Acta Pharm. Sci. Vol 64:(1), 2026
Original article
DOI: 10.23893/1307-2080.APS6401

# Phytochemical profile and antioxidant activity potential of *Campanula rapunculoides* L. subsp. *rapunculoides*

Tugba IDUG[1*], Hikmet Gulben GUC[1,2] , Fatma TOSUN[1]

1 Istanbul Medipol University, School of Pharmacy, Pharmacognosy, Istanbul, Türkiye
2 Istanbul University, Institute of Graduate Studies in Health Sciences, Pharmacognosy, Istanbul, Türkiye

**ABSTRACT**

*Campanula* species have been reported to contain polyphenols, steroids, phenylpropanoid derivatives, triterpenes, and polyacetylenes. They also show antioxidant, antimicrobial, cytotoxic, enzyme inhibitory, wound healing, and anti-inflammatory activities. There are no reports in the literature dealing with the activity and phytochemical profile of *Campanula rapunculoides* subsp. *rapunculoides* (Campanulaceae). In this study, the antioxidant activity and phytochemical profile of the methanol extract prepared from the aerial parts of the plant were investigated. Quantitative assays revealed high levels of phenolics (111.36 mg GAE/g), flavonoids (91.27 mg QE/g), phenolic acids (29.73 mg CAE/g) and proanthocyanidins (27.84 mg ECE/g). Antioxidant activity, assessed through DPPH, FRAP, and CUPRAC methods, demonstrated potent radical scavenging and reducing capacities, with results comparable to reference standards. These findings highlight *C. rapunculoides* subsp. *rapunculoides* as a promising source of natural antioxidants, supporting its potential use in functional foods, nutraceuticals, and phytopharmaceuticals targeting oxidative stress-related conditions.

**Keywords**: antioxidant activity, *Campanula rapunculoides* subsp. *rapunculoides*, phenolic compounds, phytochemical profile

* Corresponding author: Tugba IDUG
E-mail: tidug@medipol.edu.tr
ORCIDs:
Tugba IDUG: 0000-0001-8241-647X
Hikmet Gulben GUC: 0009-0002-8384-7647
Fatma TOSUN: 0000-0003-2533-5141
(Received 9 Sep 2025, Accepted 25 Nov 2025)

© Medipol University Press / ISSN: 2636-8552

## INTRODUCTION

The genus *Campanula* includes 452 accepted species distributed in Europe, Asia, North Africa, North America, Alaska and Greenland[1]. *Campanula* is represented by 129 species in Türkiye and 74 of them are endemic[2,3]. Species are annual, biennial, or predominantly perennial herbs (sometimes suffruticose), frequently adapted to rocky slopes, screes, steppes, and forest edges. Leaves are predominantly arranged alternately, including larger petiolate basal blades and increasingly smaller cauline leaves; blade shapes range from ovate to lanceolate, with edges that are either whole or serrate. Flowers may be solitary or arranged in racemose to paniculate inflorescences, generally including a 5-lobed calyx and a 5-lobed corolla that varies from campanulate to funnelform or star-shaped, predominantly blue-violet but occasionally white or pink[4].

*Campanula* species are known as "bell flower" and have historically been used for treating inflammatory disorders and abdominal pain[5,6]. Additionally, they have been documented in ethnomedicinal practices for the management of epilepsy, neurological conditions, headaches, rheumatism, tonsillitis, laryngitis, bronchitis and warts[7-9]. In addition, certain *Campanula* species are traditionally consumed as food[10]. Fresh roots have traditionally been chewed for the treatment of lung and heart ailments and infusions have been used to relieve ear inflammations. Additionally, a decoction of the plant has been used for the treatment of sore eyes[11].

Plants represent abundant natural sources of diverse bioactive phenolic compounds, which offer numerous health promoting effects for both humans and animals[12]. In recent decades, growing scientific attention has been directed toward phenolic compounds, largely due to their strong antioxidant activities that contribute to the prevention of chronic conditions and disorders associated with oxidative stress[13].

Oxidative stress is defined as a disruption in the balance between oxidants and antioxidants within cells, primarily due to the excessive production of reactive oxygen species (ROS)[14]. These include superoxide anions, hydroxyl radicals, lipid peroxyl radicals, nitric oxide and peroxynitrite, which can lead to structural and functional damage in essential biomolecules such as nucleic acids, proteins and lipids.

This damage manifests through various mechanisms, including the accumulation of 8-hydroxydeoxyguanosine in DNA, oxidative modifications of proteins and lipid peroxidation resulting in toxic products such as malondialdehyde and 4-hydroxynonenal[15]. Persistent oxidative stress plays a critical role in the

pathogenesis of numerous chronic diseases, including cancer, cardiovascular disorders, diabetes, neurodegenerative diseases and kidney dysfunction. To counteract these effects, cells rely on a complex antioxidant defense system, composed of both endogenous and exogenous antioxidants. These compounds protect cellular components through different mechanisms, such as scavenging free radicals, chelating transition metal ions and inhibiting oxidative reactions[16].

Previous studies have demonstrated that several *Campanula* species possess antioxidant, enzyme-inhibitory, antimicrobial, cytotoxic, anti-inflammatory and wound-healing activities[17-23]. Consistent with these bioactivities, *Campanula* species have also been reported to contain diverse phytochemical constituents, including polyphenols, steroids, phenylpropanoid derivatives, triterpenes and polyacetylenes, which likely underpin their observed pharmacological potential[20-25].

Various flavonoids, flavones and anthocyanins have been identified in the *Campanula* genus, notably including luteolin, quercetin and kaempferol, as well as their glycosylated derivatives. Prominent examples comprise luteolin 7-O-rutinoside, luteolin 3′,7-diglucoside, luteolin 7-O-glucoside, quercetin 3-O-glucoside, quercetin 3-O-D-galactoside, kaempferol 3-O-D-glucopyranoside and kaempferol 3-O-D-galactopyranoside. In addition, anthocyanins such as violdephin and saponin-type compounds including bisdeacylplatyconin, monodeacylcampanin and campanin have been isolated from the genus[11].

Based on this phytochemical depth, previous studies have found that several *Campanula* species are rich in phenolics. In leaf extracts, rutin is the main phenolic, while flower and foliar tissues contain chlorogenic acid. Also, stem tissues have low phenolics, indicating a notable organ-specific distribution of secondary metabolites in the species[12].

To the best of our knowledge, none of the research was found to be conducted on the activities and phytochemical profile of *Campanula rapunculoides* subsp. *rapunculoides*. This study is the first report concerning the *in vitro* antioxidant activity and phenolic, phenolic acid, flavonoid and proanthocyanidin contents of the aerial parts of *Campanula rapunculoides* subsp. *rapunculoides*. As part of this study, the antioxidant activity of *Campanula rapunculoides* subsp. *rapunculoides* was evaluated using the DPPH radical scavenging assay, Ferric reducing antioxidant power (FRAP), and Cupric reducing antioxidant capacity (CUPRAC) method. In addition, total phenolic content (TPC), total phenolic acids content (TPAC), total flavonoid content (TFC), and total proanthocyanidin content (TPRAC) were determined by several methods.

## METHODOLOGY

### Plant material

Aerial parts of *Campanula rapunculoides* subsp. *rapunculoides* were collected from the Altındere region of Trabzon. A voucher specimen (IMEF 1195) was deposited in the Istanbul Medipol University School of Pharmacy Herbarium (ISTANBUL).

### Chemicals

All chemicals and reference standards used in the experimental procedures were obtained from Sigma-Aldrich (St. Louis, MO, USA). All chemicals were of analytical grade quality.

### Preparation of extracts

The aerial parts of the plant were ground into a fine powder and prepared for extraction. 100 g of the plant material was macerated with methanol at room temperature and the procedure was repeated three times. The combined macerates were then concentrated to dryness using a rotary evaporator, yielding 13.5158 g (13.52%, w/w) of crude extract. The obtained methanol extracts were kept in the refrigerator (+4°C) until used in the analyses.

### Quantitative assessment of phytochemical profile

### Total phenolic content

The total phenolic content of the extracts was determined using the Folin-Ciocalteu colorimetric method[26]. For the assay, 5 µL of each sample was mixed with 25 µL of 0.2 N Folin–Ciocalteu reagent and 145 µL of distilled water in a microplate well. After a 7-minute incubation at room temperature, 75 µL of 7% $Na_2CO_3$ solution was added, and the mixture was thoroughly mixed. The plates were then incubated in the dark at room temperature for 2 hours. Absorbance was measured at 765 nm using a microplate reader (Synergy HTX Biotech Multimode Elisa Reader).

Gallic acid (GA) was used as the standard compound for calibration, and the results were expressed as milligrams of gallic acid equivalent (mg GAE) per gram of extract. All measurements were conducted in triplicate.

### Total phenolic acid content

The total phenolic acid content of the extracts was determined by adapting the colorimetric method developed by Mihailović et al. to a microplate format[27]. For each well, 25 µL of extract was added, followed by 25 µL of Arnow's reagent, 25 µL of 0.1 M HCl, and 25 µL of 1 M NaOH. Finally, distilled water was added

to bring the total volume to 250 µL. Absorbance was measured at 490 nm using a microplate reader (Synergy HTX Biotech Multimode Elisa Reader).

Caffeic acid (CA) was used as the standard compound for calibration, and the results were expressed as milligrams of caffeic acid equivalent (mg CAE) per gram of extract. All measurements were conducted in triplicate.

**Total flavonoid content**

In this study, a colorimetric method used originally developed by Zhang et al. and later adapted to a microplate format by Yıldırım et al. was applied to determine the total flavonoid content of the extracts[28,29]. A volume of 25 µL from each sample, prepared at concentrations of 10 mg/mL and 5 mg/mL in DMSO, was transferred into microplate wells. Subsequently, 125 µL of distilled water and 7.5 µL of 5% $NaNO_2$ solution was added. After six minutes, 15 µL of 10% $AlCl_3.6H_2O$ solution was introduced. Following a five-minute incubation, 50 µL of 1 M NaOH was added and the total volume was brought to 250 µL by adding 27.5 µL of distilled water. The absorbance of the solutions was immediately measured at 510 nm (Synergy HTX Biotech Multimode Elisa Reader).

Quercetin (QE) was used as the standard compound for calibration and the results were expressed as milligrams of quercetin equivalent (mg QE) per gram of extract. All measurements were conducted in triplicate.

**Total proanthocyanidin content**

The total proanthocyanidin content of the extracts was determined using a microplate-adapted version of the vanillin-HCl method, as described by Ariffin et al[30]. A volume of 30 µL from each sample, prepared in DMSO at concentrations of 10 mg/mL and 5 mg/mL, was transferred into the wells of a microplate. Then, 75 µL of 1% vanillin solution and 75 µL of 9 M HCl were added. The mixture was incubated at 30°C for 20 minutes, as the reaction is temperature-sensitive (an incubator was used). Following incubation, absorbance was measured spectrophotometrically at 492 nm (Synergy HTX Biotech Multimode Elisa Reader).

(-)-epicatechin (EC) was used as the standard compound for calibration and the results were expressed as milligrams of epicatechin equivalent (mg ECE) per gram of extract. All measurements were conducted in triplicate.

## Estimation of antioxidant activity based on free radical-scavenging activity

### DPPH (2,2-diphenyl-1-picrylhydrazyl) radical-scavenging activity

The antioxidant activity of the extracts was evaluated using the method described by Zou et al[31]. Extracts were initially prepared in dimethyl sulfoxide (DMSO) at a concentration of 10 mg/mL, then serially diluted with DMSO to obtain concentrations of 5 mg/mL, 2.5 mg/mL, and 1.125 mg/mL. From each concentration, 10 µL was transferred into the wells of a 96-well microplate, followed by the addition of 190 µL of 0.1 mM DPPH solution. The reaction mixtures were incubated in the dark for 30 minutes at room temperature. Absorbance was then measured at 517 nm (Synergy HTX Biotech Multimode Elisa Reader).

%RSA values were calculated according to the formula given below.

$$\%RSA=[(A0-A1)/A0]x100$$

Here, A0 is the absorbance of the control, A1 is the absorbance of the extract/standard.

Gallic acid (GA) was used as the positive control. The antioxidant capacity was evaluated based on the inhibition concentration ($IC_{50}$), which represents the concentration of extract required to scavenge 50% of the DPPH radicals. $IC_{50}$ values were calculated by plotting the inhibition percentage against the extract concentrations using GraphPad Prism 5 software. All extract measurements were performed in triplicate.

## Estimation of antioxidant activity based on metal-related activity

### Cupric Reducing Antioxidant Capacity (CUPRAC)

In this study, the CUPRAC method originally developed by Apak et al. and later adapted to a microplate format by Lahmadi et al. was employed to evaluate the antioxidant capacity of the extracts[32,33]. A volume of 40 µL from each sample was transferred into the wells of a microplate. Then, 50 µL of 10 mM $CuSO_4$, solution and 50 µL of neocuproine solution were added, followed by 60 µL of ammonium acetate (pH 7.0) buffer. The mixture was incubated for 60 minutes at room temperature. After incubation, absorbance was measured spectrophotometrically at 450 nm (Synergy HTX Biotech Multimode Elisa Reader).

Trolox (TE) was used as the standard compound for calibration, and the results were expressed as milligrams of Trolox equivalent (mg TE) per gram of extract. All measurements were conducted in triplicate.

### Ferric Reducing Antioxidant Power (FRAP)

The FRAP assay was carried out based on the method developed by Benzie and Strain[34]. Test solutions were prepared at final concentrations of 5 mg/mL and 2.5 mg/mL in DMSO. An aliquot of 10 µL from each solution was pipetted into the wells of a microplate. Subsequently, 10 µL of distilled water and 230 µL of freshly prepared FRAP reagent were added. The FRAP reagent consisted of a mixture of three components combined at a 1:1:10 ratio: 20 mM $FeCl_3 \cdot 6H_2O$, 10 mM TPTZ in 40 mM HCl, and 300 mM acetate buffer (pH 3.6). The plates were left at room temperature for 8 minutes to allow color development, after which absorbance was recorded at 593 nm using a microplate reader (Synergy HTX Biotech Multimode Elisa Reader).

Trolox (TE) was used as the standard compound for calibration, and the results were expressed as milligrams of Trolox equivalent (mg TE) per gram of extract. All measurements were conducted in triplicate.

## RESULTS AND DISCUSSION

The antioxidant properties of the methanol extract of *C. rapunculoides* subsp. *rapunculoides* have been examined about their effect on many pathways and an analysis of the plant's phytochemical composition has been completed.

As a result of the analyses, the TPC of the extract was determined as 111.36 ± 0.0170 mg GAE/g, the TFC as 91.27 ± 0.0161 mg QE/g, the TPAC as 29.733 ± 0.008 mg CA/g and the TPRAC as 27.84 ± 0.004 mg ECE/g (Table 1). The antioxidant capacity measured by the CUPRAC method was found to be 370.28 ± 0.023 mg TE/g and the FRAP test was determined as 24.035 ± 0.020 mg TE/g, indicating a high reducing potential. Similarly, the DPPH radical scavenging assay yielded a low $IC_{50}$ value of 0.346 ± 0.004 mg/mL. The strong agreement between the high CUPRAC value and the low DPPH $IC_{50}$ suggests that the extract possesses potent antioxidant activity, likely exerting its effect through both electron transfer and radical scavenging mechanisms (Table 2).

**Table 1.** Phytochemical profile of *C. rapunculoides* subsp. *rapunculoides*

| Extract | TPC (mg GAE/g) | TFC (mg QE/g) | TPAC (mg CA/g) | TPRAC (mg ECE/g) |
|---|---|---|---|---|
| CR extract | 111.36 ± 0.0170 | 91.27 ± 0.0161 | .733 ± 0.008 | 7.84 ± 0.004 |

CR extract: Methanol extract of C. *rapunculoides* subsp. *rapunculoides*
Values are presented as mean ± S.D
TPC: Total phenolic content
TFC: Total flavonoid content
TPAC: Total phenolic acid content
TPRAC: Total proanthocyanidin content

**Table 2.** Antioxidant activity of *C. rapunculoides* subsp. *rapunculoides*

| Extract | DPPH $IC_{50}$ (mg/mL) | CUPRAC (mg TE/g) | FRAP (mg TE/g) |
|---|---|---|---|
| CR extract | 0.346 ± 0.004 | 370.28 ± 0.023 | 24.035 ± 0.020 |
| Gallic acid | 0.0024 | | |

CR extract: Methanol extract of Campanula *rapunculoides* subsp. *rapunculoides*
Values are presented as mean ± S.D

A study comparing maceration, Soxhlet and ultrasonic-assisted extraction procedures using methanol extract of *Campanula lyrata* subsp. *lyrata* revealed that maceration yielded the highest total phenolic content (TPC) and total flavonoid content (TFC), measuring 41.76 mg GAE/g and 23.68 mg RE/g, respectively. The maximum DPPH activity was seen in Soxhlet extraction ($IC_{50}$: 1.17 mg/mL); the CUPRAC and FRAP test's findings were reported as ($EC_{50}$: 0.50–0.77 mg/mL)[35].

According to prior findings, the phenolic and flavonoid composition of *C. strigosa* extracts is influenced by the solvent employed. The total phenolic content of ethanol extract was 78.70 ± 2.57 mg/g, whereas the total flavonoid content was 109.05 ± 1.53 mg/g. The methanolic extract demonstrated a total phenolic content of 56.28 ± 2.72 mg GAE/g and a total flavonoid content of 108.07 ± 3.48 mg QE/g[23].

The phytochemical characteristics and antioxidant activities of the aerial parts of four Turkish *Campanula* species - *C. cymbalaria*, *C. davisii* (endemic), *C. peregrina* and *C. stricta* var. *libanotica* - were investigated in their ethyl acetate fractions. The total phenolic content ranged from 58.54 to 92.58 mg GAE/g, while the total flavonoid content varied between 22.41 and 52.74 mg CE/g. The DPPH assay revealed the highest radical scavenging activity in the

methanol extract of *C. peregrina* (86.22 ± 2.40%) and in its ethyl acetate fraction (88.96 ± 0.57%) at 2.5 mg/mL and 1.25 mg/mL, respectively. The ABTS assay showed that the ethyl acetate fraction of *C. peregrina* exhibited 97.04 ± 0.58% at 2.5 mg/mL, which was comparable to the activity of rutin (98.44 ± 0.49%). The ethyl acetate fraction of *C. peregrina* (2.029 ± 0.01 mM Trolox/L) exhibited TEAC values comparable to those of rutin (2.059 ± 0.01 mM Trolox/L) at the tested concentrations. Similarly, FRAP measurements for the *C. peregrina* ethyl acetate fraction (3.80 ± 0.09 mM $Fe^{2+}$/L) were consistent with those of rutin (3.91 ± 0.07 mM $Fe^{2+}$/L). Owing to their higher phenolic content, the ethyl acetate fractions exhibited stronger antioxidant activity than the methanol extracts. Among the tested species, *C. peregrina* displayed the highest overall antioxidant potential[14].

Previous studies have employed ethyl acetate, methanol and aqueous extracts of *C. macrostachya*. Tests for antioxidant activity indicate that the MeOH extract exhibited superior activity compared to other extracts, with DPPH assay results are at 4.15 mg/mL, ABTS at 2.05 mg/mL, CUPRAC at 1.80 mg/mL, and FRAP at 0.83 mg/mL[22].

A previous study investigated the antioxidant potential of *C. retrorsa* using dichloromethane, methanol, and aqueous extracts prepared from its leaves, flowers and stems. The antioxidant activity of the extracts was assessed using the DPPH assay. Among the aqueous preparations, those obtained by decoction exhibited the strongest radical scavenging capacity, with the decocted leaf extract showing activity comparable to that of the ascorbic acid (Vitamin C) reference standard. On the other hand, the dichloromethane crude extracts displayed only minimal antioxidant activity. These findings indicate that the polarity of the extraction solvent plays a decisive role in determining the antioxidant potential of the extracts[11].

A study investigated *C. alliariifolia*, from which chloroform and methanol extracts were prepared. The methanol extract was evaluated for its DPPH free radical scavenging capacity and ferric reducing power. The methanol extract exhibited notable antioxidant activity at a concentration of 500 mg/L; however, its effect remained lower than that of L-ascorbic acid. The methanol extract exhibited significant antioxidant activity, which was attributed to its polyphenolic constituents. These findings provide pharmacological support for the traditional medicinal use of the plant[36].

The use of diverse antioxidant capacity assays in the food, nutraceutical and dietary supplement industries is essential to ensure reliable results, enable meaningful product comparisons, manage variations, and maintain quality

standards. These methods evaluate antioxidants against peroxyl, hydroxyl and superoxide radicals using hydrogen atom transfer (HAT) or single electron transfer (SET) processes. HAT-based approaches like oxygen radical absorbance capacity (ORAC) are more relevant to human biology since peroxyl radicals dominate lipid oxidation. SET methods including Folin-Ciocalteu, Trolox equivalent antioxidant capacity (TEAC), FRAP and CUPRAC quantify electron transport or reducing capacity. Folin-Ciocalteu is fast but lacks specificity, DPPH is fast but steric accessibility affects the reaction, CUPRAC is unaffected by sugars and citric acid and TEAC can evaluate hydrophilic and lipophilic antioxidants. An ideal method for assessing antioxidant capacity should employ a biologically relevant radical source, follow a well-defined chemical mechanism, be simple and instrumentally practical, demonstrate good repeatability and be applicable to high-throughput investigations. Thus, instead of using a single "total antioxidant capacity" assessment, standardize and use numerous methodologies like ORAC, Folin-Ciocalteu, and TEAC to evaluate efficiency against various reactive oxygen species (ROS) and reactive nitrogen species (RNS)[27,37].

The findings of this study clearly demonstrate that *Campanula rapunculoides* subsp. *rapunculoides* exhibits significant antioxidant activity and contains a rich profile of phenolic compounds. The high total phenolic, phenolic acid, flavonoid and proanthocyanidin contents, along with strong performance in both CUPRAC, FRAP and DPPH assays, indicate that this plant is a potent source of natural antioxidants. These results suggest that *C. rapunculoides* subsp. *rapunculoides* may be considered a valuable candidate for use in the development of functional foods, nutraceuticals or phytopharmaceuticals aimed at combating oxidative stress-related disorders.

This study presents the initial findings on the TPC, TPAC, TFC, TPRAC and antioxidant activity of the methanol extract of *C. rapunculoides* subsp. *rapunculoides*. The findings definitively indicate that the species exhibits notable antioxidant activity. The findings indicate a significant concentration of phenolic compounds, aligning with earlier research and supporting the traditionally accepted use of the species. Nonetheless, additional investigations are essential to establish its therapeutic potential; in this regard, the present study is expected to significantly enhance the existing body of knowledge and guide future research by informing experimental designs, refining methodological strategies, and inspiring novel hypotheses in this field.

## STATEMENT OF ETHICS

This study does not require any ethical permission.

## CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

## AUTHOR CONTRIBUTIONS

The authors contributed equally to the article.


## FUNDING SOURCES

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

## ACKNOWLEDGMENTS

The authors thank Prof. M. Vural for identifying plant material.

## REFERENCES


1. Plants of the World Online. [Internet]: 2025. Kew: The Royal Botanical Gardens; [Jun 16, 2025]. Available from: http://powo.science.kew.org/

2. Damboldt J. *Campanula* L. In: Davis PH, editor. Flora of Turkey and the East Aegean islands. Vol. 6. Edinburgh: Edinburgh University Press; 1978.

3. Özhatay N, Kültür S, Gürdal B. Check-list of additional taxa to the supplement flora of Turkey IX. Istanbul J Pharm, 2019;49(2):105–120. Doi:10.26650/IstanbulJPharm.2019.19037

4. Liveri EL, Crowl AA, Cellinese N. Past, present, and future of *Campanula* (Campanulaceae) systematics–a review. Bot Chron, 2019;22:209–222.

5. Baytop T. Therapy with medicinal plants in Turkey (past and present). Istanbul: Nobel Press; 1999.

6. Kizilarslan Ç, Özhatay N. Wild plants used as medicinal purpose in the south part of İzmit (Northwest Turkey). Turk J Pharm Sci, 2012;9(2):199–218.

7. Qi Y, Choi SI, Son SR, Han HS, Ahn HS, Shin YK, et al. Chemical constituents of the leaves of *Campanula takesimana* (Korean Bellflower) and their inhibitory effects on LPS-induced $PGE_2$ production. Plants, 2020;9(9):1232. Doi:10.3390/plants9091232

8. Moosavi SR, Ardekani MRS, Vazirian M, Lamardi SNS. *Campanula latifola*, giant bellflower: ethno-botany, phytochemical and antioxidant evaluation. Tradit Integr Med. 2018;3(3):113–119.

9. Suntar İ, Akkol EK, Gonenc TM, Erdogan TF, Keles H, Kivçak B. Scientific assessment of the anti-inflammatory and wound healing potential of *Campanula lyrata* subsp. *lyrata*, a Turkish folk remedy. Turk J Pharm Sci, 2015;12(2):157–168. Doi: 10.5505/tjps.2015.58066

10. Tsiftsoglou OS, Lagogiannis G, Psaroudaki A, Vantsioti A, Mitić MN, Mrmošanin JM, et al. Phytochemical analysis of the aerial parts of *Campanula pelviformis* Lam. (Campanulaceae): documenting the dietary value of a local endemic plant of Crete (Greece) traditionally used as wild edible green. Sustainability, 2023;15(9):7404. Doi:10.3390/su15097404

11. Alhage J, Elbitar H, Taha S, Benvegnu T. *In vitro* assessment of antioxidant, antimicrobial, cytotoxic, anti-inflammatory, and antidiabetic activities of *Campanula retrorsa* crude extracts. Pharmacogn Res, 2018;10(4):397–403. Doi: 10.4103/pr.pr_73_18

12. Karalija E, Dahija S, Demir A, Bešta-Gajević R, Zeljković SĆ, Tarkowski P. Exploring new sources of bioactive phenolic compounds from western Balkan mountains. Plants, 2022;11(7):1002. Doi: 10.3390/plants11071002

13. Cosme P, Rodríguez AB, Espino J, Garrido M. Plant phenolics: bioavailability as a key determinant of their potential health-promoting applications. Antioxidants, 2020;9(12):1263. Doi: 10.3390/antiox9121263

14. Erdoğan A, Sarı A, Özsoy N. Phytochemical properties and antioxidant capacities of some *Campanula* species from Turkey. Spectrosc Lett, 2025;58(8):807–818. Doi:10.1080/003870 10.2025.2467430

15. Gandhi S, Abramov AY. Mechanism of oxidative stress in neurodegeneration. Oxid Med Cell Longev, 2012;2012(1):428010. Doi: 10.1155/2012/428010

16. Pisoschi AM, Pop A. The role of antioxidants in the chemistry of oxidative stress: a review. Eur J Med Chem, 2015;97:55–74. Doi:10.1016/j.ejmech.2015.04.040

17. Poyrazoğlu Çoban E, Barışık E. Investigation of the antimicrobial activities of solvent extracts of two endemic species from Turkey: *Campanula tomentosa* Lam. and *Verbascum mykales* Bornm. Istanbul J Pharm, 2021;51(3):348–356. Doi: 10.26650/IstanbulJPharm.2021.821070

18. Yilmaz MA, Cakir O, Izol E, Tarhan A, Behcet L, Zengin G. Detailed phytochemical evaluation of a locally endemic species (*Campanula baskilensis*) by LC-MS/MS and its in-depth antioxidant and enzyme inhibitory activities. Chem Biodivers, 2023;20(12):e202301182. Doi: 10.1002/cbdv.202301182

19. Marah S, İpek Y, Ozen T, Demirtas İ, Behçet L. Bioactivity-guided isolation of inositol as acetylcholinesterase inhibitory from endemic *Campanula baskilensis* Behcet: *In vitro* bioactivity, PCA analysis, and silico supporting studies. Kahramanmaraş Sütçü İmam Üniv Tarım Doğa Derg, 2025;28(3):717–735. Doi: 10.18016/ksutarimdoga.vi.1632935

20. Korkmaz B, Fandakli S, Barut B, Yildirim S, Sener SO, Ozturk E, et al. Volatile and phenolic components and antioxidant, acetylcholinesterase, tyrosinase, α-glucosidase inhibitory effects of extracts obtained from *Campanula latifolia* L. subsp. *latifolia*. J Essent Oil Bear Plants, 2020;23(5):1118–1131. Doi: 10.1080/0972060X.2020.1856004

21. Mihoğlugil F, Akalgan D, Tosun F. Cytotoxicity screening of some Turkish plants against renal cancer cells. J Res Pharm. 2023;27(2):636–641. Doi: 10.29228/jrp.346

22. Sarikurkcu C, Sarikurkcu RT, Tepe B. *Campanula macrostachya*: biological activity and identification of phenolics using a liquid chromatography electrospray ionization tandem mass spectrometry system. Environ Sci Pollut Res, 2021;28(17):21812–21822. Doi: 10.1007/s11356-020-11695-y

23. Mohammed FS, Uysal İ, Sabik AE, Dogan M, Sevindik M. Total phenolic and flavonoid contents, antimicrobial and antioxidant potentials of *Campanula strigosa* Banks & Sol. J Microbiol Biotechnol Food Sci, 2023;13(2):e10057. Doi: 10.55251/jmbfs.10057

24. Ortiz A, Sansinenea E. Phenylpropanoid derivatives and their role in plants' health and as antimicrobials. Curr Microbiol, 2023;80(12):380. Doi: 10.1007/s00284-023-03502-x

25. Marah S, Ozen T, Demirtas İ, İpek Y, Gül F, Behçet L. GC-MS/MS and 1H-NMR analysis of endemic *Campanula baskilensis* Behçet leaf fractions. Curr Perspect Med Aromat Plants, 2024;7(1):48–57. Doi: 10.38093/cupmap.1477900

26. Singleton VL, Rossi JA. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. Am J Enol Vitic, 1965;16(3):144–158. Doi: 10.5344/ajev.1965.16.3.144

27. Mihailović V, Kreft S, Benković ET, Ivanović N, Stanković MS. Chemical profile, antioxidant activity and stability in stimulated gastrointestinal tract model system of three *Verbascum* species. Ind Crops Prod, 2016;89:141–151. Doi: 10.1016/j.indcrop.2016.04.075

28. Zhang R, Zeng Q, Deng Y, Zhang M, Wei Z, Zhang Y, et al. Phenolic profiles and antioxidant activity of litchi pulp of different cultivars cultivated in Southern China. Food Chem, 2013;136(3-4):1169–1176. Doi: 10.1016/j.foodchem.2012.09.085

29. Yıldırım A, Şen A, Doğan A, Bitis L. Antioxidant and anti-inflammatory activity of capitula, leaf and stem extracts of *Tanacetum cilicicum* (Boiss.) Grierson. Int J Second Metabolite, 2019;6(2):211–222. Doi: 10.21448/ijsm.510316

30. Ariffin F, Chew SH, Bhupinder K, Karim AA, Huda N. Antioxidant capacity and phenolic composition of fermented *Centella asiatica* herbal teas. J Sci Food Agric, 2011;91(15):2731–2739. Doi: 10.1002/jsfa.4454

31. Zou Y, Chang SK, Gu Y, Qian SY. Antioxidant activity and phenolic compositions of lentil (*Lens culinaris* var. Morton) extract and its fractions. J Agric Food Chem, 2011;59(6):2268–2276. Doi: 10.1021/jf104640k

32. Apak R, Güçlü K, Özyürek M, Karademir SE. 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, 2004;52(26):7970–7981. Doi: 10.1021/jf048741x

33. Lahmadi S, Belhamra M, Karoune S, Kechebar MSA, Bensouici C, Kashi I, et al. *In vitro* antioxidant capacity of *Euphorbia retusa* Forssk. from Algerian desert. J Pharm Pharmacogn Res, 2019;7(5):356–366. Doi: 10.56499/JPPRES19.580_7.5.356

34. Benzie IFF, Strain JJ. The ferric reducing ability of plasma (FRAP) as a measure of "Antioxidant Power": the FRAP assay. Anal Biochem, 1996;239(1):70–76. Doi: 10.1006/abio.1996.0292

35. Kargin Solmaz FO, Kirkan B, Istifli ES, Sarikurkcu C, Tepe B. Targeted phenolic profiling, antioxidant activities, and enzyme inhibition potential of *Campanula lyrata* subsp. *lyrata* extracts with molecular docking insights. J Food Sci, 2025;90(8):e70368. Doi: 10.1111/1750-3841.70368

36. Dumlu MU, Gurkan E, Tuzlaci E. Chemical composition and antioxidant activity of *Campanula alliariifolia*. Nat Prod Res, 2008;22(6):477–482. Doi: 10.1080/14786410701640429

37. Prior RL, Wu X, Schaich K. Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. J Agric Food Chem, 2005;53(10):4290–4302. Doi: 10.1021/jf0502698