Nutritional composition, antioxidant activity and phenolic compounds of wild *Taraxacum* sect. *Ruderalia*

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Abstract

Flowers and vegetative parts of wild *Taraxacum* identified as belonging to sect. *Ruderalia* were chemically characterized in nutritional composition, sugars, organic acids, fatty acids and tocopherols. Furthermore, the antioxidant potential and phenolic profiles were evaluated in the methanolic extracts, infusions and decoctions. The flowers gave higher content of sugars, tocopherols and flavonoids (mainly luteolin *O*-hexoside and luteolin), while the vegetative parts showed higher content of proteins and ash, organic acids, polyunsaturated fatty acids (PUFA) and phenolic acids (caffeic acid derivatives and especially chicoric acid). In general, vegetative parts gave also higher antioxidant activity, which could be related to the higher content in phenolic acids (R^2=0.9964, 0.8444, 0.4969 and 0.5542 for 2,2-diphenyl-1-picrylhydrazyl, reducing power, β-carotene bleaching inhibition and thiobarbituric acid reactive substances assays, respectively). Data obtained demonstrated that wild plants like *Taraxacum*, although not being a common nutritional reference, can be used in an alimentary base as a source of bioactive compounds, namely antioxidants.

Keywords: T*araxacum* sect. *Ruderalia*; Wild; Nutritional Value; Antioxidants contribution

1. Introduction

Wild medicinal plants are used by the majority of the world's population and, therefore, still represent a milestone for ethnomedicine in the search for new and safer bioactive compounds. Beyond their nutritional properties, medicinal plants provide beneficial health effects due to the presence of antioxidant compounds and other nutraceuticals (Fabricant & Farnsworth, 2001; Bernal, Mendiola, Ibáñez & Cifuentes, 2011).

The vast genus of *Taraxacum*, commonly known as dandelion, is divided in several sections, each one with many species of this plant; Ruderalia is the largest and most widespread section (Meirmans, Calama, Bretagnolle, Felber, & Nijs, 1999). This plant genus, commonly found in the warm temperate zone of the northern hemisphere (Schütz, Carle & Schieber, 2006), is used since ancient times in folk medicine to treat dyspepsia, spleen and liver complaints, breast and uterus diseases, anorexia, but also in lactating, diuretic, and anti-inflammatory remedies (Schütz et al., 2006; Jeon et al., 2008). The young leaves and flowers are very appreciated in salads, while roasted roots are used as substitutes of coffee. They are also consumed as infusion and decoction to treat some illness (Schütz et al., 2006; Sweeney, Vora, Ulbricht & Basch, 2005; Mlcek & Rop, 2011).

The majority of reports found in literature is focused in a particular species, *T. officinalis*, and describe antioxidant properties (Hu & Kitts, 2003 and 2005; Hudec et al., 2007; Jeon et al., 2008), nutritional value (Escudero, Arellano, Fernández, Albarracín, & Mucciarelli, 2003) and fatty acids (Liu, Howe, Zhou, Hocart, & Zhang, 2002). The same occurs regarding phenolic profile being flavonoid glycosides and hidroxycinammic acids, mainly chicoric acid, reported as the most abundant compounds (Williams, Goldstone, & Greenham, 1996; Gatto et al., 2011). *T. obovatum* and *T. mongolicum* were characterized in terms of organic acids (Sánchez-Mata et al., 2012)

and phenolic compounds (Shi et al., 2007; Shi, Zhang, Zhao, & Huang, 2008), respectively.

Nevertheless, there is a lack of information regarding chemical and bioactive properties of many species of *Taraxacum* genus. Considering the medicinal properties reported for the genus, the combination of functional and nutritional characteristics should be explored (Guarrera & Savo, 2013). In this perspective, flowers and vegetative parts of wild *Taraxacum*, identified as belonging to section Ruderalia (endemic from Iberian Peninsula), were chemically characterized regarding nutritional value, free sugars, organic acids, fatty acids and tocopherols. Furthermore, the antioxidant activity of its methanolic extract, infusion and decoction was correlated to the individual phenolic profile, in order to highlight the duality of medicinal plants in terms of nutritional composition and bioactive features.

2. Materials and methods

2.1. Samples

Flowers and vegetative parts of wild *Taraxacum* sect. Ruderalia (Supplementary Material) were collected in Bragança, North-eastern Portugal, in April 2012. Key morphological characters from Flora Iberica (http://www.rjb.csic.es/floraiberica/) were used for plant identification. Voucher specimens (nº 9686) are available in Escola Superior Agrária de Bragança Herbarium (BRESA). The samples were further lyophilized (FreeZone 4.5, Labconco, Kansas, USA), reduced to a fine dried powder (20 mesh) and mixed to obtain homogenate samples.

2.2. Nutritional contribution

2.2.1. Proximate composition and energetic value. The samples were analyzed for proteins, fat, carbohydrates and ash using the AOAC procedures (AOAC, 1995). Energy was calculated according to the following equation: Energy (kcal) = 4 × (g protein) + 3.75 × (g carbohydrate) + 9 × (g fat).

2.2.2 Sugars. Free sugars were determined by high performance liquid chromatography coupled to a refraction index detector (HPLC-RI) (Pereira, Barros, Carvalho & Ferreira, 2011) using melezitose as internal standard (IS). The compounds were identified by chromatographic comparisons with authentic standards. Quantification was performed using the internal standard method.

2.2.3. Organic acids. Organic acids were determined by high performance liquid chromatography coupled to a PDA detector using 215 nm and 245 nm (for ascorbic acid) as preferred wavelengths (Pereira, Barros, Carvalho, & Ferreira, 2013). For quantitative analysis, calibration curves were prepared from oxalic, quinic malic, ascorbic, citric and fumaric acid standards.

2.2.4. Fatty acids. Fatty acids were determined by gas-liquid chromatography with flame ionization detection (GC-FID)/capillary column (Dias, Barros, Sousa, & Ferreira, 2012). Fatty acid identification was made by comparing the relative retention times of FAME peaks from samples with standards.

2.2.5. Tocopherols. Tocopherols were determined by HPLC coupled to a fluorescence detector (Pereira et al., 2011). The compounds were identified by chromatographic comparisons with authentic standards. Quantification was based on the fluorescence

signal response of each standard, using the IS (tocol) method and by using calibration curves obtained from commercial standards.

2.3. Antioxidants contribution

2.3.1. Methanolic extracts, infusions and decoctions preparation. All the preparations were obtained either from lyophilized powder of flowers or vegetative parts. Each sample (1 g) was extracted twice by stirring with 30 mL of methanol (25 ºC at 150 rpm) for 1 h and subsequently filtered through Whatman No. 4 paper. The combined methanolic extracts were evaporated at 40 ºC (rotary evaporator Büchi R-210) to dryness.

For infusion preparation the sample (1 g) was added to 200 mL of boiling distilled water and left to stand at room temperature for 5 min, and then filtered under reduced pressure. For decoction preparation the sample (1 g) was added to 200 mL of distilled water, heated (heating plate, VELP scientific) and boiled for 5 min. The mixture was left to stand for 5 min and then filtered under reduced pressure. The obtained infusions and decoctions were frozen and lyophilized.

Methanolic extracts and lyophilized infusions and decoctions were redissolved in methanol and water, respectively (final concentration 5 mg/mL) for antioxidant activity evaluation. For toxicity assay, the extracts were redissolved in water at 8 mg/mL. The final solutions were further diluted to different concentrations to be submitted to the antioxidant and toxicity assays.

2.3.2. Antioxidant activity evaluation.

The antioxidant activity was evaluated by DPPH radical-scavenging activity, reducing power, inhibition of β-carotene bleaching in the presence of linoleic acid radicals and

inhibition of lipid peroxidation using TBARS in brain homogenates (Dias et al., 2012). Trolox was used as positive control.

2.3.3. Phenolic profile.

Phenolic compounds were determined by HPLC (Hewlett-Packard 1100, Agilent Technologies, Santa Clara, USA) (Rodrigues et al., 2012). Double online detection was carried out in the diode array detector (DAD) using 280 nm and 370 nm as preferred wavelengths and in a mass spectrometer (API 3200 Qtrap, Applied Biosystems, Darmstadt, Germany) connected to the HPLC system via the DAD cell outlet. The phenolic compounds were characterized according to their UV and mass spectra and retention times, and comparison with authentic standards when available. For quantitative analysis, calibration curves were prepared from caffeic acid, luteolin-7-*O*-glucoside and quercetin-3-*O*-glucoside standards.

2.4. Evaluation of toxicity in a primary culture of porcine liver cells

A cell culture was prepared from a freshly harvested porcine liver obtained from a local slaughter house, according to an established procedure (Abreu et al., 2011); it was designed as PLP2. The cell growth was followed by using Sulphorhodamine B assay.

2.5. Statistical analysis

For each part (flowers or vegetative parts), three samples were used and all the assays were carried out in triplicate. The results were expressed as mean values and standard deviation (SD). The results were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's HSD Test with $\alpha = 0.05$. This treatment was carried out using SPSS v. 18.0 program.

3. Results and Discussion

3.1. Nutritional contribution

The results obtained for macronutrients, sugars, organic acids, fatty acids and tocopherols of flowers and vegetative parts of *Taraxacum* sect. *Ruderalia* are presented in **Table 1**. Carbohydrates (including fiber) were the major macronutrients found in both samples (similar amounts). Vegetative parts showed higher levels of proteins and ash, while flowers gave higher fat content and energy value. Escudero et al. (2003) studied the nutritional value of flour of *T. officinale* leaves from Argentina, and also reported high levels of carbohydrates and proteins (58.35 g/100 g dw and 15.48 g/100 g dw, respectively).

Fructose, glucose and sucrose were found in both flowers and vegetative parts, although flowers presented higher levels of fructose, sucrose and total sugars; trehalose and raffinose were not detected in this sample.

The highest level of total organic acids was found in vegetative parts, being oxalic acid the major one followed by malic acid; ascorbic acid was also found but in very low amounts (probably related to some degradation between the field collection and the lyophilisation of the fresh samples); quinic acid was not found in vegetative parts. Sánchez-Mata et al. (2012), studied the composition in organic acids of the basal leaves of wild *T. obovatum*, reporting the same compounds, but with malic acid as the major organic acid found, followed by ascorbic acid.

Up to twenty-six fatty acids were found in *Taraxacum* flowers, with linoleic acid (C18:2n6c) as the majority fatty acid followed by α-linolenic acid (C18:3n3). The vegetative parts showed only twenty fatty acids, being α-linolenic acid (C18:3n3) the main fatty acid followed by linoleic acid (C18:2n6c), the opposite of the observed in

flowers sample. Liu et al. (2002) obtained similar results for young leaves of *T. officinale* from Australia, being α-linolenic acid the predominant one (223 mg/100 g fw). The flour of *T. officinale* leaves also showed α-linolenic acid (34.61%) as the major fatty acid (Escudero et al., 2003). In our study, both flowers and vegetative parts presented higher contents of polyunsaturated fatty acids (PUFA) than saturated fatty acids (SFA), which increases their phytochemical value, as some PUFA are essential nutrients and have been involved in the prevention of important chronic diseases (Alonso & Maroto, 2000).

The flowers of dandelion presented higher levels of individual (mainly α- tocopherol) and total tocopherols than vegetative parts, in which δ-tocopherol was not found.

3.2 Antioxidants contribution

The antioxidant activity of methanolic extracts, infusions and decoctions of flowers and vegetative parts of *Taraxacum* sect. *Ruderalia* was studied and the results are presented in **Table 2**. The decoction of vegetative parts showed the highest DPPH scavenging activity and reducing power. The decoction of flowers, and the infusion and decoction of vegetative parts showed statistically similar results for β-carotene bleaching inhibition. The methanolic extract and infusion of vegetative parts showed the highest activity in TBARS (thiobarbituric acid reactive substances) assay presenting EC_{50} values without significant differences. Hu & Kitts (2005 and 2003) and Hudec et al. (2007), reported higher DPPH scavenging activity of different extracts from *T. officinale*. Otherwise, Jeon et al. (2008) reported a lower activity for ethanolic extracts of aerial parts of *T. officinale* from Korea. Nevertheless, these results are very difficult to compare with the herein described, due to the differences in the extraction solvents

and methodologies. Furthermore, it should be highlighted that, up to 400 µg/mL, the extracts did not show toxicity for a liver cells primary culture (**Table 2**).

The main phenolic compounds found in the flowers and vegetative parts of *Taraxacum* sect. *Ruderalia* methanolic extracts, infusions and decoctions were phenolic acids and derivatives, as also flavonoids such as flavonols and flavones (**Table 3**).

Trans-caffeic acid (peak 4 in flowers and 6 in vegetative parts), and 5-*O*-caffeoylquinic acid (compound 3 in both parts) were positively identified by comparison of their MS fragmentation patterns, UV spectra and retention times with commercial standards. Compound 7 in vegetative parts was assigned to *cis*-caffeic acid, based on its UV and mass spectral characteristics and elution order when compared to compound 6.

Compounds 1 ($[M-H]^-$ at *m/z* 311) and 2 ($[M-H]^-$ at *m/z* 341) in both samples were assigned as caffeic acid pentoside and hexoside, respectively. This identification was based on their product ion at *m/z* 179 ($[caffeic\ acid-H]^-$) resulting from the loss of 132 u and 162 u (pentosyl and hexosyl residue, respectively), and it is also supported by their UV spectra characteristic of caffeic acid derivatives. Peaks 10 and 11 in flowers and 16 in vegetative parts ($[M-H]^-$ at *m/z* 515) corresponded to dicaffeoylquinic acids and were identified based on their elution order and MS^2 fragmentation patterns as described by Clifford, Johnston, Knight, & Kuhnert (2003 and 2005). Thus, peak 10 in flowers and 16 in vegetative parts were identified as 3,5-*O*-dicaffeoylquinic acid, producing an MS^2 base peak at *m/z* 353 from the loss of one of the caffeoyl moieties $[M-H-caffeoyl]^-$, whose subsequent fragmentation yielded product ions characteristic of monocaffeoylquinic acids at *m/z* 191, 179, 173 and 135, although in the case of the dicaffeoyl derivative with a comparatively more intense signal at *m/z* 179 (56%-63% of base peak). Peak 11 in flowers was assigned to 4,5-*O*-dicaffeoylquinic acid according to its elution order and MS^2 fragmentation, with an MS^2 base peak at *m/z* 353 ([M-H-

caffeoyl]$^-$) and another intense signal at *m/z* 173, from the loss of a second caffeoyl moiety, characteristic of isomers substituted at position 4 (Clifford et al., 2003, 2005).

Compounds 5 and 6 in flowers and 10 and 11 in vegetative parts showed the same pseudomolecular ion ([M–H]$^-$ at *m/z* 473) and a fragmentation pattern that allowed assigning them as chicoric acid (dicaffeoyltartaric acid) isomers. Two chicoric acid isomers were also reported by Schütz, Kammerer, Carle, & Schieber (2005) in dandelion (*Taraxacum officinale* WEBER ex F.H.WIGG.) showing similar fragmentation behavior although with different abundances of the released product ions. In the case of Schütz and coworkers the ion was at *m/z* 311 (loss of a caffeoyl moiety) appeared as MS^2 base peak (100% abundance), whereas in our study major fragments were observed at *m/z* 179 ([caffeic acid-H]$^-$) and 149 ([tartaric acid-H]$^-$). Furthermore, in vegetative parts, peak 4, showing a pseudomolecular ion at *m/z* 635, 162 u greater than chicoric acids and with similar product ions, was identified as a chicoric acid hexoside.

Compounds 7, 8, 9, 12-14 in flowers and 12 and 14 in vegetative parts were identified as luteolin derivatives. Peaks 8 (flowers) and 14 (vegetative parts) were positively identified as luteolin 7-*O*-glucoside, and compound 13 (flowers) was identified as luteolin, by comparison of their MS and UV spectra and retention characteristics with commercial standards. The rest of luteolin derivatives were tentatively identified as luteolin *O*-rutinoside (peaks 7 in flowers and 12 in vegetative parts), luteolin *O*-hexoside (peak 9 in flowers) and luteolin *O*-acetylhexoside (peak 12 in flowers), based on their pseudomolecular ions and MS^2 fragment losses corresponding to rutinosyl (-308 u), hexosyl (-162 u) and acetylhexosyl (-42-162 u) moieties, respectively.

The remaining phenolic compounds in vegetative parts that can be attributed to quercetin derivatives (λ_{max} around 350 nm and an MS^2 fragment at *m/z* 301).

Compounds 5 and 8 ([M-H]$^-$ at *m/z* 595) were identified as quercetin containing a pentosyl and a hexosyl residues. The observation of only a MS^2 fragment at *m/z* 463 from the loss of a pentosyl moiety (-132 u) suggests that both sugars were constituting a disaccharide that would be linked to the aglycone through the hexose, otherwise a fragment from the loss of a hexosyl residue (-162 mu) should have been observed. These peaks were tentatively identified as quercetin *O*-pentosyl hexosides bearing the sugar moiety located at different position on the aglycone. Peak 15 ([M-H]$^-$ at *m/z* 505) corresponded to a quercetin *O*-acetylhexoside according to its pseudomolecular ion and MS^2 fragment released at *m/z* 301 (quercetin; [M-H-42-162]$^-$, loss of an acetylhexoside moiety). Peak 9 showed a pseudomolecular ion [M-H]$^-$ at *m/z* 667, 162 u greater than peak 15 indicating the presence of an additional hexosyl moiety. The formation of fragments due to the alternative loss of a hexosyl moiety (*m/z* at 505) and an acetylhexosyl moiety (*m/z* at 463) suggested that both residues were located at different positions on the aglycone, so that it was assigned to quercetin *O*-hexoside-*O*-acetylhexoside. Finally, peak 13, with an [M-H]$^-$ at *m/z* 433, releasing only a product ion at *m/z* 301 (quercetin; [M-H-132]-, loss of a pentosyl moiety) was assigned to s a quercetin *O*-pentoside.

Overall, hydroxycinnamic acid derivatives were the main phenolic acids found in both samples, which include caffeic acid derivatives, caffeoylquinic acid derivatives and chicoric acids, the latter being the main compounds found in all the preparations of vegetative parts and in infusion and decoction of flowers. Luteolin derivatives were the only flavonoids identified in flowers, whereas quercetin and luteolin derivatives were present in vegetative parts. The methanolic extracts showed higher amounts of total phenolic compounds than infusions and decoctions. The methanolic extract and the

infusion of the vegetative parts showed the highest content in total phenolic compounds, which are correlated with the antioxidant activity displayed by those samples in all the assays: DPPH (R^2=0.9772), reducing power (R^2=0.7362), β-carotene bleaching inhibition (R^2=0.5725) and TBARS (R^2=0.5312). Therefore, the differences observed for antioxidant activity of the samples are related to the amount of phenolic compounds and not with the phenolic compounds profile, which is similar (**Table 3**).

Schütz et al. (2005) also reported chicoric acids as the main phenolic compounds found in dandelion (*Taraxacum officinale*). Indeed, chicoric acids are relevant secondary metabolites in plants of the tribe Cichorieae (family Asteraceae), including genus *Taraxacum* or *Lactuca*, being used for taxonomic purposes (Schütz et al., 2005). Williams et al. (1996) and Gatto et al. (2011), using different extraction and analysis methods, reported similar results on flowers and leaves of *T. officinale*. Shi et al. (2008) identified caffeic acid as one of the major compounds in *T. mongolicum*.

In conclusion, flowers of wild dandelion gave higher content of total sugars (despite the lack of trehalose and raffinose), tocopherols (mainly α-isoform) and flavonoids (mainly luteolin *O*-hexoside and luteolin) than vegetative parts. In contrast, the latter showed higher content of proteins, ash, organic acids, PUFA (mainly linoleic acid) and phenolic acids (caffeic acid derivatives and especially chicoric acid), lower levels of total fat and energy, and better PUFA/MUFA (above 0.45) and n6/n3 (lower than 4.0) ratios. In general, vegetative parts of dandelion gave also higher antioxidant activity, which could be related to its higher content in phenolic acids (R^2=0.9964, 0.8444, 0.4969 and 0.5542 for DPPH, reducing power, β-carotene bleaching inhibition and TBARS assays, respectively). Particularly, vegetative parts decoction showed the highest DPPH

scavenging activity and reducing power, and its methanolic extract revealed the highest lipid peroxidation inhibition (TBARS assay).

As far as we know, this is a groundbreaking study on the nutraceutical composition, bioactivity and phenolic profile of flowers and vegetative parts of wild dandelion (*ie*, *Taraxacum* sect. *Ruderalia*). This study also demonstrates that wild plants like *Taraxacum*, although not being a common nutritional reference, can be used in an alimentary base as a source of bioactive compounds, namely antioxidants.

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Table 1. Macronutrients, free sugars, organic acids, fatty acids and tocopherols of flowers and vegetative parts of *Taraxacum* sect. *Ruderalia*.

	Flowers	Vegetative parts
Moisture (g/100 g fw)	77.43 ± 2.07[b]	79.12 ± 2.04[a]
Fat (g/100 g dw)	6.56 ± 0.15[a]	2.96 ± 0.00[b]
Proteins (g/100 g dw)	15.13 ± 1.22[b]	18.26 ± 0.90[a]
Ash (g/100 g dw)	0.86 ± 0.02[b]	1.44 ± 0.04[a]
Carbohydrates (g/100 g dw)	77.46 ± 1.28[a]	77.35 ± 0.89[a]
Energy (kcal/100 g dw)	429.36 ± 0.47[a]	409.07 ± 0.10[b]
Fructose	4.71 ± 0.32[a]	0.29 ± 0.02[b]
Glucose	1.81 ± 0.10[b]	2.08 ± 0.19[a]
Sucrose	6.88 ± 0.20[a]	3.65 ± 0.25[b]
Trehalose	Nd	0.31 ± 0.05
Raffinose	Nd	0.19 ± 0.03
Total sugars (g/100 g dw)	13.4 ± 0.62[a]	6.53 ± 0.47[b]
Oxalic acid	0.96 ± 0.01[b]	4.76 ± 0.04[a]
Quinic acid	0.07 ± 0.01	nd
Malic acid	2.12 ± 0.06[b]	4.58 ± 0.14[a]
Ascorbic acid	0.07 ± 0.00[b]	0.04 ± 0.00[a]
Citric acid	1.34 ± 0.03[a]	0.66 ± 0.00[b]
Fumaric acid	0.02 ± 0.00[a]	0.02 ± 0.00[a]
Total organic acids (g/100 g dw)	4.55 ± 0.10[b]	10.05 ± 0.10[a]
Fatty acid		
C16:0	17.01 ± 3.12	10.09 ± 2.06
C18:2n6c	33.03 ± 1.33	24.21 ± 1.86
C18:3n3	23.14 ± 1.17	57.38 ± 4.96
SFA	33.53 ± 4.12[a]	14.99 ± 2.73[b]
MUFA	2.97 ± 0.00[a]	2.20 ± 0.04[b]
PUFA	63.50 ± 4.11[b]	82.82 ± 2.77[a]
PUFA/MUFA	1.92 ± 0.36[b]	5.64 ± 1.21[a]
n6/n3	1.12 ± 0.06[a]	0.44 ± 0.08[b]
α – tocopherol	21.60 ± 1.76[a]	16.85 ± 1.26[b]
β – tocopherol	11.24 ± 0.93[a]	0.64 ± 0.12[b]
γ – tocopherol	5.61 ± 0.54[a]	1.70 ± 0.23[b]
δ – tocopherol	6.31 ± 0.78	nd
Total tocopherols (g/100 g dw)	44.76 ± 4.02[a]	19.19 ± 1.61[b]

nd- not detected; fw- fresh weight; dw- dry weight. In each row different letters mean significant differences (p<0.05). Palmitic acid (C16:0); Linoleic acid (C18:2n6c); α-Linolenic acid (C18:3n3); SFA – saturated fatty acids; MUFA – monounsaturated fatty acids; PUFA – polyunsaturated fatty acids.

Table 2. Antioxidant activity of methanolic extracts, infusions and decoction of flowers and vegetative parts of *Taraxacum* sect. *Ruderalia*.

	Flowers			Vegetative parts		
	Methanolic	Infusion	Decoction	Methanolic	Infusion	Decoction
Extraction yield (%)	29.8 ± 3.10	21.8 ± 0.15	23.4 ± 3.23	27.6 ± 2.70	20.15 ± 2.85	21.60 ± 1.52
DPPH scavenging activity (EC_{50}, mg/mL)	0.80 ± 0.01^{b}	0.53 ± 0.12^{c}	0.42 ± 0.03^{d}	0.89 ± 0.03^{a}	0.35 ±0.03^{d}	0.12 ± 0.00^{e}
Reducing power (EC_{50}, mg/mL)	0.41 ± 0.01^{b}	0.30 ± 0.00^{d}	0.47 ± 0.01^{a}	0.39 ± 0.01^{c}	0.31 ± 0.02^{d}	0.16 ± 0.00^{e}
β-carotene bleaching inhibition (EC_{50}, mg/mL)	1.89 ± 0.09^{b}	2.63 ± 0.70^{a}	0.40 ± 0.09^{c}	1.61 ± 0.58^{b}	0.46 ± 0.03^{c}	0.76 ± 0.09^{c}
TBARS inhibition (EC_{50}, mg/mL)	0.39 ± 0.08^{c}	0.23 ± 0.02^{d}	0.60 ± 0.02^{b}	0.13 ± 0.02^{e}	0.16 ± 0.03^{e}	0.71 ± 0.08^{a}
PLP2- liver cells primary culture (GI_{50}, µg/mL)	> 400	> 400	> 400	> 400	> 400	> 400

EC_{50} values correspond to the sample concentration achieving 50% of antioxidant activity or 0.5 of absorbance in reducing power assay. GI_{50} > 400 indicates that no toxicity was found when testing samples up to 400 µg/mL. In each row different letters mean significant differences ($p<0.05$).

Table 3. Retention time (Rt), wavelengths of maximum absorption in the visible region (λ_{max}), mass spectral data, tentative identification of flavonoids and phenolic acids in flowers and vegetative parts of wild *Taraxacum* sect. *Ruderalia*.

Flowers

Peak	Rt (min)	λ_{max} (nm)	Molecular ion $[M-H]^-$ (*m/z*)	MS^2 (*m/z*)	Tentative identification	Quantification (mg/g extract)		
						Methanolic	Infusion	Decoction
1	5.5	330	311	179(100), 135(94)	Caffeic acid pentoside*	0.32 ± 0.02	0.75 ± 0.01	0.77 ± 0.01
2	5.9	330	341	179(100)	Caffeic acid hexoside*	0.33 ± 0.04	0.20 ± 0.01	0.22 ± 0.00
3	8.1	328	353	191(100),179(14),173(6),135(21)	5-*O*-Caffeoylquinic acid*	1.18 ± 0.02	1.29 ± 0.01	1.21 ± 0.01
4	11.3	322	179	135(100)	*trans*-Caffeic acid*	0.33 ± 0.01	0.55 ± 0.01	0.54 ± 0.00
5	16.5	328	473	311(52),293(58),219(32),179(98),149(100),135(66)	Chicoric acid isomer*	3.28 ± 0.07	5.77 ± 0.23	5.95 ± 0.07
6	17.0	330	473	311(46),293(47),219(22),179(100),149(98),135(47)	Chicoric acid isomer*	0.28 ± 0.00	1.09 ± 0.16	0.83 ±0.14
7	19.8	350	593	285(100)	Luteolin *O*-rutinoside**	4.08 ± 0.04	2.20 ± 0.02	1.99 ± 0.04
8	20.9	348	447	285(100)	Luteolin 7-*O*-glucoside**	0.61 ± 0.03	4.26 ± 0.09	4.19 ± 0.09
9	21.5	350	447	285(100)	Luteolin *O*-hexoside**	11.06 ± 0.93	0.59 ± 0.06	0.51 ± 0.05
10	22.5	328	515	353(100),191(85),179(63),173(10),163(8),135(40)	3,5-di-*O*-caffeoylquinic acid*	1.19 ± 0.02	1.24 ± 0.04	0.93 ± 0.00
11	25.1	330	515	353(100),191(42),179(81),173(97),135(28)	4,5-di-*O*-caffeoylquinic acid*	0.02 ± 0.00	0.19 ± 0.00	0.38 ± 0.01
12	26.2	350	489	285(100)	Luteolin *O*-acetylhexoside*	0.23 ± 0.00	0.20 ± 0.01	0.20 ± 0.03
13	34.3	348	285	175(12),151(16),133(23)	Luteolin**	4.29 ± 0.20	2.81 ± 0.24	3.15 ± 0.21
					Total Flavonoids	20.16 ± 1.03[a]	10.07 ± 0.26[b]	10.04 ± 0.36[b]
					Total Phenolic acids	6.94 ± 0.00[c]	11.09 ± 0.11[a]	10.83 ± 0.03[b]
					Total Phenolic compounds	27.22 ± 1.19[a]	21.16 ± 0.37[b]	20.87 ± 0.33[b]

Vegetative parts

1	5.5	330	311	179(100), 135(94)	Caffeic acid pentoside*	3.24 ± 0.10	3.64 ± 0.06	0.67 ± 0.04
2	5.9	330	341	179(28),135(100)	Caffeic acid hexoside*	3.30 ± 0.17	0.23 ± 0.01	0.22 ± 0.00
3	8.1	328	353	191(100),179(14),173(6),135(21)	5-*O*-Caffeoylquinic acid*	0.83 ± 0.04	0.49 ± 0.02	0.31 ± 0.01
4	10.1	328	635	473(90),455(29),341(82),311(3),293(44),219(10),179(100),149(7),135(15)	Chicoric acid hexoside*	1.74 ± 0.16	0.62 ± 0.01	0.25 ± 0.03
5	10.4	358	595	463(40),301(15)	Quercetin *O*-pentosyl hexoside***	0.48 ± 0.00	0.40 ± 0.03	0.07 ± 0.00
6	11.3	322	179	135(100)	*trans*-Caffeic acid*	1.00 ± 0.02	0.46 ± 0.00	0.32 ± 0.00
7	11.8	330	179	135(100)	*cis*-Caffeic acid*	0.60 ± 0.04	0.31 ± 0.01	0.16 ± 0.01
8	13.9	358	595	463(41),301(19)	Quercetin *O*-pentosyl hexoside***	0.34 ± 0.04	0.10 ± 0.01	0.02 ± 0.00
9	15.2	354	667	505(40),463(29),301(10)	Quercetin *O*-hexoside-*O*-acetyl-dihexoside***	0.17 ± 0.03	0.06 ± 0.01	0.02 ± 0.00
10	16.5	328	473	311(55),293(60),219(34),179(100),149(92),135(60)	Chicoric acid isomer*	26.36 ± 0.64	11.93 ± 0.02	2.86 ± 0.19
11	17.4	330	473	311(55),293(47),219(28),179(94),149(100),135(54)	Chicoric acid isomer*	5.68 ± 0.87	1.90 ± 0.03	4.99 ± 0.15
12	19.8	350	593	285(100)	Luteolin *O*-rutinoside**	2.59 ± 0.22	0.60 ± 0.06	0.53 ± 0.01
13	20.3	350	433	301(100)	Quercetin *O*-pentoside***	0.22 ± 0.03	0.06 ± 0.01	0.13 ± 0.00
14	20.9	348	447	327(6), 285(100)	Luteolin 7-*O*-glucoside**	5.67 ± 0.08	1.74 ± 0.03	0.75 ± 0.01
15	22.3	346	505	463(68),301(32)	Quercetin *O*-acetylhexoside***	0.22 ± 0.01	0.08 ± 0.01	0.04 ± 0.00
16	22.5	330	515	353(100),191(75),179(56),173(5),161(6),135(21)	3,5-di-*O*-caffeoylquinic acid*	0.48 ± 0.06	0.11 ± 0.00	0.06 ± 0.00
					Total Flavonoids	9.69 ± 0.23[a]	3.04 ± 0.06[b]	1.74 ± 0.04[c]
					Total Phenolic acids	43.24 ± 0.44[a]	19.70 ± 0.04[b]	9.84 ± 0.05[c]
					Total Phenolic compounds	52.93 ± 0.21[a]	22.74 ± 0.09[b]	11.41 ± 0.07[c]

Calibrations curve used: *- Caffeic acid; **- Luteolin 7-*O*-glucoside; ***- Quercetin 3-*O*-glucoside. The results are expressed in mg per g of methanolic extract or lyophilized infusion and decoction.