]. However, the edible flowers must be grown without chemical pesticides. Several flowers are not allowed to be consumed as a food due to grayanotoxin, which can be fatal to human [19].

However, physicochemical and functional components analyses on edible roses are relatively few in comparison with other horticultural products, such as fruits and vegetables. The present study aimed to investigate antioxidant compounds such as anthocyanins, flavonoids, and phenolics, as well as their total antioxidant activity, in edible roses cultivated in Korea, in order to identify correlations between their antioxidant compounds and antioxidant activity.

Materials and methods

Plant materials

Nine cultivars of edible roses *Rosa hybrida* spp., cultivated in a farm in Jincheon, Chungbuk, were purchased for use in this investigation (Table 1). The roses were transported to the horticultural product processing laboratory at Dankook University, and the pistils and stamens were removed from the flowers. Petals were then freeze-dried with liquid nitrogen and stored in a freezer at −25 °C for subsequent use in antioxidant analysis.

Chemical reagents

Ethanol, Folin–Ciocalteu's phenol reagent, 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), sodium nitrite, aluminum chloride hexahydrate, (+)-catechin, gallic acid monohydrate reagent, potassium chloride, sodium acetate anhydrous, hydrochloric acid, and sodium carbonate anhydrous were purchased from Sigma (St. Louis, MO, USA).

Table 1 Cultivar names, colors, and the origin of nine edible roses used in the present experiment

Cultivar	Color	Origin
Arisu	Red	Korea
Dahongi	Light red	Korea
Lovely Pink	Pink	Korea
Lucky Day	Red	Korea
Mister Lincoln	Red	USA
Orange Meillandina	Red	France
Princess de Monaco	Light pink	France
Tokimeki	Pink	Japan
Yellow Beauty	Light yellow	Korea

Extraction for measurement of antioxidant and activity

Freeze-dried samples were ground with a mortar and pestle using liquid nitrogen. Thereafter, 300 mL of 80% ethanol was added to 30 g of ground petals and homogenized three times for 3 min each using a commercial blender (HR-2171, Phillips, Korea). The homogenate was filtered through Whatman #2 paper (Whatman International Limited, Kent, England), and the ethanol was gradually eliminated using a rotary evaporator (N-1000, Eyela, Japan). The concentrated extract was transferred to a 1.5-mL tube and stored at 25 °C for subsequent analyses.

Total anthocyanin measurement

Total anthocyanin concentrations in edible rose petal extract were measured using a modified pH differential method [21, 28]. The solutions were prepared by diluting the edible rose petal extract to an optimal dilution ratio and then adding pH 1.0 potassium chloride buffer (0.025 M) and pH 4.5 sodium acetate buffer (0.4 M). Resulting absorbance at wavelengths of 510 and 700 nm was measured using a spectrophotometer (Optizen POP, Mecasys, Daejeon, Korea), and the total anthocyanin concentrations were expressed as milligrams of cyanidin 3-O-glucoside equivalents (CGE) per 100 g fresh weight (FW).

$$\text{Total anthocyanin concentrations (mg CGE/100g FW)} = \frac{A \times \text{MW} \times \text{D} \times 1000}{\varepsilon}$$

$$A\ (\text{absorbance value}) = \left[(A_{510\,\text{nm}} - A_{700\,\text{nm}})_{\text{pH1.0}} - (A_{510\,\text{nm}} - A_{700\,\text{nm}})_{\text{pH4.5}}\right]$$

MW (molecular weight of cyanidin-3-O-glucoside) = 449.2

D = dilution factor.

ε (molar absorptivity coefficient of cyanidin-3-O-glucoside) = 26900.

Total flavonoid measurement

The total flavonoid concentrations of edible rose petal extracts were measured with a colorimetric assay [21, 28]. After diluting the edible rose petal extract to an optimal ratio, 0.3 mL of 5% $NaNO_2$ was added. After 5-min reaction time had elapsed, 0.3 mL of 10% $AlCl_3$ was added. After a further 6 min, 2 mL of 1 M NaOH was added to the solutions. Finally, 2.4 mL of water was added, and sample absorbance at wavelength of 510 nm was measured using a spectrophotometer. Catechin was used as a standard to produce a reference standard curve, with solutions prepared to concentrations of 100, 150, 200, and 250 mg/L. The total flavonoid concentrations were expressed as milligrams of catechin equivalents (CE) per 100 g FW.

Total phenolics measurement

The total phenolic compound concentrations of the edible rose petal extract were measured with Folin–Ciocalteu colorimetric method [21, 28]. For the test solutions, 2.6 mL of distilled water was added to 0.2 mL of rose petal extract, followed by 0.2 mL of Folin–Ciocalteu reagent. This was left for 6 min at room temperature. Finally, 2 mL of 7% Na_2CO_3 was added, and the sample was placed in the dark for 90 min at room temperature. Once the test solutions had completely reacted, absorbance at wavelengths of 750 nm was measured using a spectrophotometer. Gallic acid was used as a standard to produce a reference standard curve, with solutions prepared to concentrations of 50, 100, 150, 200, and 250 mg/L. The total phenolic compound concentrations were expressed as milligrams of gallic acid equivalents (GAE) per 100 g FW.

DPPH radical scavenging activity

The measurement of total antioxidant activity was performed with DPPH assay [3, 28]. The solutions were prepared by mixing 50 μL of edible rose petal extract and 2950 μL of 0.2 mM DPPH solution and then allowing these to react for 30 min in the dark at room temperature. Absorbance at wavelengths of 517 nm was measured using a spectrophotometer. Vitamin C was used as a standard to produce a reference standard curve, with solutions prepared to concentrations of 50, 100, 150, and 200 mg/L. The measured values of total antioxidant activity were expressed as milligrams of vitamin C equivalents (VCE) per 100 g FW.

ABTS radical scavenging activity

The method developed by Floegel et al. [10] was used in this study. The ABTS radical scavenging activity of edible rose extracts was expressed on the FW basis as milligrams of vitamin C equivalents (VCE) per 100 g FW. Samples of each extraction were analyzed in triplicate.

Statistical analysis

Each test was replicated three times and assessed using analysis of variance (ANOVA) in the SAS statistics program (SAS Institute, Cary, NC, USA) and SPSS program (SPSS Inc., Chicago, IL, USA). Significance was analyzed via Duncan's multiple range test ($p < 0.05$), and correlations among antioxidant compounds and activity were analyzed using Pearson's correlation coefficient.

Results and discussion

The total anthocyanin concentrations of the nine cultivars of edible roses were found to be 0.61–502.64 mg/100 g FW and showed significant differences based on the color

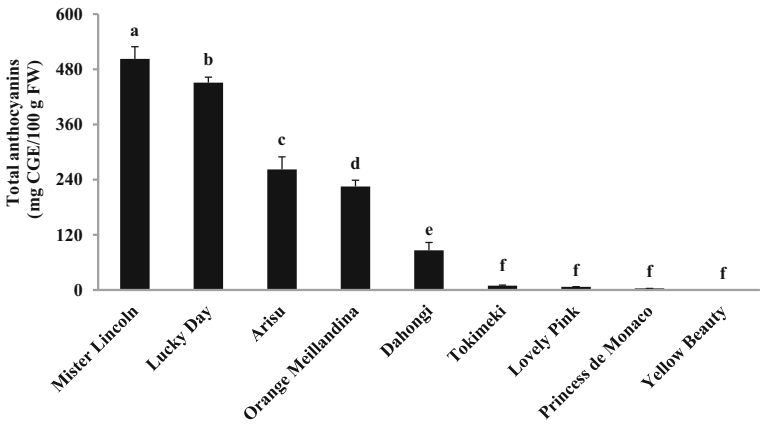

Fig. 1 Total anthocyanin concentrations of nine edible roses. The concentrations were expressed as mg of cyanidin 3-O-glucoside equivalents (CGE) per 100 g fresh weight (FW). Mean values with different *letter* are significantly different at $p < 0.05$ (Duncan's multiple range test)

of the petal (Fig. 1). Mister Lincoln, a red-colored cultivar (502.64 mg/100 g FW), showed the highest value with significant differences against other cultivars ($p < 0.05$). This was followed in order by the cultivars Lucky Day (451.20 mg/100 g FW), Arisu (262.28 mg/100 g FW), and Orange Meillandina (224.93 mg/100 g FW) among the red-colored cultivars. Among the pink-colored cultivars, Princess de Monaco, Lovely Pink, and Tokimeki showed values of 3.31, 6.92, and 9.55 mg/100 g FW, respectively, while yellow-colored cultivar Yellow Beauty showed a significantly lower level of 0.61 mg/100 g FW. According to a study by Yoon and Kim [35], polyphenol content in red roses is higher than that in pink, yellow, and white roses, reportedly attributable to the influence of red-colored anthocyanin pigments. Moreover, in a study that measured the total anthocyanin concentrations in different colored tulips, anthocyanin was not detected at all in yellow-colored tulips, and dark red-colored petals showed the highest anthocyanin concentrations [26]. Our finding that anthocyanin content in edible roses is higher in cultivars with stronger red coloration, with differences based on color intensity, is in agreement with a previous study by Friedman et al. [11], wherein the 'San Francisco' red rose cultivar was found to have the highest anthocyanin content. The major anthocyanin in edible roses is comprised of cyanidin and pelargonidin, as is found in strawberries. With the level of pelargonidin being only 10% of cyanidin, cyanidin is the dominant component contributing to antioxidant activity [7]. Notably, anthocyanin pigments have been reported to be influenced by various factors such as environmental stress, genetic variability, and cultivation conditions [1, 18].

The total flavonoid concentrations of the nine cultivars of edible roses were measured to be 78.64–531.54 mg/100 g FW (Fig. 2). The total flavonoid concentration of Mister Lincoln, a red-colored cultivar, was significantly higher than others with 531.54 mg/100 g FW ($p < 0.05$), followed in order by Lucky Day (392.69 mg/100 g FW), Arisu (357.13 mg/100 g FW), and Orange Meillandina (212.47 mg/100 g FW) among the red-colored cultivars. Measurement results on the other cultivars appeared in the order of Princess de Monaco (188.75 mg/100 g FW), Yellow Beauty (156.88 mg/100 g FW), Tokimeki (136.42 mg/100 g FW), Dahongi (117.56 mg/100 g FW), and Lovely Pink (78.64 mg/100 g FW). The results demonstrated that Mister Lincoln, a red-colored cultivar, had significantly higher total anthocyanin and total flavonoid concentrations than all other cultivars. According to a study by Rop et al. [25], the total flavonoid contents of edible roses were ranged from 123 mg to 227 mg/100 g FW. Mlcek and Rop [22] concluded that in most edible flowers, higher total anthocyanin concentrations also meant higher total flavonoid concentrations, with this was reported to be one of the determinants for strong antioxidant activity. However, another study reported that because flower cultivars can be divided into those that can produce and anthocyanins and those that cannot, flavonoid content may vary significantly among species and varieties [23]. Moreover, despite having low anthocyanin content, pink and yellow bayberries showed high antioxidant activity due to other flavonoids, such as myricetin and rutin [1].

The total phenolic concentrations of the nine cultivars of edible roses are shown in Fig. 3. Significant differences were found among all cultivars with values ranging between 798.67 and 2978.89 mg/100 g FW (Fig. 3). Red-colored cultivars Mister Lincoln (2978.89 mg/100 g FW) and Orange Meillandina (2805.56 mg/100 g FW) showed significantly higher values than other cultivars ($p < 0.05$). These cultivars were followed in order by Lucky Day (2084.44 mg/100 g FW), Arisu (1972.44 mg/100 g FW), Dahongi (1801.33 mg/100 g FW), and Yellow Beauty (1711.11 mg/100 g FW), where these cultivars showed similar values with no significant differences between one another. Finally, the group with the lowest concentrations consisting of Tokimeki (970.67 mg/100 g FW Lovely Pink (969.33 mg/100 g FW), and Princess de Monaco

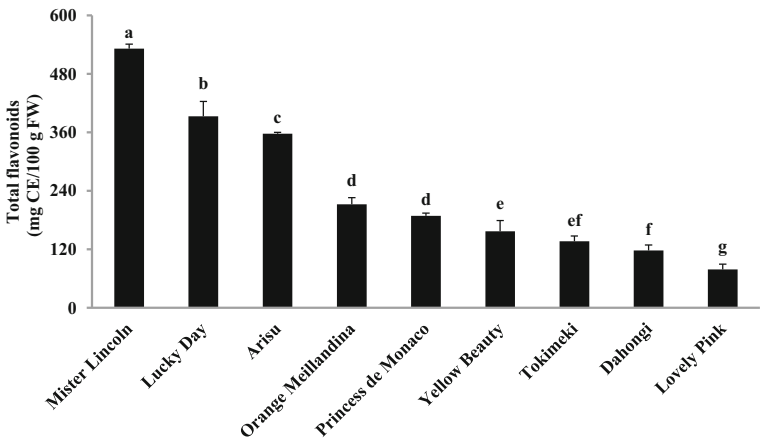

Fig. 2 Total flavonoids concentrations of nine edible roses. The concentrations were expressed as mg of catechin equivalents (CE) per 100 g FW. Mean values with different *letter* are significantly different at $p < 0.05$ (Duncan's multiple range test)

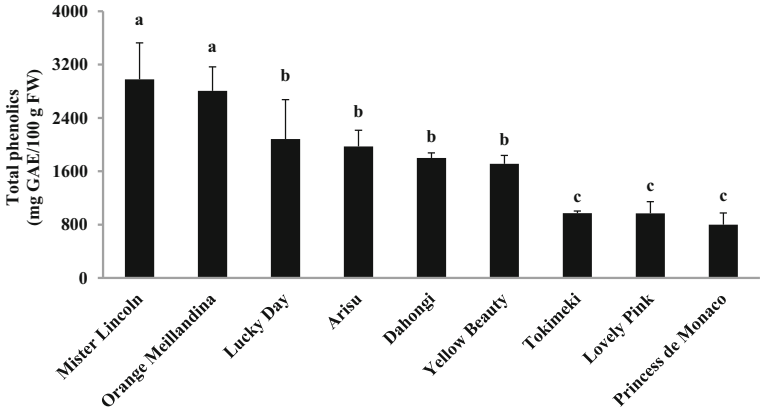

Fig. 3 Total phenolics concentrations of nine edible roses. The concentrations were expressed as mg of gallic acid equivalents (GAE) per 100 g FW. Mean values with different *letter* are significantly different at $p < 0.05$ (Duncan's multiple range test)

(798.67 mg/100 g FW) also did not show significant differences between one another ($p < 0.05$). Similar to the total anthocyanins and total flavonoids, the total phenolic concentrations were also found to be highest in red-colored cultivars of Mister Lincoln and Orange Meillandina. Yoon and Kim [35] reported that red roses had higher polyphenol concentrations than pink roses, azaleas, and yellow and white hydrangeas, which is similar to the results in the present study. According to the study by Kumar et al. [15], the total phenolic contents of roses were various from 14.5 g to 25.4 g GAE/100 g of FW, which were even higher than ours. On the other hand, the results from a study by Rop et al. [25] showed that the total phenolic concentrations measured in 12 cultivars of edible flowers were from 253 mg to 528 mg GAE/100 g FW, which were similar to the levels found in fruits, such as plum, blueberry, and raisin, while being much higher than vegetables, such as cabbage, cucumber, and onion.

The total antioxidant activity of the nine cultivars of edible roses using DPPH and ABTS radical scavenging

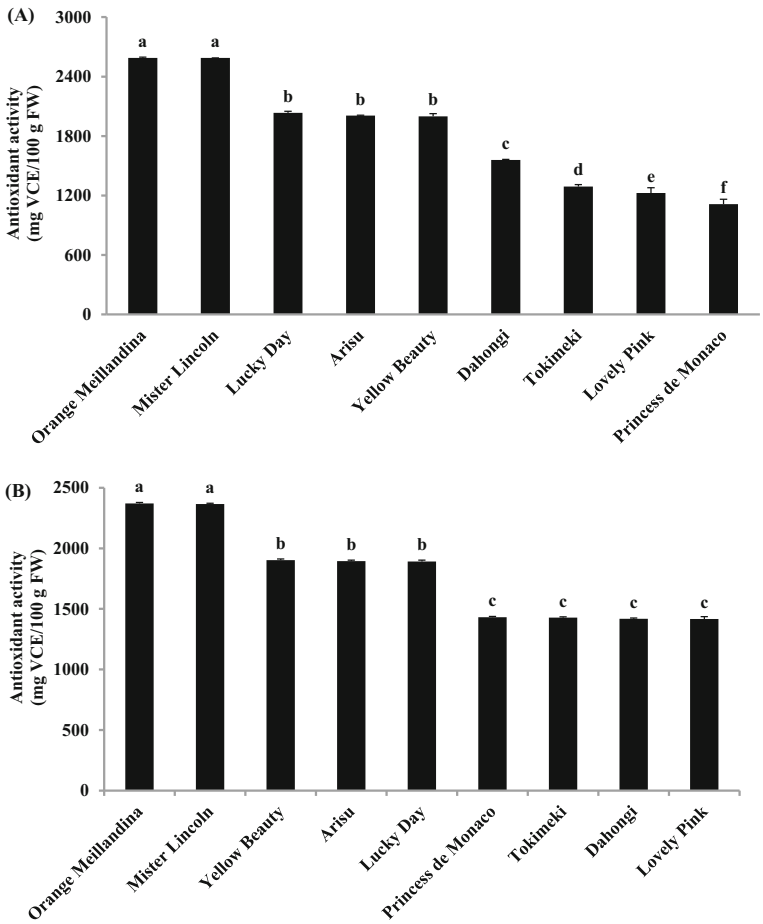

Fig. 4 Total antioxidant activity of nine edible roses using DPPH (**A**) and ABTS method (**B**). The measured values of total antioxidant activity were expressed as mg of vitamin C equivalents (VCE) per 100 g FW. Mean values with different *letter* are significantly different at $p < 0.05$ (Duncan's multiple range test)

Table 2 Correlation between antioxidant concentrations and activity of nine edible roses

	Total anthocyanin	Total flavonoids	Total phenolics	DPPH
Total flavonoids	0.927***	–	–	
Total phenolics	0.751***	0.638***	–	
DPPH	0.747***	0.678***	0.915***	
ABTS	0.720***	0.692***	0.870***	0.974***

Pearson correlation: *** significance at $p < 0.001$; ** significance at $p < 0.01$; * significance at $p < 0.05$

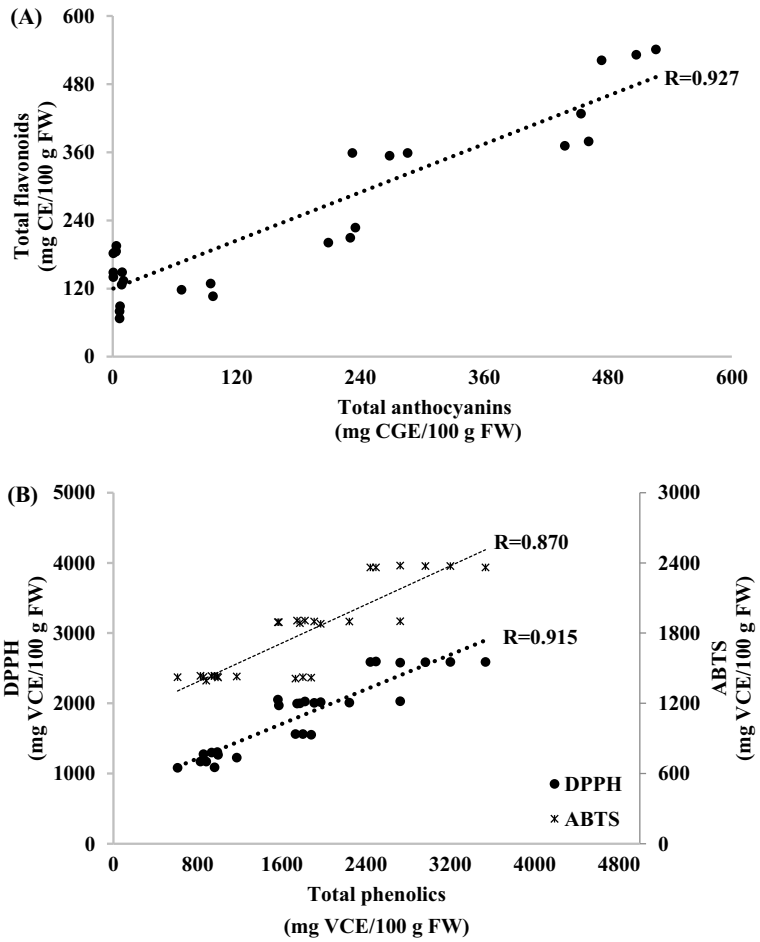

Fig. 5 Correlation between total anthocyanins and total flavonoids (**A**) and total phenolics and antioxidant activities (**B**) of edible roses

activity method was found to be 1113.62–2589.03 mg VCE/100 g FW and 1416.33–2370.77 mg VCE/100 g FW, respectively, with significant differences between the cultivars (Fig. 4). The total antioxidant activity using DPPH method showed that Orange Meillandina (2589.03 mg/100 g FW) and Mister Lincoln (2588.50 mg/100 g FW) showed significantly higher activity than the other cultivars ($p < 0.05$). The result of ABTS radical scavenging activity also showed same pattern with DPPH method. Based on such results, it was determined that antioxidant compounds such as anthocyanin, flavonoids, and phenolics contained in Mister Lincoln and Orange Meillandina were closely associated with their total antioxidant activity. Benvenuti et al. [2] reported that having higher total anthocyanin concentrations was correlated with higher total antioxidant activity, where stronger antioxidant activity was found with higher total phenolics concentrations in edible flowers, fruits, vegetables, and grains [16, 33, 36]. These results were consistent with the findings in the present study. Furthermore, just as for the total phenolic compounds, the antioxidant activity of edible roses in the present study was analyzed to be similar to or much higher than those of other edible flowers or fruits and vegetables [28, 35]. Based on these results, it is believed that antioxidant compounds contained in edible roses represent an important factor that can influence antioxidant activity.

The correlations between antioxidant compounds and antioxidant activity are shown in Table 2 and Fig. 5. A

strong correlation was found between total anthocyanins and total flavonoid ($R = 0.927$, Fig. 5A). Considering that the total flavonoid concentrations were higher for the most part in red-colored cultivars than in cultivars with other colors, it is believed that this is associated with cyanidin, a red pigment among anthocyanin pigments [7]. The correlation between total phenolics and DPPH radical scavenging activity was found to be very strong ($R = 0.915$, Fig. 5B). ABTS and DPPH radical scavenging activity was also highly correlated ($R = 0.974$, Table 2). Based on this, it was determined that phenolic compounds in edible roses are an important factor involved in antioxidant activity. Other studies have also reported that phenolic compounds present in plant extracts have strong correlations with antioxidant activity [8, 28].

In summarizing the results in the present study, we found differences in antioxidant compounds and activity among the nine cultivars of edible roses, and it was found that such differences were due to the unique floral coloration of each cultivar. Moreover, we also found that the total flavonoid concentrations increased according to the total anthocyanin concentrations, and that having higher total phenolic concentrations resulted in higher total antioxidant activity as well. Anthocyanin, one of the natural edible pigments found in edible roses, is non-toxic and has high antioxidant activity while being rich in phenolic compounds and is believed to play an important role as an antioxidant. It is also believed that it has the potential for having applications in health foods and functional cosmetics. However, the use of edible roses in food industry is somewhat low in comparison to their potential, due to their limited production period, difficulty of storage, difficulty in handling due to their soft petals, and consumer aversion to using flowers as food. Therefore, we suggest that in order to overcome these limitations and to increase the utilization of edible roses, additional future studies on cultivation methods, storability, and production and distribution system, as well as physiological studies on their effects within the human body are needed.

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