Journal of Ornamental Plants
https://sanad.iau.ir/en/Journal/jornamental/
ISSN (Print): 2821-0093 ISSN (Online): 2783-5219

Research Article
Volume 14, Number 1: 37-50, March, 2024

Antioxidant Compounds, Minerals, and Nutrients of Different Chrysanthemum Genotypes

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Received: 19 October 2023 **Accepted:** 23 January 2024

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Abstract

Chrysanthemum is a major ornamental flower in the world that is important medicinally and nutritionally. This research in 2022 investigated on 20 chrysanthemum genotypes produced and bred in the Ornamental Plants Research Center of Mahallat with regard to their nutritional, mineral, and antioxidant compounds in a completely randomized design. The results showed that the genotypes differed in all studied traits. The highest Ca (74.1 mg/kg FW), Fe (2.231 mg/kg FW), and Se (0.233 mg/kg FW) were obtained from codes 326, 110, and 562, respectively. The highest Zn content (0.315 mg/kg FW) was related to codes 562 and 134. Codes 540 and 603 were related to the highest vitamin A (0.086 mg/kg) and vitamin C (13.58 mg/100 g FW), respectively. Code 751 had the highest protein level of 1.483%. Codes 540 and 138 exhibited the lowest and highest fiber percentages of 13.06 and 22.34%, respectively. The best genotypes in petal anthocyanins and carotenoids were codes 674 and 108, respectively. codes 684 and 354 had the highest and code 751 had the lowest flavonoid content. The highest and lowest total phenols were observed in codes 326 and 462, respectively. Based on the results8, the 20 genotypes of chrysanthemum bred and produced in Iran, codes 110 and 326 are the most appropriate option in terms of nutritional and biological value, and these species can be used as a new and available food source to partially supply the nutrient requirement of the human body.

Keywords: Edible flower, Healthy eating, New food source, Plant protein, Vegetarianism.

INTRODUCTION

Our ancestors have proven that flowers are edible, but their culinary use has flourished in recent years. In the past, flowers were mostly consumed for their medicinal effects. However, they are used in modern nutrition and gastronomy as an ingredient or decorative material of various foods, and their effect on improving the appearance, taste, flavor, smell, and texture of foods, as well as their nutritional value, have increased their use in preparing various stews, sauces, soups, salads, desserts, and beverages. Presently, edible flowers are especially popular among the proponents of healthy lifestyles as a complete or part of the food (Nicolau and Gostin, 2015; Saurabh and Barman, 2020).

Marigold, primrose, hollyhock, chrysanthemum, carnation, rose, common sage, garden nasturtium, violet, and yucca are examples of famous edible flowers (Nicolau and Gostin, 2015; Guiné *et al*., 2019). Past studies have revealed that edible flowers are a rich source of proteins, carbohydrates, fatty acids, phenol compounds, sugars, vitamins, flavonoids, alkaloids, and antioxidants, that their application can significantly meet the food requirements of humans, and that they can even substitute main foods, especially during the shortage of seasonal or fresh foods (Fakhri *et al*., 2021; Netam, 2021).

Chrysanthemum (*Chrysanthemum morifolium* L.) from the family of Asteraceae is in the list of top ten cut flowers in the world. This species is medicinally, nutritionally, industrially, and environmentally important, in addition to its decorative value, so its consumption as a medicinal and edible plant in its origin, China, has a history of over 3000 years (Chen *et al*., 2021; Hadizadeh *et al*., 2022). Vitamins, flavonoids, sesquiterpenes, and unsaturated fatty acids are some biologically active compounds detected in chrysanthemums. Almost all parts of chrysanthemums (roots, stems, leaves, and petals) have medicinal applications (Skrajda-Brdak *et al*., 2020; Long *et al*., 2022). But, petals are their edible part, which is consumed in fresh, dried, steam-cooked, and cooked forms (Sugawara and Igarashi, 2009; Long *et al*., 2022).

Owing to the ornamental value of cut chrysanthemum flowers in the world, it has been subject to extensive breeding efforts, which have resulted in the production of many genotypes with significant ornamental traits, especially in Iran. New cultivars are often developed to improve the visual and qualitative features, such as flower color, size, form, aroma, quality, and longevity (Yan *et al*., 2019), which are some of the most important features considered by the consumers of edible flowers when deciding on flower selection and consumption. Many genotypes of chrysanthemum have been produced in Mahallat County, Iran, but no research has ever been conducted on their edibility. Thus, the present research aimed to determine the nutritional value and antioxidant compounds of 20 chrysanthemum genotypes produced in this county as edible flowers.

MATERIALS AND METHODS

To determine the minerals, vitamins, and antioxidant compounds of 20 chrysanthemum genotypes, an experiment was conducted based on a completely randomized design. The flowers were selected out of 1000 chrysanthemum genotypes produced and bred in the Ornamental Plants Research Center of Mahallat. The rooted cuts of the 20 target genotypes were planted in a controlled greenhouse in Mahallat in mid-September 2022. Fig. 1 show the characteristics of the genotypes used in this study. The flowers were harvested in late October 2022 when they were fully open. The harvested flowers were transferred to the experimental location (Islamic Azad University of Rasht) in proper packages and taking care of safe transportation principles.

To assess the traits, 10 flowers were selected from each genotype and were packed in lidded containers. The flowers were kept in a refrigerator (4 ºC) during the experiment.

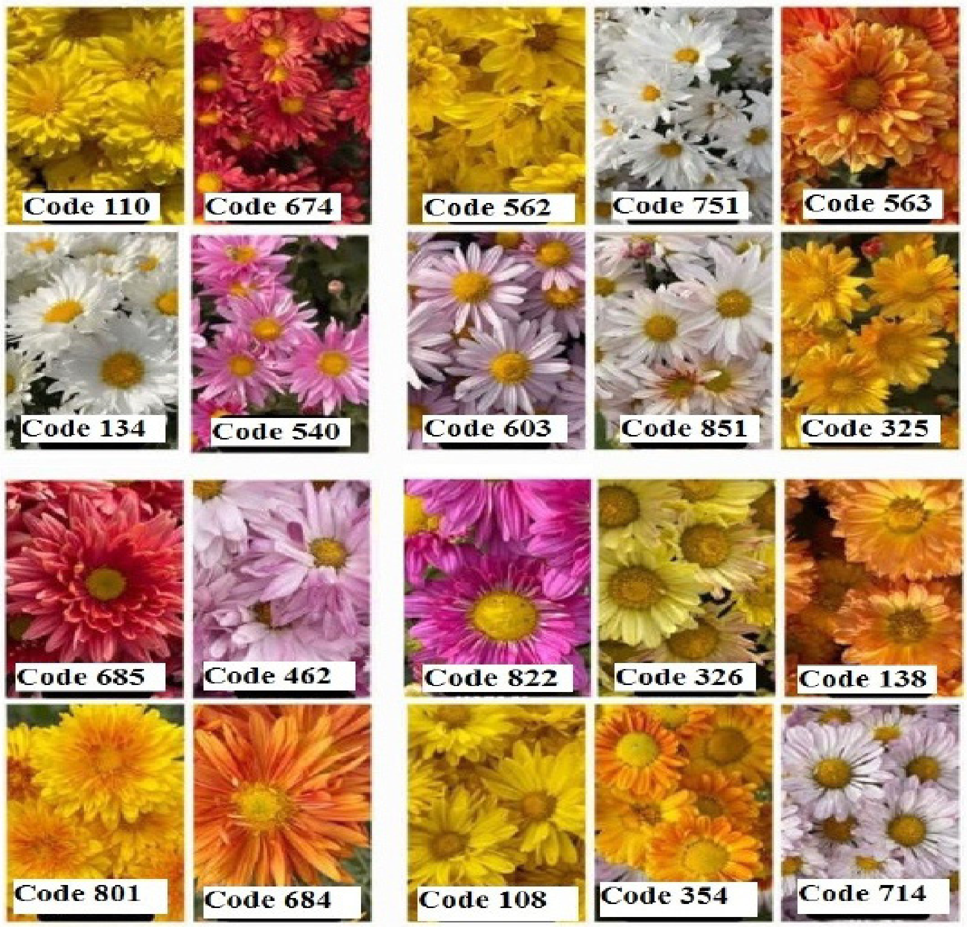

Fig. 1. Chrysanthemum genotypes used in the present study.

Assessment of traits

Minerals (Ca, Fe, Zn, and Se)

To measure the concentrations of minerals in chrysanthemum petals, their 1-g ash was extracted by Rengel and Romheld's (2000) method. Then, Ca, Fe, Zn, and Se concentrations were determined by the atomic absorption device.

Petal protein

The Kjeldahl method was employed to find out the petal protein content of the genotypes. In this method, the N percentage of the samples was determined, and the following formula was, then, used to estimate the petal protein percentage:

$$\text{Protein } (\%) = N \times 6.25$$

Vitamin C

The vitamin C content was determined by using the method of titration with 2,6-dichlorophenolindophenol. The vitamin C content of the petals was calculated by the following equation in mg/100 g fresh weight (FW) (Mazumdar and Majumdar, 2003):

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

in which a is the sample weight, b is the volume of metaphosphoric used in extraction, c is the volume of solution taken for titration, e is the volume of the dye solution consumed for each sample, and d is the dye factor, which is calculated by the following equation:

$$d = \frac{0.5}{\text{The amount of dye solution used for the titration of the standard sample}}$$

Petal anthocyanin and carotenoid

Mazumdar and Majumdar's (2003) method was used to measure the anthocyanin and carotenoid content of the chrysanthemum petals. So, 0.5 of the fresh petal was extracted by acid method to determine the anthocyanin content and by acetone 80% to determine the carotenoid content. Then, their absorbance was read with a PD-103 UV APEL spectrophotometer at 535 nm for anthocyanin and at 440, 645, and 663 nm for carotenoid. Finally, the anthocyanin and carotenoid contents were estimated by the following equations:

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

in which e is the sample weight, b is the volume of the sample used for measurement, c is the whole of the synthesized solution, d is the volume of the sample taken, and a is the reading of the spectrophotometer.

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

Raw fiber

The percentage of raw fiber was calculated by the following equation as per the procedure described by Aryapak and Ziarati (2014):

$$\text{Raw fiber percentage} = \frac{\text{Raw fiber weight}}{\text{Initial sample weight}} \times 100$$

Tota phenol content

The total phenol content was determined by Singleton *et al.*'s (1999) method for which a reaction mixture was made of the plant extract, distilled water, diluted Folin, and sodium carbonate. Also, the standard solution was developed by gallic acid and pure methanol at the rates of 0, 6.25, 12.5, 25, 50, and 100 µL. Eventually, an APEL PD-303UV spectrophotometer and a standard curve were used to find out the total phenol content of the petals in mg gallic acid equivalent (GAE) per 100 g FW.

Total flavonoid content

The total flavonoid content was measured by Du *et al.*'s (2009) method. After the petal extract was prepared, the absorbance of the samples was read at 506 nm with a spectrophotometer, and the total flavonoid content was calculated in mg catechin equivalent (CE) per 100 g FW using a standard curve.

Data analysis

The data collected were analyzed by the SPSS 19 statistical software package. The means were compared by the LSD test at the $P < 0.05$ and $P < 0.01$ levels.

RESULTS

Minerals

According to the analysis of variance (ANOVA), the 20 studied genotypes differed in minerals (Fe, Zn, Ca, and Se) significantly (Table 1). The comparison of means showed that Codes 110, 326, and 603 had the highest (3.231, 2.403, and 2.368 mg/kg FW, respectively) and Codes 685, 801, and 138 had the lowest Fe content (1.143, 1.248, and 1.295 mg/kg FW, respectively). Regarding Zn, Codes 562 and 134 had the highest content (0.315 mg/kg FW) and did not differ from Code 354 (0.303 mg/kg FW) significantly. The lowest Zn content (0.175 mg/kg FW) was observed in Codes 674, 325, 326, and 684. The highest Ca content was 74.1 mg/kg FW exhibited by Code 326. Also, Codes 684, 138, and 801 had the lowest Ca content (45.46, 45.83, and 47.03 mg/kg FW, respectively), showing no significant differences from one another. The highest and lowest Se contents were observed in Codes 562 (0.233 mg/kg FW) and 603 (0.026 mg/kg FW), respectively (Table 2).

Table 1. Analysis of variance of the effect of different genotype on traits measured in chrysanthemum.

S.o.V	df	MS					
		Fe (ppm)	Zn	Ca	Se	Vitamin A	Vitamin C
Repetition	2	0.0085^{ns}	0.00653^{**}	7.15^{ns}	0.00058^{ns}	0.000011^{ns}	0.061^{ns}
Genotype	19	0.05467^{*}	0.000519^{*}	483.3^{**}	0.00593^{**}	0.00558^{**}	0.879^{**}
Error	38	0.01524	0.000137	64.04	0.0002	0.0000045	0.079
CV (%)	-	6.95	5.07	13.49	24.38	21.7	12.29

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

Vitamins A and C

The chrysanthemum genotypes differed in vitamins A and C significantly ($P < 0.01$) (Table 1). Code 540 was the best genotype in the vitamin A content (0.0868 mg/kg FW) followed by Codes 674 (0.028 mg/kg FW) and 138 (0.020 mg/kg FW) in the second and third ranks, respectively. The weakest genotypes in this trait were Codes 851 (0.0016 mg/kg FW) and 110 (0.0017 mg/kg FW). There was no significant difference between these two genotypes (Table 2).

Code 603 was the richest genotype in vitamin C (13.58 mg/100 g FW), but it did not show any significant differences from Codes 462, 562, 82, and 540 (13.39, 13.33, 13.30, and 13.10 mg/100 g FW, respectively). The lowest vitamin C contents were recorded by Codes 685 (11.71 mg/100 g FW), 354 (11.86 mg/100 g FW), and 751 (11.96 mg/100 g FW), respectively (Table 2).

Table 2. Mean comparison of the effect of different genotype on traits measured in chrysanthemum.

Genotype	Fe (mg/kg F.W.)	Zn (mg/kg F.W.)	Ca (mg/kg F.W.)	Se (mg/kg F.W.)	Vitamin A (mg/kg F.W.)	Vitamin C (mg/100 g F.W.)
Code 108	1.936^{cde}	0.187^{ih}	57.86^{e-h}	0.048^{b-f}	0.0073^{de}	12.70^{cde}
Code 110	3.231^{a}	0.268^{b}	53.76^{jk}	0.060^{bcd}	0.0017^{h}	12.10^{f-i}
Code 134	1.866^{de}	0.315^{a}	61.00^{de}	0.052^{b-e}	0.0028^{fgh}	12.93^{bcd}
Code 138	1.295^{ghi}	0.245^{cd}	45.83^{l}	0.058^{b-e}	0.0200^{c}	12.23^{e-h}
Code 325	1.435^{fgh}	0.175^{i}	55.90^{g-j}	0.068^{bc}	0.0020^{gh}	12.26^{e-h}
Code 326	2.403^{b}	0.175^{i}	74.10^{a}	0.045^{c-f}	0.0025^{fgh}	12.46^{def}
Code 354	1.481^{fg}	0.303^{a}	62.66^{cd}	0.060^{bcd}	0.0023^{gh}	11.86^{hi}
Code 462	2.100^{c}	0.198^{gh}	59.96^{d-f}	0.052^{b-e}	0.0033^{fgh}	13.39^{ab}
Code 540	1.528^{f}	0.222^{ef}	70.60^{b}	0.035^{ef}	0.0868^{a}	13.10^{abc}
Code 562	1.90^{cde}	0.315^{a}	54.60^{i-k}	0.233^{a}	0.0098^{d}	13.33^{ab}
Code 563	1.750^{e}	0.268^{b}	52.86^{jk}	0.052^{b-e}	0.0055^{efg}	12.36^{e-g}
Code 603	2.368^{b}	0.257^{cb}	57.5^{f-i}	0.026^{f}	0.0024^{gh}	13.58^{a}
Code 674	1.458^{fg}	0.175^{i}	69.30^{b}	0.035^{ef}	0.0280^{b}	12.53^{def}
Code 684	1.306^{ghi}	0.175^{i}	45.46^{l}	0.043^{def}	0.0022^{gh}	12.13^{f-i}
Code 685	1.143^{i}	0.210^{gf}	55.30^{h-k}	0.046^{c-f}	0.0025^{fgh}	11.71^{i}
Code 714	1.820^{de}	0.268^{b}	64.70^{c}	0.036^{ef}	0.0041^{e-h}	12.56^{def}
Code 751	1.365^{fgh}	0.222^{ef}	52.26^{k}	0.043^{d-f}	0.0036^{fgh}	11.96^{g-i}
Code 801	1.248^{hi}	0.187^{ih}	47.03^{l}	0.069^{b}	0.0060^{ef}	12.36^{e-g}
Code 822	1.960^{cd}	0.233^{ed}	58.56^{efg}	0.046^{b-f}	0.00233^{gh}	13.30^{ab}
Code 851	1.878^{de}	0.222^{ef}	54.70^{h-k}	0.0603^{bcd}	0.0016^{h}	12.46^{d-f}

*In each column, means with similar letter(s) are not significantly different (P < 0.05) using the LSD test.

Total protein

Based on ANOVA, the studied 20 chrysanthemum genotypes differed in protein content significantly (P < 0.01) (Table 3). As is seen in fig. 2, Code 751 was the superior genotype (1.483%) followed by Codes 603, 562, and 108 in the next ranks, respectively. The lowest protein content was related to Code 801 (0.771%), but it had no statistically significant difference from Codes 563, 326, and 462 (Fig. 2).

Table 3. Analysis of variance of the effect of different genotype on traits measured in chrysanthemum.

		MS					
S.o.V	df	Total protein	Total fiber	Total flavonoids	Total phenol	Total anthocyanin	Petal carotenoid
Repetition	2	0.0015^{ns}	0.867^{ns}	2.683^{*}	0.189^{ns}	14.7^{ns}	53903^{**}
Genotype	19	0.1147^{**}	21.406^{*}	16.7^{**}	16.07^{**}	924.42^{*}	44798^{**}
Error	38	0.0063	7.38	0.7481	3.67	20.66	941.205
CV (%)	-	8.12	16.42	21.74	18.41	20.57	14.59

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

Total raw fiber

The raw fiber content was significantly (P < 0.05) influenced by the genotype (Table 3). The best genotype was Code 138, which contained 22.34% fiber. Codes 108, 326, 110, and 134 did not differ from one another significantly and were all the best treatments as a source of raw fiber. The lowest raw fiber content was observed in Codes 540 (13.06%) and 822 (13.78%), not differing from one another significantly (Fig. 3).

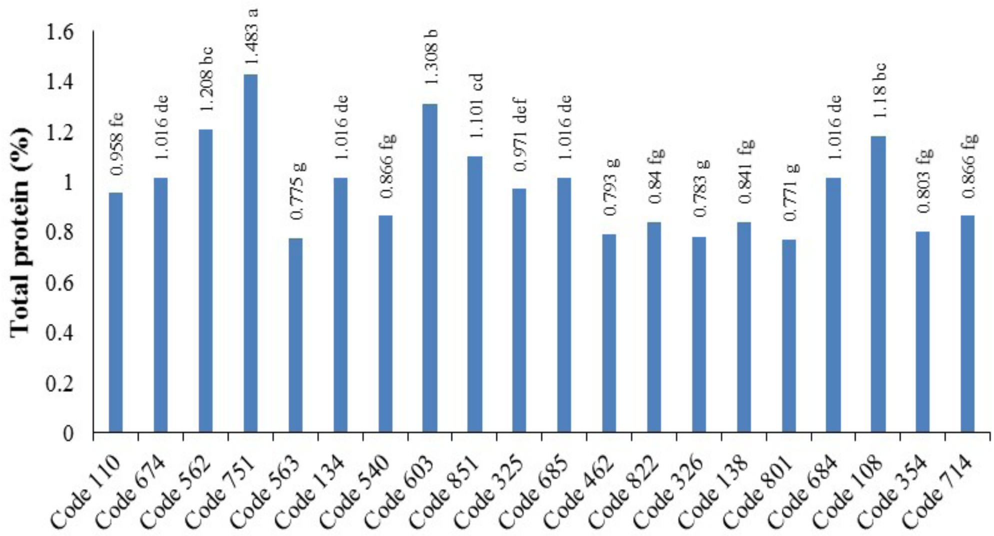

Fig. 2. Mean comparison of the effect of different genotype on total protein.

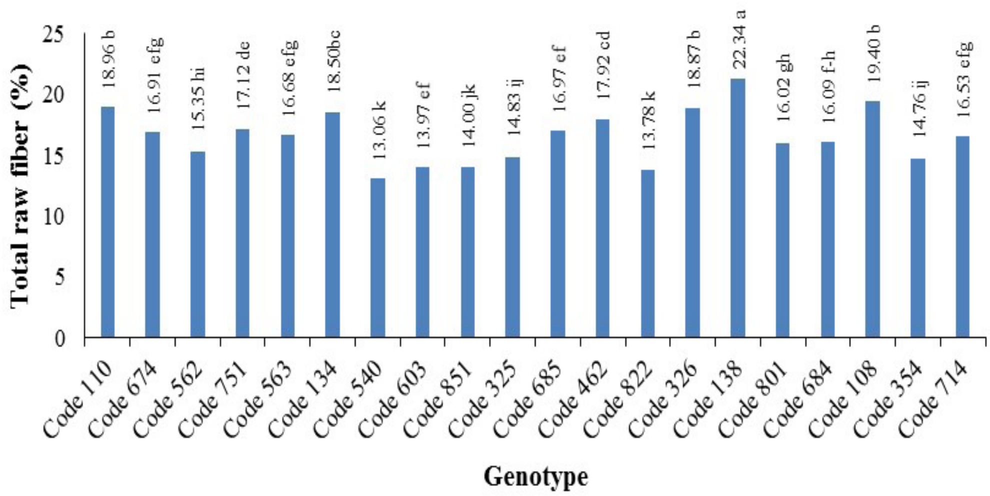

Fig. 3. Mean comparison of the effect of different genotype on total row fiber.

Total phenols

There were statistically significant ($P < 0.01$) differences among the genotypes in total phenols (Table 3). The total phenols content was the lowest in Code 462 (7.93 mg/g FW) and the highest in Code 326 (12.546 mg/g FW). However, the superior genotype did not differ from Codes 138 (11.566 mg/g FW) and 603 (11.536 mg/g FW) significantly. So, all these three genotypes were the best in total phenols (Fig. 4).

Total flavonoid

As revealed by ANOVA, the studied genotypes differed in total flavonoid significantly at the $P < 0.01$ level (Table 3). The best genotypes in this trait, which did not differ significantly from one another, were Codes 684 (5.81 mg/g FW) and 354 (5.39 mg/g FW). In contrast, Code 751 had the lowest total flavonoid content of 3.50 mg/g FW (Fig. 5).

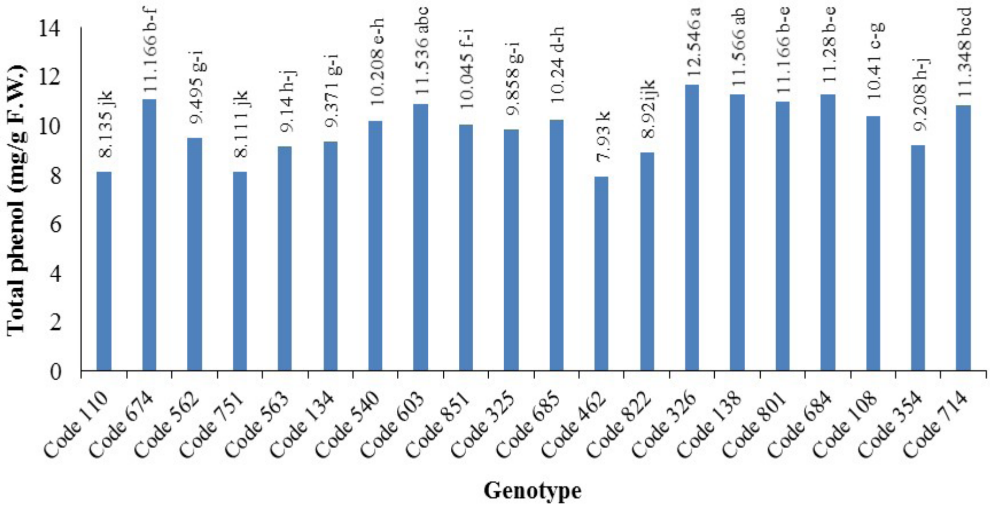

Fig. 4. Mean comparison of the effect of different genotype on total phenol.

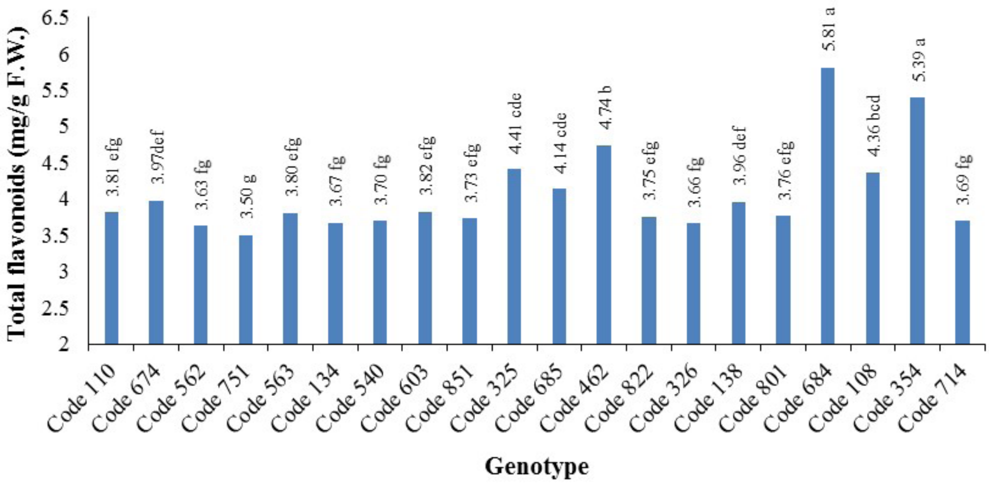

Fig. 5. Mean comparison of the effect of different genotype on total flavonoids.

Total anthocyanin in petals

The genotypes significantly ($P < 0.05$) differed in total anthocyanin content (Table 3). The highest anthocyanin content was 60.83 mg/100 g FW observed in Code 674 and the second-highest was 52.56 mg/100 g FW observed in Code 822. The lowest anthocyanin contents were observed in Codes 134 (5.60 mg/100 g FW), 751 (6.20 mg/100 g FW), and 108 (6.86 mg/100 g FW), respectively (Fig. 6).

Total carotenoid in petals

It was found from ANOVA that the carotenoid content of the petals differed among the genotypes significantly ($P < 0.01$; Table 3). Code 108 (482.3 µg/g FW) was the best. Codes 801, 563, 684, and 674 were also successful genotypes in this trait. But, the lowest petal carotenoid content (71.7 µg/g FW) was related to Code 603, which did not differ from Codes 134, 540, 751, 851, 462, 822, and 714 significantly (Fig. 7).

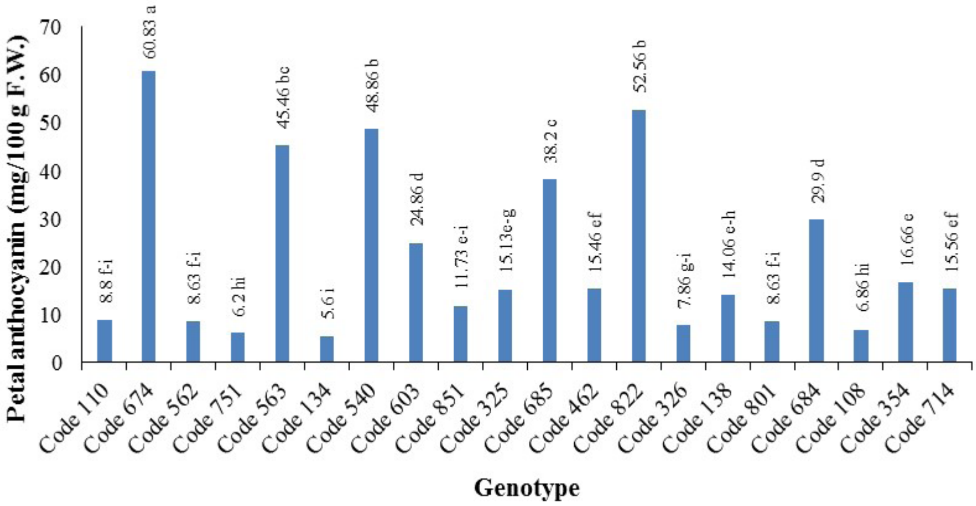

Fig. 6. Mean comparison of the effect of different genotype on total anthocyanin.

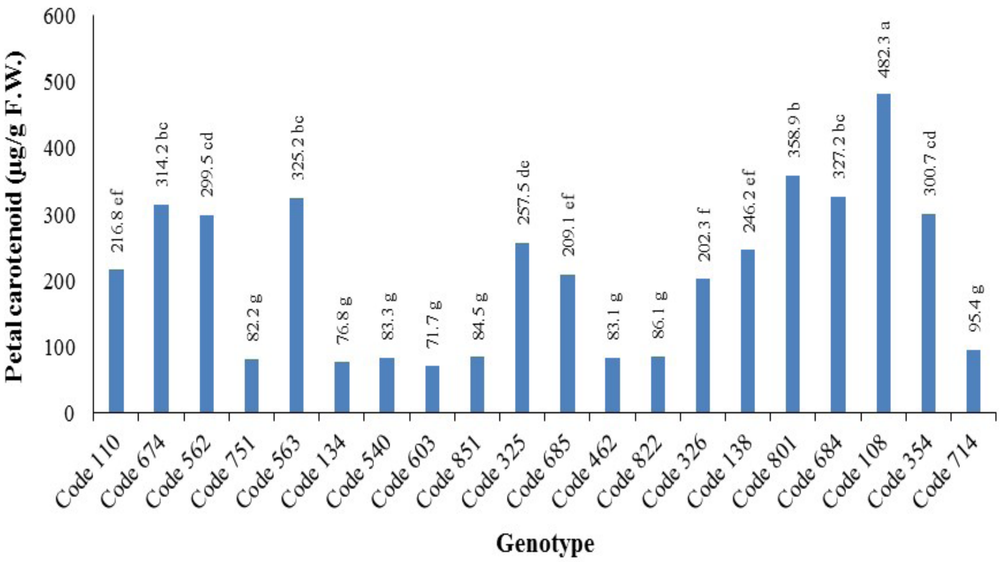

Fig. 7. Mean comparison of the effect of different genotype on petal carotenoid.

CORRELATION RESULTS

Table 4 shows the correlation between the measured traits. As can be seen, there was a positive and significant correlation between phenol, flavonoid and vitamin C, which can be mentioned as the most important characteristics of an edible flower. Also, there was a positive and significant correlation between the amount of carotenoid and vitamin C, phenol, flavonoid, fiber and element selenium. The amount of fiber in the studied edible flowers was positive and significant with all traits except anthocyanin, selenium and protein. The relationship between protein and vitamin C, phenol, flavonoid, iron, zinc, calcium and fiber was also positive and significant. The positive correlation between the investigated traits is a desirable feature for the consumption of edible flowers.

Table 4. Correlation between measured traits.

	Carotenoid	**Anthocyanin**	**Vitamin C**	**Phenol**	**Flavonoid**	**Fe**	**Zn**	**Ca**	**Se**	**Fiber**	**Protein**
Carotenoid	1.000										
Anthocyanin	0.054	1.000									
Vitamin c	0.254*	0.270*	1.000								
Phenol	0.384**	0.239	0.803**	1.000							
flavonoid	0.471**	0.216	0.744**	0.649**	1.000						
Fe	0.021	-0.053	0.632**	0.395**	0.343**	1.000					
Zn	0.075	0.044	0.713	0.452**	0.472**	0.557**	1.000				
Ca	0.130	0.343**	0.846**	0.737**	0.595**	0.599**	0.572**	1.000			
Se	0.262*	-0.249*	0.146	-0.012	0.014	0.089	0.352**	-0.026	1.000		
Fiber	0.422**	-0.006	0.772**	0.716**	0.646**	0.540**	0.563**	0.632**	0.047	1.000	
Protein	0.154	0.016	0.684**	0.538**	0.480**	0.417**	0.522**	0.503**	0.196	0.539**	1.000

*and **: Significant at $P < 0.05$ and $P < 0.01$, respectively.

DISCUSSION

The introduction of a new nutrient into the human food regime depends on various factors, such as its nutritional and mineral compounds, antioxidants, and effect on human health. Edible flowers, e.g., chrysanthemums, are an invaluable source of biologically active compounds that have drawn the attention of people, especially the proponents of a healthy lifestyle (Alves *et al*., 2021; Chen *et al*., 2021). Edible flowers have different concentrations of minerals, vitamins, proteins, sugars, fatty acids, and antioxidant compounds (Espejel *et al*., 2019). Minerals are important constituents in foods and play an essential role in preserving the natural functioning of the human body. For instance, Ca is a vital element in the structure of bones and teeth, and Fe, Zn, and Se are vital elements in the structure of enzymes (Charibzadeh and Jafari, 2017). The minerals required by the human body are received from the food regime directly or indirectly. So, an ideal food regime for human health must be rich in minerals (Huang *et al*., 2020).

Our results showed that the chrysanthemum genotypes had varying concentrations of Ca (45.46-74.10 mg/kg FW), Fe (1.143-3.231 mg/kg FW), Zn (0.175-0.315 mg/kg FW), and Se (0.026-0.233 mg/kg FW). Since the daily human demand for Ca, Fe, Zn, and Se has been estimated at 550-650, 5.6-6.5, 7-9, and 0.02-0.025 mg, respectively (Huang *et al*., 2020), it is evident that the chrysanthemum genotypes cannot supply these daily mineral demands by themselves, but they can only partially meet them as a new food ingredient.

In Mlcek *et al*.'s (2021) study, the Fe content was recorded at 3.12 and 4.02 mg/kg in edible begonia and rose flowers, respectively. So, the Fe content of chrysanthemum Code 110 (3.231 mg/kg FW) was higher than that of the begonia and lower than that of the rose. The begonia and rose flowers outperformed the studied genotypes of chrysanthemums in Zn and Ca. All flowers studied by Rop *et al*. (2012) (carnation, marigold, and violet) except for rose (3.55 mg/kg) had higher Fe, Zn, and Ca contents than our studied chrysanthemum genotypes.

Vitamin C is a strong antioxidant that plays a key role in the body's natural metabolism. The vitamin C content has been recorded at 2.6-44.9 mg/kg FW in many edible flowers (Demasi *et al*., 2021). It was 11.71-13.58 mg/kg FW in the studied genotypes of chrysanthemum, which is acceptable among edible flowers. The human body's daily need for vitamin C is 95-100 mg. The vitamin C content of the apple, orange, and kiwifruit has been estimated at 5, 35, and 93 mg/100 g FW, respectively (Cruz-Rus *et al*., 2012; Demasi *et al*., 2021). So, all studied genotypes of chrysanthemum had higher vitamin C content than the apple.

Vitamin A was among the vitamins assessed in this research and its content in different genotypes was estimated at 0.0016-0.0868 mg/kg FW. Since carotenoids are the precursor of vitamin A (Skrajda-Brdak *et al*., 2020), the genotypes were expected to have higher carotenoids than vitamin A, but it was the opposite.

Proteins and fibers are other invaluable compounds in edible flowers so that plant fibers are regarded as an essential component of the food regime that can reduce the risk of cardiovascular diseases, diabetes, hypertension, and so on. The human body daily needs 25-35 g of fiber, which should be supplied from food sources (Jakubczyk *et al*., 2022). Previous research has reported the raw fiber percentage at 1.468 and 0.491% of FW in carnation and orange day-lily (Stefaniak and Crzeszczuk, 2019) and 12.7, 13.89, and 28 g/kg in agave, aloe vera, and broccoli, respectively (Fernandes *et al*., 2017) whereas it was in the range of 13.06-22.34% of FW for chrysanthemum genotypes in our study. Code 138 had the highest raw fiber content (22.34%), so it was the most appropriate source of raw fiber among the studied genotypes. Also, the chrysanthemum genotypes had 0.771-1.483% of proteins, which was lower than that of carnation (5.61%) and orange day-lily (3.346%) (Stefaniak and Crzeszczuk, 2019). Mlcek *et al*. (2021) reported the protein content of begonia, pot marigold, and marigold at 4.51, 8.98, and 9.34 mg/kg FW, respectively. Thus, the chrysanthemum genotypes studied in this research were richer in protein than these three edible flowers.

The health benefits of edible flowers largely depend on their antioxidants (phenols, flavonoids, anthocyanins, and carotenoids). So, it is important to identify and quantify the antioxidants of edible flowers as a natural food source (Zheng *et al*., 2019). We found that the total phenols, total flavonoids, and anthocyanins were 7.93-12.546, 3.50-5.81, and 5.6-60.83 mg/g FW in different genotypes of chrysanthemum, respectively. It has been reported that the total flavonoids, phenols, and anthocyanins in the apple flesh were 0.501-1.41, 0.379-3.77, and 0.65-5.66 mg/g FW, respectively (Rabiei *et al*., 2019), so the chrysanthemum genotypes had higher total phenols, flavonoids, and anthocyanins than the apple cultivars studied by Rabiei *et al*. (2019).

Mlcek *et al*. (2021) found that the total phenols in begonia, pod marigold, rose, and marigold were 4.82, 3.65, 4.45, and 4.78 g/kg FW, respectively. Rop *et al*. (2012) reported the total flavonoids in the edible flowers of carnation, rose, marigold, and violet at 2.27, 2.04, 1.90, and 1.99 g/kg FW, respectively. So, the chrysanthemum genotypes were superior to these flowers in total phenols. The total phenols and flavonoids of nine rose cultivars were in the ranges of 798.67-2978.89 and 78.64-531.54 mg/100 g FW, which are much greater than that in chrysanthemums. Espejel *et al*. (2019) state that purple, orange, red, and violet flowers have higher anthocyanin content than yellow and white flowers. In our research too, the chrysanthemum genotypes whose flowers were white (Codes 134 and 751) had lower anthocyanin. The highest anthocyanin content was related to Code 674 whose petals were red. However, in addition to flower color, anthocyanin content is influenced by environmental conditions, genotype, and flowering steps and may even be lower in some flowers with higher antioxidant capacity (Espejel *et al*., 2019). Compared to Stefaniak and Crzeszczuk (2019), the anthocyanin content of the chrysanthemum genotypes was lower and higher than that of carnation (443.47 mg/100 g FW) and daylilies (2.77 mg/100 g FW), respectively. Yang and Shin (2017) showed that the anthocyanin content was 0.61-502.64 mg/100 g FW in nine rose cultivars and that the cultivars with dark (red) color had higher anthocyanins. In the present work, the highest anthocyanin content was observed in the genotype with red flowers.

CONCLUSION

Based on the results, the chrysanthemum genotypes that were investigated here had nutritional and antioxidant values and differed in nutrients, minerals, and antioxidants significantly. The genotypes that had the highest Fe, Ca, Se, total phenols, and total carotenoids were Codes 110, 326, 562, 326, and 108, respectively. It should be noted that the flowers of these genotypes were yellow. Code 751, which had white flowers, had the highest protein content. The highest raw fiber and total flavonoid were recorded by Codes 138 and 684 whose flowers were orange. Finally, the genotypes whose flowers were purple produced the highest anthocyanins (Code 674), vitamin A (Code 540), and vitamin C (Code 603). Therefore, the studied genotypes of chrysanthemum can be used as a nutritious source in the food regime to enjoy their high food and antioxidant values.

ACKNOWLEDGMENT

The authors are obliged to express their gratitude to the Deputy of Research in the Rasht Branch, Islamic Azad University for their financial support.

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How to cite this article:

Bayanifar, H., Hashemabadi, D., Allahyari, M.S. and Kaviani, B. (2024). Antioxidant Compounds, Minerals, and Nutrients of Different Chrysanthemum Genotypes. Journal of Ornamental Plants, 14(1), 37-50.

https://sanad.iau.ir/en/Journal/jornamental/Article/1033219