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Evaluation of phytochemicals content, antioxidant activity and mineral composition of selected edible flowers

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RESEARCH ARTICLE

Abstract

Fourteen edible flowers used in cooking were investigated in order to obtain quantitative information on the phytochemicals content and mineral composition. Additionally, the antioxidant capacity was also evaluated by employing 1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2-azino-bis3-ethylbenzothiazoline-6-sulfonic acid (ABTS) methods. These analyses were performed in extracts prepared from flowers and vegetative parts and the results showed that contents of total phenolics, ortho-diphenols and flavonoids were high in flower extracts. Results also revealed considerable variation among the fourteen edible flowers extracts in total phenols (9.89-79.78 mg gallic acid equivalent/g of dry weight), orthodiphenols (14.90-238.61 mg gallic acid equivalent/g of dry weight) and flavonoids (2.62-56.86 mg catechin equivalents/g of dry weight). Correlation analysis indicated a moderately positive correlation between antioxidant activity and the contents of phenolic and ortho-diphenol compounds. In addition, the results of this study also showed that all edible flowers are major sources of mineral elements, especially potassium, magnesium, calcium, and sodium with an average concentration of 5,861, 542.0, 274.2 and 218.0 mg/100 g of dry weigh, respectively. Flowers also contain appreciable amounts of essential trace metals, such as zinc, selenium and manganese. Data obtained confirmed that edible flowers are good sources of minerals and phytochemicals, namely antioxidants, therefore their inclusion in cooking can provide health benefits.

Keywords: edible flowers, phenolics, flavonoids, antioxidants, mineral composition

1. Introduction

In recent years the increase in consumer demand for healthy natural food has risen the interest in the usage of plants in human nutrition. Despite several types of plants having been used since ancient times with both medicinal as well as nutritional purposes, nowadays there is a renewed interest in looking for potential new edible plants for cooking (Franzen *et al.*, 2018). Therefore, cooking and garnishing with edible fresh or dried flowers from ornamental plants are in vogue. Not only can flowers be used to add colour, taste and aroma to food, but also provide beauty to the culinary preparation which is an important quality parameter for consumers (Benvenuti *et al.*, 2016). In addition, the usage of edible flowers in food can also be responsible for a positive impact on health. Several studies have demonstrated that edible flowers are rich in health-promoting phytochemicals, such as polyphenolics and anthocyanins (Fernandes *et al.*, 2017; Lu *et al.*, 2016; Wang *et al.,* 2016).

The main health benefits attributed to these compounds are related to their antioxidant, anti-carcinogenic, anti-inflammatory and antibacterial properties (Kumar and Pandey, 2013; Lima *et al.*, 2014). Moreover, evidence-based studies have demonstrated that diets high in phytonutrients-rich foods are strongly associated with reduced risks of major chronic diseases, including heart disease, many cancers, type 2 diabetes and obesity (Govers *et al.*, 2018; Liu, 2013; Pandey and Rizvi, 2009).

Another important nutrient class present in edible flowers are mineral elements, resulting from the plants' ability to uptake the mineral salts from the soil. These nutrients are usually found in plants as constituents of bioactive molecules, necessary for their growth, development and reproduction. Furthermore, several mineral elements are also essential for human health, as they execute important functions in the human body as components of structural proteins, cofactors and activators of enzymes, regulators of nerve transmission, osmotic pressure and salt-water balance (Stathopoulou *et al.*, 2012).

In Portugal, there is a tradition in the use of edible plants for therapeutic and gastronomic purpose. For example, several medicinal plants have been used in the preparation of homemade herbal hot beverages for the treatment of various diseases and culinary herbs to add flavour and enhance the palatability of food (Gião *et al.*, 2007; Guiné and Gonçalves, 2016). In contrast, the use of edible flowers in cooking is relatively recent and not very common. However, the interest in edible flowers has increased and, at this time, several restaurant chefs and innovative home cooks incorporate flowers into dishes. Nevertheless, most consumers regard flowers only as ornamental elements and do not eat them, probably because they unaware of the fact that edible flowers contain valuable health nutrients. Indeed, information about mineral composition and phytochemical content of those edible flowers is scarce. Therefore, the goal of this study was to evaluate the phytochemical composition, antioxidant capacity and metal content of fourteen edible flowers used in the preparation of several types of dishes.

2. Materials and methods

Samples

Fourteen types of edible flowers species were studied, specifically, *Agastache foeniculum*, *Borago officinalis* L., *Calendula officinalis*, *Coriandrum sativum*, *Lavandula stoechas, Lavandula angustifolia*, *Lonicera japonica, Oenothera biennis, Rosa* sp., *Rosmarinus officinalis, Salva elegans, Tagetes patula, Tropaeolum majus* and *Viola tricolor*. The flowers were purchased from a local greenhouse company (Ervas Finas) located in Vila Real city, in northern interior of Portugal, in a region called Trás-os-Montes e Alto Douro. Briefly, the edible flowers were cultivated in an unheated greenhouse using organic fertilizers and no pesticides. The samples were provided as fresh plants, with fully opened flowers, placed in special plastic containers (the same as those used for packets on sale), as can be seen in the Figure 1.

In the laboratory, the plants were cleaned by using ultra-pure water and the flowers were separated from vegetative parts. Flowers were dried in an oven at 40 °C to a constant weight (48 h) and ground (about 5-15 s) in a grinding mill before use.

Figure 1. Image of some flowers used in this study (as provided in the plastic containers). Top (from left to right): *Agastache foeniculum; Tropaeolum majus; Viola tricolor.* Bottom (from left to right): *Lonicera japonica; Rosmarinus officinalis; Salvia elegans.*

Chemicals

Folin Ciocalteu phenol reagent, gallic acid, 1,1-diphenyl-2-picrylhydrazyl (DPPH), catechin, 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS), 2,3-diaminonaphthalene (DAN), trolox and catechin were supplied by Sigma Aldrich (Steinheim, Germany). The solvents (methanol and ethanol) were HPLC grade quality and were from Panreac (Barcelona, Spain). All other chemical reagents were of analytical grade and supplied by Merck (Darmstadt, Germany) and Sigma Aldrich (Steinheim, Germany). Stock standard solutions of 1000 mg/l (Pb, Cd, Co, Cr, Mn, Ni, Cu, Zn, Fe, Na, K, Se) were supplied from Merck (Darmstadt, Germany).

Preparation of the flowers extracts

Flowers extracts were used for the analysis of antioxidant activity, phenolic and flavonoid contents. The extracts were prepared according to Loizzo *et al.* (2016) with few modifications. Forty milligrams of dried powder plant material were extracted with 1.5 ml of 85% ethanol at room temperature for 30 minutes, on a reciprocating shaker. The residue was then extracted with two additional portions of 85% ethanol solution. The final volume of combined ethanolic extracts was adjusted to 5.0 ml with 85% ethanol solution. The extraction procedure, for each flower material, was performed in triplicate and the ethanolic extracts were pooled together.

Determination of total phenolic content

Total phenolic content was determined according to the Folin-Ciocalteau method with minor modifications (Singleton and Rossi, 1999). Results were expressed as gallic acid equivalents in milligrams per gram of dry weight (mg GAE/g dw).

Determination of total flavonoids content

The flavonoid content was determined spectrophotometrically using a method based on the formation of a flavonoid-aluminium complex which exhibited absorbance at 510 nm (Zhishen *et al.*, 1999). Results were expressed as catechin equivalents in milligrams per gram of dry weight (mg CE/g dw).

Determination of orto-diphenols content

The colorimetric method used for the determination of *ortho*-diphenols content was adapted from Bendini *et al.* (2003). Results were expressed as gallic acid equivalents in milligrams per gram of dry weight (mg GAE/g dw).

DPPH radical-scavenging activity

The antioxidant activity of the extracts was determined based on the scavenging activity of the stable DPPH radical according to the method described by Brand-Williams *et al.* (1995). Results are expressed in mmol of Trolox equivalent per gram of dry weight (mmol TE/g dw).

ABTS radical-scavenging activity

The antioxidant activity of the extracts was determined based on the scavenging activity of the stable ABTS radical cation ($ABTS^+$) according to the method described Re *et al.* (1999). Results are expressed in mmol of Trolox equivalent per gram of dry weight (mmol TE/g dw).

Determination of mineral element

A portion of dry flower material (0.1-0.15 g) was mineralized in a mixture of concentrated nitrate acid and 30% hydrogen peroxide in digestion tubes placed in a heating block digester (Digital Thermobloc, Falc, Treviglio, Italy). The mineralized residue was dissolved with 1% HNO_3 and quantitatively transferred into a 10 ml volumetric flask. This analysis was performed only for the flowers.

The analyses of Fe, Zn, Cu, Mg, Ca and Mn were performed by flame atomic absorption spectroscopy using an iCE 3000 flame atomic absorption spectrometer (Thermo Scientific, Madison, WI, USA) equipped with deuterium-lamp background correction. The analyses of Na and K were conducted by flame atomic emission spectroscopy. An air-acetylene flame was used in both analyses.

The analyses of Al, Pb, Cd, Co, Ni were conducted by graphite furnace atomic absorption spectroscopy using an Unicam 939 atomic absorption spectrometer (Unicam, Leeds, UK) with a Zeeman corrector equipped with a Unicam GF90 electrothermal atomizer and a Unicam FS90 autosampler.

Selenium was determined by fluorometric assay according to the methodology proposed by Lesvesque and Vendette (1971) based on the reaction of DAN with Se(IV) to form a fluorescent Se-DAN complex. The method involves sample digestion (HNO_3 and H_2O_2), complexation using DAN to form Se-DAN complex and cyclohexane extraction. The fluorophore extracts, which reflect total Se, were determined by fluorescence spectroscopy. The fluorescence readings were made on a Varian Cary Eclipse (Agilent, Santa Claram CA, USA) fluorescence spectrophotometer. The fluorescence intensities were measured at an excitation wavelength of 360 nm and at an emission wavelength of 360 nm, using a 10 mm quartz cuvette.

Statistical analysis

All data were expressed as means ± standard deviations (SD) of triplicate measurements. Descriptive statistical analysis, Pearson correlation coefficients, one-way analysis of variance (ANOVA) were performed using the statistical software SPSS 10.0 and *P*-values <0.05 were considered significant.

3. Results and discussion

Total phenolic compound and ortho-diphenols

The content of phenolic compounds obtained in the analysis of flowers extracts is presented in Table 1. There were significant differences ($P<0.05$) amongst the total content of phenolic compounds in the extracts of the fourteen edible flowers tested. Results show that the content of phenolic compounds in flowers extracts ranged from 9.89 mg GAE/g dw to 79.78 mg GAE/g dw. *T. patula* had the highest phenolic content (79.78 mg/g dw) followed by *V. tricolor* (63.43 mg GAE/g dw) and *A. foeniculum* (52.06 mg GAE/g dw). In contrast, the *Rosa* sp. and *C. sativum* presented the lowest phenolic content, 9.89 mg GAE/g dw and 12.17 mg GAE/g dw, respectively.

Although a variability in the content of phenolic compounds was expected, according to the flower type, the results obtained are within range of what had been reported in previous studies for the total phenolic content in edible flowers from other countries, such as the Czech Republic (Rop *et al.*, 2012), Spain (Navarro-González *et al.*, 2015),

Table 1. Total phenolics, *ortho*-diphenols and flavonoids contents in edible flowers extract.

Scientific name	Total phenolics (mg GAE/g)	*Ortho*-diphenols (mg GAE/g)	Flavonoids (mg CE/g)
Agastache foeniculum	52.06±2.30^{e}	125.24±5.82^{fg}	16.96±1.3^{cde}
Borago officinalis L.	16.58±0.44^{ab}	28.91±0.54^{abc}	12.59±1.91^{bcd}
Calendula officinalis	16.33±1.20^{ab}	26.54±2.07^{ab}	9.40±0.33^{abc}
Coriandrum sativum	12.17±0.95^{a}	44.64±2.55^{bcd}	16.51±0.73^{cde}
Lavandula angustifolia	17.28±0.44^{ab}	26.54±2.07^{ab}	18.63±1.07^{def}
Lavandula stoechas	46.26±3.23^{de}	137.38±7.78^{g}	54.88±2.25^{i}
Lonicera japonica	41.20±0.29^{cd}	238.61±0.62^{j}	49.02±3.31^{i}
Oenothera biennis	34.96±1.33^{c}	106.42±0.37^{f}	56.86±2.87^{i}
Rosa sp.	9.89±0.11^{a}	14.90±1.24^{a}	2.62±0.07^{a}
Rosmarinus officinalis	23.02±0.39^{b}	69.43±1.24^{e}	27.94±0.07^{a}
Salva elegans	40.86±1.97^{cd}	113.25±4.31^{f}	24.26±2.46^{gh}
Tagetes patula	79.78±3.64^{g}	170.57±5.60^{h}	26.47±1.41^{fgh}
Tropaeolum majus	22.96±1.75^{b}	49.38±1.50^{cde}	5.13±0.04^{ab}
Viola tricolor	63.43±3.13^{f}	197.30±4.70^{i}	32.84±2.39^{g}

[1] Means with different letters within each column were significantly different at the level $P<0.05$.

China (Xiong *et al.*, 2014) and Thailand (Kaisoon *et al.*, 2011). In comparison with other plants used in culinary, the phenolic content of edible flowers under study was higher than those in several culinary herbs which are also traditionally used in small amounts to enhance and complement the flavouring of food, for example parsley, fennel, thyme, chives, caraway and spearmint which varied from 0.68 mg GAE/g fw to 1.78 mg GAE/g fw (Zheng and Wang, 2001). Nevertheless, other culinary herbs such as oregano and marjoram presented higher phenolic content, 17.51 and 11.80 mg GAE/g fw, respectively, considering that the results are expressed on fresh weight (fw) basis and the moisture of edible flowers samples studies are in the range 79.7-93.4%.

Furthermore, fruits and vegetables are good sources of phenolic compounds and their consumption is highly recommended as a way to prevent major diseases, such as cardiovascular diseases and certain cancers (WHO/FAO, 2004). Our results revealed a higher total phenolic content as compared to those reported by Stratil *et al.* (2006) who found that the concentration of phenolic compounds from 32 species of commonly consumed vegetables was in the range of 4.5-36.3 mg GAE/g dw. Additionally, Pantelidis *et al.* (2007) have reported that the total phenolic content ranged from 657 to 2,611 mg GAE/100 g dw in different cultivars of small fruits, specifically raspberry, blackberry, red currant, gooseberry and Cornelian cherry. Our data show that seven edible flowers possess higher phenolic content than the Cornelian cherry, the fruit with the highest phenolic content.

Total *ortho*-diphenols content in the flowers extracts, expressed in gallic acid equivalent, ranged from 14.90 mg GAE/g dw to 238.61 mg GAE/g dw (Table 1). To the best of our knowledge, there is no data in literature regarding the *ortho*-diphenols content in edible flowers and, in general, the data about the content of these compounds in food is very limited. However, ortho-diphenols have been recognized as the class of phenolic compounds with highest antioxidant activity (Cai *et al.*, 2006). For instance, Guedes *et al.* (2019) determined the *ortho*-diphenols content in four varieties of common beans (Kidney bean, Pinto bean, Borlotti bean, Black bean) and soy bean, reporting values ranged between 0.43-1.13 mg GAE/g dw. Another study, Santos *et al.* (2014), reported that the content of *ortho*-diphenols in pear pulp of the Rocha variety, collected from five different geographical regions in Portugal, varied from 442.2 to 666.2 mg GAE/100 g dw. These results indicate that the content of *ortho*-diphenols in both types of food is considerably lower than the values obtained in this work for edible flowers.

Total flavonoid content

The results of total flavonoid content in the extracts under study are represented in Table 1. The flavonoid content ranged from 2.62 mg CE/g dw to 56.86 mg CE/g dw. It was observed that three flowers' extracts had high flavonoid content: *O. biennis* (56.86 mg CE/g dw), *L. stoechas* (54.88 mg CE/g dw) and *L. japonica* (49.02 mg CE/g dw). In contrast, *Rosa* sp. presented the lowest flavonoid content (2.62 mg CE/g dw), followed by *T. majus* (5.13 mg CE/g dw) and *C. officinalis* (9.40 mg CE/g dw).

Zeng *et al.* (2014) reported that the flavonoid content in 19 Chinese edible flowers ranged from 10.837 (*Chrysanthemum morifolium* Ramat) and 83.797 (*Trollius chinensis* Bunge) mg CE/g dw, showing a slightly higher concentration compared to those obtained in our study.

Antioxidant activity

The antioxidant activity of the ethanolic extracts under study determined by DPPH and ABTS radical scavenging methods are shown in Table 2. The total antioxidant activity of flowers extracts determined by DPPH and ABTS methods ranged from 0.148±0.021 to 0.583±0.018 mmol TE/g dw and 0.076±0.009 to 0.684±0.015 mmol TE/g dw, respectively. *T. patula* had the highest value in both antioxidant assays. In contrast, the extracts with the lowest values were *Rosa* sp. and *C. sativum* for DPPH and ABTS assays, respectively. The results yielded in this study are in agreement with those reported in literature (Xiong *et al.*, 2014), which ranged from 0.033 to 1.06 mmol TE/g dw (DPPH method) and from 0.037 to 2.06 mmol TE/g dw (ABTS method).

The antioxidant properties of plant extracts are attributed to their constituent polyphenols and a positive correlation between the content of these compounds and the antioxidant activity which has already been observed in several studies (Pandey and Rizvi, 2009; Wojdylo *et al.*, 2007). Our results showed a moderate positive correlation between total phenolic content in flower extracts and antioxidant activity measured as DPPH (r=0.846) and ABTS (r=0.673) scavenging capacity (Table 3). Positive correlations were also obtained between *ortho*-diphenols content and antioxidant capacity of r=0.691 and r=0.610, respectively, for DPPH and ABTS methods. In addition, non-significant correlation was found in the case of flavonoid content with both antioxidant activity methods, the Pearson correlation coefficients are positive but less than 0.44. These results indicate that high antioxidant activity of flower extracts is associated with high phenolic and *ortho*-diphenols contents, suggesting that these compounds were the major contributors to the antioxidant activity of the flowers extracts. Our results are in agreement with Xiong *et al.* (2014) who found a strong positive correlation between the antioxidant activities of ten edible flowers from China and the phenolic content and a poor correlation with flavonoid content.

Overall, the results yielded indicate that the plants extracts contain chemical compounds exhibiting antioxidant activity to scavenge free radicals, which could exert a beneficial action against pathological alterations caused by the generation of free radicals, such as aging and neurodegenerative diseases (Lima *et al.*, 2014; Liu, 2013; Wojdylo *et al.*, 2007). However, further studies should be directed to clarify *in vivo* this therapeutic potential. In addition, the higher antioxidant capacity exhibited by some vegetative parts of the plants indicated that they could be used as a source of natural antioxidants.

Metal content

The mineral composition obtained for the dry flowers materials is presented as macro (Table 4) and microminerals (Table 5) and confirms the presence of several metal elements at a wide range of concentration.

The mineral content in flowers, which depends on the natural absorption of minerals by plants from the soil and the environment, is one of the most essential aspects which influence the use of edible flowers in human nutrition.

Table 2. Antioxidant capacity of edible flowers extracts.[1,2]

Scientific name	ABTS (TEAC mM/g)	DPPH (TEAC mM/g)
Agastache foeniculum	0.242±0.045^{c}	0.461±0.030^{g}
Borago officinalis L.	0.246±0.017^{c}	0.331±0.046^{cdef}
Calendula officinalis	0.124±0.022^{ab}	0.153±0.03^{a}
Coriandrum sativum	0.076±0.009^{a}	0.187±0.042^{ab}
Lavanda stoechas	0.390±0.017^{de}	0.437±0.027^{abc}
Lavandula angustifolia	0.186±0.022^{abc}	0.220±0.021^{abc}
Lonicera japonica	0.492±0.029^{e}	0.362±0.016^{defg}
Oenothera biennis	0.130±0.024^{ab}	0.297±0.014^{bcd}
Rosa sp.	0.456±0.028^{de}	0.148±0.021^{a}
Rosmarinus officinalis	0.228±0.033^{bc}	0.398±0.015^{efg}
Salva elegans	0.375±0.016^{d}	0.277±0.023^{bcd}
Tagetes patula	0.684±0.015^{f}	0.583±0.018^{h}
Viola tricolor	0.454±0.044^{de}	0.466±0.030^{g}

[1] ABTS = 2,2-azino-bis3-ethylbenzothiazoline-6-sulfonic acid; DPPH = 1,1-diphenyl-2-picrylhydrazyl; TEAC = Trolox equivalent antioxidant capacity.
[2] Means with different letters within each column were significantly different at the level $P<0.05$.

Table 3. Pearson correlation coefficients of antioxidant activity and phenolics content.[1]

	DPPH	ABTS	TPC	TFC	OFC
DPPH	1	0.374	0.846	0.44	0.691
ABTS	–	1	0.673	0.259	0.61
TPC	–	–	1	0.014	0.489
TFC	–	–	–	1	0.229
OFC	–	–	–	–	1

[1] ABTS = 2,2-azino-bis3-ethylbenzothiazoline-6-sulfonic acid; DPPH = 1,1-diphenyl-2-picrylhydrazyl; OFC = ortho-diphenols content; TFC = total flavonoids content; TPC = total phenolics content.

Table 4. Macro minerals content in dry flower material of the fourteen edible flowers.[1]

Scientific name	K	Na	Mg	Ca	Fe	Zn	Cu	Mn
	mg/100 g dw							
Agastache foeniculum	9,691±102^{g}	116.2±8.6^{bc}	675.6±14.7 ^{e}	433.0±28.^{d}	20.9±0.6^{bc}	13.0±0.9 ^{cd}	2.02±0.05^{ab}	12.73±0.61^{f}
Borago officinalis	5,574±170^{bc}	610.1±35.4^{f}	623.8±12.8^{d}	520.1±24.^{e}	11.3±0.^{a}	10.4±0.6^{bc}	2.82±0.08^{c}	4.18±0.05^{b}
Calendula officinalis	7,639±401^{ef}	649.2±12.3^{f}	452.7±6.4^{b}	188.7±7.2^{ab}	20.0±2.3^{b}	6.03±0.11^{a}	2.00±0.12^{ab}	1.58±0.11^{ab}
Coriandrum sativum	6,566±12de	395.1±20.5^{e}	886.1±6.7^{f}	647.2±3.5^{f}	28.4±1.1^{c}	21.2±0.5^{e}	3.57±0.22^{d}	7.28±0.49^{de}
Lavandula stoechas	4,161±349^{ab}	93.1±4.8^{ab}	561.6±52.9^{cd}	315.5±2.2^{c}	24.1±0.1^{bc}	11.4±1.1^{c}	2.84±0.11^{c}	26.9±1.6^{g}
Lavandula angustifolia	4,446±665^{ab}	75.2±2.1^{ab}	574.8±62.8^{cde}	360.4±57.1^{cd}	24.4±2.7^{bc}	11.1±0.7^{c}	1.88±0.21^{ab}	13.67±2.10^{f}
Lonicera japonica	4,605±20^{bc}	85.9±0.6^{ab}	441.8±5.5^{b}	143.4±1.4^{a}	19.3±1.6^{ab}	7.51±0.29^{a}	1.84±0.02^{ab}	5.31±0.01^{cd}
Oenothera biennis	7,995±438^{f}	152.4±7.4^{cd}	325.2±1.5^{a}	135.3±7.6^{a}	21.2±0.3^{bc}	8.29±0.19^{ab}	1.85±0.15^{ab}	1.02±0.10^{a}
Rosa sp.	2,948±160^{a}	79.5±7.1^{ab}	490.4±14.5^{bc}	118.8±6.6^{a}	21.3±0.4^{bc}	11.6±0.6^{c}	2.25±0.04^{b}	5.29±0.57^{cd}
Rosmarinus officinalis	4,862±268^{bc}	72.5±4.6^{a}	317.4±21.1^{a}	166.6±2.3^{ab}	20.2±4.2^{b}	7.08±0.40^{a}	2.80±0.06^{c}	8.97±0.19^{e}
Salvia elegans	2,605±46^{a}	104.7±2.3^{abc}	347.8±15.5^{b}	173.4±8.1^{ab}	21.3±2.1^{bc}	9.43±0.12^{bc}	1.63±0.02^{a}	9.53±0.01^{ef}
Tagetes patula	4,496±73^{ab}	73.2±7.4^{a}	629.1±22.8^{de}	524.5±4.4^{e}	24.6±0.8^{bc}	11.0±0.6^{c}	2.94±0.03^{c}	4.68±0.01^{cd}
Tropaeolum majus	6,187±187^{cd}	185.6±9.1^{d}	576.6±19.8^{cde}	225.6±10.3^{b}	20.4±2.6^{bc}	15.5±0.7^{d}	1.73±0.09^{ab}	6.85±0.05^{cde}
Viola tricolor	7,019±144de	145.4±16.9^{cd}	491.1±13.2^{bc}	185.2±3.8^{ab}	38.6±3.3^{d}	15.2±0.7^{d}	2.11±0.20^{ab}	6.74±0.06^{cde}

[1] Means with different letters within each column were significantly different at the level $P<0.05$.

Table 5. Micro minerals content in dry flower material of the fourteen edible flowers.[1]

Scientific name	Ni	Co	Se	Al	As	Cd	Pb
	µg/100 g dw						
Agastache foeniculum	62.6±3.7^{bcde}	82.7±3.6^{d}	5.88±0.61^{a}	14.4±0.6 ^{abcd}	0.188±0.008^{bcd}	1.39±0.42^{a}	90.2±3.3^{e}
Borago officinalis	50.7±1.8^{ab}	11.4±1.0^{a}	28.4±1.6^{h}	19.9±2.1^{de}	0.105±0.031^{a}	5.53±0.54^{bc}	37.4±4.3^{ab}
Calendula officinalis	67.9±0.5^{bcde}	37.7±4.4^{bc}	10.9±1.9^{de}	15.8±1.9^{bcde}	0.121±0.012^{ab}	n.d.	83.0±9.8^{de}
Coriandrum sativum	74.7±5.3^{bcde}	36.7±4.2^{bc}	4.89±0.21^{a}	20.6±1.1^{e}	0.186±0.008^{bcd}	26.7±1.1^{e}	52.6±3.7^{abc}
Lavandula stoechas	29.6±1.3^{a}	46.6±0.6	7.62±0.18	11.8±1.8^{ab}	0.149±0.022^{abc}	3.84±0.19^{ab}	49.6±7.8^{abc}
Lavandula angustifolia	85.4±8.1^{de}	37.8±4.7	9.45±0.10^{bcde}	15.7±0.4^{bcde}	0.205±0.008^{cde}	n.d.	79.7±2.3^{de}
Lonicera japonica	81.7±8.7^{de}	45.8±1.0	7.20±0.76^{ab}	11.5±1.9^{ab}	0.096±0.019^{a}	7.20±0.33^{c}	57.9±8.6^{bc}
Oenothera biennis	78.0±6.2^{cde}	37.7±5.0	19.9±2.8^{g}	19.9±0.2^{de}	0.189±0.031^{bcd}	n.d.	83.8±3.1^{de}
Rosa sp.	54.8±8.8^{abc}	47.3±0.7	10.4±0.9^{cde}	9.68±0.66 ^{a}	0.147±0.019^{abc}	8.25±1.29^{c}	43.5±2.3^{ab}
Rosmarinus officinalis	88.2±11.2^{e}	80.0±4.3	7.72±0.54^{abc}	15.3±1.8^{abcde}	0.271±0.018^{ef}	n.d.	33.2±2.8^{a}
Salvia elegans	52.4±5.1^{abc}	32.4±1.1	12.0±0.8^{e}	16.3±1.4^{bcde}	0.158±0.019^{bc}	5.27±0.33^{bc}	27.4±2.3^{a}
Tagetes patula	59.6±1.3^{bcd}	60.7±6.7	8.94±0.66^{bcd}	17.8±1.8^{cde}	0.149±0.021^{abc}	15.2±1.9^{d}	66.6±0.8^{cd}
Tropaeolum majus	71.5±7.2^{bcde}	50.1±5.0	9.94±1.03^{bcde}	12.5±0.8^{abc}	0.222±0.022^{def}	18.1±0.1^{d}	36.2±2.3^{ab}
Viola tricolor	53.8±9.7^{abc}	57.1±7.3	15.2±3.6	28.9±2.2^{f}	0.290±0.016^{f}	57.9±1.0^{f}	96.2±2.8^{e}

[1] Means with different letters within each column were significantly different at the level $P<0.05$. n.d. = not detected.

The accumulation of metals in the edible parts of flowers represents a direct pathway for their incorporation into the human food chain. From a nutritional point of view elements such Na, K, Ca, Mg, Fe, Cu, Zn, and Mn are essential nutrients for human growth and health. The inadequate supply of these nutrients results in a variety of deficiency diseases and syndromes. On the other hand, other metals such as Cd, Pb, Hg, and As have no established biological functions and are classified as potentially toxic, as they can cause adverse health effects (Uttara *et al.*, 2009).

The results obtained show that edible flowers are rich sources of several essential mineral elements, especially potassium, magnesium, calcium, and sodium. Potassium

was the most abundant mineral content ranging from 2,605 mg/100 g dw to 9,691 mg/100 g dw, followed by magnesium 317.4 mg/100 g dw to 886.1 mg/100 g dw, calcium 118.8 mg/100 g dw to 647.2 mg/100 g dw, and sodium 72.5 mg/100 g dw to 649.2 mg/100 g dw. These results are in line with a previous study which indicated that those four elements were the most abundant in twelve species of edible flowers (Rop *et al.*, 2012).

Concerning essential trace elements (iron, zinc, manganese, selenium, and copper), results show that iron has the highest content in edible flowers and selenium the lowest. Iron content ranged from 11.3 mg/100 g dw (*B. officinalis*) to 38.6 mg/100 g dw (*V. tricolor*). The Zn, Mn and Cu content in the analysed samples varied from 6.03 to 21.2 mg/100 g dw, 1.02 to 26.9 mg/100 g dw and 1.73 to 3.57 mg/100 g dw, respectively. Among the 14 edible flowers the levels of Se ranged between 4.89 mg/100 g dw (*C. sativum*) to 28.4 mg/100 g dw (*B. officinalis*).

The toxic heavy metals (Al, As, Cd and Pb) analysed in the flower extracts were detected in concentrations between 0.096 mg/100 g dw and 96.2 mg/100 g dw (Table 4). Results showed that Cd and Pb contents in the flowers fall below concentration limits established in European legislation for some vegetables, which are 0.30 mg/kg for Pb and 0.20 mg/kg for Cd (EC, 2006).

Overall, the results of mineral analysis in the edible flowers showed that metal elements' content varies over a wide range of values, which could be attributed to differences in the plant metal uptake and translocation capabilities. Indeed, although flowers were harvested in the same place, and were subject to similar environmental conditions and agricultural practices, it is known that the metal uptake mechanism is also influenced by plant species, growth stage and metal elements.

4. Conclusions

In this study data on phytochemical content and mineral composition of fourteen edible flowers was obtained. The results showed that the edible flowers under study are sources of different classes of phenolic compounds in a wide range of concentration and possess significant antioxidant capacity. *T. patula* and *V. tricolor* flower extracts contains the highest amount of phenolic compounds and also high levels of *ortho*-diphenols and flavonoids. Regarding to antioxidant capacity, both extracts showed considerable values, verifying that *T. patula* exhibited the highest values for ABTS and DPPH assays. Correlation analysis revealed a positive relationship between antioxidant capacity and the total phenolics and *ortho*-diphenols, indicating that these compounds are the main responsible for the antiradical activity in the extracts examined in this study. Additionally, all edible flowers contain appreciable amounts of several essential mineral elements, which are known to be beneficial for health. The analyzed flowers present higher levels of K, Mg, Ca and significant amount of Zn and Se. On average, flowers are eaten in small quantities compared with other foods and may not make a large contribution to average dietary intake of these nutrients. However, for regular consumers, the flowers can become significant sources of phytochemicals and minerals in their diets. In conclusion, the results of this study indicate that the consumption of edible flowers can provide a good source of antioxidants and mineral nutrients and, therefore, the culinary use of flowers should be stimulated. In addition, these results can form a basis for further studies regarding the isolation and identification of bioactive compounds in flowers as well as *in vivo* studies to confirm their potential benefits for human health.

Conflict of interest

The authors declare that there is no conflict of interest.

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References

Bendini, A., Bonoli, M., Cerretani, L., Biguzzi, B., Lercker, G. and Toschi, T.G., 2003. Liquid-liquid and solid-phase extractions of phenols from virgin olive oil and their separation by chromatographic and electrophoretic methods. Journal of Chromatography A 985(1): 425-433.

Benvenuti, S., Bortolotti, E. and Maggini, R., 2016. Antioxidant power, anthocyanin content and organoleptic performance of edible flowers. Scientia Horticulturae 199: 170-177.

Brand-Williams, W., Cuvelier, M.E. and Berset, C.L., 1995. Use of a free radical method to evaluate antioxidant activity. LWT – Food Science and Technology 28(1): 25-30.

Cai, Y.-Z., Sun, M., Xing, J., Luo, Q. and Corke, H., 2006. Structure-radical scavenging activity relationships of phenolics compounds from traditional Chinese medicinal plants. Life Science 78(25): 2872-2888.

European Commission (EC), 2006. Regulation No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Union L 364: 5-24.

Fernandes, L., Casal, S., Pereira, J.A., Saraiva, J.A. and Ramalho, E., 2017. Edible flowers: a review of the nutritional, antioxidant, antimicrobial properties and effects on human health. Journal of Food Composition and Analysis 60: 38-50.

Franzen, F.L., Lidório, H.F. and Oliveira, M.S., 2018. Edible flowers considerations as ingredients in food, medicine and cosmetics. Journal of Analytical and Pharmaceutical Research 7(3): 271-273.

Gião, M.S., González-Sanjosé, M.L., Rivero-Pérez, M.D., Pereira, C.I., Pintado, M.E. and Malcata, F.X., 2007. Infusions of Portuguese medicinal plants: dependence of final antioxidant capacity and phenol content on extraction features. Journal of the Science of the Food and Agriculture 87(14): 2638-2647.

Govers, C., Kasikci, M.B., Van der Sluis, A.A. and Mes, J.J., 2018. Review of the health effects of berries and their phytochemicals on the digestive and immune systems. Nutrition Review 76(1): 29-46.

Guedes, C.I., Oppolzer, D., Barros, A.I. and Wilson, C.P., 2019. Impact of cooking method on phenolic composition and antioxidant potential of four varieties of *Phaseolus vugaris* L. and *Glycine max* L. LWT – Food Science and Technology 103: 238-246.

Guiné, R.P.F. and Gonçalves, F.J., 2016. Bioactive compounds in some culinary aromatic herbs and their effects on human health. Mini-Reviews in Medicinal Chemistry 16(11): 855-866.

Kaisoon, O., Siriamornpun, S., Weerapreeyakul, N. and Meeso, N., 2011. Phenolic compounds and antioxidant activities of edible flowers from Thailand. Journal of Functional Foods 3(2): 88-99.

Kumar, S. and Pandey, A.K., 2013. Chemistry and biological activities of flavonoids: an overview. The Scientific Word Journal, Article ID: 162750.

Lesvesque, M. and Vendette, E.D., 1971. Selenium determination in soil and plant materials. Canadian Journal Soil Science 51(1): 85-93.

Lima, G.P.P., Vianello, F., Corrêa, C.R., Campos, R.A.S. and Bourguini, M.G., 2014. Polyphenols in fruits and vegetables and its effect on human health. Food and Nutrition Sciences 5(11): 1065-1082.

Liu, R.H., 2013. Dietary bioactive compounds and their health implications. Journal of Food Science 78(S1): A18-A25.

Loizzo, M.R., Bonesi, M., Menichini, F., Tenuta, M.C., Leporini, M. and Tundis, R., 2016. Antioxidant and carbohydrate-hydrolysing enzymes potential of *Sechium edule* (Jacq.) Swartz (Cucurbitaceae) peel, leaves and pulp fresh and processed. Plant Foods for Human Nutrition 71: 381-387.

Lu, B., Li, M. and Yin, R., 2016. Phytochemical content, health benefits, and toxicology of common edible flowers: a review. Critical Reviews in Food Science and Nutrition 56: S130-S148.

Navarro-González, I., González-Barrio, R., García-Valverde, V., Bautista-Ortín, A.B. and Periago, M.J., 2015. Nutritional composition and antioxidant capacity in edible flowers: characterization of phenolic compounds by HPLC-DAD-ESI/MS^n. International Journal of Molecular Sciences 16(1): 805-822.

Pandey, K.B. and Rizvi, S.I., 2009. Plant polyphenols as dietary antioxidants in human health and disease. Oxididative Medicine and Cellular Longevity 2(5): 270-278.

Pantelidis, G.E., Vasilakakis, M., Manganaris, G.A. and Diamantidis, G., 2007. Antioxidant capacity, phenol, anthocyanin and ascorbic acid contents in raspberries, blackberries, red currents, gooseberries and Cornelian cherries. Food Chemistry 102(3): 777-783.

Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M. and Rice-Evans, C., 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radical Biology and Medicine 26(9-10): 1231-1237.

Rop, O., Mlcek, J., Jurikova, T., Neugebauerova, J. and Vabkova, J., 2012. Edible flowers – a new promising source of mineral elements in human nutrition. Molecules 17(6): 6672-6683.

Santos, S.C., Guiné, R.P. and Barros, A., 2014. Effect of drying temperatures on the phenolic composition and antioxidant activity of pears of Rocha variety (*Pyrus communis* L.). Journal of Food Measurement and Characterization 8(2): 105-112.

Singleton, V.L. and Rossi, J.A., 1999. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. American Journal of Enology and Viticulture 16(3): 144-158.

Stathopoulou, M., Kanon,i S., Papanikolaou, G., Antonopoulous, S., Nomikos, T. and Dedoussis, G., 2012. Mineral intake. Progress in Molecular Biology and Translational Science 108: 201-236.

Stratil, P., Klejdus, B. and Kubán, V., 2006. Determination of total content of phenolic compounds and their antioxidant activity in vegetables – evaluation of spectrophotometric methods. Journal of Agricultural and Food Chemistry 54(3): 607-616.

Uttara, B., Singh, A.V., Zamboni, P. and Mahajan, R.T., 2009. Oxidative stress and neurodegenerative diseases: a review of upstream and downstream antioxidant therapeutic options. Current Neuropharmacology 7(1): 65-74.

Wang, F., Miao, M., Xia, H., Yang, L.G., Wang, S.K. and Sun, G.J., 2016. Antioxidant activities of aqueous extracts from 12 Chinese edible flowers *in vitro* and *in vivo*. Food and Nutrition Research 61(1): 1265324.

Wojdylo, A., Oszmianski, J. and Czemerys, R., 2007. Antioxidant activity and phenolic compounds in 32 selected herbs. Food Chemistry 105(3): 940-949.

World Health Organization and Food and Agriculture Organization (WHO/FAO), 2004. Fruit and vegetables for health: report of a joint FAO/WHO workshop. Kobe, Japan, pp. 9.

Xiong, L., Yang, J., Jiang, Y., Lu, B., Hu, Y., Zhou, F., Mao, S. and Shen, C., 2014. Phenolic compounds and antioxidant capacities of 10 common edible flowers from China. Journal of Food Science 79(4): C517-C525.

Zeng, Y., Deng, M., Lv, Z. and Peng, Y., 2014. Evaluation of antioxidant activities of extracts from 19 Chinese edible flowers. SpringPlus 3: 315-319.

Zheng, W. and Wang, S.Y., 2001. Antioxidant activity and phenolic compounds in selected herbs. Journal of Agricultural and Food Chemistry 49(11): 5165-5170.

Zhishen, J., Mengcheng, T. and Jianming, W., 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chemistry 64(4): 555-559.