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A Study on Six Rose Cultivars in Terms of Minerals, Vitamins, and Antioxidant Compounds

Firoozeh Pourzarnegar[1], Davood Hashemabadi[1*], Mohammad Sadegh Allahyari[2]

[1]Department of Horticultural Science, Rasht Branch, Islamic Azad University, Rasht, Iran
[2]Department of Agricultural Management, Rasht Branch, Islamic Azad University, Rasht, Iran

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***Corresponding author's email:** davoodhashemabadi@yahoo.com

Abstract

Rose, the queen of ornamental plants, is used as a new food source that is rich in nutrients and biologically active compounds in modern cuisine. Despite the popularity of rose flowers in cooking, many rose cultivars and species have not yet been subjected to research on their edibility. So, the present study aimed to determine the nutrients, minerals, and antioxidant compounds of six rose cultivars ('Hella', 'Crimson Siluetta', 'Rainbows End', 'Dolce Vita', 'Samurai', and 'Avalanche') in an experiment based on completely randomized design with three replications. The cultivars were procured at the full-blooming stage at an authentic producer in Tehran province and were transferred to the laboratory in proper packages. The petals were used to determine the nutritional and antioxidant properties. The results showed that 'Crimson Siluetta' was the richest in dry matter (22.75%), total phenols (20.20 mg GAE/100 g FW), antioxidant capacity (85.83% DPPH), P (33.48 mg/100 g FW), and Mn (2.76 mg/100 g FW). The best cultivars in vitamin C and anthocyanin were 'Crimson Siluetta' and 'Samurai', which did not differ significantly from one another. The richest cultivars in total flavonoids, carotenoids, N, and protein were 'Rainbows End' and 'Dolce Vita'. Also, 'Dolce Vita' had the highest vitamin A (0.39 µg/100 g FW) and S content (356 mg/100 g FW). The highest fibre, Fe, Zn, Cu, Ca, Mg, Ni, and B were recorded by 'Hella', the best cultivar in K, along with 'Samurai'. All six cultivars were good sources of minerals, nutrients, and antioxidant compounds. Among them, 'Hella' was richer in fibre and minerals, 'Crimson Siluetta' was richer in antioxidant compounds, and 'Dolce Vita' and 'Rainbows End' were more affluent in vitamin A and carotenoids, so they are recommended in human food regime as they are good for their health.

Keywords: Edible flower, Flavonoids, Human nutrition, Ornamental plant, Vitamin A.

INTRODUCTION

Edible flowers, which are a good source of minerals, vitamins, fibre, carbohydrates, amino acids, alkaloids, essential oils, and antioxidants, have many health benefits. Fruit tree flowers, vegetables, and medicinal and aromatic herbs are three main groups of edible flowers, which have long been used in food decoration owing to their unique texture, pleasant aroma and taste, and attractive and diverse colouration and also for their medicinal, nutritional, and biochemical properties. The consumption of edible flowers in fresh and processed form has significantly increased in recent decades due to the increasing tendency toward the consumption of healthy and organic, and at the same time, visually appealing foods, and this trend has triggered an enormous development in global food markets (Kumari and Bhurgava, 2021; Jadhav *et al*., 2023; Pires Jr. *et al*., 2023).

Ornamental flowers and plants have a special place in global markets, and attention to their edibility and nutritional properties, besides aesthetics, can develop the supply of edible flowers and effectively prevent the waste of decorative plants, including cut flowers (Kumari and Bhargava, 2021).

Rose (*Rosa* sp.) from the family of Rosaceae is the most essential ornamental flower in the world. So far, 200 species and 25,000 cultivars have been identified in the genus *Rosa*, all distributed in Asia, North America, and Europe (D'angiolillo *et al*., 2018). Roses are divided into three groups in terms of origin and application: modern garden roses, old garden roses, and wild roses (Kalisz *et al*., 2023). Many identified rose species have nutritional and medicinal value. Phenolic compounds, flavonoids, anthocyanins, carotenoids, and vitamins are some phytochemical compounds detected in roses, which are responsible for their antioxidant, antitumor, antimicrobial, anti-inflammation, anti-ageing, and anti-depression activity (Hegde *et al*., 2022; Kalisz *et al*., 2023). Hegde *et al*. (2022) found that rose petals were rich in minerals, e.g., potassium, phosphorous, and calcium, as well as carotenoids, organic acids, proteins, and carbohydrates. They also stated that in addition to their nutritional and medicinal value, roses are an excellent candidate to be used as an edible flower in modern cuisine due to their unique colour and aroma. Kalisz *et al*. (2023) investigated 23 garden rose cultivars in terms of nutritional and medicinal value and reported that these flowers, especially red cultivars, were rich sources of phenols, flavonoids, and anthocyanins. In addition, all cultivars contained high quantities of vitamin C and had desirable antioxidant capacity. These researchers state that rose petals are popular edible flowers in modern cuisine and food and pharmaceutical industries owing to their visual attractiveness and diverse phytochemical compounds.

Although, the rose has a long history as an ornamental, medicinal, and edible flower, there is no comprehensive information about its different cultivars' nutritional value and minerals. In this regard, the present research aimed to determine the nutritional compounds and minerals of six rose cultivars ('Hella', 'Crimson Siluetta', 'Rainbows End', 'Dolce Vita', 'Samurai', and 'Avalanche') for food consumption.

MATERIALS AND METHODS

To determine the nutrients and minerals of six rose cultivars, including 'Hella', 'Crimson Siluetta', 'Rainbows End', 'Dolce Vita', 'Samurai', and 'Avalanche' (Fig. 1), an experiment was conducted laid upon a randomized complete block design with three replications. All six cultivars were procured from an authentic rose producer in Tehran province. They were harvested at full bloom in the early morning and were transferred in proper packages to the

study site in Rasht Branch, Islamic Azad University. The flowers were packed in lidded glass containers in 10-branch packages and were maintained at -20 °C in a refrigerator during the experiment and the assessment of the traits.

Rosa hybrida 'Hella'

Rosa hybrida 'Rainbows End'

Rosa hybrida 'Crimson Siluetta'

Rosa hybrida 'Dolce Vita'

Rosa hybrida 'Avalanche'

Rosa hybrida cv. 'Samurai'

Fig. 1. The rose cultivars used in the research.

Assessment of traits

Dry matter

After the fresh weight of the petals was recorded, they were oven-dried at 75 °C for 24 hours, and their dry weight was measured with a 0.01 g precision digital scale. Dry matter content was calculated by Eq. (1) as follows:

$$\text{Dry matter}=\frac{\text{Dry weight}}{\text{Fresh weight}}\times 100 \qquad (1)$$

Nitrogen and protein

In order to measure nitrogen and protein content, 0.5 g of petal extract was extracted by a mixture of acids (100 mL of sulfuric acid + 6 g of salicylic acid + 18 mL of H_2O_2) for 24 hours. In the next step, the samples were digested by an electric heater until bleaching. The resulting samples were filtered through a Whatman paper and then adjusted to 50 mL by adding distilled water. The samples were used to measure the nitrogen content with a Kjeldahl device. After the Kjeldahl operation terminated (the colour changed from purple to yellow), the titration of the samples was initiated by using 0.5 N sulfuric acid and ended when a purple colour appeared. Finally, the nitrogen and protein contents were calculated by Eq. (2) and (3), respectively:

$$N\ (\%)=0.56\times t\times (a-b)\times\frac{v}{w}\times\frac{100}{DM} \qquad (2)$$

in which t: The concentration of the acid used for titration in mol/L, a: The amount of acid used as the sample in mL, b: The amount of acid used as the control in mL, V: The volume of the extract derived from digestion in mL, W: The weight of the fruit sample used for digestion in g, and DM: The dry matter percentage of the petal.

$$\text{Protein}\ (\%)=\text{Nitrogen}\times 6.25 \qquad (3)$$

Crude fibre

To measure crude fibre, 1 g of dried petal was mixed in two stages – first with 50 mL of 0.3 N sulfuric acid and then with 25 mL of 1.5 N sodium hydroxide. Then, it was heated for 30 minutes. Next, the resulting sample was cooled down and filtered. The cooled-down sample was continuously washed, first with 50 mL of hot water and 50 mL of sulfuric acid, then with 50 mL of hot water and 25 mL of alcohol 75%. The resulting sample was oven-dried at 105 °C for six hours and weighed (a). In the next step, they were oven-dried at 550 °C for six hours to turn into ash whose weight was measured with a digital scale (b). To calculate crude fibre weight, weight at step (a) was divided by weight recorded at step (b) as per the following equation (Aryapak and Ziarati, 2014):

$$\text{Crude fibre (\%)} = \frac{\text{Crude fibre weight}}{\text{Initial sample weight}} \times 100$$

Vitamin C

Vitamin C was measured by titration with 2,6-dichlorophenolindophenol, for which, first, 2 g of the fresh rose petal was ground in liquid nitrogen and well mixed with 15 mL of meta-phosphoric acid 3%. The samples were then filtered with No. 2 Whatman filter paper and were adjusted to 10 mL using meta-phosphoric acid. Next, they were titrated with 2,6-dichlorophenolindophenol, and the process was stopped upon the appearance of a pink colour. Finally, vitamin C content was calculated by the following equation in mg/100 g FW (Mazumdar and Majumder, 2003):

$$\text{Vitamin C} = \frac{e \times d \times b}{c \times a} \times 100$$

in which a: The sample weight, b: The volume of meta-phosphoric used for extraction, c: The volume of the solution taken for titration, e: The volume of the colour solution consumed for each sample, and d: The colour factor that is calculated by:

$$d = \frac{0.5}{\text{Amount of colour solution consumed for standard sample titration}}$$

Petal anthocyanin

To measure the anthocyanin content, 0.5 g of fresh petal was first extracted by acidic methanol (pure methanol + hydrochloric acid). It was then filtered through No. 2 Whatman paper, and the absorbance of the samples was read at 535 nm with a spectrophotometer (APEL, PD-103UV). Finally, petal anthocyanin was calculated by the following equation (Mazumdar and Majumder, 2003):

$$\text{Anthocyanin (mg/100 FW)} = \frac{e \times b \times c}{d \times a} \times 100$$

in which e: The sample weight, b: The sample volume for measurement, c: The total solution made, d: The sample volume, and a: The reading of the spectrophotometer.

Petal carotenoid

In order to determine petal carotenoid, 0.5 g of fresh petal was extracted using acetone 80%. The extract was then filtered through a No. 2 Whatman filter paper. The absorbance of the plant extract was then read at 440, 645, and 663 nm with a spectrophotometer (APEL, PD-

103UV). Finally, petal carotenoid was determined by the following equation (Mazumdar and Majumder, 2003):

$$\text{Petal carotenoid } \left(\frac{\mu g}{g} FW\right) = 4.69 \times A_{440} - 0.268 \times (20.2)\, A_{645} + (8.02)\, A_{663}$$

Minerals (N, Ca, P, K, Mg, Na, S, Fe, Zn, Cu, B, Mn, and Ni)

To determine the minerals, 1 g of petal ash was mixed with 3 mL of distilled water and 5 mL of hydrochloric acid 2 M and was put in a bain marie at 70 °C. After 15 minutes, the samples were cooled down at room temperature. They were filtered through Whatmat filter paper and adjusted to 50 mL with distilled water. The plant sample was used to determine mineral contents using atomic absorbance, flame-photometry, and spectrophotometry (Rengel and Romheld, 2000).

Total phenols and flavonoids

To measure total phenols and flavonoids, 5 g of fresh petal was ground with liquid nitrogen. Then, 1 of this ground tissue was mixed with 10 mL of pure ethanol and was kept at room temperature for one hour. In the next step, the extract was filtered through Whatman filter paper and was used as the plant extract to measure phenols and total flavonoids.

Total phenols were measured by Singleton *et al*.'s (1999) method, for which 200 µL of the extract was diluted with 300 µL of distilled water and 2500 µL of folin. Then, it was well mixed with 2000 µL of sodium carbonate 7.5%. The resulting mixture was kept at room temperature in darkness for 2 hours to extract the phenol compounds fully. To prepare the standard solution, 0.1 g of gallic acid was mixed with pure methanol and was adjusted to 100 mL. Then, the solution was poured into separate test tubes at 0, 6.25, 12.5, 25, 50, and 100 µL. All the steps mentioned for the petal samples were conducted on these samples, too. Finally, the absorbances of the petal sample and standard sample were read at 760 nm with a spectrophotometer (ALEP PD-303UV). After drawing the standard curve, the total phenols of the petals were determined and reported in mg gallic acid equivalent (GAE)100 g FW.

Total flavonoids were measured by Du *et al*.'s (2009) method. So, 150 µg of the plant extract was mixed with 1700 µL of ethanol 30%, 75 µL of sodium nitrite 0.5 M, and 75 µL of aluminium chloride 0.3 M. Then, 500 µL of sodium hydroxide 1 M solution was added, and it was vortexed for 15 minutes. These steps were applied to the plant sample at catechin concentrations of 0, 25, 50, 100, 200, and 400 mg/L as the standard solution. Then, the absorbance of the plant samples and the standard sample were read at 506 nm with a spectrophotometer (APEL PD-303UV), and the total flavonoid content was calculated by drawing the standard curve in mg catechin equivalent (CE) per 100 g FW.

Antioxidant capacity

In order to determine antioxidant capacity, 50 µL of plant extract was mixed with 950 µL of 2,2-diphenyl-1-picrylhydrazyl (DPPH) and was kept at room temperature in darkness for 15 minutes. Then, the absorbance of the filtered samples was read at 515 nm with a spectrophotometer (APEL PD-303UV), and the antioxidant capacity of the extracts was calculated and reported by the following equation as per cent inhibition (%DPPHsc) (Brand-Williams *et al*., 1995):

$$\%DPPHsc=\frac{A_{cont}-A_{samp}}{A_{cont}}\times 100$$

in which %DPPHsc represents per cent inhibition, A_{cont} represents the absorbance of the sample and DPPH, and A_{samp} represents the absorbance of DPPH.

Statistical analysis

All data were analyzed by the statistical suites of SPSS 19 and Excel, and the means were compared by the LSD test at the $P < 0.05$ and $P < 0.01$ levels.

RESULTS

Analysis of variance

The analysis of variance (ANOVA) revealed that the studied rose cultivars differed in dry matter, crude protein, crude fibre, carotenoid, anthocyanins, vitamins A and C, total phenols, total flavonoids, and antioxidant capacity significantly ($P < 0.01$). Also, they significantly differed in N, P, K, Ca, Fe, Zn, Cu, S, Mn, Ni, B, and Na ($P < 0.01$) and Mg ($P < 0.05$) (Table 1).

Dry matter

The dry matter percentage varied from 13.47% to 22.75% among the rose cultivars. 'Crimson Siluetta' and 'Rainbows End' were the richest, and 'Dolca Vita' and 'Avalanche' were the poorest cultivars in dry matter percentage, respectively (Table 2).

Protein

The protein content recorded for the rose cultivars varied in a range of 0.983-1.433%. The lowest was related to 'Crimson Siluetta'. The highest was related to 'Rainbows End', but it did not significantly differ from 'Dolce Vita' (1.29%). 'Hella' and 'Avalanche' were similar in protein content (1.196%) (Table 2).

Table 1. Analysis of variance of the effect of different rose cultivars on the studied traits.

S.o.V	df	Dry matter	Protein	Crude fibre	Carotenoid	Anthocyanin	Vitamin C	Vitamin A
Replication	2	0.397^{ns}	0.00028^{ns}	0.000078^{ns}	0.00051^{ns}	0.704^{ns}	0.308^{ns}	0.00126^{ns}
Cultivar	5	39.3^{**}	0.081^{**}	0.000821^{**}	0.0512^{**}	4215^{**}	1.911^{**}	0.0471^{**}
Error	10	1.15	0.01015	0.0000661	0.0021	0.983	0.115	0.0021
CV (%)	-	6.15	8.47	38.42	1.96	2.74	3.26	33.67

** and ^{ns}: Significant at $P < 0.01$ and insignificant based on the LSD test, respectively.

Table 1. Continued.

S.o.V	df	Total phenol	Total flavonoids	Antioxidant activity	N	P	K	Ca	Na
Replication	2	0.6071^{ns}	0.1345^{ns}	1.0458^{ns}	0.00002^{ns}	25.7^{**}	0.278^{ns}	6.213^{ns}	0.138^{ns}
Cultivar	5	24.8^{**}	1.743^{**}	22.02^{**}	0.00207^{**}	174.9^{**}	487.9^{**}	69.4^{**}	3.19^{**}
Error	10	0.564	0.21	0.717	0.00034	3.06	4.85	5.64	0.187
CV (%)	-	4.96	6.727	1.045	9.36	6.39	1.29	9.63	3.57

** and ^{ns}: Significant at $P < 0.01$ and insignificant based on the LSD test, respectively.

Table 1. Continued.

S.o.V	df	Mg	S	Fe	Zn	Cu	Mn	Ni	B
Replication	2	2.99^{ns}	626^{ns}	0.0079^{ns}	0.00186^{ns}	0.00047^{ns}	0.151^{ns}	0.0000058^{ns}	0.00000067^{ns}
Cultivar	5	8.37^{*}	9079^{**}	0.843^{**}	0.0161^{**}	0.00392^{**}	1.043^{**}	0.000039^{**}	0.00033^{**}
Error	10	1.65	402	0.00757	0.00192	0.00027	0.199	0.0000028	0.00000147
CV (%)		23.41	7.32	14.58	22.47	33.34	21.8	30.45	22.01

*, ** and ^{ns}: Significant at $P < 0.05$, $P < 0.01$ and insignificant based on the LSD test, respectively.

Table 2. The comparison of means for the effect of different rose cultivars on the studied traits.

	Dry matter (%)	Protein (%)	Crude fibre (%)	Petals carotenoid (µg/g FW.)	Petals anthocyanin (mg/100 g FW.)	Vitamin C (mg/100 g FW.)	Vitamin A (µg/100 g F.W.)
'Hella'	16.34^{c}	1.196^{bc}	0.049^{a}	2.123^{d}	5.43^{d}	10.08^{b}	0.030^{c}
'Crimson Siluetta'	22.75^{a}	0.983^{d}	0.015^{c}	2.253^{b}	83.10^{a}	11.45^{a}	0.090^{bc}
'Rainbows End'	20.62^{b}	1.433^{a}	0.005^{c}	2.450^{a}	26.10^{b}	9.74^{b}	0.140^{b}
'Dolce Vita'	13.47^{d}	1.290^{ab}	0.014^{c}	2.446^{a}	13.07^{c}	9.86^{b}	0.380^{a}
'Samurai '	17.22^{c}	1.036^{cd}	0.011^{c}	2.273^{b}	83.80^{a}	11.44^{a}	0.100^{bc}
'Avalanche '	14.24^{d}	1.196^{bc}	0.033^{b}	2.213^{b}	5.09^{d}	9.973^{b}	0.070^{bc}

*In each column, averages that have at least one common letter are in statistically similar groups based on the LSD test at the $P < 0.05$ level.

Crude fibre

The crude fibre content was recorded from 0.005 to 0.049% among the studied cultivars. 'Hella' and 'Avalanche' had the highest fibre content, respectively. The lowest was recorded by 'Rainbows End', 'Samurai', 'Dolce Vita', and 'Crimson Siluetta', respectively. They showed no significant differences in this trait (Table 2).

Vitamins A and C

The cultivars differed in vitamin A (0.03-0.38 µg/100 g FW) and vitamin C (9.74-11.45 µg/100 g FW). 'Dolce Vita' and 'Crimson Siluetta' had the highest and lowest vitamin A content, respectively. Furthermore, 'Avalanche', 'Crimson Siluetta', 'Samurai', and 'Rainbows End' did not differ in vitamin A significantly (Table 2). 'Crimson Siluetta' and 'Samurai' had the highest vitamin C content of 11.45 and 11.44 mg/100 g FW, respectively. There were no significant differences in vitamin C content among 'Rainbows End', 'Dolce Vita', 'Avalanche', and 'Hella' (Table 2).

Pigments: Carotenoids and anthocyanins

The comparison of means showed that the carotenoid content among the six cultivars differed from 2.123 µg/g FW in 'Hella' to 2.45 µg/g FW in 'Rainbows End'. However, 'Dolce Vita' (2.446 µg/g FW) did not significantly differ from 'Rainbows End' and were both the best cultivars in the carotenoid content (Table 2). Petal anthocyanin was in a range of 5.09-83.8 mg/100 g FW. 'Samurai' and 'Crimson Siluetta' had the highest, and 'Avalanche' and 'Hella' had the lowest anthocyanin content, respectively (Table 2).

Total phenols

The comparison of means revealed that the total phenol content varied from 11.94 to 20.20 mg GAE/100 g FW among the cultivars. 'Crimson Siluetta' was the best, and 'Dolce Vita' was the worst cultivar in total phenols. However, 'Dolce Vita' had no significant differences from 'Avalanche', 'Hella', 'Rainbows End', and 'Samurai' (Fig. 2).

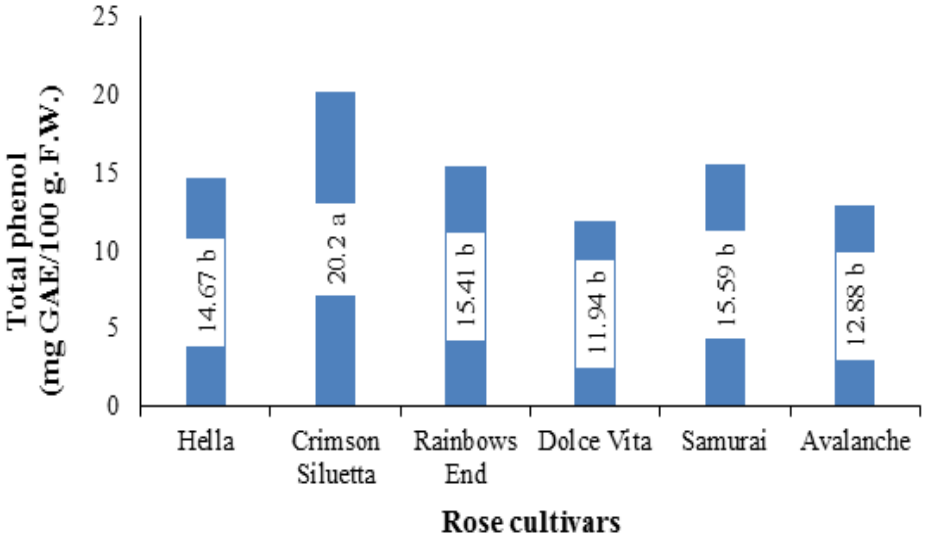

Fig. 2. The total phenols in different cultivars of rose.

Total flavonoids

It was revealed by the comparison of means that 'Rainbows End' had the highest total flavonoid content of 7.66 mg CE/100 g FW, but it did not differ from 'Dolce Vita' and 'Samurai' significantly. The lowest total flavonoid content was 5.51 mg CE/100 g FW obtained from 'Hella', which was named the poorest cultivar in this trait (Fig. 3).

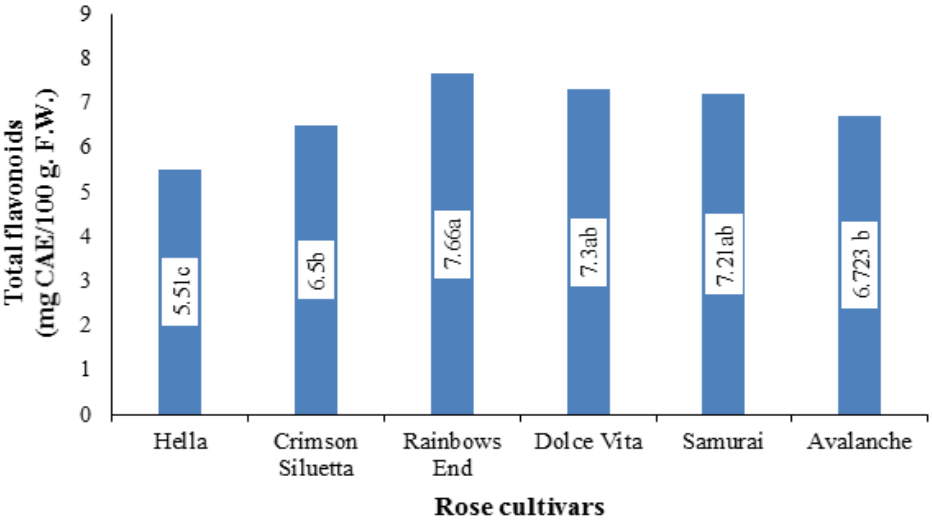

Fig. 3. The total flavonoid content of different rose cultivars.

Antioxidant capacity

The antioxidant capacity of the six studied cultivars was in a range of 78.61-85.83% DPPH. The best and worst cultivars in antioxidant capacity were 'Crimson Siluetta' and 'Avalanche', respectively (Fig. 4).

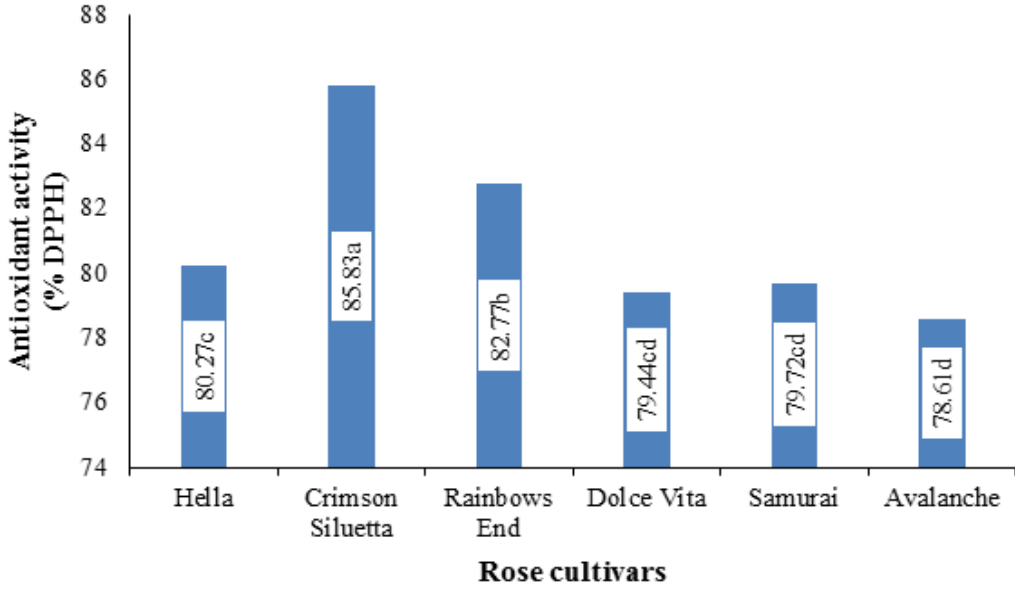

Fig. 4. The antioxidant activity of different rose cultivars.

Minerals

Table 3 reveals that the N, P, K, Ca, Mg, Na, and S content of the studied cultivars were in ranges of 0.15-0.22%, 13.22-33.48 mg/100 g FW, 157.1-186.2 mg/100 g FW, 19.74-32.7 mg/100 g FW, 4.17-7.54 mg/100 g FW, 11.08-13.9 mg/100 g FW, and 207-356 mg/100 g FW, respectively. 'Rainbows End' and 'Dolce Vita' had the highest, and 'Crimson Siluetta' had the lowest N content. Furthermore, 'Crimson Siluetta', 'Rainbows End', and 'Hella' had the highest and 'Avalanche' had the lowest P content (Table 3).

Table 3. The comparison of means for the effect of different rose cultivars on petal minerals.

Rose cultivars	Nitrogen	P	K	Ca	Na	Mg	S
	(%)	mg/100g FW					
'Hella'	0.190^{ab}	31.02^{ab}	184.8^{a}	32.70^{a}	11.33^{bc}	7.54^{a}	271^{b}
'Crimson Siluetta'	0.150^{c}	33.48^{a}	157.1^{c}	26.73^{ab}	11.08^{c}	6.71^{ab}	227^{c}
'Rainbows End'	0.220^{a}	32.39^{ab}	163.5^{b}	22.09^{b}	11.90^{b}	4.99^{bc}	207^{c}
'Dolce Vita'	0.203^{a}	29.78^{b}	160.6^{bc}	25.69^{ab}	11.48^{bc}	6.02^{abc}	356^{a}
'Samurai'	0.160^{bc}	24.33^{c}	186.2^{a}	20.92^{b}	11.48^{bc}	4.17^{c}	286^{b}
'Avalanche'	0.190^{ab}	13.22^{d}	164.2^{b}	19.74^{b}	13.9^{a}	4.55^{bc}	298^{b}

*In each column, averages that have at least one common letter are in statistically similar groups with Duncan's multiple range tests at the $P < 0.05$ possibility level.

'Samurai' and 'Hella' had the highest, and 'Crimson Siluetta' had the lowest K content. The highest Ca content was observed in 'Hella', 'Crimson Siluetta', and 'Dolce Vita' and the lowest in 'Avalanche', 'Samurai', and 'Rainbows End'. They did not differ significantly. 'Hella' had the highest Mg content, and 'Dolce Vita' had the highest S content. The highest and lowest Na contents were recorded by 'Avalanche' and 'Crimson Siluetta', respectively (Table 3).

Table 4 shows that the cultivars had Fe in a range of 0.116-1.466 mg/100 g FW, Zn in a range of 0.140-0.340 mg/100 g FW, Cu in a range of 0.02-0.116 mg/100 g FW, Mn in a range of 1.07-2.76 mg/100 g FW, Ni in a range of 0.0011-0.0093 mg/100 g FW, and B in a range of 0.0039-0.0072 mg/100 g FW. As is evident in Table 4, 'Hella' was the richest in Fe, Zn, and Cu. They also had the highest Ni and B contents. 'Samurai' had the lowest Fe and Zn content. Nevertheless, 'Samurai' and 'Avalanche' were the poorest in Cu.

Table 4. The comparison of means for the effect of different rose cultivars on petal micro-minerals.

Rose cultivars	Fe	Zn	Cu	Mn	Ni	B
	mg/100g FW					
'Hella'	1.466^{a}	0.340^{a}	0.116^{a}	2.51^{a}	0.0093^{a}	0.0072^{a}
'Crimson Siluetta'	0.960^{b}	0.160^{b}	0.063^{b}	2.76^{a}	0.0064^{b}	0.0050^{c}
'Rainbows End'	0.686^{c}	0.180^{b}	0.033^{c}	1.62^{b}	0.0064^{b}	0.0061^{b}
'Dolce Vita'	0.213^{d}	0.193^{b}	0.035^{bc}	1.99^{ab}	0.0012^{c}	0.0048^{c}
'Samurai'	0.116^{d}	0.140^{b}	0.026^{c}	2.13^{ab}	0.0091^{a}	0.0059^{b}
'Avalanche'	0.216^{d}	0.156^{b}	0.020^{c}	1.07^{c}	0.0011^{c}	0.0039^{d}

*In each column, averages that have at least one common letter are in statistically similar groups with Duncan's multiple range tests at the $P < 0.05$ possibility level.

DISCUSSION

Rose cultivars are unique in visual beauty and medicinal and nutritional values, so it is vital to research rose as a popular edible flower to detect its nutrients and minerals (Hedge *et al*., 2022). The results showed that cultivars with red petals ('Crimson Siluetta' and 'Samurai') and those with red-yellow petals ('Rainbows End') had higher dry matter than the cultivars with light petals ('Dolce Vita' and 'Avalanche'). Genetic diversity and flower colour are essential to determine dry matter accumulation (Hallmann, 2020). Hallmann (2020) stated that the dry matter percentage in the edible flowers of *Robinia pseudozcacia*, which had pink petals, was higher than that in the cultivar of *R. hispidaobinia* with white flowers. In a study, the dry matter percentage in the edible flowers of *Begonia* × *tuberhybrida*, *Calendula officinalis*, *Hemerocallis*, *Tagetes patula*, *Tropaeolum majus*, and *Rosa* was in the range of 7.38-14.39%. Based on the results, *T. majus*, and *Rosa* had the lowest and highest dry matter, respectively (Mlcek *et al*., 2021). Compared to Mlcek *et al*. (2021), who reported the dry matter of *Rosa* at 14.39%, 'Crimson Siluetta', 'Rainbows End', 'Hella', and 'Samurai' in our research were richer in dry matter that the cultivar studied by these researchers. In Rop *et al.*'s (2012) study, the petal dry matter of *Rosa odorata* was 10.09%, which is lower than that of our six cultivars. Also, the dry matter percentage of *Rosa grandiflora* (15.44%) in de Lima Franzen *et al*.'s (2019) study was greater than that of 'Dolce Vita' and 'Avalanche' and lower than that of the other cultivars in our research.

Mlcek *et al.* (2021) reported the protein content of *Rosa* at 2.89%, which was greater than the crude protein content we calculated in our cultivars. Chensom *et al*. (2019) reported that the crude protein content of 'Purple Fragrance' and 'Yves Piget' were 1.4 and 1.3 g/100 g FW,

respectively, which are similar to our study. Prate *et al*. (2017) reported that 'Avalanche' was richer in protein than 'Dolce Vita' (30.64 versus 30.13 mg/100 g FW), which was the opposite in our study. Mlcek *et al*. (2021) estimated the protein content of *Rosa* 'Gloria Dei' at 2.89%, so it was more prosperous than our cultivars.

Edible flowers have significant amounts of fibre (Jadhav *et al.*, 2023). In Prata *et al.*'s (2017) research, the crude fibre content of two rose cultivars, including 'Dolce Vita' and 'Avalanche', was 15.91 and 13.50 mg/100 FW, respectively, which were higher than those recorded for our rose cultivars.

Many edible flowers are rich in various vitamins, such as vitamin C (Jadhav *et al*., 2023). In the present work, the highest vitamin A was recorded by 'Dolce Vita' and the second-highest by 'Rainbows End', which were the richest in carotenoids. Carotenoids are the precursor of vitamin A, so consuming carotenoid-rich foods will significantly improve the body's vitamin A (Prata *et al*., 2017). Vitamin C was more in cultivars that were richer in anthocyanin. Prata *et al.* (2017) estimated the vitamin C content in 'Avalanche' and 'Dolce Vita' at 64.65 and 57.70 mg/100 g FW, which were greater than the numbers obtained in the present research. Kalisz *et al*. (2023) studied 23 garden rose cultivars and found that all were rich in vitamin C, but they had trivial amounts of vitamin B.

Anthocyanin, carotenoids, phenol compounds, and flavonoids are the most important naturally occurring antioxidants. Rose petals are a rich source of natural antioxidants (Yang and Shin, 2017). Prata *et al.* (2017) stated that 'Dolce Vita' had a higher anthocyanin content than 'Avalanche', which agrees with our findings. Also, 'Dolce Vita' had significantly higher total carotenoid, total phenols, and antioxidant capacity than 'Avalanche'.

In the present study, the highest anthocyanin content was obtained from 'Samurai' and 'Crimson Siluetta', which had red petals. The lowest anthocyanin content was related to the cultivars with white flowers. Yang and Shin (2017) found that among nine rose cultivars, those with red colour had the highest anthocyanin content. Kalisz *et al*. (2023) found that rose cultivars with red petals were richer in anthocyanin. Sagdic *et al*. (2013) also reported that the effect of the red colour was significant on the anthocyanin content of tulips. It can, therefore, be said that the red colour of petals has a decisive effect on the anthocyanin content.

The phenol compounds of roses are essential for their antioxidant activity. As was stated in the results, the highest phenol was recorded for the cultivars with red flowers, which is consistent with Yang and Shin (2017), according to whom the cultivars with red flowers recorded the highest phenol and flavonoid contents. Kalisz *et al*. (2023) studied 23 garden rose cultivars and recorded the highest phenol and flavonoid content in cultivars whose flowers were red. Zheng *et al.* (2018) compared *R. centifolia, R. chinensis*, *R. gallica*, and *R. rugosa* regarding flavonoids, phenols, and antioxidant capacity. They revealed that the total flavonoid content ranged from 10.91 mg CAE/g FW in *R. centifolia* to 24.13 mg CAE/g FW in *R. chinensis*. *R. rugosa* had the highest, and *R. centifolia* had the lowest total phenol content. Also, the antioxidant capacity of these cultivars varied from 243.34% for *R. gallica* to 521.99% for *R. rugosa*. Compared to our cultivars, all four cultivars studied by Zheng *et al.* (2018) had higher total phenols, total flavonoids, and antioxidant capacity. Araujo *et al*. (2019) recorded the rose's total phenol and flavonoid content at 9.89 mg GAE/g FW and 2.62 mg CE/g FW, respectively, reflecting that they were richer in these two traits than our cultivars.

Edible flowers are an excellent source of minerals; even the mineral content of some edible flowers is, in some cases, higher than that of common fruits and vegetables we consume daily (Jadhav *et al*., 2023). Research shows that K, P, and Ca were the main minerals detected in

rose petals (Hegde *et al.,* 2022; Pires *et al*., 2017).

Prata *et al.* (2017) found that 'Avalanche' outperformed 'Dolce Vita' in N, P, K, Mg, Na, and Zn, whereas 'Dolce Vita' outperformed 'Avalanche' in Ca, S, Cu, Fe, and Mn. Araujo *et al*. (2019) state that although the daily consumption of edible flowers is meagre, permanent consumers can meet a significant part of their mineral and biologically active compound demands. These researchers recorded the K, Na, Mg, Ca, Fe, Zn, Cu, and Mn content of rose petals at 2.948, 79.5, 490.4, 118.8, 21.3, 11.6, 2.25, and 5.29 mg/100 g FW, respectively. Another research reported the P, K, Ca, Na, Fe, Cu, and Zn content of the *Rosa* 'Gloria Dei' petals at 245.15, 2033.44, 285.58, 79.23, 4.02, 2.31, and 4.62 mg/kg FW, respectively (Mlcek *et al*., 2021). Compared to *Rosa* 'Glorial Dei' (Mlcek *et al.,* 2021), all our six cultivars exhibited lower K, Na, Cu, and Zn content. Among our cultivars, 'Hella' was richer in Ca, and 'Hella', 'Crimson Siluetta', and 'Rainbows End' were richer in Fe than *Rosa* 'Glorial Dei'.

CONCLUSIONS

The studied traits were measured based on 100 g of fresh petal weight. Although, the daily consumption of 100 g of fresh flowers is far-fetched in the human diet, the results show that the daily consumption of all six studied cultivars can act as a good source of minerals, fibre, proteins, and antioxidant compounds and partially supply human needs. In general, 'Crimson Siluetta' was the best cultivar in antioxidant compounds and 'Hella' was a rich source of minerals. However, 'Hella' contained higher amounts of Ni and B. The organic production of edible flowers can mitigate the risk of toxic elements.

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