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Volatile composition and antioxidant activity of the essential oil and hydrosol extract from the aerial parts of *Ferula communis* growing in Algeria

Asma Allal¹, Nassima Benmansour², Chaouki Selles^{2*}, Alain Muselli³

¹Department of Material Science, Faculty of Sciences and Technology, University of Ain Temouchent, Ain Temouchent, Algeria

²Department of Chemistry, Faculty of Science, Laboratory of Natural and Bioactive Substances LASNABIO, University of Tlemcen, Tlemcen, Algeria

³UMR CNRS 6134, Laboratory of Natural Products Chemistry CPN, University of Corse Campus Grimaldi BP 52, Corte, France

*Correspondence: Chaouki Selles (chaouki.selles@univ-tlemcen.dz)

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ABSTRACT

In traditional medicine, *Ferula communis* L. (Apiaceae) is used to treat various ailments, including fever and infections. This study investigated the chemical profile and antioxidant potential of the essential oil and hydrosol extract derived from the aerial parts of *F. communis* growing in Algeria. The essential oil was obtained by hydrodistillation, while the hydrosol extract was prepared via hydrodistillation followed by liquid-liquid extraction. Chemical compositions were determined by GC and GC-MS. DPPH and reducing power (Oyaizu) assays were employed to evaluate the antioxidant capacity. The oil's composition was dominated by sesquiterpenes (71.5%), with (*E*)- β -caryophyllene (22.1%) as the major constituent. Conversely, the hydrosol extract was primarily composed of oxygenated compounds (58.9%), mainly alcohols. The hydrosol extract exhibited higher antioxidant activity than the essential oil, with an IC_{50} value of 15.19 mg mL⁻¹ in the DPPH assay and an EC_{50} value of 1.65 mg mL⁻¹ in the reducing power assay, compared with 21.11 mg mL⁻¹ and 4.64 mg mL⁻¹, respectively, for the essential oil. This study represents the first report on the composition of *F. communis* hydrosol extract, highlighting its antioxidant potential and warranting further investigation.

Keywords: Essential oil, Hydrosol extract, Antioxidant activity, *Ferula communis* L., GC-MS

INTRODUCTION

Oxidative stress is recognized as a key contributor to the pathogenesis of numerous diseases and can negatively affect neuronal health (Barbosa et al., 2020). Antioxidants are substances capable of inhibiting or delaying lipid peroxidation by scavenging free radicals and breaking chain reactions (Liu, 2022). Driven by safety and nutritional concerns associated with synthetic antioxidants, the search for natural alternatives from aromatic plants has intensified (Embuscado, 2015). Essential oils (EOs) are complex mixtures of volatile compounds with diverse biological activities, leading to their expanding use in food preservation, medicine, and cosmetics (Amorati et al., 2013). During the distillation process, a byproduct known as hydrosol extract is obtained. While EOs have been extensively studied, hydrosol extracts, which contain water-soluble compounds and trace volatiles, remain less investigated despite

their distinct organoleptic and biological properties (Shen et al., 2017; D'Amato et al., 2018; Yin et al., 2023).

The Apiaceae family is one of the most researched plant families, comprising approximately 3780 species, primarily in the Mediterranean and Central Asia (Sayed-Ahmad et al., 2017). Within this family, the genus *Ferula*, with about 180 species, has gained significant interest due to its diverse bioactivities (Yaqoob and Nawchoo, 2016). In Algeria, the flora includes species such as *Ferula communis* L., *F. lutea* (Poiret) Maire, and *F. tingitana* L., as well as the endemic *F. cossoniana* Batt. & Trab. and *F. vesceritensis* Coss. & Dur. (Quézel and Santa, 1962; Ozenha, 2004). Commonly known as « alk kelakh » or « fassoukh », *F. communis* is a perennial Mediterranean plant adapted to various soil types (Hammiche et al., 2013).

Historically, *Ferula* species have been used in traditional medicine to treat intestinal parasites, skin infections, diabetes, rheumatism, and neurological disorders (Bnouham et al., 2002; Kljuykov et al., 2004; Akaberi et al., 2015; Mohammadhosseini et al., 2019; Shukla et al., 2024). Locally, *F. communis* is specifically applied for treating fever, headaches, throat infections, and as an antispasmodic or diuretic agent (Boulos, 1983; Bellakhdar et al., 1991; Hammiche et al., 2013). However, its ingestion requires caution, as it has been linked to poisoning cases in cattle and humans due to specific toxic constituents (Miski and Jakupovic, 1990).

Previous chemical investigations of *F. communis* EOs have revealed substantial variability linked to geographical origin, plant part, and extraction methods. Studies on populations from Corsica, Italy, Greece, and Tunisia have identified diverse profiles dominated by either monoterpene hydrocarbons (e.g., myrcene, α -pinene) or various sesquiterpenoids (Ferrari et al., 2005; Maggi et al., 2009; Manolakou et al., 2013; Maggi et al., 2016; Ngwir et al., 2016; Rahali et al., 2016; Alansari et al., 2024). Furthermore, the choice of extraction technique, such as hydrodistillation versus supercritical CO₂, significantly influences the resulting chemical composition (Marongiu et al., 2005). In Algeria, research on this species remains limited, with only one previous report on fresh aerial parts identifying myrcene and α -pinene as major components (Chibani et al., 2012).

Pharmacologically, *F. communis* exhibits a wide spectrum of activities, including antibacterial, cytotoxic, antiviral, and antiproliferative effects (Al-Yahya et al., 1998; Mossa et al., 2004; Poli et al., 2005; Alruways, 2023; Hamidian et al., 2024). Specific compounds like ferutinin have been associated with antitumoral, aphrodisiac, and hypoglycemic

properties (Zavatti et al., 2016; Sattar and Iranshahi, 2017; Latifi et al., 2019). Despite these findings, the chemical profile and antioxidant potential of its hydrosol extracts have not been scientifically investigated to date.

The present study aims to characterize, for the first time, the chemical composition of EOs and a liquid-liquid hydrosol extract obtained from wild Algerian *F. communis* using GC and GC-MS, while evaluating their antioxidant properties.

MATERIALS AND METHODS

Plant material

The aerial parts of *F. communis* were collected in the Tounane area (35°01'54.0"N 1°50'25.7"W, at 100 m altitude), located about 50 km from Tlemcen, in northwestern Algeria. The collection was performed in March 2022 during the flowering stage. After collection, the plant material was carefully washed with distilled water and then air-dried in the shade, protected from direct light, at room temperature for 10 days until a constant weight was achieved. The plant authentication was performed by taxonomists from the “Laboratory of Ecology and Ecosystem Management,” and a voucher specimen (No. NB.FC1.3.17) was deposited in the herbarium of the University of Tlemcen, Algeria.

Isolation of the essential oil and hydrosol extract

We extracted the essential oil from 800 g of dried aerial parts via hydrodistillation for 4 h in a Clevenger-type apparatus with 4 L of distilled water. The resulting oil was then dried over anhydrous sodium sulfate (Na₂SO₄). To obtain the hydrosol extract, we recovered the first liter of the condensed aqueous phase and subjected it to liquid-liquid extraction three times using 300 mL of diethyl ether at room temperature. The combined organic layers were evaporated to dryness and subsequently dried over Na₂SO₄. Both the final oil and the hydrosol extract were stored in sealed amber glass vials at 4 °C until required for analysis.

GC and GC-MS analysis conditions

The chemical composition of the essential oil and hydrosol extract was analyzed using a PerkinElmer Clarus 600 gas chromatograph (Waltham, MA, USA) equipped with a single injector and a dual flame ionization detection (FID) system. Analyses were performed on two fused-silica capillary columns: a non-polar Rtx-1 (polydimethylsiloxane) and a polar Rtx-Wax (polyethylene glycol) (both 60 m × 0.22 mm i.d., film thickness 0.25 µm). The oven

temperature program was set to start at 60 °C, then ramped to 230 °C at a rate of 2 °C min⁻¹, followed by an isothermal hold for 35 min. Both injector and detector temperatures were maintained at 280 °C. Helium was used as the carrier gas with a constant flow rate of 0.7 mL min⁻¹. An injection volume of 0.2 µL was used with a split ratio of 1:50.

For the GC-MS analysis, a PerkinElmer TurboMass quadrupole analyzer was used, coupled to a PerkinElmer Autosystem XL equipped with the same Rtx-1 and Rtx-Wax columns. The oven program and carrier gas conditions were identical to those described for GC-FID. The ion source temperature was set at 150 °C and the ionization energy (EI) at 70 eV. EI mass spectra were acquired over a mass range of 35–350 Da with a scan time of 1 s. For GC-MS, the split ratio was adjusted to 1:80.

Component identification and quantification

The identification of individual components was carried out using a two-fold method. First, retention indices (RI) were determined on both polar and non-polar columns via linear interpolation against a series of n-alkanes (C8–C30) and compared with those of authentic compounds or literature data (König et al., 2001). Second, identifications were confirmed by matching the experimental mass spectra against commercial libraries (NIST 08 and Wiley) and the in-house library of the ‘Laboratoire Chimie des Produits Naturels’ (University of Corsica, France).

The relative concentration of each component was determined using GC-FID area normalization. The percentages were calculated from the peak areas obtained on the Rtx-1 column without the use of response factor corrections. All analyses were performed in triplicate (n=3) to ensure reproducibility.

Estimation of antioxidant activity

2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging effect

We determined the free-radical scavenging effect of the extracts using the DPPH method, following the protocol of C. Sánchez-Moreno (Sánchez-Moreno, 2002), which is a modified version of the original Blois (1958) method that includes a minor change as detailed in our previous work (Allal et al., 2019). The samples were tested at concentrations ranging from 1 to 30 mg mL⁻¹. Briefly, a 50 µL sample was added to 1950 µL of a freshly prepared methanolic DPPH solution (0.025 g·L⁻¹). After vigorous shaking, we incubated the mixture for 30 min in the dark at ambient temperature. The absorbance was then measured at 517 nm against a methanol blank using a UV-Visible spectrophotometer (OPTIZEN POP, Daejeon,

South Korea). We calculated the DPPH radical inhibition percentage using the following formula: Inhibition (%) = $[(A_0 - A)/A_0] \times 100$, where A_0 and A represent the absorbance of the control and the sample, respectively. Ascorbic acid served as the positive control for this assay. The scavenging activity on DPPH radical was expressed as IC_{50} , which is the concentration of extract needed to decrease the initial absorbance by 50%; The IC_{50} value were determined using linear regression analysis. All experiments were conducted in triplicate (n=3).

Reducing power assay (Oyaizu assay)

The reducing power assay for the extracts was performed based on the procedure originally reported by Oyaizu (1986), with slight modifications as described in our earlier study (Allal et al., 2019). The samples were tested at concentrations ranging from 1 to 10 mg mL^{-1} . Briefly, 2.5 mL of phosphate buffer (0.2 mol L^{-1} , pH 6.6) and 2.5 mL of a 1% potassium ferricyanide solution were added to varying concentrations of the oil or hydrosol extracts, previously diluted in 1 mL of methanol. The resulting mixtures were incubated at 50 °C for 20 minutes. Once cooled to room temperature, 2.5 mL of 10% trichloroacetic acid was introduced. After centrifugation at 570 $\times g$ for 10 minutes, 2.5 mL of the supernatant was combined with 5.5 mL of distilled water and 0.5 mL of 0.1 % ferric chloride solution. The absorbance was then measured at 700 nm after 10 minutes using a UV-Visible spectrophotometer (OPTIZEN POP, Daejeon, South Korea). Ascorbic acid served as the reference antioxidant. An increase in absorbance indicated a greater reducing power. The results were reported as EC_{50} values, representing the concentration at which the absorbance reached 0.5. The EC_{50} values were calculated using linear regression analysis. All analyses were conducted in triplicate (n=3).

Statistical analysis

All assays were performed in analytical triplicates (n=3), and the results were expressed as mean $\pm$ standard deviation (SD). All assays were performed in analytical triplicate (n=3), and the results are expressed as mean $\pm$ standard deviation (SD). As these were analytical replicates, no inferential statistical tests were applied.

RESULTS AND DISCUSSION

Essential oil and hydrosol extract chemical compositions

Hydrodistillation of the aerial parts of *F. communis* L. afforded a pale yellow essential oil, while liquid-liquid extraction provided a yellowish hydrosol extract, with yields of 0.05% (w/w) and 0.01% (w/w) respectively. We calculated the yield percentage (w/w) for both the oil and the hydrosol extract relative to the initial dry matter weight.

The essential oil yield obtained in our study from mixed aerial parts is consistent with the findings of Maggi et al. (2009) and Maggi et al. (2016), who reported yields ranging from 0.02-0.07% and 0.03-0.13%, respectively (Maggi et al., 2009), (Maggi et al., 2016). However, our observed yield was lower than those reported by Ngwir et al. (2016), Demirpolat et al. (2018), and Chibani et al. (2012), whose findings ranged from 0.11-0.18%, 0.2%, and 0.8%, respectively (Chibani et al., 2012; Ngwir et al., 2016). Furthermore, the total volatiles of aerial parts obtained by supercritical fluid extraction displayed a better yield than ours with an average of 0.14% (Marongiu et al., 2005). It is well-established that several factors can influence the yield of plant EOs. These include genetic and environmental conditions like altitude, temperature, and humidity (Ložienė and Venskutonis, 2005; Rajabi et al., 2014; Moghaddam and Farhadi, 2015; Mollaei et al., 2020). as well as the harvest period and storage duration (Selles et al., 2013; Liu et al., 2019). Otherwise, diverse extraction variables may influence EOs yields, such as extraction method, extraction time, extraction temperature, and solvent / material ratio (Azmir et al., 2013; Aguele et al., 2023).

We analyzed the chemical compositions of the essential oil and hydrosol extract by GC-FID and GC-MS, with the detailed results presented in Table 1. Based on retention indices, we identified a total of 73 components in the essential oil and 56 in the hydrosol extract, which accounted for 98.5% and 97.1% of their total compositions, respectively.

The chemical analysis revealed that sesquiterpenes were the most abundant class of compounds in both the essential oil (71.5%) and the hydrosol extract (47.9%). The other predominant classes that come after are monoterpenes (13.6% and 22.3%, respectively) and non terpenic compounds (12.3% and 26.6%, respectively). Hydrosol extract showed only oxygenated compounds dominated by alcohols (58.9%) ; however, no hydrocarbons were found.

F. communis EOs were characterized by a high percentage of (E)- β -caryophyllene (22.1%) followed by caryophyllene oxide (5.1%), (E)-nerolidol (4.9%), α -cadinol (4.1%), and γ -

eudesmol (2.9%) while the hydrosol extract was dominated by caryophyllene oxide (8.1%), (E)-nerolidol (7.5%), linalool (6.5%), α -cadinol (6.1%), and γ -eudesmol (5.8%) taking into account other compounds at significant percentages such as hexadecanoic acid (4.6%), hinesol (4.5%), and β -ionone (4.1%). Therefore, to our knowledge, an essential oil composition with these major components has not been previously reported for the genus *Ferula*.

The pharmacological potential of these various components warrants further consideration. Indeed, owing to their characteristic woody and spicy aromas, both (E)- β -caryophyllene and caryophyllene oxide have been utilized as flavors and fragrances since the 1930 (Sköld et al., 2006). Similarly, (E)-nerolidol, a major component in both our essential oil and hydrosol extract, is widely employed as a food-flavoring agent and in various cosmetic and non-cosmetic products (Sekkout et al., 2024). Our findings on the chemical composition of *F. communis* essential oil differ from those of Demirpolat et al. (2018), who identified α -eudesmol (35.5%) as the main constituent and reported only 0.6% of nerolidol in the Turkish EOs.

Consistent with the aforementioned studies (Ferrari et al., 2005; Maggi et al., 2009; Manolakou et al., 2013; Maggi et al., 2016; Nguir et al., 2016; Rahali et al., 2016; Jiang et al., 2022), the majority of the components identified in our EOs belong to the monoterpene and sesquiterpene classes. These terpenoid compounds have various interesting biological activities like antioxidant, antimicrobial (Dahham et al., 2015) neuroprotective (Chang et al., 2013; Askari and Shafiee-Nick, 2019), anticonvulsant (Hashiesh et al., 2021), antidiabetic (Basha and Sankaranarayanan, 2014; Basha and Sankaranarayanan, 2016) and chemopreventive effects (Fidyt et al., 2016).

In addition, other exciting biological activities of these compounds have been reported (Astani et al., 2011; Wang et al., 2018).

Furthermore, the wide range of components identified in all the samples from published researches highlight the great EOs chemical variability of *F. communis*. However, direct comparison of these findings is challenging because the chemical composition of EOs is influenced by numerous factors, including both exogenous and endogenous ones (Barra, 2009). In fact, various extraction methods are confirmed to be an important factor in influencing the chemical composition of volatile constituents (Zhu et al., 2020). The biosynthesis of secondary metabolites like those in EOs is particularly sensitive to developmental stages and climatic conditions, including temperature, altitude, and

precipitation levels (Sangwan et al., 2001; Barra, 2009; Li et al., 2020). In addition, the variation in the compositions of EOs can be due to genetic factors (Nurzyńska-Wierdak et al., 2012).

Estimation of antioxidant activity

We evaluated the antioxidant capacities of both the essential oil and the hydrosol extract using two common assays: DPPH and reducing power assay. Ascorbic acid served as the synthetic antioxidant standard (positive control). To further quantify the antioxidant activity, we calculated the IC₅₀ (for DPPH) and EC₅₀ (For reducing power) values, which are presented in Table 2. A lower IC₅₀ or EC₅₀ value signifies a stronger antioxidant activity.

When DPPH is used as a reagent to assess the in vitro free-radical scavenging activity of *F. communis* extracts, its purple color fades to pale yellow upon accepting an electron from a radical scavenger. Similarly, the reductive capability was assessed by monitoring the transformation of Fe³⁺ to Fe²⁺.

Based on the IC₅₀ and EC₅₀ values from both assays, the hydrosol extract showed slightly higher antioxidant activity than the essential oil, although both were less potent than the ascorbic acid standard. The superior performance of the *F. communis* hydrosol extract is notable, with IC₅₀ of 15.19 ± 0.22 mg mL⁻¹ (DPPH) and EC₅₀ of 1.65 ± 0.01 mg mL⁻¹ (reducing power assay), compared to 21.11 ± 0.39 mg mL⁻¹ and 4.64 ± 0.49 mg mL⁻¹ for the essential oil, respectively.

It is important to note that the observed antioxidant activity is dependent on the chemical classes present in both the essential oil and the hydrosol extract (Allal et al., 2019). Specifically, the reducing power of such extracts has often been linked to a high content of polyphenolic compounds (Hsieh et al., 2008). Indeed, the interesting activity of hydrosol extract in comparison to EOs may be due to its high concentration in oxygenates, especially phenolic compounds (Lemouchi et al., 2017; Benmansour et al., 2020; Değirmenci and Erkurt, 2020). Conversely, the moderate antioxidant activity of the essential oil could be attributed to the prolonged extraction time, during which some hydrophilic bioactive compounds may have been lost to the aqueous phase or degraded by the high temperature of the boiling water (Djeridane et al., 2006; López et al., 2007).

CONCLUSIONS

This study was designed to evaluate the chemical composition and antioxidant activity of the essential oil and a liquid-liquid extracted hydrosol extract from *Ferula communis* L. native to Algeria.

To the best of our knowledge, this work represents the first report on the chemical profile of a hydrosol extract from any *Ferula* species.

Our findings regarding the essential oil composition of *F. communis* differ from previously reported analyses. Specifically, our oil was characterized by a high concentration of (E)- β -caryophyllene. EOs composition and yield among *Ferula* species exhibited diversity due to the geographical environmental conditions and other factors. Furthermore, the hydrosol extract, being a polar mixture, showed a high concentration of interesting oxygenated bioactive compounds, with caryophyllene oxide, (E)-nerolidol, linalool, α -cadinol, and γ -eudesmol present in appreciable amounts.

The notable antioxidant activity of the hydrosol extract, when compared to the essential oil, may be related to the presence of phenolic compounds and their characteristic hydroxyl groups. Therefore, the hydrosol extract should be considered as a valuable co-product of hydrodistillation that deserves to be valorized. However, further investigations would be required on main components to elucidate possible more interesting antioxidant activities.

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CRedit AUTHORSHIP STATEMENT

A. ALLAL: analyzed chemical profiles of the oils using GC-MS, refined the manuscript, and helped structure the discussion section **N. BENMANSOUR**: performed the antioxidant activity, Involved in discussing and interpreting the results **C. SELLES**: initiated the study idea, oversaw the research activities, and led the drafting of the manuscript **A. MUSELLI**: organized chromatographic analysis

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no competing interests, financial or otherwise, that are relevant to the work described in this manuscript.

ETHICAL APPROVALS AND RESEARCH PERMITS

No ethical approval or research permit was required for this study.

DATA AVAILABILITY STATEMENT

All data generated or analysed during this study are included in this published article. Additional information is available from the corresponding author upon reasonable request.

AI USE STATEMENT

The authors declare that no generative AI or AI-assisted technologies were used in the preparation of this manuscript.

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Table 1. Chemical compositions of the essential oil and hydrosol extract of *F. communis* (Retention indices of literature on the apolar column (**König et al., 2001**))

N°	Compound ^a	RI _a ^{literature}	RI _a ^b	RI _p ^c	Essential oil ^d (%)	Hydrosol (%)
1	Hexanal	770	769	1516	0.2	0.2
2	Furfural	820	823	1454	0.2	0.4
3	(E)-3-Hexanol	832	831	1324	0.1	0.3
4	Hexanol	854	844	1337	0.2	0.9
5	Benzaldehyde	929	928	1501	0.1	1.1
6	α -Pinene	931	930	1018	1.3	–
7	Octen-3-ol	959	958	1443	–	0.6
8	6-Methyl-hept-5-en-2-one	966	968	1324	tr	0.2
9	β -Pinene	970	972	1105	0.4	–
10	Myrcene	976	978	1153	1.1	–
11	α -Phellandrene	1002	1004	1142	0.2	–
12	Phenylacetaldehyde	1011	1009	1616	–	1.5
13	Limonene	1020	1019	1193	0.5	–
14	(E)-Sabinene hydrate	1051	1051	1458	tr	0.9
15	Octanol	1058	1556	1540	0.2	0.5
16	(E)-Linalool oxide	1058	1559	1427	tr	0.2
17	(Z)-Linalool oxide	1073	1070	1434	–	0.3
18	Linalool	1083	1084	1531	2.3	6.5
19	Camphor	1123	1129	1511	0.7	1.4
20	(E)-2-Nonenal	1135	1132	1554	0.3	0.4
21	Borneol	1150	1155	1683	0.2	0.2
22	Terpinen-4-ol	1164	1160	1579	0.1	0.5
23	α -Terpineol	1176	1172	1675	2.7	3.6
24	Myrtenol	1178	1178	1760	0.9	0.6
25	Verbenone	1184	1182	1681	0.2	0.3

26	β -cyclocitral	1195	1192	1606	0.3	0.4
27	Nerol	1210	1208	1769	0.5	2.1
28	Carvone	1214	1213	1731	0.8	0.6
29	Geraniol	1232	1233	1829	1.2	2.9
30	(E)-Myrtanol	1234	1241	1869	0.1	0.3
31	Bornyl acetate	1269	1266	1569	tr	0.5
32	Carvacrol	1278	1282	2212	0.1	1.4
33	Eugenol	1331	1326	2158	tr	0.1
34	Neryl acetate	1342	1333	1697	tr	0.2
35	Geranyl acetate	1362	1358	1756	0.6	1.5
36	Methyl eugenol	1369	1367	2110	0.5	1.6
37	α -Copaene	1379	1371	1483	1.2	–
38	Neryl acetone	1410	1407	1830	0.4	3.5
39	(E)-β-Caryophyllene	1424	1417	1588	22.1	–
40	Geranyl acetone	1430	1425	1846	1.4	2.3
41	β -Copaene	1431	1435	1591	0.8	–
42	(E)- β -Farnesene	1446	1446	1664	1.1	–
43	α -Himachalene	1450	1449	1629	0.6	–
44	α -Humulene	1456	1458	1652	1.7	–
45	Allo-aromadendrene	1462	1459	1944	0.3	–
46	β -Ionone	1466	1467	1934	3.2	4.1
47	B-Acoradiene	1468	1468	1678	2.5	–
48	α -Curcumene	1471	1474	1738	2.3	–
49	γ -Curcumene	1474	1478	1660	1.9	–
50	β -Selinene	1483	1489	1705	2.1	–
51	2-Tridecanone	1491	1491	1808	0.6	1.9
52	(E, E)- α -Farnesene	1498	1501	1745	1.2	–
53	(E)- β -Bisabolene	1503	1505	1775	0.7	–
54	γ -Cadinene	1507	1510	1771	1.6	–
55	δ -Cadinene	1515	1519	1757	1.2	–
56	(E)- α -Bisabolene	1531	1529	1748	0.4	–
57	α -Cadinene	1535	1534	1815	0.2	–

58	(E)-Nerolidol	1553	1554	2059	4.9	7.5
59	Epiglobulol	1558	1559	2003	0.3	0.8
60	Spathulenol	1572	1565	2132	2.5	3.7
61	Caryophyllene oxide	1578	1582	1951	5.1	8.1
62	Globulol	1589	1589	2074	0.4	0.6
63	Guaiol	1591	1591	2081	0.3	–
64	Viridiflorol	1591	1599	2086	0.5	0.5
65	Humulene epoxide II	1602	1609	2032	1.3	1.9
66	γ- Eudesmol	1610	1613	2192	2.9	5.8
67	Cubenol	1630	1625	2069	1.2	2.6
68	τ -Cadinol	1632	1632	2135	2.4	3.9
69	Hinesol	1636	1637	2182	2.8	4.5
70	β -Eudesmol	1644	1639	2249	0.3	0.5
71	α-Cadinol	1645	1649	2225	4.1	6.1
72	α -Eudesmol	1653	1654	2201	Tr	0.2
73	Bulnesol	1659	1658	2206	0.1	0.3
74	α -Bisabolol	1673	1673	2221	0.3	0.4
75	(Z, E)-Farnesol	1694	1695	2332	0.2	0.5
76	Tetradecanoic acid	1761	1751	2648	0.2	0.1
77	Phytone	1817	1822	2113	0.7	–
78	(E, Z)-Farnesyl acetone	1871	1875	2344	0.1	0.2
79	Hexadecanoic acid	1951	1948	2859	2.1	4.6
80	Geranyl linalool	2019	2013	2530	0.2	0.3
81	(Z)-Phytol	2080	2090	2575	0.6	–
82	(E)-Phytol	2114	2112	2622	0.3	–
83	Pentacosane	2500	2494	2498	1.2	–
	Total identification %				98.5	97.1
	Oxygenated diterpenes				1.1	0.3
	Sesquiterpenes compounds				71.5	47.9
	Oxygenated sesquiterpenes				29.6	47.9
	Sesquiterpene hydrocarbons				41.9	–
	Monoterpenes compounds				13.6	22.3

	Oxygenated monoterpenes				10.1	22.3
	Monoterpene hydrocarbons				3.5	–
	Non terpenic compounds				12.3	26.6
	Non terpenic oxygenated				11.1	26.6
	Non terpenic hydrocarbons				1.2	–
	Alcohols				32.7	58.9

^a Elution order on apolar column (Rtx-1)

^b Retention indices on the apolar Rtx-1 column (RIa)

^c Retention indices on the polar Rtx-Wax column (RIp)

^d Normalized % abundances given on the apolar column

tr, trace (< 0.05%), RI, retention indices, Bold values show the major components

Table 2. DPPH and reducing power assay radical-scavenging activities (IC₅₀ / EC₅₀) of essential oil and hydrosol extract from *Ferula communis* L.

Extracts	DPPH (IC ₅₀ mg mL ⁻¹)	Reducing power assay (EC ₅₀ mg mL ⁻¹)
Essential oil	21.11 ± 0.39	4.64 ± 0.49
Hydrosol extract	15.19 ± 0.22	1.65 ± 0.01
Ascorbic acid	0.04 ± 0.01	0.01 ± 0.01

Values are expressed as mean ± standard deviation (n=3). IC₅₀ values refer to the DPPH assay, and EC₅₀ values refer to the reducing power assay.