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Chemical composition and antioxidant activity of aerial partsof *Ferula longipes* Coss. ex Bonnier and Maury

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KEYWORDS *Ferula longipes* coss. ex Bonnier and Maury; apiaceae; flavonoid; antioxidant activity; reducing power assays

ABSTRACT

This is the first study on the phytochemistry and antioxidant activity of *Ferula longipes* Coss. ex Bonnier and Maury (Apiaceae). A new flavonoid quercetin-3-*O*- α -L-rhamnopyranoside-7-*O*- β -D-[2-*O*-caffeoyl]-glucopyranoside (**1**), along with 10 known compounds kaempferol-3-*O*- α -L-rhamnopyranoside (**2**), quercetin-3-*O*- α -L-rhamnopyranoside (**3**), kaempferol-3-*O*- β -D-glucopyranoside-7-*O*- α -L-rhamnopyranoside (**4**), isorhamnetin-3-*O*- α -L-rhamnopyranoside-7-*O*- β -D-glucopyranoside (**5**), quercetin-3-*O*- α -L-rhamnopyranoside-7-*O*- β -D-glucopyranoside (**6**), isorhamnetin-3,7-di-*O*- β -D-glucopyranoside (**7**), apigenin (**8**), apigenin-7-*O*- β -D-glucopyranoside (**9**), 3,5-

dicafeoylquinic acid (**10**), deltoin (**11**) were isolated from the aerial parts of *Ferula longipes* Coss. Structures elucidation was performed by comprehensive 1D and 2D NMR analyses, mass spectrometry and by comparison with literature data. The compounds **1**, **3**, **4**, **6**, **7** and **10** were evaluated for their antioxidant activity, compound **1** exhibited the best antiradical activity potential and showed IC₅₀ and A_{0.5} values 5.70, 7.25, 5.00, and 2.63 μ g/mL towards DPPH free radical-scavenging, ABTS, CUPRAC, and reducing power assays, respectively compared with BHA, BHT and ascorbic acid which were used as positive controls.

1. Introduction

The genus *Ferula* L. (Apiaceae) is represented by about 208 perennial herbaceous species occurring from Central Asia, westward throughout the Mediterranean region to Northern Africa and the Macaronesian Region (Mabberley 2008). Some species of this genus have been used throughout the history in traditional medicine, but also as spices and in human diet. Many *Ferula* species were used for upper respiratory conditions (asthma, bronchitis, etc.), for gastrointestinal disorders as spasmolytic, antifatulence, and antidiarrhoeal agent, as well as anthelmintic and aphrodisiac herbal drugs (Sadraei et al. 2001; Hadidi et al. 2003; Iranshahy & Iranshahi 2011). Previous chemical investigations of the genus *Ferula* have led to the identification of more than 200 compounds, including, sesquiterpene coumarins and coumarin esters (Ahmed 1999; Iranshahy & Iranshahi 2011; Meng et al. 2013; Razavi & Janani 2015; Asghari et al. 2016; Dastan et al. 2016; Razavi et al. 2016) and prenylated coumarins (Appendino et al. 1988; Arnoldi et al. 2004). Sesquiterpene coumarins, the most abundant class of secondary metabolites in *Ferula* species, are biologically active compounds and so far they have demonstrated promising chemopreventive, antitumour, anti-inflammatory and antileishmanial activities (Nazari and Iranshahi 2011). Plants of this genus also contain sesquiterpene chromone derivatives (Meng et al. 2013), daucane esters (Appendino et al. 1997), prenyl-benzoyl-furanone-type sesquiterpenoids (Kojima et al. 1999) and essential oils (Labeled-Zouad et al. 2015; Maggi et al. 2016). The present work describes the isolation and structural identification of a new flavonoid (**1**) and 10 known compounds (**2–11**) from the aerial parts of *Ferula longipes* Coss. In addition, the antioxidant activity of the compounds **1**, **3**, **4**, **6**, **7** and **10** was investigated.

2. Results and discussion

The *n*-BuOH and the ethyl acetate fractions of the aerial parts of *F. longipes* Coss. were fractionated and purified by combination of chromatographic methods to obtain a new flavonoid quercetin-3-*O*- α -L-rhamnopyranoside-7-*O*- β -D-[2-*O*-caffeoyl]-glucopyranoside (**1**) and ten known compounds (**2–11**). They were elucidated as kaempferol-3-*O*- α -L-rhamnopyranoside (**2**) (Berrehal et al. 2010), quercetin-3-*O*- α -L-rhamnopyranoside (**3**)

(Berrehal et al. 2010), kaempferol-3-*O*- β -D-glucopyranoside-7-*O*- α -L-rhamnopyranoside (**4**) (Berrehal et al. 2010), isorhamnetin-3-*O*- α -L-rhamnopyranoside-7-*O*- β -D-glucopyranoside (**5**) (Wolbiś, 1989), quercetin-3-*O*- α -L-rhamnopyranoside-7-*O*- β -D-glucopyranoside (**6**) (Maji and Banerji 2016), isorhamnetin-3,7-di-*O*- β -D-glucopyranoside (**7**) (Yokozawa et al. 2002), apigenin (**8**) (Nacer et al. 2006), apigenin-7-*O*- β -D-glucopyranoside (**9**) (Markham and Chari 1982), 3,5-dicaffeoylquinic acid (**10**) (Timmermann et al. 1983), deltoin (**11**) (Bensalem et al. 2013). Their structural assignments were made by ESI-MS, 1D-, and 2D-NMR analyses and by comparison with spectral data from the literature values. Compound **1** was isolated as a yellow amorphous powder. The positive ESI-MS spectrum showed the pseudo-molecular ion [M + Na]⁺ at *m/z* 795.1758, compatible with the molecular formula of C₃₆H₃₆O₁₉.

In the UV spectrum of compound **1** recorded in MeOH and MeOH + NaOH, a flavonol or a substituted flavonol at C3 with a free hydroxyl group at C-4' (Mabry et al. 1970; absorption bands were observed at 256, 346 nm and 266, 394 nm, respectively indicating Markham and Chari 1982).

The ¹H-NMR spectrum of compound **1** shows a typical pattern of quercetin aglycone. The two doublets at δ 6.42 and 6.71 (*J* = 2.2 Hz) assignable to H-6 and H-8, respectively were downfield indicating that there is a substitution at C7 (Berrehal et al. 2010) An ortho and meta coupled ABX-type protons were also observed at δ 6.92 (1H, d, *J* = 8.3 Hz, 5'-H), 7.33 (1H, dd, *J* = 8.3, 2.0 Hz, 6'-H), and 7.37 (1H, d, *J* = 2.0 Hz, 2'-H). In addition, 1H-NMR spectrum of **1** exhibited two doublets at δ 5.39 (1H, d, *J* = 1.5 Hz, H-1'') and at δ 5.37 (1H, d, *J* = 7.9 Hz, H-1''') assignable to two anomeric protons. The sugars were identified as β -glucopyranosyl (glc) and α -rhamnopyranosyl (rham) on the basis of the 1H-1H COSY and HSQC spectra. The *J* values of their anomeric protons indicated the anomeric configurations of β -glc and α -rham. On acid hydrolysis, compound **1** gave D-glucose and L-rhamnose which were identified by R_f values on TLC with authentic samples (Touafek et al. 2011). Another ABX spin system can be assigned as δ 6.78 (1H, d, *J* =

8.2 Hz, 5^{'''}-H), 6.96 (1H, dd, $J = 8.2, 2.0$ Hz, 6^{'''}-H), 7.06 (1H, d, $J = 2.0$ Hz, 2^{'''}-H). Furthermore, two doublets with a splitting of $J_{7''''',8''''} = 15.8$ Hz clearly indicated *trans* caffeoyl group.

In the HMBC spectrum a cross peak was observed between C-7 at δ 162.7 and 1^{'''}-H at δ 5.37 indicating the attachment of the β -D-glucose at C-7 of quercetin. Another HMBC correlation was observed between C-3 at δ 135.1 and H-1^{''} at δ 5.39 indicating the linkage position of the α -L-rham. Along range correlation was observed between H-2^{'''} (δ 5.13, 1H, dd, $J = 9.6, 7.9$ Hz) and the caffeoyl-carbonyl carbon δ 166.8 indicating that caffeoyl group was attached to C-2^{'''} of the glc. Consequently, the structure of compound **1** was determined as quercetin-3-*O*- α -L-rhamnopyranoside-7-*O*- β -D-[2-*O*-caffeoyl]-glucopyranoside (Figure 1).

The antioxidant activity of compounds **1**, **3**, **4**, **6**, **7** and **10** was tested using DPPH free radical-scavenging, CUPRAC, ABTS and reducing power assays. BHA, BHT and ascorbic acid were used as positive standards. The tests were performed at different concentrations to calculate the IC₅₀ and A_{0.50} values. Results were statistically significant ($p < 0.05$) when compared with those of controls in each test

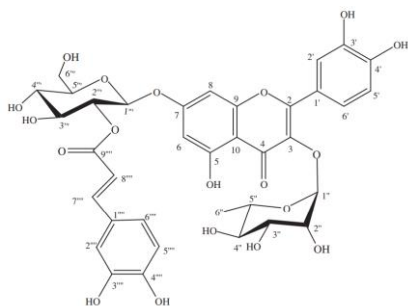


Figure 1. chemical structure of compound **1** isolated from *Ferula longipes* coss. ex Bonnier and Maury.

In DPPH and ABTS assays, all compounds have a high-scavenging activity, compound **1** showed the best antiradical activity (IC₅₀: 5.70 \pm 0.82 and 5.00 \pm 0.65 μ g/mL, respectively) followed by compound **3** (IC₅₀: 7.37 \pm 0.31 and 5.94 \pm 0.08 μ g/mL, respectively) and **6** (7.53 \pm 0.34 and 6.07 \pm 0.37 μ g/mL, respectively) with a higher antiradical activity than the standards BHA (IC₅₀: 7.96 \pm 1.01 and 5.56 \pm 0.77 μ g/mL, respectively) and BHT (IC₅₀: 14.73

\pm 0.52 and 8.52 \pm 0.67 μ g/mL, respectively). Compounds **7** (IC₅₀: 9.42 \pm 0.59 and 6.13 \pm 0.72 μ g/mL, respectively), **10** (IC₅₀: 12.87 \pm 0.09 and 10.12 \pm 1.01 μ g/mL, respectively) and **4** (IC₅₀: 15.57 \pm 0.32 and 11.54 \pm 0.09 μ g/mL, respectively) also showed a good activity compared with the standards.

In the same order, with the CUPRAC and reducing power assays, compounds **1** (A_{0.50}: 7.25 \pm 0.12 and 2.63 \pm 0.55 μ g/mL, respectively), **3** (A_{0.50}: 7.85 \pm 0.32 and 2.75 \pm 0.24 μ g/mL, respectively) and **6** (A_{0.50}: 8.50 \pm 0.40 and 2.86 \pm 0.14 μ g/mL, respectively) exhibited a higher activity than the standards BHA (A_{0.50}: 8.56 \pm 0.36 and 3.23 \pm 0.27 μ g/mL, respectively), BHT (A_{0.50}: 8.75 \pm 0.11 and 3.83 \pm 0.67 μ g/mL, respectively) and ascorbic acid (A_{0.50}: 8.01 \pm 1.46 μ g/mL). Compounds **7** (A_{0.50}: 9.23 \pm 0.72 and 3.02 \pm 0.82 μ g/mL, respectively), **10** (A_{0.50}: 11.56 \pm 0.89 and 15.08 \pm 0.77, respectively) and **4** (A_{0.50}: 13.48 \pm 0.38 and 23.01 \pm 0.50 μ g/mL, respectively) were also found to be active. In all antioxidant assays, the flavonoids **1**, **3** and **6** showed a higher antioxidant activity than the standards. Compound **4** had only one -OH group but **1**, **3** and **6** have two *ortho* -OH groups which increases the antioxidant activity (Muhammad et al. 2016). The antioxidant activity of **7** is higher than that of **4** because the H at C-3' position has been replaced by OCH₃ group in the B ring.

3. Experimental

3.1. General experimental procedures

¹H and ¹³C NMR spectra were recorded in CD₃OD on a Bruker AVANCE DRX 600 NMR spectrometer (Karlsruhe, Germany) (¹H at 600 MHz and ¹³C at 150 MHz). 2D-NMR experiments were performed using standard Bruker sequences. ESI-MS experiments were performed using a Micromass Q-TOF instrument (Manchester, UK).

Polyamide SC6 was purchased from Fluka (Steinheim, Germany). Silica gel 60 F₂₅₄ pre-coated aluminium plates (0.2 mm, Merck) were used for VLC analysis. The VLC spots were visualised under UV light (254 and 366 nm) followed by spraying with 50% H₂SO₄ and heating. Column chromatography was carried out on Kieselgel 60 (63–200 mesh) Merck.

1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2'-azinobis (3-ethyl-benzothiazoline-6-sulphonic Butylated-hydroxyl anisole (BHA), butylatedhydroxytoluene (BHT), ascorbic acid, acid) diammonium salt (ABTS), neocuproine, tri-chloro acetic acid, ferric chloride, potassium ferricyanide, were obtained from Sigma Chemical Co. (Sigma-Aldrich GmbH, Steinheim, Germany). Electronic Single channel micropipette (Eppendorf AG, Hamburg, Germany). All other chemicals and solvents were of analytical grade.

Plant material

Aerial parts of *F. longipes* Coss. ex Bonnier and Maury were collected from Bejaia (North-east of Algeria) in May 2012 and authenticated by Prof. Gérard De Belair (University of Annaba, Algeria). The voucher specimen (LOST/FI/05/12) has been kept in the Herbarium of the Faculty of Sciences (University of Mentouri Constantine).

3.2. Extraction and isolation

Air-dried and powdered aerial parts (900 g) of *F. longipes* Coss. were macerated in a methanolic solution (70%). The residue was filtered, concentrated and successively extracted with petroleum ether, dichloromethane, ethyl acetate and *n*-butanol.

The *n*-butanol fraction (14 g) was concentrated under reduced pressure and subjected to a column chromatography on polyamide SC6 with a gradient of toluene–MeOH of increasing polarity to give three fractions [F₁: 300 mg, F₂: 550 mg, F₃: 900 mg]. Fraction F₁ was sub-

jected to a column chromatography on silica gel eluted with the system AcOEt–MeOH–H₂O (10:1:0.5) affording four compounds, **1** (14 mg), **2** (28 mg), **3** (11 mg), and **8** (20 mg). Compound **4** (12 mg) precipitated in fraction F₂. Fraction F₃ was subjected to a silica gel CC using the isocratic system *n*-hexane / acetone (9/1), to obtain compounds **5** (39 mg) and **6** (26 mg).

The ethyl acetate fraction (6 g) was concentrated under reduced pressure and subjected to fractionation by liquid chromatography under vacuum (VLC) over C18 reverse phase, eluted with the system H₂O

/ MeOH (60:40, 40:60, 30:70, 20:80, 0:100) to obtain 7 fractions. Fraction F₃ (870 mg) was chromatographed on a silica gel CC with the isocratic system CHCl₃:MeOH:H₂O (10:1:0.5), to obtain compounds **7** (25 mg) and **10** (31 mg). Fraction F₅ (405 mg) was chromatographed on a silica gel column with the isocratic system AcOEt:MeOH:H₂O (8:2:1) leading to compounds **9** (25 mg) and **11** (16 mg).

3.2.1. Quercetin-3-O- α -L-rhamnopyranoside-7-O-[2-O-caffeoyl]- β -D-glucopyranoside (1)

Yellow amorphous powder; $[\alpha]_D^{20} +41.2$ (c 0.20, MeOH), mp 329 °C, UV λ_{max} (MeOH, nm):256, 346 and (MeOH + NaOH, nm): 266, 394, ¹H NMR (600 MHz, CD₃OD) : δ_H 6.42 (d, *J* = 2.2 Hz, H-6), 6.71 (d, *J* = 2.2 Hz, H-8), 7.37 (d, *J* = 2.0 Hz, H-2'), 6.92 (d, *J* = 8.3 Hz, H-5'), 7.33 (dd, *J* = 8.3, 2.0 Hz, H-6'), 5.39 (d, *J* = 1.5 Hz, H-1''), 4.23 (dd, *J* = 3.3, 1.7 Hz, H-2''), 3.75 (dd, *J* = 9.5, 2.9 Hz, H-3''), 3.34 (t, *J* = 9.5 Hz, H-4''), 3.42 (m, H-5''), 0.94 (d, *J* = 6.1 Hz, H-6''), 5.37 (d, *J* = 7.9 Hz, H-1'''), 5.13 (dd, *J* = 9.6, 7.9 Hz, H-2'''), 3.76 (t, *J* = 9.5 Hz H-3'''), 3.54 (t, *J* = 9.4 Hz, H-4'''), 3.65 (m, H-5'''), 3.99 (dd, *J* = 12.2, 2.2 Hz, H-6'''a), 3.78 (dd, *J* = 12.2, 5.8 Hz, H-6'''b), 7.06 (d, *J* = 2.0 Hz, H-2''''), 6.78 (d, *J* = 8.2 Hz, H-5''''), 6.96 (dd, *J* = 8.2, 2.0 Hz, H-6''''), 7.63 (d, *J* = 15.8 Hz, H-7''''), 6.33 (d, *J* = 15.8 Hz, H-8''''), ¹³C NMR (150 MHz, CD₃OD): δ_C 156.6 (C-2), 135.1 (C-3), 178.4 (C-4), 161.6 (C-5), 99.2 (C-6), 162.8 (C-7), 94.5 (C-8), 158.5 (C-9), 106.4 (C-10), 126.3 (C-1'), 115.6 (C-2'), 145.0 (C-3'), 148.6 (C-4'), 121.3 (C-5'), 121.6 (C-6'), 102.1 (C-1''), 70.5 (C-2''), 69.9 (C-3''), 71.8 (C-4''), 61.0 (C-5''), 16.2 (C-6''), 98.3 (C-1'''), 74.6 (C-2'''), 71.8 (C-3'''), 70.6 (C-4'''), 77.2 (C-5'''), 60.9 (C-6'''), 73.3 (C-1''''), 113.7 (C-2''''), 146.2 (C-3''''), 148.3 (C-4''''), 115.1 (C-5''''), 121.6 (C-6''''), 145.4 (C-7''''), 113.3 (C-8''''), 166.8 (C-9''''). HR-ESI-MS *m/z* 795.1758 [M + Na]⁺ [calc for C₃₆H₃₆O₁₉Na, 795.1749].

3.2.2. Acid hydrolysis

The pure compound was treated with 2 M HCl at 100 °C for 1 h. The hydrolysate was extracted with EtOAc. The two sugars were identified as

glucose and rhamnose in the aqueous residue by comparison with authentic samples on silica gel TLC impregnated with 0.2 M NaH₂PO₄ [solvent Me₂CO–H₂O (9:1)] and revealed with aniline malonate. The optical rotation of each purified sugar was measured and compared with authentic samples to afford D-glucose and L-rhamnose.

3.3. Antioxidant activity

Four methods were used to evaluate the antioxidant activity: DPPH free radical-scavenging, ABTS, CUPRAC and reducing power assay.

3.3.1. DPPH free radical-scavenging assay

The free radical-scavenging activity of compounds **1**, **3**, **4**, **6**, **7** and **10** isolated from *F. longipes* Coss. was determined by the DPPH assay (Blois 1958; Lakhali et al. 2011). In its radical form, DPPH absorbs at 517 nm, a 0.1 mM solution of DPPH in methanol was prepared and 160 μL of this solution was added to 40 μL of sample solutions in methanol at different concentrations. Thirty minutes later, the absorbance was measured at 517 nm. The following equation was used to calculate the scavenging of DPPH radical: % inhibition $[(A_{b_{control}} - A_{b_{sample}}) / A_{b_{control}}] \times 100$. DPPH solution in MeOH was used as a control. The curve of the % scavenging activity against the concentration of sample was prepared by the MS Excel-based programme to obtain the IC₅₀. All the tests were conducted in triplicate. The experimental data were expressed as mean ± standard deviation.

3.3.2. ABTS cation radical decolourisation assay

The ABTS scavenging activity was done by the method of Re et al. (1999) with slight modifications. The ABTS was produced by the reaction between 7 mM ABTS in H₂O and 2.45 mM potassium persulfate, stored in the dark at room temperature for 12 h. The oxidation of ABTS commenced immediately, but the absorbance was not maximal and stable until more than 6 h had elapsed. The radical cation was stable in this form for more than 2 days with storage in the dark at room temperature. Before usage, the ABTS solution was diluted to get an absorbance of 0.700 ± 0.020 at 734 nm with ethanol. Then, 180 μL of ABTS solution

were added to 20 μL of sample solution in methanol at different concentrations. After 10 min, the percentage inhibition at 734 nm was calculated for each concentration relative to a blank absorbance (methanol). The scavenging capability of ABTS was calculated using the following equation: ABTS^{•+} scavenging activity

Cupric reducing antioxidant capacity (CUPRAC) assay

CUPRAC was determined according to the method developed by Apak et al. (2004). The method comprises mixing of 40 μL of antioxidant solution with 50 μL of a copper(II) chloride solution, 50 μL of neocuproine alcoholic solution, and 60 μL of ammonium acetate aqueous buffer at pH 7. After 30 min the absorbance was read at 450 nm.

3.3.3. Reducing power assay

The reducing power of the tested compounds was determined according to the method of Oyaizu (1986). 10 μL of sample solutions at different amounts were mixed with 40 μL of 0.2M phosphate buffer (pH 6.6) and 50 μL of potassium ferricyanide (1%). The mixture was incubated at 50 °C for 20 min. After that 50 μL of TCA (10%) was added and mixed with distilled water (40 μL) and 10 μL of ferric chloride (0.1%), the absorbance was read at 700 nm. Higher absorbance of the reaction mixture indicates greater reducing power.

4. Conclusions

In summary, one new flavonoid, along with ten known compounds, were isolated from the aerial parts of *F. longipes* Coss. Compounds **1**, **3**, **4**, **6**, **7** and **10** exhibited a high antioxidant activity towards DPPH free radical scavenging, ABTS, CUPRAC and reducing power assays, respectively compared with BHA, BHT and ascorbic acid which were used as positive controls.

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Disclosure statement

No potential conflict of interest was reported

by the authors.

References

- Ahmed AA. 1999. Sesquiterpene coumarins and sesquiterpenes from *Ferula sinaica*. *Phytochemistry*. 50:109–112.
- Apak R, Güçlü K, Özyürek M, Karademir SE. 2004. Novel total antioxidant capacity index for dietary polyphenols and vitamins C and E, using their cupric ion reducing capability in the presence of neocuproine: CUPRAC method. *J Agric Food Chem*. 52:7970–7981.
- Appendino G, Tagliapietra S, Nano GM, Picci V. 1988. Ferprenin, a prenylated coumarin from *Ferula communis*. *Phytochemistry*. 27:944–946.
- Appendino G, Jakupovic J, Alloatti S, Ballero M. 1997. Daucane esters from *Ferula arrigonii*. *Phytochemistry*. 45:1639–1643.
- Arnoldi L, Ballero M, Fuzzati N, Maxia A, Mercalli E, Pagni L. 2004. HPLC-DAD-MS identification of bioactive secondary metabolites from *Ferula communis* roots. *Fitoterapia*. 75:342–354.
- Asghari J, Atabaki V, Baher E, Mazaheritehrani M. 2016. Identification of sesquiterpene coumarins of oleo-gum resin of *Ferula assa-foetida* L. from the Yasuj region. *Nat Prod Res*. 30:350–353.
- Bensalem S, Jabrane A, Harzallah-Skhiri F, Benjannet H. 2013. New bioactive dihydrofuranocoumarins from the roots of the Tunisian *Ferula lutea* (Poir.). *Bioorg Med Chem Lett*. 23:4248–4252.
- Berrehal D, Khalfallah A, Bencharif-Betina S, Kabouche Z, Kacem N, Kabouche A, Calliste CA, Duroux JL. 2010. Comparative antioxidant activity of two algerian *Reseda* species. *Chem Nat Compd*. 46:385–387.
- Blois MS. 1958. Antioxidant determinations by the use of a stable free radical. *Nature*. 81:1199–1200.
- Dastan D, Salehi P, Aliahmadi A, Gohari AR, Hossein Maroofi M, Afshan Ardalan A. 2016. New coumarin derivatives from *Ferula pseudalliacea* with antibacterial activity. *Nat Prod Res*. 30:2747–2753.
- Hadidi KA, Aburjai T, Battah AK. 2003. A comparative study of *Ferula hermonis* root extracts and sildenafil on copulatory behaviour of male rats. *Fitoterapia*. 74:242–246.
- Iranshahy M, Iranshahi MJ. 2011. Traditional uses, phytochemistry and pharmacology of asafoetida (*Ferula assa-foetida* oleo-gum-resin) – A review. *J Ethnopharmacol*. 134:1–10.
- Kojima K, Isaka K, Ondognii P, Zevgeegiin O, Davgiin K, Mizukami H, Ogihara Y. 1999. Sesquiterpenoid Derivatives from *Ferula feruloides*. *Chem Pharm Bull*. 47:1145–1147.
- Labeled-Zouad I, Labeled A, Laggoune S, Semra Z, Kabouche A, Kabouche Z. 2015. Chemical compositions and antibacterial activity of four essential oils from *Ferula vesceritensis* Coss. & Dur. against clinical isolated and food-borne pathogens. *Rec Nat Prod*. 9:518–525.
- Lakhhal H, Boudiar T, Kabouche A, Laggoune S, Kabouche Z, Topçu G. 2011. Flavonoids and antioxidant activity of *Stachys ocymastrum*. *Chem Nat Compd*. 46:964–966.
- Mabberley DJ. 2008. *Mabberley's Plant Book: A Portable Dictionary of Plants*. 3rd ed. Cambridge University Press.
- Mabry TJ, Markham KR, Thomas MB. 1970. *The systematic identification of flavonoids*. New York, NY: Springer.
- Maggi F, Papa F, Dall'Acqua S, Nicoletti M. 2016. Chemical analysis of essential oils from different parts of *Ferula communis* L. growing in central Italy. *Nat Prod Res*. 30:806–813.
- Maji AK, Banerji P. 2016. Phytochemistry and gastrointestinal benefits of the medicinal spice, *Capsicum annum* L. (Chilli). *J Complement Integr Med*. 13:97–122.
- Meng H, Li G, Huang J, Zhang K, Wang H, Wang J. 2013. Sesquiterpene coumarin and sesquiterpene chromone derivatives from *Ferula ferulaeoides* (Steud.) Korov. *Fitoterapia*. 86:70–77.
- Muhammad A, Tel-Çayan G, Mehmet Öztürk M, Duru ME, Nadeem S, Anis A, Weng Ng S, Raza Shah M. 2016. Phytochemicals from *Dodonaea viscosa* and their antioxidant and anticholinesterase activities with structure–activity relationships. *Pharm Biol*. 54:1649–1655.
- Nacer A, Bernard A, Boustie J, Touzani R, Kabouche Z. 2006. Aglycone flavonoids of *Centaurea tougourensis* from algeria. *Chem Nat Compd*. 42:190–191.
- Nazari ZE, Iranshahi M. 2011. Biologically active sesquiterpene coumarins from *Ferula* species. *Phytother Res*. 25:315–323.
- Oyaizu M. 1986. Studies on products of browning reactions: antioxidative activities of browning reaction prepared from glucosamine. *Jpn J Nutr*. 44:307–315.
- Razavi SM, Janani M. 2015. A new ester coumarin

- from *Ferula Persica* wild, indigenous to Iran. Nat Prod Res. 29:717–721.
- Razavi SM, Nahar L, Talischi H, Sarker SD. 2016. Ferulone A and ferulone B: two new coumarin esters from *Ferula orientalis* L. roots. Nat Prod Res. 30:2183–2189.
- Re R, Pellegrini N, Proteggente A, Pannala A, Yang M, Rice-Evans C. 1999. Antioxidant activity applying an improved ABTS radical cation decolorization assay. Free Radic Bio Med. 26:1231–1237.
- Sadraei H, Asghari GR, Hajhashemi V, Kolagar A, Ebrahimi M. 2001. Spasmolytic activity of essential oil and various extracts of *Ferula gummosa* Boiss. on ileum contractions. Phytomedicine. 8:370–376.
- Timmermann BN, Joseph JH, Shivanand D, Jolad KH, Schram RE, Klenck RB. 1983. Constituents of *Chrysothamnus paniculatus* 3: 3,4,5-Tricaffeoylquinic Acid (a new shikimate prearomatic) and 3,4-, 3,5- and 4,5-dicaffeoylquinic acids. J Nat Prod. 46:365–368.
- Touafek O, Kabouche Z, Brouard I, Barrera-Bermejo J. 2011. Flavonoids of *Campanula alata* and their antioxidant activity. Chem Nat Compd. 46:8259–8826.
- Wolbiś M. 1989. Flavonol glycosides from *Sedum album*. Phytochemistry. 28(8):2187–2189.
- Yokozawa T, Kim HY, Cho EJ, Choi JS, Chung HY. 2002. Antioxidant effects of isorhamnetin 3, 7-di-O-beta-D-glucopyranoside isolated from mustard leaf (*Brassica juncea*) in rats with streptozotocin-induced diabetes. J Agric Food Chem. 50:5490–5495.