

Chemical Composition of Hexane Extracts and the Total Phenolic and Flavonoid Contents of Ethanolic Extracts from the Flowers and Leaves of *Helichrysum arenarium* (L.) Moench Growing in Al-Furonlq Forests, Syria

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□ ABSTRACT □

Helichrysum arenarium (L.) Moench (Asteraceae), commonly known as Sandy Everlasting or Immortelle, is an aromatic perennial subshrub traditionally valued for its choleric and dermatological properties.. The study aimed to identify the chemical composition of the plant's flowers and leaves collected from the Furnalq forests in Syria. The plant parts were collected during the flowering season (July 2024). The total phenol and flavonoid content (TPC) and total flavonoid content (TFC) were determined using spectrophotometry in 70% alcoholic extracts using the Folin-Ciocalteu reagent and ammonium chloride, respectively. Additionally, the chemical composition of hexane extracts from both plant parts was analyzed using gas chromatography-mass spectrometry (GC-MS). The results revealed that flower ethanolic extracts contained significantly higher TPC (71.00 ± 0.41 mg GAE/g dry weight) and TFC (32.5 ± 0.33 mg QE/g dry weight) compared to leaf extracts (23.25 ± 0.80 mg GAE/g and 18.8 ± 0.47 mg QE/g, respectively). GC-MS analysis identified distinct the chemical compounds in the hexane extracts: the leaf extract was dominated by stearic acid (44.98%), nonacosane (18.42%), and methyl palmitate (12.65%), consistent with cuticular wax and fatty-acid derivatives, while the flower hexane extract was rich in tricosane (17.70%), nonacosane (11.98%), cyclohexanol (12.79%), and 2-hexenal (11.35%), reflecting a mixture of long-chain alkanes and volatile oxygenated compounds. These findings highlight the flowers as the primary reservoir of phenolic antioxidants in *H. arenarium*, whereas the leaves, available year-round, represent a valuable alternative source of bioactive compounds. This study provides a scientific basis for the traditional uses of this plant and supports its potential as a source of natural antioxidants and bioactive phytochemicals.

Keywords: *Helichrysum arenarium*, phenolic compounds, flavonoids, GC-MS analysis, hexane extract, total phenolic content, total flavonoid content.

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التركيب الكيميائي لمستخلصات الهكسان والمحتوى الكلي للفينولات والفلافونويدات في المستخلصات الايتانولية لأزهار وأوراق نبات العشبة الخالدة *Helichrysum* *arenarium* (L) النامي في غابات الفرندل، سوريا

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(تاريخ الإيداع 5 / 8 / 2026. قبل للنشر في 26 / 8 / 2026)

□ ملخص □

العشبة الخالدة من العائلة النجمية، هي شجيرة معمرة عطرية ذات أهمية طبية في تحفيز العصارة الصفراوية والعناية بالجلد. هدف البحث إلى دراسة التركيب الكيميائي لأزهار وأوراق النبات التي جُمعت من غابات الفرندل بسوريا. تم جمع الأجزاء النباتية خلال موسم الإزهار (يوليو 2024). تم تحديد المحتوى الكلي للفينولات والفلافونويدات (TPC) وإجمالي محتوى الفلافونويد (TFC) بطريقة التحليل الطيفي في مستخلصات كحولية بنسبة 70٪ باستخدام كاشف الفولين سيكالتو و كلوريد الألومنيوم، على التوالي. بالإضافة إلى ذلك، تم تحليل التركيب الكيميائي للمستخلصات الهكسانية من كلا الجزئين النباتيين بواسطة الكروماتوغرافيا الغازية الموصولة مع مطياف الكتلة (GC-MS). كشفت النتائج أن المستخلصات الكحولية من الأزهار تحتوي على محتوى مرتفع من الفينولات الكلية (0.41 ± 71.00 ملغ/GAE من الوزن الجاف) والفلافونويدات الكلية (0.33 ± 32.5 ملغ/QE من الوزن الجاف) مقارنة بمستخلصات الأوراق (0.80 ± 23.25 ملغ/GAE و 0.47 ± 18.8 ملغ/QE على التوالي). كما أظهر تحليل GC-MS مركبات مميزة في مستخلصات الهكسان، حيث سيطر *stearic acid* (44.98%)، *nonacosan* (18.42%)، *methyl palmitate* (12.65%) على مستخلص الأوراق، بينما كان مستخلص الأزهار غنياً بـ *tricosane* (17.70%)، *nonacosane* (11.98%)، *cyclohexanol* (12.79%)، و *2-hexenal* (11.35%)، مما يعكس خليطاً من الألكانات طويلة السلسلة والمركبات المؤكسجة الطيارة. هذه النتائج تُبرز الأزهار كمصدر رئيسي لمضادات الأكسدة الفينولية في *arenarium*، بينما تمثل الأوراق، المتوفرة طوال العام، مصدراً بديلاً قيماً للمركبات النشطة بيولوجياً. تقدم هذه الدراسة أساساً علمياً للاستخدامات التقليدية لهذا النبات وتدعم إمكاناته كمصدر لمضادات الأكسدة الطبيعية والمركبات النباتية النشطة بيولوجياً.

الكلمات المفتاحية: العشبة الخالدة، المركبات الفينولية، الفلافونويدات، تحليل GC-MS، المستخلص بالهكسان، محتوى الفينولات الكلي، محتوى الفلافونويدات الكلي.



حقوق النشر : مجلة جامعة اللاذقية (تشرين سابقاً) - سورية، يحتفظ المؤلفون بحقوق النشر بموجب

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1. INTRODUCTION:

Phenolic compounds form a diverse and complex group of secondary metabolites synthesized by plants, and they are widespread across a broad range of medicinal species. This group includes flavonoids, catechins, tannins, gallic acid derivatives, chlorogenic acid derivatives, and resveratrol derivatives, all of which contribute substantially to the biological activity of medicinal plants [1, 2].

Helichrysum arenarium (L.) Moench belongs to the Asteraceae (Compositae) family. It is a small, evergreen, perennial aromatic shrub characterized by slender, thread-like silvery leaves and golden-yellow flowers (Figure 1). The flowering stage between July and August and is commonly known as sand everlasting or immortelle. The genus *Helichrysum* comprises around 600 species distributed worldwide. *H. arenarium* is found throughout the Mediterranean basin, where it favors poor, sandy, dry soils at elevations of up to 2200 meters. It is also cultivated as an ornamental, particularly in rock gardens, owing to its drought tolerance[18]. .

H. arenarium flowers have long been used in folk medicine as a choleric agent and for treating various skin conditions[18]. Recent scientific studies have revealed several pharmacological properties of the plant, including hepatoprotective, antioxidant, anti-inflammatory, antimicrobial, and antiproliferative effects [3, 4]. Most previous phytochemical studies focused on the essential oil composition of the flowers or of the whole aerial parts, while the phenolic and flavonoid content of the leaves, or the chemical composition of the hexane extract, has received comparatively little attention. This gap is particularly notable given that the plant's flowering period is relatively short (July–August), whereas, being evergreen, its leaves can be harvested year-round.

Recent advances in analytical techniques have allowed for more precise characterization of the phenolic profile of *H. arenarium*. For instance, LC-MS/MS analysis identified luteolin, quercetin, naringenin, caffeic acid, and kaempferol as major phenolic constituents in methanolic extracts, with luteolin reaching a concentration of 744.57 mg/100 g dry weight [5]. Similarly, HPLC-DAD-TOF studies on Lithuanian samples confirmed the dominance of luteolin-7-O-glucoside, naringenin and its glucoside, apigenin, chlorogenic acid, arenol, and arzanol in methanolic extracts [6]. Furthermore, a recent study on Lithuanian samples found that leaf extracts collected at the onset of flowering exhibited the highest phenolic content (72.21 mg GAE/ g dry weight) and antioxidant activity (1116.54 μ mol Trolox equivalent/ g dry weight by the ABTS assay), even surpassing inflorescence extracts at certain phenological stages [7]. These findings underscore the dynamic nature of phytochemical accumulation across plant organs and developmental stages.

This study therefore aimed to: (1) determine the total phenolic and flavonoid content of 70% ethanol extracts; (2) analyze the chemical composition of the hexane extract; and (3) compare these parameters between the flowers and leaves of sandy everlasting (*Helichrysum arenarium*) growing in the furonlq forests of Syria.



[Figure 1: *Helichrysum arenarium*]

2. MATERIALS AND METHODS:

2.1 Plant Material Collection and Preparation:

Flowers and leaves of *Helichrysum arenarium* were collected from their natural habitat in the Al- furonlq forests, Syria, during the flowering stage in July 2024. Botanical identification was confirmed by DR RACHA ALKHATIB in the Department of Pharmacognosy , Faculty of Pharmacy, Damascus University. The collected plant materials were air-dried in the shade at ambient temperature. Subsequently, the leaves and flowers were ground separately into a fine powder using an electric grinder and stored in airtight containers at room temperature until extraction.

2.2 Chemicals and Reagents

All chemicals and solvents used were of analytical grade. *n*-Hexane, absolute ethanol, and quercetin were procured from Sigma-Aldrich (Germany). Absolute methanol and ascorbic acid were obtained from Panreac (Spain). Gallic acid and anhydrous sodium carbonate were sourced from AvonChem (United Kingdom). Folin-Ciocalteu reagent was acquired from Merck (Darmstadt, Germany). Sodium acetate and aluminum chloride were purchased from Riedel-de Haën (Germany).

2.3 Preparation of Plant Extracts

Extraction was carried out by ultrasound-assisted maceration. Briefly, 1 g of ground plant material (flowers or leaves) was extracted separately with 250 mL of 70% ethanol (v/v). The mixture was placed in an ultrasonic bath (Elmasonic) at 40 °C for 20 minutes to extract phenolic and flavonoid compounds from the plant material. Extraction conditions (temperature and time) were selected based on the study of Xia et al. [8]. The process was repeated three times, and the extracts were pooled. The solvent was removed using a rotary evaporator (Heidolph, Germany), and evaporation continued until dry extracts were obtained. The dried extracts were stored in tightly sealed amber vials at 6 °C until further analysis. For the hexane extracts, 500 mg of plant powder was extracted with 50 ml of hexane, Soaked for 48 hours and exposed to Ultrasound assisted extraction for 15 min, the extract was injected to GC-MS without further treatment

The extraction yield was calculated as a percentage using the following formula:

$$\text{Extraction Yield (\%)} = (\text{Weight of Dry Extract} \div \text{Weight of Dry Plant Material}) \times 100$$

2.4 Determination of Total Phenolic Content (TPC)

Total phenolic content was determined spectrophotometrically using the Folin-Ciocalteu method [9] with minor modifications. A stock solution of gallic acid (1000 mg/L) was

prepared in distilled water and serially diluted to construct a calibration curve over a concentration range of 0–500 mg/L. Plant extracts were dissolved in absolute ethanol to a final concentration of 1000 mg/L.

The assay was performed by mixing 1 mL of sample (gallic acid standard or plant extract), 4.8 mL of distilled water, 0.2 mL of undiluted Folin-Ciocalteu reagent, and 4 mL of 20% (w/v) sodium carbonate (Na_2CO_3) solution. The mixture was thoroughly mixed, incubated in the dark at room temperature for one hour, and the absorbance was measured at 762 nm against a blank using a UV-Vis spectrophotometer (Optizen 3220UV, Mecasys Co., Ltd., Korea). All analyses were performed in triplicate on three independently prepared extracts. Total phenolic content was expressed as milligrams of gallic acid equivalent (GAE) per gram of dry plant material (mg GAE/g).

2.5 Determination of Total flavonoid content (TFC)

Total flavonoid content was determined using the aluminum chloride colorimetric method [10, 11]. A stock solution of quercetin (1000 mg/L) in absolute methanol was used to construct a calibration curve over a concentration range of 0–80 mg/L. Plant extracts were prepared at a concentration of 200 mg/L in absolute ethanol.

In this assay, 0.5 mL of sample (quercetin standard or plant extract) was mixed with 0.1 mL of 1 M Sodium acetate, 0.1 mL of 10% (w/v) methanolic aluminum chloride solution, and 2.8 mL of distilled water. The reaction mixture was mixed and incubated in the dark at room temperature for 30 minutes. The absorbance of the resulting yellow complex was measured at 415 nm against a methanol blank. All measurements were performed in triplicate on three independently prepared extracts. Total flavonoid content was calculated and expressed as milligrams of quercetin equivalent (QE) per gram of dry plant material (mg QE/g).

2.6 GC-MS analysis of hexane extracts

The Chemical compounds of the hexane extracts were analyzed by gas chromatography-mass spectrometry (GC-MS) (Agilent Technologies 5977C), following previously reported procedures. The temperature program applied was as follows: 60 °C for 1 minute; ramped to 70 °C at 4 °C/min; then to 130 °C at 5 °C/min; followed by 160 °C at 4 °C/min; then to 220 °C at 5 °C/min; and finally to 280 °C at 15 °C/min, with a total run time of 80 minutes. Helium was used as the carrier gas at a flow rate of 1 mL/min and a pressure of 8.2317 KPa. The column used was an HP-5MS (5% phenyl methylpolysiloxane), with dimensions of 30 m × 250 µm × 0.25 µm, operated at 325 °C. Spectra were identified by comparison with the NIST library (National Institute of Standards and Technology).

2.7 Statistical analysis

All experiments were performed in triplicate ($n = 3$) on independently prepared extracts. Results are presented as mean ± standard deviation (SD). Statistical analysis was carried out using Microsoft Excel 2016.

3. RESULTS

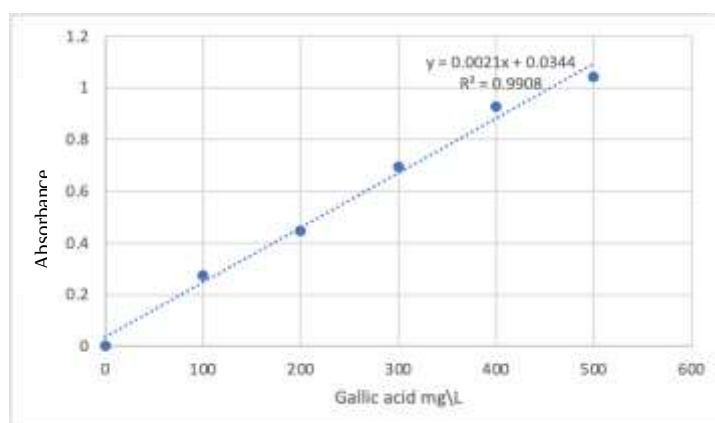
3.1 Extraction yield

Extraction efficiency varied between the different plant parts. The 70% ethanolic leaf extract gave a yield of 8% (w/w) of dry extract, whereas the flower extract gave a yield of 5% (w/w). Despite this lower yield, the flower extract showed higher concentrations of bioactive phenolic and flavonoid compounds (see Sections 3.2 and 3.3).

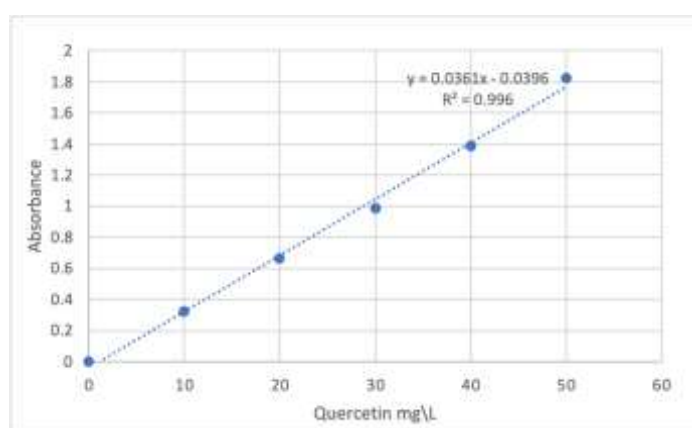
3.2 Calibration curves

The gallic acid calibration curve ($y = 0.0021x + 0.0344$, $R^2 = 0.9908$) and the quercetin calibration curve ($y = 0.0036x - 0.00396$, $R^2 = 0.996$) both showed excellent linearity

across the tested concentration ranges, confirming the reliability of the spectrophotometric methods used (Figures 2 and 3).



[Figure 2: Standard calibration curve for total phenolic content (gallic acid)



[Figure 3: Standard calibration curve for total flavonoid content (quercetin)]

3.3 Estimation of phenolic and flavonoid content

Total phenolic content (TPC) and total flavonoid content (TFC) were determined using the validated calibration curves. As shown in Table 1, the flower extract contained a significantly higher total phenolic content of 71.00 ± 0.41 mg GAE/g dry plant material compared with the leaf extract at 23.25 ± 0.80 mg GAE/g. Similarly, total flavonoid content was significantly higher in the flower extract (32.5 ± 0.33 mg QE/g) than in the leaf extract (18.8 ± 0.47 mg QE/g).

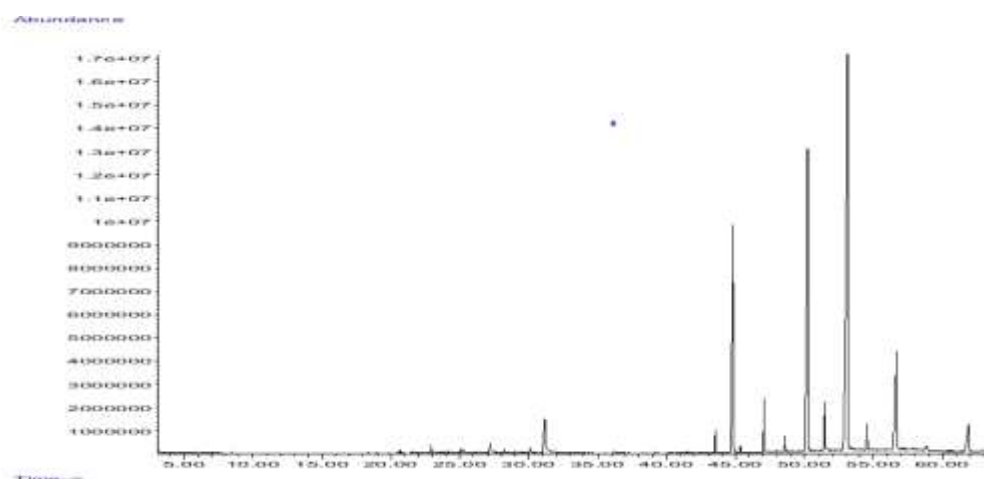
Table 1. Total phenolic content (TPC) and Total flavonoid content (TFC) of *Helichrysum arenarium* **ethanolic** absolute **extracts**

Plant part	TPC (mg GAE/g dry plant material)	TFC (mg QE/g dry plant material)
Flowers	71.00 ± 0.41	32.5 ± 0.33
Leaves	23.25 ± 0.80	18.8 ± 0.47

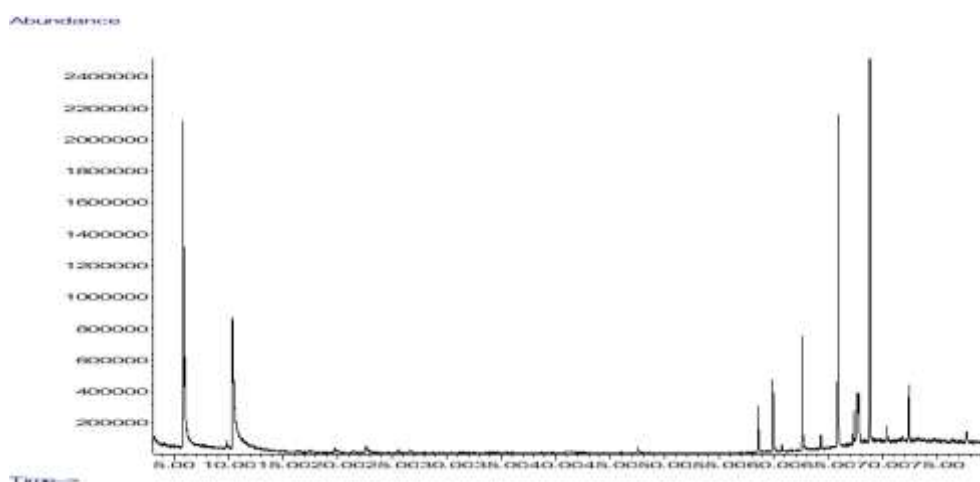
*Values are expressed as mean $\pm$ standard deviation ($n = 3$ independent extracts). GAE: gallic acid equivalent; QE: quercetin equivalent.

3.4 GC-MS analysis of hexane extracts

GC-MS analysis revealed distinct chemical patterns for the leaf and flower hexane extracts. The major identified compounds are summarized in Tables 2 and 3.

[Figure 4: GC-MS analysis of the hexane extract — *H. arenarium* leaves]Table 2. GC-MS analysis of the hexane extract — *H. arenarium* leaves

PK	RT	Area (%)	Compound
1	31.18	3.43	Palmitic acid
2	44.77	12.65	Methyl palmitate
3	47.06	2.10	Heptacosane
4	50.17	18.42	Nonacosane
5	53.07	44.98	Stearic acid
6	54.53	1.22	Tricosane
7	61.84	2.72	Octacosane

[Figure 5: GC-MS analysis of the hexane extract — *H. arenarium* flowers]Table 3. GC-MS analysis of the hexane extract — *H. arenarium* flowers

PK	RT	Area (%)	Compound
1	5.82	12.79	Cyclohexanol
2	5.99	11.35	(E)-2-Hexenal
3	58.58	2.34	Heneicosane
4	60.75	0.36	Dodecane
5	62.65	4.38	Heptacosane
6	65.90	11.98	Nonacosane
7	68.79	17.70	Tricosane
8	77.68	1.14	Octadecane

4. Discussion

This study provides a comprehensive phytochemical characterization of *Helichrysum arenarium* (L.) Moench growing wild in the forested areas of Syria, with particular emphasis on comparing the phenolic, flavonoid, and chemical profile of hexane extract between flowers and leaves.

4.1 Extraction efficiency

The extraction of ultrasound using 70% aqueous ethanol resulted in a greater yield from the leaves (8% w/w) than the flowers (5% w/w). Nonetheless, this total yield is not necessarily an indication of how rich the extract is in terms of compounds because this total is composed of all the compounds solubilized in the aqueous ethanol extract, which include carbohydrates, organic acids, proteins, minerals, and gums and which can be higher in the leaves. Studies have established that it is impossible to predict the efficacy of extraction of phenolic compounds based on estimation of the extracted solids (extraction yield).

Nevertheless, the flower yield is less, yet they were found to contain a considerably larger amount of phenols (71.00 mg GAE/g dry plant material) and flavonoids (32.5 mg QE/g dry plant material) than the leaves (23.25 and 18.8 mg/g dry plant material correspondingly), proving that the flowers are the primary source of these bioactive compounds. The reason for the low flower yield does not have anything to do with the fact that they are rich in non-polar compounds; the analysis of the hexane extract through GC-MS shows the fatty composition (wax) and volatile compounds on the surface, which are separated by non-polar solvents and have nothing to do with the yield in the polar solvent, ethanol [20,21].

4.2 Quantitative analysis of Total phenolic and flavonoid contents

Quantitative assays revealed a clear and marked gradient in bioactive content between the two plant parts. Total phenolic content (TPC) in the flowers (71.00 mg GAE/g) was roughly three times higher than in the leaves (23.25 mg GAE/g). Similarly, total flavonoid content (TFC) in the flowers (32.5 mg QE/g) was about 1.7-fold higher than in the leaves (18.8 mg QE/g). This distribution suggests that flowers are the primary site of synthesis and/or accumulation of these antioxidant compounds in *Helichrysum arenarium*.

These results are consistent with research on other *Helichrysum* species. Popa et al. [12], for example, reported that an ethanol absolute extract of *H. arenarium* inflorescences showed the highest polyphenol and flavonoid content among the solvents tested, with values of 19.26 ± 0.193 mg GAE/g dry matter and 59.58 ± 0.125 mg QE/g dry matter, respectively. Similarly, Fidan et al. [13] reported a total polyphenol content of 7.56 mg GAE/g dry weight and a total flavonoid content of 3.13 mg QE/g dry weight in 95% ethanolic extracts of *H. arenarium* flowers from Turkey. The higher TPC values observed in the present study may be attributed to differences in geographic origin, climatic conditions, harvest timing, and extraction method, while the lower TFC compared with Popa et al. may reflect differences in plant population, environmental stress, or analytical conditions [12].

These findings are also consistent with earlier phytochemical work on sandy everlasting flowers (*Helichrysum flos*): Czinner et al. [14] showed that *Helichrysum flos* extracts inhibit microsomal lipid peroxidation in vitro, while Czinner et al. [15] used LC-DAD-MS to identify a range of phenolic compounds in these extracts, lending further support to the phenolic composition documented in the present study.

Recent LC-MS/MS studies by Uğur & Güzel [5] on Turkish samples showed that luteolin (744.57 mg/100 g), naringenin (229.60 mg/100 g), and quercetin (113.13 mg/100 g) are the dominant flavonoid compounds in methanolic extracts, confirming the high flavonoid potential of this species. Judzentiene et al. [6] further used HPLC-DAD-TOF to characterize Lithuanian samples, identifying luteolin-7-O-glucoside, naringenin and its glucoside, apigenin, chlorogenic acid, arenol, and arzanol as major constituents. The antioxidant activity of sand everlasting extracts was found to be considerably higher than that of the essential oils, with leaf extracts showing free-radical scavenging activity ranging from 11.18 to 19.13 mmol/L Trolox equivalent, and inflorescence extracts ranging from 1.96 to 6.13 mmol/L [6]. Notably, a 2024 Lithuanian study reported that leaf extracts collected at the onset of flowering surpassed inflorescence extracts in both TPC (72.21 mg GAE/g dry plant material) and ABTS antioxidant activity (1116.54 μ mol Trolox equivalent/g dry plant material), suggesting that leaf phenolic content peaks during the early reproductive stages [7].

The substantial flavonoid content of the flowers highlights the plant's capacity to produce valuable secondary metabolites known to contribute significantly to antioxidant, anti-inflammatory, and hepatoprotective activities. The choleric and hepatoprotective effects of *Helichrysum arenarium* inflorescences have been attributed to the antioxidant properties of their phenolic and flavonoid compounds, particularly the chalcone isosalipurposide and the flavanones naringenin and naringenin-5-O-glucoside (helichrysins A and B), which are characteristic components of sand everlasting flowers [16]. In a randomized double-blind trial, Kenig et al. found that infusions of *H. arenarium* and *H. italicum* significantly reversed features of metabolic syndrome, further supporting the therapeutic potential of these phenolic-rich preparations. [17]

4.3 Chemical composition of hexane extracts

GC-MS analysis revealed clearly distinct profiles between the leaf and flower hexane extracts, consistent with the compositions given in Tables 2 and 3. The leaf extract consisted mainly of stearic acid (44.98%), nonacosane (18.42%), and methyl palmitate (12.65%), along with smaller amounts of palmitic acid (3.43%), octacosane (2.72%), heptacosane (2.10%), and tricosane (1.22%). This pattern, dominated by long-chain saturated fatty acids, their methyl esters, and long-chain alkanes, is compatible with the composition of plant cuticular, the protective lipid layer covering the plant's aerial surfaces that limits water loss. These findings suggest that surface-associated waxy lipids may contribute substantially to the non-polar fraction of the leaf extract[22].

By contrast, the flower hexane extract showed a more diverse pattern, with major components including tricosane (17.70%), nonacosane (11.98%), cyclohexanol (12.79%), and (E)-2-hexenal (11.35%), alongside heptacosane (4.38%), heneicosane (2.34%), octadecane (1.14%), and dodecane (0.36%). This combination of medium- and long-chain alkanes together with the oxygenated compounds cyclohexanol and 2-hexenal suggests that the flower extract combines alkane compounds compatible with wax-associated constituents and oxygenated metabolites.

Overall, the hexane extract chemistry highlights a clear differentiation at the plant-organ level: the leaves reflect a relatively homogeneous cuticular waxy pattern rich in fatty acids and long-chain alkanes, consistent with their year-round protective role, whereas the flowers combine alkanes with volatile oxygenated compounds likely to contribute to floral scent and short-range chemical signaling during the flowering season [23].

4.4 Comparative significance and practical applications

The clear differences in phytochemical patterns between the flowers and leaves of *H. arenarium* carry important practical implications. While the flowers represent the principal reservoir of phenolic antioxidants and are traditionally used in herbal medicine, their harvest is restricted to the short flowering period (July–August). The leaves, available year-round given the plant's evergreen habit, represent a valuable alternative source of bioactive compounds, albeit at lower concentrations. This finding supports the sustainable use of the plant by allowing leaves to be harvested outside the flowering season, thereby preserving flower populations and ensuring a continuous supply of raw material.

The high phenolic and flavonoid content documented in this study supports the traditional use of *H. arenarium* flowers as a choleric agent and for treating skin conditions [19]. The antioxidant properties of these compounds may help mitigate oxidative stress, a key pathogenic factor in liver disorders and inflammatory skin conditions. Furthermore, the antimicrobial activity of ethanolic extracts against *Staphylococcus aureus*, *Bacillus megaterium*, and dermatophytic fungi, reported by Eren et al. for *H. arenarium* subsp. *aucherii*, further reinforces the ethnopharmacological relevance of this species for dermatological applications [4].

5. Conclusions:

This study provides a foundational phytochemical characterization of *Helichrysum arenarium* (L.) Moench growing wild in the Frunlouk forests of Syria. The results conclusively demonstrate that this species, and its flowers in particular, is a significant source of bioactive phenolic compounds with notable antioxidant potential.

Quantitative analysis revealed a substantial concentration of phenolics and flavonoids in the ethanolic flower extract — 71.00 mg GAE/g and 32.5 mg QE/g dry plant material, respectively — markedly exceeding the levels found in the leaf extract, which contained 23.25 mg GAE/g and 18.8 mg QE/g. GC-MS analysis identified distinct Chemical profiles in the hexane extracts: the leaf extract was dominated by stearic acid (44.98%), nonacosane (18.42%), and methyl palmitate (12.65%), a pattern consistent with cuticular wax rich in long-chain fatty acids and alkanes, whereas the flower extract was rich in tricosane (17.70%), nonacosane (11.98%), cyclohexanol (12.79%), and 2-hexenal (11.35%), reflecting a mixture of long-chain alkanes and volatile oxygenated compounds associated with floral scent.

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