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Nutritional and chemical characterization of edible petals and corresponding infusions: Valorization as new food ingredients

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ABSTRACT

Edible flowers provide new colours, textures and vibrancy to any dish, and apart from the "glam" factor, they can constitute new sources of bioactive compounds. In the present work, the edible petals and infusions of dahlia, rose, calendula and centaurea, were characterized regarding their nutritional value and composition in terms of hydrophilic and lipophilic compounds. Carbohydrates were the most abundant macronutrients, followed by proteins and ash. Fructose, glucose and sucrose were identified in all the petals and infusions. Rose petals and calendula infusions gave the highest content of organic acids, mainly due to the presence of malic and quinic acids, respectively. Polyunsaturated fatty acids predominated over saturated fatty acids, mainly due to the contribution of linoleic acid. Calendula presented the highest content in tocopherols, with α-tocopherol as the most abundant. These results highlight the interest of edible petals "as" and "in" new food products, representing rich sources of bioactive nutrients.

1. Introduction

Consumption habits are becoming more diversified and directed towards more sustainable food options (Falguera, Aliguer, & Falguera, 2012). The range of plant species used for food is also becoming more varied, seeking to combine new ingredients with some potential health benefits, that could improve the health of the consumers but also with a major importance in ecological sustainability (Leonti, 2012). This search for new food products is also a pursuit for new colours, textures and flavours that can be achieved with the use of edible flowers, such as has been done by several restaurant chefs worldwide (Kelley, Behe, Biernbaum, & Poff, 2001; Łuczaj et al., 2012); leading to the recovery of earlier lifestyles in which flower cookery had an important role in old civilizations (Cunningham, 2015; Rop, Mlcek, Jurikova, Neugebauerova, & Vabkova, 2012).

Apart from the "glam" factor, edible flowers have important nutritional characteristics and can constitute new sources of bioactive compounds (Lara-Cortés et al., 2014; Mlcek & Rop, 2011). They represent an unexplored niche market with great economic and social importance being used since ancient times in culinary preparations, such as sauces, liquors, salads and desserts (Koike et al., 2015; Mlcek & Rop, 2011), and also in the preparation of hot beverages (tisane and infusion), mainly in European countries, due to their medicinal properties (Navarro-González, González-Barrio, García-Valverde, Bautista-Ortín, & Periago, 2015). In ancient Rome, various species of rose flowers (*Rosa* spp.) were used to prepare purée and omelets (Cunningham, 2015). In Medieval France, the flowers of calendula (*Calendula officinalis* L.) were used to prepare omelets but also salads or as an accompaniment cheese (Lara-Cortés et al., 2014). In Mexico, Dahlia flowers are commonly consumed in different type of dishes, for example in dried soups (Lara-Cortés et al., 2014).

The composition on proteins, vitamins, fat and carbohydrates of flowers is not very distinct from other parts of the plant, however protein and fat content are considered to be low (Navarro-González et al., 2015); water represents more than 80% of the flower composition, and carotenoids, phenolic compounds and essential oils have been the most studied bioactive compounds (Navarro-González et al., 2015; Rop et al., 2012). Edible flower consumption is being encouraged, through the sell of packed bunches and boxes, and also through dietary supplements, functional ingredients, and additives (Loizzo et al., 2016; Rop et al., 2012). The innumerous phytochemicals present in edible flowers are related to their health benefits, such as antioxidant, anti-inflammatory, anti-cancer, anti-obesity, hypoglycemic, neuro, hepatic and gastro protective properties (Cunningham, 2015; Loizzo et al., 2016; Lu, Li, & Yin, 2016).

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In particular, the nutritional and chemical composition of rose (*Rosa canina* L.) and calendula flowers have already been studied (Barros, Carvalho, & Ferreira, 2011; Miguel et al., 2016), also the fatty acids composition of calendula seeds oils (Dulf, Pamfil, Baciu, & Pintea, 2013) and the crude protein of centaurea (*Centaurea cyanus* L.) flowers (Rop et al., 2012). Despite the existence of some publications regarding edible flowers, it is important to compare their potential to be used in different forms, namely as fresh produces or in infusion preparations. Therefore, in the present work, edible petals of different species (dahlia, rose, calendula and centaurea) were characterized in terms of macronutrients composition, energetic value, fatty acids, soluble sugars, organic acids and tocopherols, and compared to the nutritional composition of their infusions.

2. Materials and methods

2.1. Standards and reagents

HPLC grade acetonitrile, *n*-hexane and ethyl acetate were from Fisher Scientific (Lisbon, Portugal). A reference standard mixture (standard 47885-U) for fatty acids methyl ester (FAME) was purchased from Sigma (St. Louis, MO, USA), as also other standards: α- and δ-tocopherols, sugars and organic acids. The isoforms β- and γ-tocopherols and tocol (50 mg/ml) were purchased from Matreya (Pleasant Gap, PA, USA). All other general laboratory reagents were purchased from Panreac Química S.L.U. (Barcelona, Spain) and water was treated in a Milli-Q water purification system (TGI Pure Water Systems, USA).

2.2. Samples and infusion preparation

The samples were kindly supplied by RBR Foods, a farming company producer of fruits and flowers from Castro Daire (Portugal), as dry material to be used directly or for infusion's preparation. Petals of four different species were used in the present study: Dahlia mignon (commercial seeds mixture), *Rosa damascena* 'Alexandria' and *R. gallica* 'Francesa' draft in *R. canina*, *Calendula officinalis* L. and *Centaurea cyanus* L. (Fig. 1). These samples are designated throughout the manuscript by their common names: dahlia, rose, calendula and centaurea, respectively. All the samples were reduced to a fine powder (20 mesh) and mixed to obtain homogenate samples.

For infusions preparation, boiling distilled water (100 ml) (pH 6.6) at 100 °C was added to each sample (500 mg) and left to stand at room temperature for 5 min. Afterwards, the infusions were filtered under reduced pressure (0.22 μm) and stored at −5 °C (1 week) until further analysis.

2.3. Nutritional value-proximate composition and energetic value

The samples (dried powdered petals) were analyzed for proteins, fat, carbohydrates and ash according to the AOAC (Association of Official Analytical Chemists) procedures (AOAC, 2005). The crude protein content (N × 6.25) was estimated by the macro-Kjeldahl method (AOAC, 991.02); the crude fat (AOAC, 989.05) was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus; the ash content (AOAC, 935.42) was determined by incineration

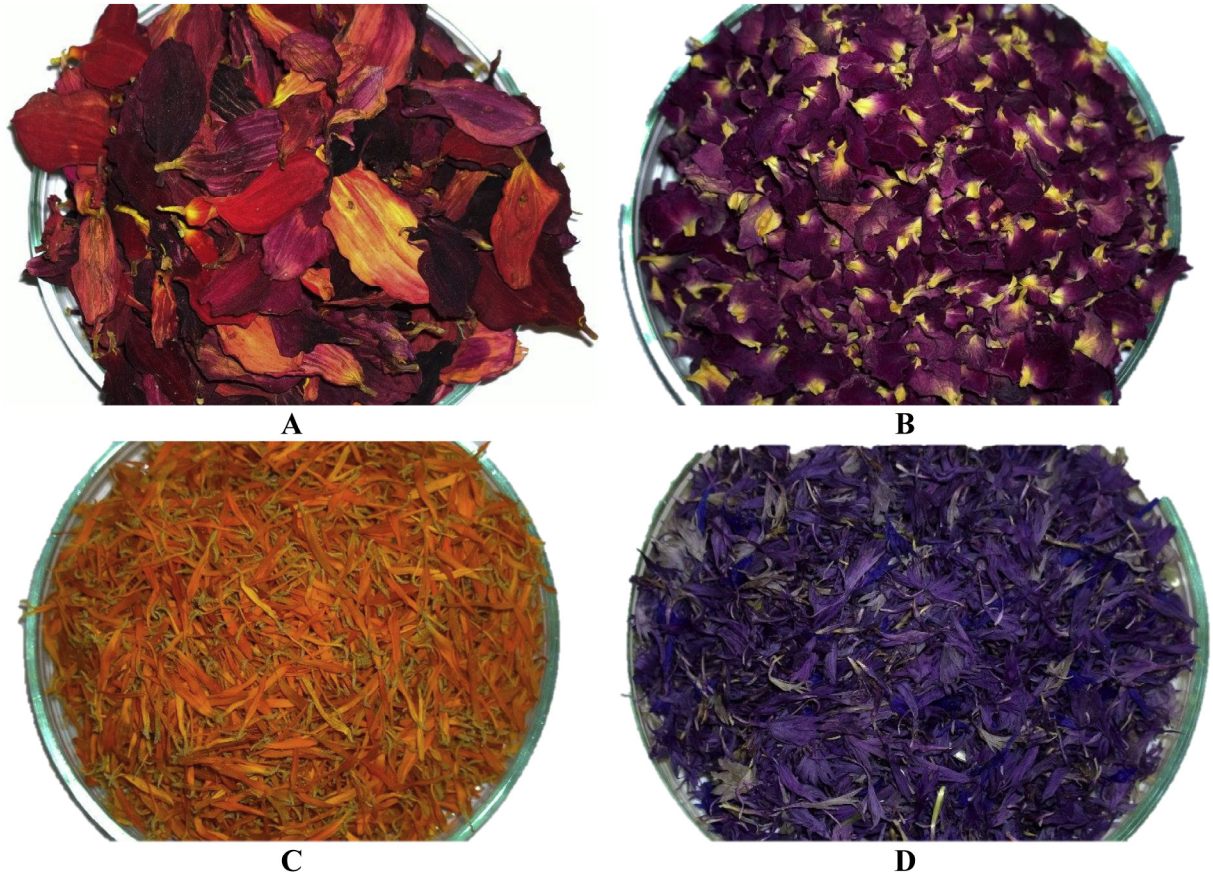

Fig. 1. Petals from (A) Dahlia; (B) Rose; (C) Calendula; (D) Centaurea.

at 550 ± 15 °C. Total carbohydrates (including fibre) were calculated by difference [Total carbohydrates (g/100 g) = 100 − (g fat + g protein + g ash)]. Total energy was calculated according to the following equation: Energy (kcal/100 g) = 4 × (g proteins + g carbohydrates) + 9 × (g fat). For infusions, total carbohydrates were calculated on the basis of total soluble sugars (Section 2.4.1) and the energetic value was calculated taking into account those results.

2.4. Hydrophilic compounds

2.4.1. Soluble sugars

Soluble sugars in dried powdered petals and infusions were determined according to a previously described procedure (Barros et al., 2013), using high performance liquid chromatography system coupled to a refraction index detector (HPLC-RI; Knauer, Smartline system 1000, Berlin, Germany). The quantification was performed using the internal standard (melezitose) method or external standard method for infusions. The results were expressed in g per 100 g of plant dry weight or in g per 100 ml of infusion.

2.4.2. Organic acids

Organic acids were determined in dried powdered petals and infusions by ultra-fast liquid chromatography coupled to photodiode array detector (UFLC-PDA; Shimadzu Coperation, Kyoto, Japan), according to the previously described procedure (Barros, Pereira, & Ferreira, 2013). The quantification was performed by comparison of the peak area recorded at 215 nm as the preferred wavelength. The results were expressed in g per 100 g of plant dry weight or in mg per 100 ml of infusion.

2.5. Lipophilic compounds

2.5.1. Fatty acids

Fatty acids were determined by GC-FID (DANI model GC 1000 instrument, Contone, Switzerland), using dried powdered petals and after a trans-esterification process, according to the previously described procedure (Barros et al., 2013). The results were expressed in relative percentage of each fatty acid.

2.5.2. Tocopherols

The four isoforms of tocopherols were determined in dried powdered petals, according to the previously described procedure (Barros et al., 2013), using HPLC (Knauer, Smartline system 1000, Berlin, Germany) coupled to a fluorescence detector (FP-2020; Jasco, Easton, MD, USA), the quantification was based on the fluorescence signal response of each standard, using the internal standard (tocol) method or external standard method for infusions. The results were expressed in mg per 100 g of dry plant weight.

2.6. Statistical analysis

Three samples were used for each species and all the assays were carry out in triplicate. Results were expressed as mean values and standard deviation (SD) and analyzed using one-way analysis of variance (ANOVA) followed by Tukey's HSD Test with $\alpha = 0.05$. This analysis was carried out using IBM SPSS Statistics for Windows, Version 22.0. (IBM Corp., Armonk, New York, USA).

3. Results and discussion

3.1. Proximate composition and energetic value of edible petals and corresponding infusions

Data on the nutritional composition and energetic value of edible petals from four different species-dahlia, rose, calendula and centaurea-, and of the corresponding infusions are shown in Table 1.

Carbohydrates were the most abundant macronutrients in all the dried petals, followed by proteins and ash in dahlia (5.93 and 5.83 g/100 g dw, respectively), rose (7.58 and 4.29 g/100 g dw, respectively) and centaurea (5.79 and 5.68 g/100 g dw, respectively). Rop et al. (2012) presented lower values of crude protein in *C. officinalis* flowers (0.673 g/100 g) originated from Czech Republic. Calendula petals presented a higher amount of fat (5.33 g/100 g dw) and ash (6.93 g/100 g dw) when compared to the other samples, and also a higher energetic contribution (421.58 kcal/100 g). These results are in accordance with the ones described by Miguel et al. (2016) who reported similar values of fat and energy in calendula flowers. Dias et al. (2014) described higher fat (6.56 g/100 g dw) content in dried flowers of *Taraxacum* sect. Ruderalia. Regarding the infusions, rose and dahlia samples presented the highest contribution in carbohydrates (0.19 mg/100 ml), and also the highest energetic value (0.80 and 0.76 kcal/100 ml, respectively). Pereira, Barros, and Ferreira (2015) reported lower energy values and carbohydrates content (0.060 kcal/100 ml and 0.015 g/100 ml, respectively) in the infusions of *Chamaemelum nobile* L., and also lower amounts of sugars, though having a similar profile (fructose, glucose and sucrose). In the same study, no sugars were detected in the infusions of *Gomphrena globosa*, *G. globosa* var. albiflora, *G. haageana* and *Gomphrena* sp., and consequently, carbohydrates content and energetic value could not be calculated.

3.2. Hydrophilic compounds of edible petals and corresponding infusions

Soluble sugars and organic acids composition of the studied dried petals and corresponding infusions is presented in Table 2 and Fig. 2. Dahlia and rose dried petals (10.24 and 10.75 g/100 g dw)

Table 1
Proximate composition and energy of dried petals and corresponding infusions (mean ± SD).

	Dried petals (g/100 g dw)				Infusions (g/100 ml infusion)			
	Dahlia	Rose	Calendula	Centaurea	Dahlia	Rose	Calendula	Centaurea
Nutritional value								
Fat	2.23 ± 0.05b	2.01 ± 0.04b	5.33 ± 0.45a	0.140 ± 0.001	nd	nd	nd	nd
Proteins	5.93 ± 0.2bc	7.58 ± 0.84a	6.43 ± 0.68b	5.79 ± 0.1c	nd	nd	nd	nd
Ash	5.83 ± 0.04b	4.29 ± 0.1d	6.93 ± 0.14a	5.68 ± 0.13c	np	np	np	np
Total available carbohydrates	86.02 ± 0.2b	86.12 ± 0.8b	81.32 ± 0.75c	88.39 ± 0.13a	0.19 ± 0.02a	0.19 ± 0.01a	0.17 ± 0.01b	0.14 ± 0.01c
	Dry petals (kcal/100 g dw)				Infusions (kcal/100 mL infusion)			
Energy	387.83 ± 0.37c	392.87 ± 0.58b	421.58 ± 3.54a	377.99 ± 0.50d	0.76 ± 0.08a	0.80 ± 0.08a	0.68 ± 0.02b	0.56 ± 0.04c

dw – dry weight basis; np – not performed; nd – not detected. In each row and within dry petals or infusions different letters mean significant differences between samples ($p < 0.05$), where "a" and "d" correspond to the highest and lowest values, respectively.

Table 2
Soluble sugars and organic acids composition in dried petals and corresponding infusions (mean ± SD).

	Dried petals (g/100 g dw)				Infusions (mg/100 ml)			
	Dahlia	Rose	Calendula	Centaurea	Dahlia	Rose	Calendula	Centaurea
Soluble sugars								
Fructose	3.87 ± 0.23b	5.14 ± 0.48a	1.47 ± 0.12c	0.65 ± 0.04d	0.10 ± 0.01a	0.10 ± 0.01a	0.066 ± 0.001b	0.07 ± 0.004b
Glucose	3.23 ± 0.25a	3.23 ± 0.41a	0.61 ± 0.07b	0.47 ± 0.02b	0.079 ± 0.02a	0.064 ± 0.004b	0.021 ± 0.001c	0.04 ± 0.001d
Sucrose	3.14 ± 0.15a	2.39 ± 0.17b	1.53 ± 0.18c	0.38 ± 0.01d	0.016 ± 0.001c	0.035 ± 0.001b	0.078 ± 0.001a	0.03 ± 0.01b
Sum	10.24 ± 0.62 a	10.75 ± 1.05a	3.61 ± 0.37b	1.5 ± 0.1c	0.19 ± 0.02a	0.19 ± 0.01a	0.17 ± 0.01b	0.14 ± 0.01c
Organic acids								
Oxalic acid	0.23 ± 0.01c	0.26 ± 0.01b	0.702 ± 0.002a	0.18 ± 0.01d	tr	1.31 ± 0.01	tr	tr
Quinic acid	0.466 ± 0.003b	1.52 ± 0.01a	0.35 ± 0.01b	nd	nd	9.33 ± 0.41b	14.5 ± 0.3a	7.4 ± 0.3c
Malic acid	0.74 ± 0.01c	1.23 ± 0.02a	1.14 ± 0.02b	nd	nd	4.1 ± 0.4a	1.16 ± 0.15b	tr
Shiquimic acid	0.0497 ± 0.0003c	0.062 ± 0.001b	nd	0.108 ± 0.001a	tr	0.368 ± 0.001b	tr	1.05 ± 0.003a
Citric acid	nd	1.2 ± 0.1	nd	nd	nd	nd	nd	15.5 ± 0.5
Succinic acid	nd	nd	1.77 ± 0.03	nd	nd	nd	11.2 ± 0.5	nd
Fumaric acid	tr	0.011 ± 0.001	tr	tr	nd	tr	tr	tr
Sum	1.49 ± 0.01c	4.26 ± 0.13a	3.98 ± 0.02b	0.29 ± 0.01d	tr	15.01 ± 0.1c	26.9 ± 0.3a	23.9 ± 0.8b

dw – dry weight basis; nd – not detected; tr-traces (LOD (μg/mL) and LOQ (μg/mL) for oxalic acid (12.6 and 42, respectively), quinic acid (24 and 81, respectively), malic acid (36 and 1.2 × 10^2, respectively), shiquimic acid (6 and 19, respectively), citric acid (10 and 35, respectively), succinic acid (19 and 64, respectively) and fumaric acid (0.080 and 0.26, respectively). Calibration curves for organic acids: oxalic acid ($y = 9 \times 10^6x + 45973$, $R^2 = 0.9901$); quinic acid ($y = 610607x + 46061$, $R^2 = 0.9995$); malic acid ($y = 912441x + 92665$, $R^2 = 0.999$); shiquimic acid ($y = 7 \times 10^7x + 175156$, $R^2 = 0.9999$); citric acid ($y = 1 \times 10^6x + 45682$, $R^2 = 0.9997$); succinic acid ($y = 592888x + 50689$, $R^2 = 0.9996$) and fumaric acid ($y = 154862x + 1 \times 10^6$, $R^2 = 0.9977$). In each row and within dry petals or infusions different letters mean significant differences between samples ($p < 0.05$), where "a" and "d" correspond to the highest and lowest values, respectively.

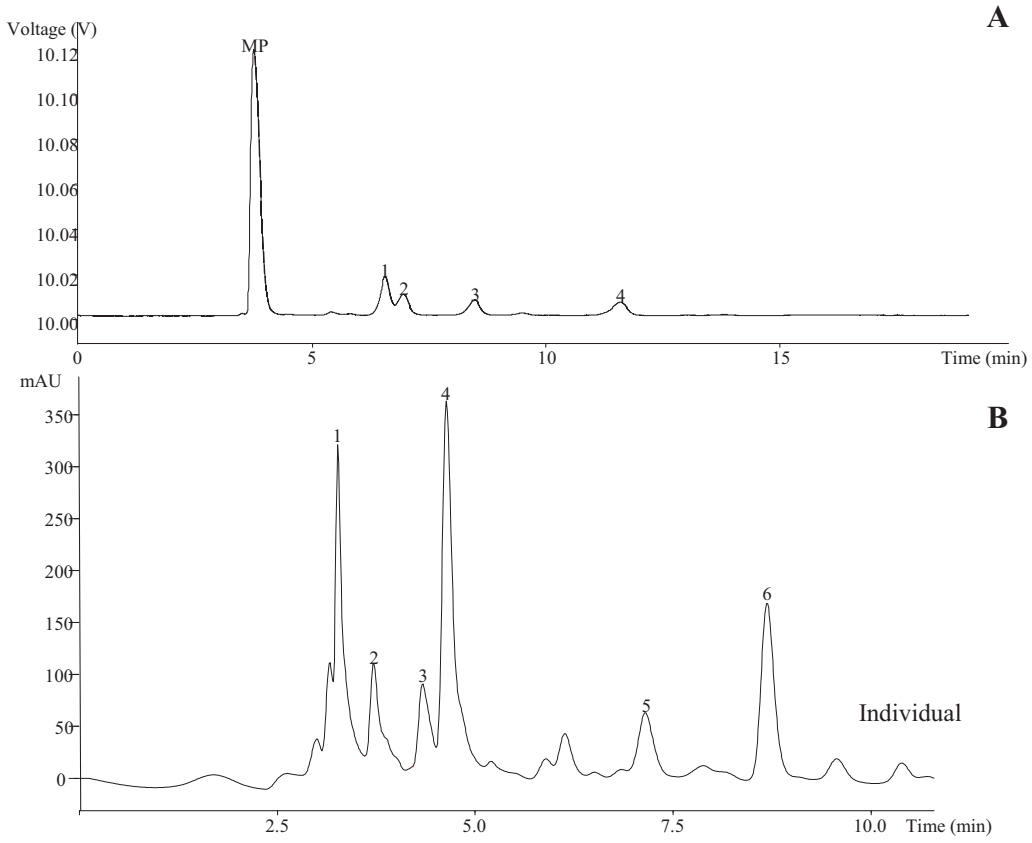

Fig. 2. Individual chromatograms of hydrophilic compounds in rose dried petals. (A) Free sugars profile: 1-fructose; 2-glucose; 3-sucrose; 4-melezitose (IS). (B) Organic acids profile: 1-oxalic acid; 2-quinic acid; 3-malic acid; 4-shiquimic acid; 5-citric acid; 6-fumaric acid. MP-mobile phase.

and infusions (0.19 g/100 ml of infusion) gave the highest total sugars amount, while centaurea dried petals (1.5 g/100 g dw) and infusion (0.14 mg/100 ml) presented the lowest levels of total sugars. Fructose, glucose and sucrose were detected in the dried petals and infusions, being fructose the main sugar present in dahlia and rose samples; with the exception of calendula dry petals and centaurea infusion, where sucrose was predominant. This is in accordance with the results reported by Barros et al. (2011) in *R. canina*. petals, in which fructose was also the main sugar. On the other hand, Dias et al. (2014) reported higher amounts of sugars in flowers of dandelion, despite having a similar profile (fructose, glucose and sucrose). Nonetheless, this tendency was not observed in *C. officinalis* samples analysed by Miguel et al. (2016), where fructose was the main sugar detected, followed by sucrose and xylose. Currently, EFSA does not have a recommended daily dose for sugars intake, since the data on the matter is

insufficient to set an upper limit of consumption for these compounds (EFSA, 2010a). Nonetheless, WHO recommends the reduce of free sugars intake to be less than 10% of total energy intake in a normal daily diet (Brouns, 2015). However, the studied flowers can be used "in" and "as" foods and contribute for sugar's daily intake.

Regarding the organic acids profile, the studied samples presented very distinct profiles (Table 2). The highest amount of organic acids was found in rose dried petals, mainly due to the presence of quinic and malic acids (1.53 and 1.23 g/100 g dw, respectively). Among the infusions, calendula and centaurea presented the highest concentrations, mainly due to the presence of quinic (14.5 mg/100 ml) and citric acids (15.5 mg/100 ml), respectively. The dried petals of calendula also presented high amounts of organic acids, mainly due to the contribution of malic and succinic acids (1.14 and 1.77 g/100 g dw, respectively). The presence of high quantities of malic acid was also detected in *C. officinalis* flowers by Miguel et al. (2016), however the presence of succinic acid was not reported, while citric acid was the main organic acid. The same tendency was also described by Dias et al. (2014) in flowers of dandelion, where malic acid was the most abundant one, showing also the highest level of total organic acids. Fumaric acid was only found in trace amounts in the analysed dahlia and centaurea dried petals. Dahlia revealed the lowest content of organic acids, presenting only traces of oxalic and shiquimic acids.

3.3. Lipophilic compounds of edible petals

The content in lipophilic compounds, namely fatty acids and tocopherols, was determined in the dried petals and the results are shown in Table 3 and Fig. 3. Twenty-four fatty acids were identified, being polyunsaturated fatty acids (PUFA) predominant in all the samples, with the exception of dahlia that showed higher concentration of saturated fatty acids (SFA). Linoleic acid (C18:2n6) was the major fatty acid found in dahlia and rose samples (36.54 and 31.87%, respectively), followed by palmitic acid (C16:0) and linolenic acid (C18:3n3), respectively. Calendula presented linolenic acid (36.90%) as the main fatty acid, followed by palmitic acid (21.70%), while centaurea presented eicosapentaenoic acid (C20:5n3, 26.93%) as the main fatty acid, followed by linolenic acid (18.75%). The results found for *C. officinalis* are in accordance with the ones described by Dulf et al. (2013) in which PUFA content is around 60–64%, and the saturated fraction is mainly consisted by palmitic acid. The same tendency was not reported by Miguel et al. (2016) in calendula samples, that presented a SFA fraction much higher than the PUFA fraction (78% and 21%, respectively). According with the recommendations of EFSA, the recommended daily intake of SFA is the lowest possible (EFSA, 2010b), and therefore, calendula edible flowers are good options presenting the lowest content of SFA. On the other hand, it is recommended a daily intake of 4% of the total dietary energy in linoleic acid and

Table 3
Fatty acids and tocopherols composition in dried petals (mean ± SD).

	Dahlia	Rose	Calendula	Centaurea
Fatty acids (***relative percentage, %***)				
C6:0	0.89 ± 0.07	0.18 ± 0.01	0.27 ± 0.01	0.17 ± 0.01
C8:0	0.90 ± 0.09	0.23 ± 0.02	0.28 ± 0.06	0.07 ± 0.00
C10:0	0.99 ± 0.04	0.33 ± 0.05	0.18 ± 0.08	0.12 ± 0.00
C11:0	nd	nd	0.13 ± 0.03	nd
C12:0	0.74 ± 0.03	1.22 ± 0.05	1.65 ± 0.18	nd
C13:0	nd	0.03 ± 0.00	nd	nd
C14:0	3.11 ± 0.20	2.55 ± 0.14	9.92 ± 0.39	0.89 ± 0.05
C14:1	0.59 ± 0.03	0.31 ± 0.00	nd	0.21 ± 0.02
C15:0	0.66 ± 0.00	0.31 ± 0.01	0.18 ± 0.01	0.37 ± 0.01
C16:0	24.61 ± 0.77	17.10 ± 1.06	21.70 ± 0.10	15.40 ± 0.10
C16:1	0.87 ± 0.00	0.22 ± 0.00	0.23 ± 0.03	0.28 ± 0.02
C17:0	0.91 ± 0.09	0.53 ± 0.04	0.19 ± 0.04	0.82 ± 0.02
C18:0	7.60 ± 0.28	16.80 ± 0.27	3.95 ± 0.08	9.67 ± 0.08
C18:1n9	5.75 ± 0.08	1.95 ± 0.19	1.56 ± 0.06	4.41 ± 0.04
C18:2n6	36.54 ± 0.85	31.87 ± 0.33	20.35 ± 0.14	6.72 ± 0.08
C18:3n3	8.60 ± 0.56	19.54 ± 0.79	36.90 ± 0.55	18.75 ± 0.14
C20:0	1.57 ± 0.08	3.62 ± 0.03	0.63 ± 0.02	5.34 ± 0.05
C20:2	0.40 ± 0.03	nd	nd	nd
C20:3n3	0.63 ± 0.10	0.33 ± 0.00	0.26 ± 0.01	0.51 ± 0.08
C20:5n3	nd	nd	nd	26.93 ± 0.29
C22:0	2.15 ± 0.19	1.81 ± 0.13	0.56 ± 0.04	2.04 ± 0.00
C22:1n9	nd	nd	nd	6.01 ± 0.12
C23:0	0.21 ± 0.02	0.08 ± 0.01	0.13 ± 0.03	0.15 ± 0.00
C24:0	2.31 ± 0.01	1.01 ± 0.07	0.93 ± 0.09	1.14 ± 0.10
SFA	46.64 ± 1.46a	45.79 ± 1.30b	40.70 ± 0.70c	36.18 ± 0.28d
MUFA	7.20 ± 0.11b	2.47 ± 0.19c	1.79 ± 0.02d	10.91 ± 0.13a
PUFA	46.16 ± 1.35d	51.74 ± 1.11c	57.51 ± 0.68a	52.91 ± 0.15b
Tocopherols (***mg/100 g dw***)				
α-Tocopherol	4.36 ± 0.07c	8.16 ± 0.08b	56.78 ± 1.06a	0.55 ± 0.02d
β-Tocopherol	1.77 ± 0.01a	0.18 ± 0.01c	1.16 ± 0.06b	nd
γ-Tocopherol	0.72 ± 0.02b	0.77 ± 0.01b	2.94 ± 0.08a	0.29 ± 0.02c
δ-Tocopherol	0.43 ± 0.01a	0.14 ± 0.01b	nd	nd
Sum	7.28 ± 0.04c	9.25 ± 0.04b	60.88 ± 0.92a	0.84 ± 0.04d

dw – dry weight basis; nd – not detected. C6:0 – Caproic acid; C8:0 – Caprylic acid; C10:0 – Capric acid; C11:0 – Undecylic acid; C12:0 – Lauric acid; C13:0 – Tridecanoic acid; C14:0 – Myristic acid; C14:1 – Myristoleic acid; C15:0 – Pentadecanoic acid; C16:0 – Palmitic acid; C16:1 – Palmitoleic acid; C17:0 – Heptadecanoic acid; C18:0 – Stearic acid; C18:1n9 – Oleic acid; C18:2n6 – Linoleic acid; C18:3n3 – Linolenic acid; C20:0 – Arachidic acid; C20:2 – *cis*-11,14 – Eicosadienoic acid; C20:3n3 – Eicosatrienoic acid; C20:5n3 – Eicosapentaenoic acid; C22:0 – Behenic acid; C22:1n9 – Erucic acid; C23:0 – Tricosanoic acid; C24:0 – Lignoceric acid. SFA – saturated fatty acids, MUFA – monounsaturated fatty acids, PUFA – polyunsaturated fatty acids. In each row different letters mean significant differences between samples ($p < 0.05$), where "a" and "d" correspond to the highest and lowest values, respectively.

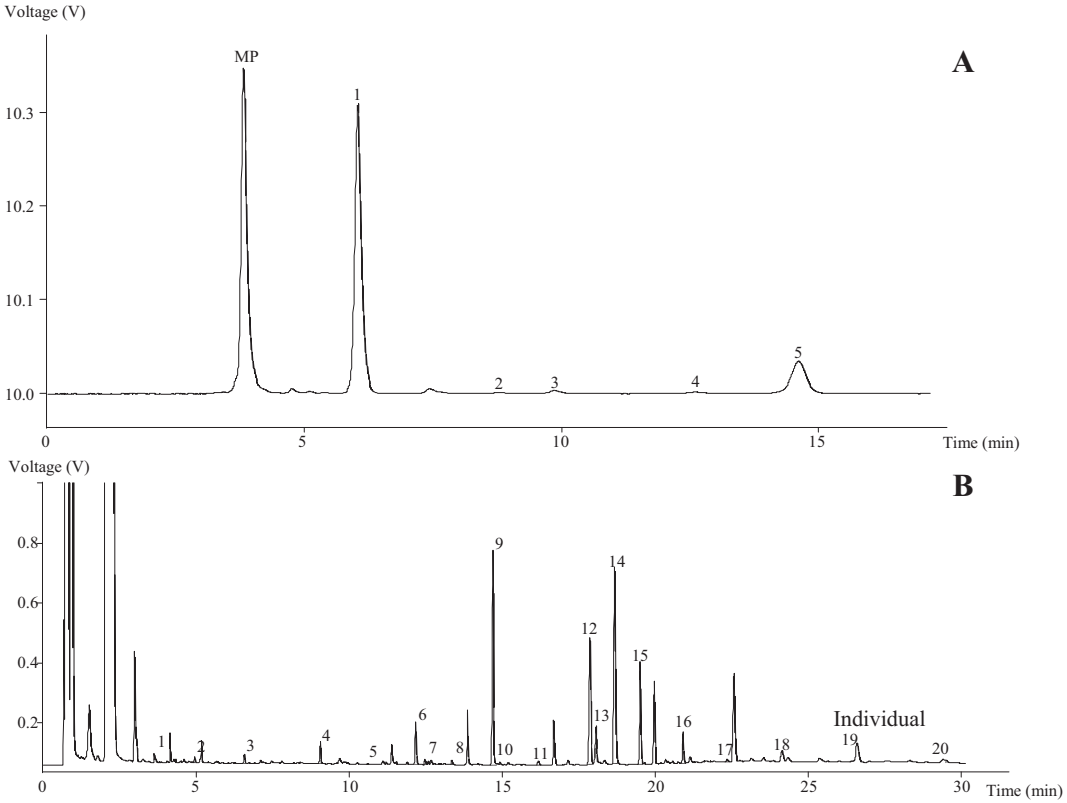

Fig. 3. Individual chromatograms of lipophilic compounds in rose dried petals. (A) Tocopherols profile: 1-α-tocopherol; 2-β-tocopherol; 3-γ-tocopherol; 4-δ-tocopherol; 5-tocol (PI). (B) Fatty acids profile: 1-C6:0; 2-C8:0; 3-C10:0; 4-C12:0; 5-C13:0; 6-C14:0; 7-C14:1; 8-C15:0; 9-C16:0; 10-C16:1; 11-C17:0; 12-C18:0; 13-C18:1n9; 14-C18:2n6; 15-C18:3n3; 16-C20:0; 17-C20:3n3; 18-C22:0; 19-C23:0; 20-C24:0. MP-mobile phase.

also the presence of eicosapentaenoic acid (C20:5n3), especially for pregnant women (EFSA, 2010b); only centaurea samples presented this last compound. For PUFA intake, WHO recommends more than 15% of the total dietary intake for infants (0–24 months) and 11% of the total dietary intake for children (2–18 years) (World Health Organization, 2008).

Regarding tocopherols, *C. officinalis* was the sample that revealed the highest content (60.88 mg/100 g dw), mainly due to the presence of α-tocopherol isoform (56.78 mg/100 g dw). Miguel et al. (2016) also described α-tocopherol as the main isoform in calendula flowers, however, the authors described lower values of total tocopherols. In all the samples, α-tocopherol isoform appears in higher amounts than the remaining isoforms. β- and δ-Tocopherols were not detected in centaurea, being the latter isoform also not present in calendula. The daily recommended dose for tocopherols consumption in adults is 300 mg/day (EFSA, 2008). Despite the lower values of the studied samples, the daily consumption of edible flowers could contribute to supply this vitamin to the organism.

Overall, calendula petals gave the highest content in total fat, ash and energetic contribution, polyunsaturated fatty acids (mainly due to the presence of linolenic acid) and total tocopherols (with the major contribution of α-tocopherol). On the other hand, rose petals presented the highest values of total proteins, soluble sugars and organic acids. Centaurea presented the highest carbohydrates content and the lowest percentage of saturated fatty acids. Regarding the infusions, dahlia and rose showed the highest content in carbohydrates, and the latter the highest energetic contribution. Calendula infusion presented the highest content in sugars, while the highest content in organic acids was found in centaurea infusion. These results demonstrate that edible petals can be consumed in a daily diet as a nutrient source, and could also be used to prepare infusions to be consumed worldwide.

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