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Seasonal Variation of *Lavandula angustifolia* Mill. Antioxidant Capacity

Liudmyla Svydenko[1], Evá Ivanišová[2], Andrii Svydenko[3], Olena Vergun[4]*, Oksana Shymanska[4]

[1]Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Department of Introduction and Selection of Rare Fruit, Ornamental and Aromatic Plants, Odesa, Ukraine
[2]Slovak University of Agriculture in Nitra, Faculty of Biotechnology and Food Sciences, Institute of Food Sciences, Nitra, Slovak Republic
[3]Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine, Department of Geographic Information Technologies, Management and Economic Research, Odesa, Ukraine
[4]M.M. Gryshko National Botanical Garden of the National Academy of Sciences of Ukraine, Department of Cultural Flora, Kyiv, Ukraine

Liudmyla Svydenko: https://orcid.org/0000-0002-4043-9240
Evá Ivanišová: https://orcid.org/0000-0001-5193-2957
Andrii Svydenko: https://doi.org/0000-7143-4872
Olena Vergun: https://orcid.org/0000-0003-2924-1580
Oksana Shymanska: https://orcid.org/0000-0001-8482-5883

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Lavandula angustifolia Mill. is one of the most widely used medicinal and aromatic plants, known for its diverse biological activities attributed to its secondary metabolites. The present study aimed to evaluate the total polyphenol content (TPC), total flavonoid content (TFC), total phenolic acid content (TPAC), as well as antioxidant activity determined by the DPPH radical scavenging assay (FRSA) and molybdenum-reducing power (MRP) in ethanol extracts of different plant parts of *L. angustifolia* during the vegetation period. Plant material was collected from experimental fields of the Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine during 2024–2025. The ethanol extracts exhibited considerable variation depending on growth stages and plant organs. Specifically, TPC ranged from 22.02 to 80.84 mg GAE·g^{-1}, TFC from 10.27 to 36.18 mg QE·g^{-1}, TPAC from 4.61 to 39.04 mg CAE·g^{-1}, MRP from 26.97 to 172.94 mg TE·g^{-1}, and FRSA from 3.64 to 9.20 mg TE·g^{-1}. The highest levels of phenolic compounds and antioxidant activity were observed in bud extracts, indicating that the budding stage is the most favorable period for harvesting biologically active raw material. Strong correlations between phenolic content and antioxidant activity further confirmed the key role of polyphenols in the antioxidant potential of *L. angustifolia* extracts. Overall, the obtained results suggest that bud-derived material of *L. angustifolia* represents a promising source for pharmacological and breeding applications. These findings also provide a basis for further biochemical investigations of *Lavandula* species across different stages of vegetation.

Keywords: common lavender, polyphenols, phenolic acids, flavonoids, correlation

***Corresponding Author:** Olena Vergun, M.M. Gryshko National Academy of Sciences of Ukraine of the National Academy of Sciences of Ukraine, Sadovo-Botanichna 1, 01103 Kyiv
olenavergun8003@gmail.com

Introduction

The phytochemical composition of plants depends on environmental factors and harvest time (Liebelt et al., 2019). Seasonal peculiarities affected the accumulation of various polyphenol groups in the plant raw material of medicinal plants (Soni et al., 2015).

Plants from the genus *Lavandula* L. are one of the most widespread aromatic essential oil plants in the world. They are used as medicinal (Radulescu et al., 2017), cosmetic, culinary, ornamental plants (Habán et al., 2023), and include approximately 40 species distributed across the Mediterranean region, North Africa, and Southwest Asia (Perović et al., 2024). The most commonly used species in this genus is *L. angustifolia* Mill., which is widely cultivated in many countries worldwide (Kajjari et al., 2022).

L. angustifolia herbs are characterized by antioxidant (Robu et al., 2012), antimicrobial (Jianu et al., 2013; Bogatyrova et al., 2024), antiproliferative (Nikšić et al., 2017), neuroprotective (Radulescu et al., 2017), anticancer (Aboalhaija et al., 2022), and neurologic (Batiha et al., 2023) activities.

The plant raw material from these plants is distinguished by its valuable biochemical composition, regardless of the region where it is grown. Among volatile components in leaf extracts were identified limonene, m-cymene, eucalyptol, 3-carene, *p*-cymene, and camphene, whereas the flower extracts were rich in ocimene isomers, linalyl acetate, β-caryophyllene, limonene, myrcene, linalool, etc. (Betlej et al., 2024). Inflorescence extracts characterized by the presence of phenolics such as rosmarinic acid (2.52–10.82 mg·g^{-1}), ferulic acid glucoside (2.94–8.67 mg·g^{-1}), caffeic acid (1.70–3.10 mg·g^{-1}), morin (1.02–13.63 mg·g^{-1}), coumarin (1.01–5.97 mg·g^{-1}), and herniarin (1.05–8.02 mg·g^{-1}) (Dobros et al., 2022). The essential oil of *L. angustifolia* is a valuable plant raw material that is used in medicine, especially in dentistry (Kajjari et al., 2022) and contains as main components caryophyllene (24.1%), beta-phellandrene (16%), and eucalyptol (15.6%), while the essential oil of *Lavandula* × *intermedia* contains camphor (32.7%) and eucalyptol (26.9%) (Jianu, 2013). The essential oil of this species exhibited anticancer (Gezici, 2018), antifungal (Slimani et al., 2022), antioxidant, and antimicrobial activities, and the main components were linalool, linalyl acetate, *p*-cymene, α-campholenal, and terpinen-4-ol (Bogdan et al., 2021; Slimani et al., 2022).

Industrial distillation for the production of essential oils generates significant amounts of solid waste that may also contain biologically active compounds. The *L. angustifolia* wastes obtained by the steam distillation exhibited higher flavonoid content (3.72 mg·g^{-1} DW) than those obtained by CO_2-extraction (2.91 mg·g^{-1} DW) and are a potential antioxidant source (Slavov et al., 2018).

It should be noted that only a limited number of researchers have compared the antioxidant activities

Figure 1 *Lavandula angustifolia* Mill. at the flowering stage

and phenolic content of the investigated plant parts during the vegetation period.

This study aimed to investigate the seasonal variation in different polyphenol compounds and the antioxidant activity of the plant raw material extracts of *L. angustifolia*, which is important for determining the availability of polyphenols for pharmacological purposes. Also, seasonal fluctuations in polyphenol accumulation across various plant parts can be used in breeding work.

Material and Methodology

Plant material

Lavandula angustifolia plants were collected from the experimental fields of the Institute of Climate Smart Agriculture of the National Academy of Agrarian Sciences of Ukraine ("Martienko" farm, Okny village, Podilskyi District, Odesa Oblast, Ukraine). The study region is characterized by a temperate continental climate with hot, dry summers and mild winters with low snowfall. The average annual temperature ranges from -5 °C in January to +21 °C in July. The soil of the experimental site is classified as typical chernozem with a humus content of 5.2% in the arable layer.

Plant material was collected seasonally during the vegetation period from healthy plants of the same age and at comparable developmental stages. The aerial parts of the plants were harvested, air-dried at room temperature under shaded and well-ventilated conditions until constant weight, and subsequently ground to a fine powder. The powdered material was stored in airtight containers at room temperature until analysis.

Chemicals

All chemicals were analytical grade and purchased from Reachem (Slovakia) and Sigma-Aldrich (USA).

Sample preparation

Dried powdered plant material (0.2 g) was extracted with 20 mL of 80% ethanol for 2 h at room temperature under continuous shaking. The extracts were centrifuged at 4,000 × g for 10 min using a Rotofix 32 A centrifuge (Hettich, Germany). The obtained supernatants were used for determination of total polyphenol, flavonoid, and phenolic acid contents, as well as antioxidant activity assays.

Total polyphenol content (TPC)

The total polyphenol content was determined using the Folin–Ciocalteu method according to Singleton and Rossi (1965). Briefly, 0.1 mL of plant extract was mixed with 0.1 mL of Folin–Ciocalteu reagent, 1.0 mL of 20% sodium carbonate solution, and 8.8 mL of distilled water. After incubation for 30 min in darkness at room temperature, the absorbance was measured at 765 nm using a Jenway 6405 UV/Vis spectrophotometer (England). Gallic acid was used as the calibration standard (25–250 mg·L^{-1}; R^2 = 0.996), and the results were expressed as mg gallic acid equivalents per g dry weight (mg GAE·g^{-1} DW).

Total flavonoid content (TFC)

The total flavonoid content was determined according to the modified method of Shafii et al. (2002). An aliquot of 0.5 mL of extract was mixed with 0.1 mL of 10% ethanolic aluminum chloride solution, 0.1 mL of 1 M sodium acetate, and 4.3 mL of distilled water. The reaction mixture was incubated in the dark at room temperature for 30 min, and the absorbance was measured at 415 nm. Quercetin was used as the calibration standard (0.01–0.5 mg·L^{-1}; R^2 = 0.997), and the results were expressed as µg quercetin equivalents per g dry weight (mg QE·g^{-1} DW).

Total phenolic acid content (TPAC)

Total phenolic acid content was determined according to Árvay et al. (2017). Briefly, 0.5 mL of plant extract was mixed with 0.5 mL of 0.5 M hydrochloric acid, 0.5 mL of Arnova reagent, 0.5 mL of 1 M sodium hydroxide, and 0.5 mL of distilled water. The absorbance was measured at 490 nm using a Jenway 6405 UV/Vis spectrophotometer (England). Caffeic acid served as the calibration standard (1–200 mg·L^{-1}; R^2 = 0.999), and the results were expressed as mg caffeic acid equivalents per g dry weight (mg CAE·g^{-1} DW).

Free radical scavenging assay (FRSA)

The free radical-scavenging activity was evaluated using the DPPH assay as described by Sanchez-Moreno et al. (1998). A volume of 0.5 mL of extract was mixed with 3.6 mL of freshly prepared DPPH solution (0.025 g DPPH in 100 mL ethanol). The reaction mixture was incubated in the dark at room temperature for 30 min, and the absorbance was measured at 515 nm. Trolox was used as the calibration standard (10–100 mg·L^{-1}; R^2 = 0.988), and the results were expressed as mg Trolox equivalents per g dry weight (mg TE·g^{-1} DW).

Molybdenum reducing power (MRP)

The reducing power of the extracts was determined using the phosphomolybdenum method described by Prieto et al. (1999) with slight modifications. A reaction mixture consisting of 1.0 mL of extract, 2.8 mL of 0.1 M monopotassium phosphate, 6.0 mL of 1 M sulfuric acid, 0.4 mL of 0.1 M ammonium heptamolybdate, and 0.8 mL of distilled water was incubated at 90 °C for 120 min. After rapid cooling to room temperature, the absorbance was measured at 700 nm using a Jenway 6405 UV/Vis spectrophotometer (England). Trolox was used as the calibration standard (10–1,000 mg·L^{-1}; R^2 = 0.998), and the results were expressed as mg Trolox equivalents per g dry weight (mg TE·g^{-1} DW).

Statistical analysis

All analyses were performed in triplicate, and the results are presented as mean ± standard deviation (SD). Statistical analysis was conducted using one-way analysis of variance (ANOVA), followed by the Tukey–Kramer post hoc test to determine significant differences among means at $p < 0.05$.

Results and Discussion

Polyphenols are natural secondary metabolites, water-soluble compounds widely distributed in plant raw materials, including flavonoids and phenolic acids, that exhibit antioxidant, antifungal, antimicrobial, anti-inflammatory, and anticancer activities (Saad et al., 2025). They play an important role in stress-tolerance mechanisms (Rao and Zheng, 2025). Flavonoids, as well as phenolic acids, are a large class of polyphenols with numerous pharmacological activities and are used to treat various diseases (Pinto et al., 2021). Additionally, these compounds play an important role as antistress agents, and their presence gives flowers and fruits their colors (Xu and Wang, 2025). Monitoring the accumulation of polyphenolic compounds, flavonoids, and phenolic acids during vegetation can help optimize extraction conditions for subsequent biochemical and pharmacological studies (Staveckienė et al., 2023; Andonova et al., 2024).

The content of phenolic compounds in *Lavandula angustifolia* extracts significantly depended on both the vegetation stage and the analyzed plant part (Figure 2). The highest values of total polyphenol content (TPC), total flavonoid content (TFC), and total phenolic acid content (TPAC) were detected at the budding stage. In contrast, the lowest accumulation of TPC and TPAC was observed in fruit extracts collected during the fruiting stage, whereas the minimum TFC was determined in flower extracts at the flowering stage.

The investigated extracts exhibited considerable variability in the accumulation of bioactive compounds. TPC ranged from 22.02 to 80.84 mg GAE·g^{-1}, TFC from 10.27 to 36.18 mg QE·g^{-1}, and TPAC

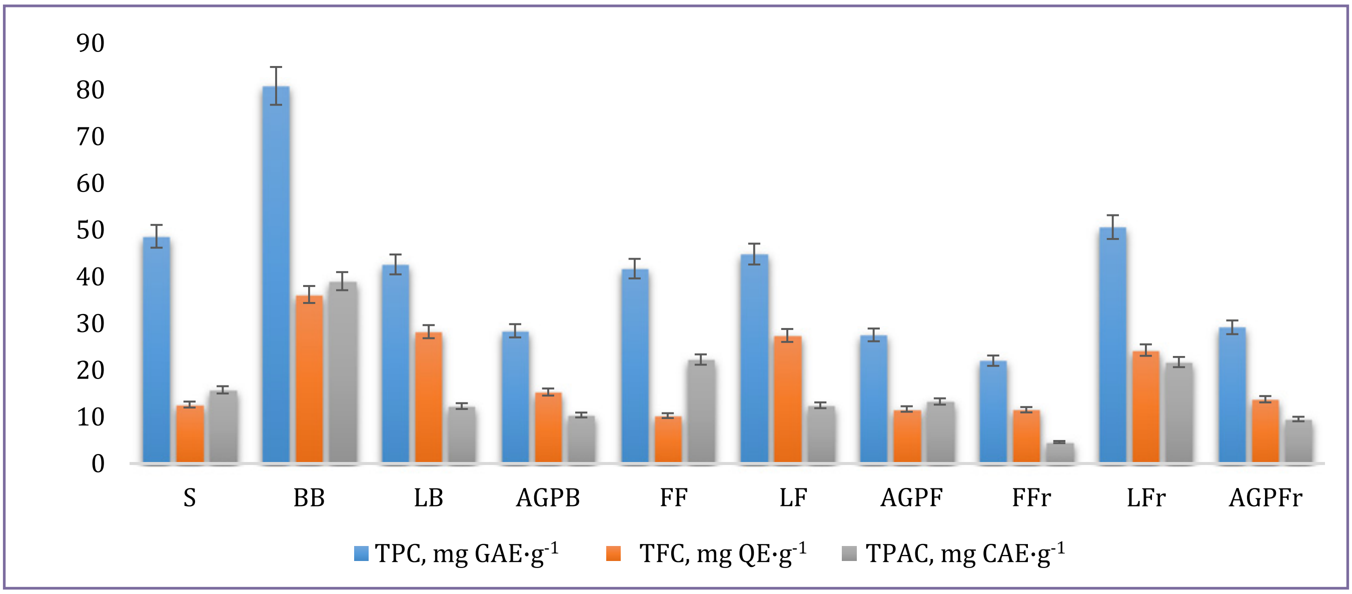

Figure 2 The total polyphenol, flavonoid, and phenolic acid content of *Lavandula angustifolia* Mill. extracts: TPC – total polyphenol content; TFC – total flavonoid content; TPAC – total phenolic acid content; S – sprouting; BB – buds, budding; LB – leaves, budding; AGPB – above-ground part, budding; FF – flowers, flowering; LF – leaves, flowering; AGPF – above-ground part, flowering; FFr – fruits, fruiting; LFr – leaves, fruiting; AGPFr – above-ground part, fruiting

from 4.61 to 39.04 mg CAE·g^{-1}. Leaf extracts showed the highest TPC and TPAC values during the fruiting stage, while maximal TFC was recorded at the budding stage. In the above-ground plant parts, the highest TPC, TFC, and TPAC values were observed during the fruiting, budding, and flowering stages, respectively.

The obtained results confirm that the accumulation of phenolic compounds in lavender is strongly influenced by ontogenetic development and plant organ specificity. Similar observations have been reported for *Lavandula* species, in which polyphenol accumulation varies with plant part, genotype, extraction procedure, and vegetation stage (Blažeković et al., 2010; Détár et al., 2020; Popoviciu and Panaitescu, 2021; Mykhailenko et al., 2025; Doubi et al., 2026). The increased accumulation of phenolic compounds during the budding stage may be associated with intensified secondary metabolism and enhanced biosynthesis of protective phytochemicals before flowering.

Our results are generally consistent with the findings of Blažeković et al. (2010), who reported the highest TPC, TFC, and TPAC values in leaf extracts of *L. angustifolia* and *Lavandula* × *intermedia*. Similarly, the present study demonstrated that leaf tissues accumulated substantial amounts of phenolic compounds compared with reproductive organs.

Aboalhaija et al. (2022) reported wide variations in phenolic composition depending on extraction solvent, with TPC ranging from 14.43 to 204.87 mg GAE·g^{-1} and TFC from 3.20 to 100.77 mg QE·g^{-1} in *L. angustifolia* extracts. The ethanol extract in their study contained 82.90 mg GAE·g^{-1} of TPC, which is very close to the maximal value obtained in the present study for bud extracts (80.84 mg GAE·g^{-1}). However, the TFC reported by these authors (50.22 mg QE·g^{-1}) exceeded the highest value determined in our samples (36.18 mg QE·g^{-1}). Such discrepancies may be due to differences in environmental conditions, plant origin, extraction protocols, and the developmental stage of the analyzed material.

The flower extracts analyzed in this study contained 41.73 mg GAE·g^{-1} of TPC and 10.27 mg QE·g^{-1} of TFC. These values are generally higher than those reported for Polish *L. angustifolia* inflorescences by Dobros et al. (2022), where TPC ranged from 14.88 to 32.82 mg GAE·g^{-1} depending on the extraction method. Likewise, Betlej et al. (2024) reported lower TPC values in flower (9.70–15.84 mg GAE·g^{-1}) and leaf extracts (16.95–24.49 mg GAE·g^{-1}), indicating that the Ukrainian-grown lavender investigated in the present study may possess enhanced phenolic accumulation potential.

In contrast, some studies demonstrated substantially higher phenolic concentrations than those obtained in our work. For example, Gadouche et al. (2025) reported 125.28 mg GAE·g^{-1} DW of TPC in ethanol extracts of Algerian *Lavandula dentata*, suggesting that species-specific characteristics and ecological conditions strongly influence secondary metabolite biosynthesis. Similarly, Slimani et al. (2022) observed elevated TPC (67.97 mg GAE·g^{-1}) and particularly high TFC values (53.58 mg QE·g^{-1}) in aqueous extracts of *L. angustifolia*.

The differences among published data may also be explained by solvent polarity and extraction efficiency. Although ethanol is considered an effective and environmentally safe solvent for phenolic extraction, several studies have demonstrated that aqueous and methanolic extracts may yield higher concentrations of certain phenolic compounds. Talić et al. (2023) reported the highest TPC in water extracts (45.30 mg GAE·g^{-1}), followed by ethanol extracts (14.40 mg GAE·g^{-1}) and ethyl acetate extracts (8.50 mg GAE·g^{-1}). Therefore, solvent selection remains a key factor in the recovery of antioxidant compounds from lavender biomass. Overall, the obtained results indicate that the budding stage represents the most favorable developmental phase for the accumulation of antioxidant phenolics in *L. angustifolia*.

The antioxidant activity of plant extracts is generally associated with the concentration of phenolic compounds, particularly polyphenols and flavonoids, which can scavenge free radicals and reduce oxidizing agents. In the present study, the antioxidant potential of *L. angustifolia* extracts was evaluated using the DPPH free radical scavenging assay (FRSA) and molybdenum-reducing power assay (MRP) at different vegetation stages (Figure 3).

The obtained results demonstrated significant seasonal and organ-specific variation in antioxidant activity. MRP values of ethanol extracts ranged from 26.97 to 172.94 mg TE·g^{-1}, while FRSA values varied from 3.64 to 9.20 mg TE·g^{-1} during vegetation. The highest antioxidant activity was generally observed during the budding stage. Specifically, maximal MRP was detected in bud extracts, whereas the highest FRSA was recorded in extracts of the above-ground plant parts collected at budding. In contrast, the lowest FRSA values were determined in bud extracts, while minimal MRP values were observed in above-ground parts at the fruiting stage.

Leaf extracts exhibited distinct seasonal patterns of antioxidant activity. The highest MRP values were observed during flowering, whereas FRSA reached its maximum at the fruiting stage. These differences may be associated with changes in the biosynthesis and distribution of antioxidant metabolites during plant ontogenesis. Increased antioxidant activity during budding and flowering stages likely reflects intensified metabolic processes and enhanced accumulation of protective phytochemicals during active plant development.

The obtained results are in agreement with previous studies indicating a strong relationship between phenolic composition and antioxidant capacity in medicinal plants (Dontha, 2016; Untea et al., 2018). Since phenolic compounds act as hydrogen or electron donors, higher TPC and TFC values observed during budding may explain the elevated antioxidant activity detected in the corresponding extracts.

Comparison with literature data demonstrated both similarities and differences depending on species, extraction conditions, and environmental factors. Carvalho et al. (2025) reported considerably higher MRP values for *Lavandula* viridis extracts (438.83 mg TE·g^{-1}) than those obtained in the present study (maximum 172.94 mg TE·g^{-1}). This discrepancy may be attributed to interspecific variability, ecological conditions, extraction efficiency, and differences in phytochemical composition between *Lavandula* species.

Comparable antioxidant activity values were reported for other members of the Lamiaceae family. Svydenko et al. (2022) demonstrated that MRP values in Salvia species ranged from 56.25 to 218.67 mg TE·g^{-1} depending on developmental stage, with maximal activity observed in leaf extracts during flowering. These findings are partially consistent with the present study, where leaf extracts of *L. angustifolia* also exhibited elevated reducing power at the flowering stage.

Overall, the present results confirm that antioxidant activity in *L. angustifolia* is strongly influenced by vegetation stage and plant organ. The budding stage appeared to be the most favorable period for obtaining extracts with high antioxidant potential.

The obtained data are consistent with those of previous studies on the correlation between polyphenols and the antioxidant activity of extracts from plants of the family Lamiaceae (Stagos et al., 2012; Yu et al., 2021). In our study, a very strong correlation was found between MRP and TPC, TFC, and TPAC (r = 0.867–0.997) at the budding stage, whereas FRSA demonstrated a strong negative relation (r = -0.863–0.998) (Table 1). However, in our study, very strong correlations were found between all investigated parameters and MRP (r = 0.960–0.986). The same results were found for FRSA related to TPC, TFC, and TPAC (r = 0.873–0.974) at the fruiting stage. In contrast, negative correlations were found between FRSA and TPC, and between FRSA

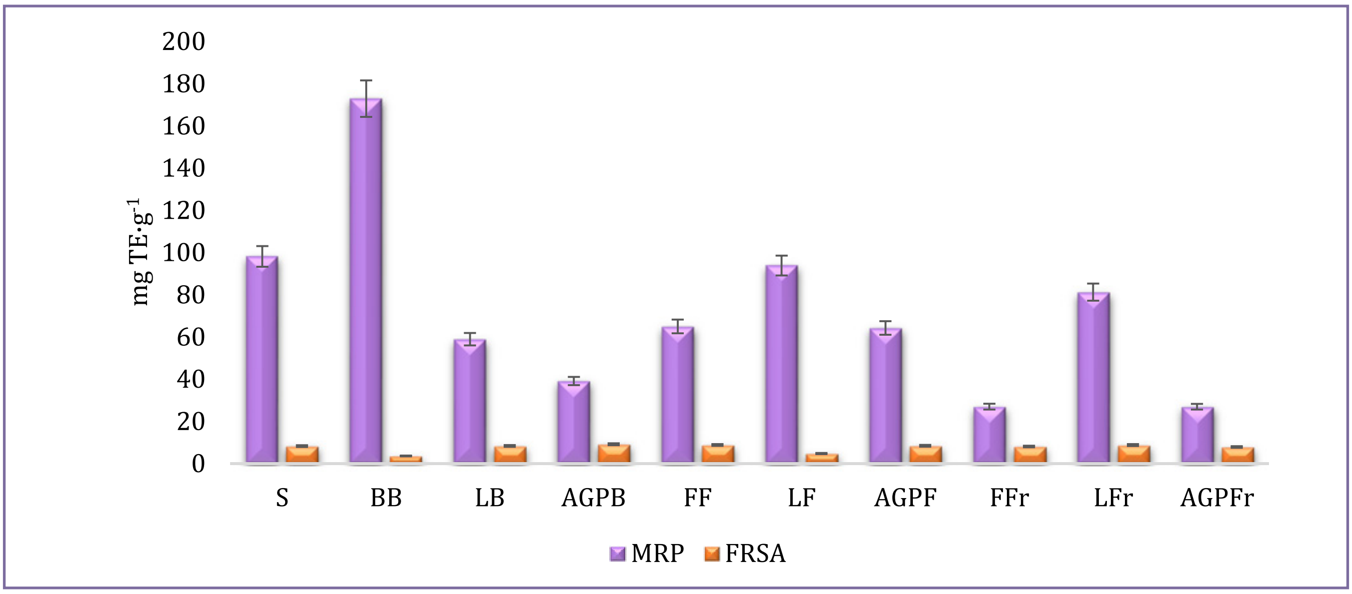

Figure 3 The molybdenum-reducing power and free radical scavenging activity of *Lavandula angustifolia* Mill. extracts (mg TE·g^{-1}): MRP – molybdenum-reducing power; FRSA – free radical scavenging activity; S – sprouting; BB – buds, budding; LB – leaves, budding; AGPB – above-ground part, budding; FF – flowers, flowering; LF – leaves, flowering; AGPF – above-ground part, flowering; FFr – fruits, fruiting; LFr – leaves, fruiting; AGPFr – above-ground part, fruiting.

Table 1 The correlation between the investigated parameters of *Lavandula angustifolia* Mill.

Parameters	TPC	TFC	TPAC	MRP	FRSA
			Budding		
TPC	1.000				
TFC	0.923**	1.000			
TPAC	0.979**	0.825*	1.000		
MRP	0.992**	0.867*	0.997**	1.000	
FRSA	-0.991**	-0.863*	-0.998**	-0.998**	1.000
			Flowering		
TPC	1.000				
TFC	0.581	1.000			
TPAC	0.274	-0.624	1.000		
MRP	0.655	0.996**	-0.547	1.000	
FRSA	-0.569	-0.998**	0.635	-0.994**	1.000
			Fruiting		
TPC	1.000				
TFC	0.997**	1.000			
TPAC	0.999**	0.993**	1.000		
MRP	0.971**	0.986**	0.960**	1.000	
FRSA	0.891	0.924**	0.873*	0.974**	1.000

Notes: TPC – total polyphenol content; TFC – total flavonoid content; TPAC – total phenolic acid content; MRP – molybdenum-reducing power; FRSA – free radical scavenging activity; ** – correlation is significant at the level of 0.01; * – correlation is significant at the level of 0.05

and TFC, at the flowering stage. Also, MRP is strongly correlated with TFC and with TPC in this period.

The FRSA of *L. angustifolia* extracts was strongly correlated with TPAC in the study by Wierdak-Nurzyńska and Zawiślak (2016), which was similar to our results obtained at the fruiting stage. Both FRSA and TPC, as well as FRSA and TFC, demonstrated a very strong correlation of 0.881 in the study of Marovska et al. (2023).

Conclusions

The obtained results demonstrate that *L. angustifolia* is a valuable source of polyphenolic compounds with pronounced antioxidant activity. The total polyphenol, total flavonoid, and total phenolic acid contents, as well as antioxidant activity of ethanol extracts, were strongly influenced by the growth stage and plant organ. The highest accumulation of TPC, TFC, and TPAC, accompanied by the strongest antioxidant activity (MRP and FRSA), was observed at the budding stage. These parameters showed strong positive correlations, indicating that phenolic compounds are the main contributors to the antioxidant potential of the investigated extracts. In particular, bud extracts of *L. angustifolia* can be considered the most promising raw material for further pharmacological and phytochemical studies due to their consistently high bioactive compound content. Leaf extracts demonstrated a more stage-dependent profile. They exhibited higher TPC and TPAC values at the fruiting stage, while TFC reached its maximum at the budding stage. This suggests that leaves may serve as an alternative source of antioxidant compounds, although their activity is more variable depending on the developmental phase. Overall, the results confirm that the optimal harvesting period for obtaining antioxidant-rich *L. angustifolia* biomass is the budding stage. The observed seasonal and organ-specific differences should be taken into account in the selection of plant material for medicinal, nutraceutical, and breeding purposes. The obtained data provide a useful basis for further biochemical and pharmacological investigations of *Lavandula* species across different vegetation stages.

Conflict of interest

The authors have no competing interests to declare.

Ethical statement

This article doesn't contain any studies that would require an ethical statement.

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References

Aboalhaija, N., Syaj, H., Afifi, F., Sunoqrot, S., Al-Shalabi, E., & Talib, W. (2022). Chemical evaluation, *in vitro* and *in vivo* anticancer activity of *Lavandula angustifolia* grown in Jordan. *Molecules*, 27, 5910. https://doi.org/10.3390/molecules27185910

Andonova, T., Rusinova-Videlova, S., Bojilov, D., Apostolova, E., Mladenova, T., Slavov, I., & Dimitrova-Dyulgerova, I. (2024). Seasonal dynamic of main classes phenolics and radical scavenging activity of invasive tree *Ailanthus altissima* extracts. *Ecologia Balkanica*, 16(1), 112–122.

Árvay, J., Hauptvogl, M., Ivanisova, E., Tidil'ová, I., Hrstková, M., Bajčan, D., & Lazor, P. (2017). Methylxanthines and catechines in different teas (*Camellia sinensis* L. Kuntze) – influence on antioxidant properties. In *Potravinarstvo Slovak Journal of Food Science*, 11(1), 510–516. https://doi.org/10.5219/796

Barar, A., & Bensebia, O. (2025). Surfactant assisted extraction for the recovery of bioactive compounds from solid wastes of lavender (*Lavandula angustifolia* Mill): optimization by box–Behnken design. *Process Biochemistry*, 153, 170–181. https://doi.org/10.1016/j.procbio.2025.03.013

Batiha, G.E.S., Teibo, J.O., Wasef, L., Shaheen, H.M., Akomolafe, A.P., Teibo, T.K.A., Al-kuraishy, H.M., Al-Garbeeb, A.I., & Alexiou, A. (2023). A review of the bioactive components and pharmacological properties of *Lavandula* species. *Naunyn-Schmiedeberg's Archives of Pharmacology,* 396, 877–900. https://doi.org/10.1007/s00210-023-02392-x

Bayram, N.E., Yunigun, B., & Gercek, Y.C. (2025). Extraction of phenolic compounds from lavender (*Lavandula angustifolia* L.) plant by natural deep eutectic solvent and greenness assessment of analytical method with modified green analytical procedure index. *Chemistry and Biodiversity,* 22(9), e202500194. https://doi.org/10.1002/cbdv.202500194

Betlej, I., Andres, B., Cebulak, T., Kapusta, I., Balawejder, M., Zurek, N., Jaworski, S., Lange, A., Kutwin, M., Pisulewska, E., Kidacka, A., Krochmal-Marzak, B., Boruszewski, P., & Borysiuk, P. (2024). Phytochemical composition and antimicrobial properties of new *Lavandula angustifolia* ecotypes. *Molecules*, 29, 1740. https://doi.org/10.3390/molecules29081740

Blažeković, B., Vladimir-Knežević, S., Brantner, A., & Stefan, M.B. (2010). Evaluation of antioxidant potential of *Lavandula × intermedia* Emeric ex Loisel. 'Budrovka': a comparative study with *L. angustifolia* Mill. *Molecules*, 15, 5971–5987. https://doi.org/10.3390/molecules15095971

Bogatyrova, O., Hurina, V., Naboka, O., Filimonova, N., Dzhoraieva, S., Mykhailenko, O., & Georgiyants, V. (2024). *Lavandula angustifolia* Mill. of Ukrainian origin: a comprehensive study of the chemical composition and antimicrobial potential and of herb extracts. *ScienceRise: Pharmaceutical Science,* 5(51), 4–14. https://doi.org/10.15587/2519-4852.2024.313236

Bogdan, M.A., Bungau, S., Tit, D.M., Zaha, D.C., Nechifor, A.C., Behl, T., Chambre, D., Lupitu, A.I., & Copolovici, D.M. (2021). Chemical profile, antioxidant capacity, and antimicrobial activity of essential oils extracted from three different varieties (Moldoveanca 4, Vis Magic 10, and Alba 7) of *Lavandula angustifolia*. *Molecules,* 26, 4381. https://doi.org/10.3390/molecules26144381

Carvalho, J.S., Viegas, C., Markiewicz, M., Galanty, A., Paśko, P., Jakupović, L., & Končić, M. (2025). Plant-based potential in diabetes management: *in vitro* antioxidant, wound-healing, and enzyme inhibitory activities of Southern Algarve species. *Molecules,* 30, 2432. https://doi.org/10.3390/molecules30112432

Détár, E., Nemeth, Z., & Pluhar, Z. (2020). Antioxidant capacity and total polyphenol content of *Lavandula* cultivars at different growing areas in Hungary. *International Journal of Horticultural Science*, 26, 65–69. https://doi.org/10.31421/IJHS/26/2020/5748

Dobros, N., Zawada, K., & Paradowska, K. (2022). Phytochemical profile and antioxidant activity of *Lavandula angustifolia* and *Lavandula × intermedia* cultivars extracted with different methods. *Antioxidants*, 11, 711. https://doi.org/10.3390/antiox11040711

Dontha, S. 2016. A review on antioxidant methods. *Asian Journal of Pharmaceutical and Clinical Research,* 9(2), 1–19. http://dx.doi.org/10.22159/ajpcr.2016.v9s2.13092

Doubi, M., Moussaoui, F., Laabar, A., Torres, C., El Khomsi, M., Khemmou, N., Allali, A., Lahkimi, A., & Hmouni, D. (2026). Optimization of polyphenol and flavonoid extraction from *Lavandula* multifida using a D-optimal experimental design: phytochemical screening and yield evaluation. *Ecological Engineering and Environmental Technology,* 27(5), 200–216. https://doi.org/10.12912/27197050/220198

Duda, S.C., Mărghitaș, L.A., Dezmirean, D., Duda, M., Mărgăoan, R., & Bobiș, O. (2015). Changes in major bioactive compounds with antioxidant activity of Agastache foeniculum, *Lavandula angustifolia*, *Melissa officinalis* and *Nepeta cataria*: effect of harvest time and plant species. *Industrial Crops and Products*, 77, 499–507. http://dx.doi.org/10.1016/j.indcrop.2015.09.045

Habán, M., Korczyk-Szabó, J., Čerteková, S., & Ražná, K. (2023). *Lavandula* species, their bioactive phytochemicals, and their biosynthetic regulation. *International Journal of Molecular Sciences*, 24, 8831. https://doi.org/10.3390/ijms24108831

Jianu, C., Pop, G., Gruia, A.T., & Horhat, F.C. (2013). Chemical composition and antimicrobial activity of essential oils of lavender (*Lavandula angustifolia*) and lavandin

(*Lavandula* × *intermedia*) grown in Western Romania. *International Journal* of Agriculture & Biology, 15, 772–776.

Gadouche, L., Riati, S., Mekraf, S., Bahraoui, S.E., & Rekmouche, K. (2025). Antioxidant and antimicrobial activities of *Lavandula dentata* extracts: a comparative study of solvent efficacy. *Notulae Scientia Biologicae,* 17(4), 12748. https://doi.org/10.55779/nsb17412748

Gezici, S. (2018). Promising anticancer activity of lavender (*Lavandula angustifolia* Mill.) essential oil through induction of both apoptosis and necrosis. *Annals of Phytomedicine*, 7(2), 38–45. https://doi.org/10.21276/ap.2018.7.2.5

Kajjari, Sh., Joshi, R., Hugar, S.M., Gokhale, N., Meharwade, P., & Uppin, C. (2022). The effects of lavender essential oil and its clinical implications in dentistry: a review. *International Journal of Clinical Pediatric Dentistry*, 15(3), 285–388. https://doi.org/10.5005/jp-journals-10005-2378

Liebelt, D.J., Jordan, J.T., & Doherty, C.J. (2019). Only a matter of time: the impact of daily and seasonal rhythms on phytochemicals. *Phytochemical Reviews*, 4, 1–25. https://doi.org/10.1007/s11101-019-09617-z

Marovska, G.I., Hambarliyska, I.P., Petkova, N.T., Ivanov, I.G., Vasileva, I.N., & Slavov, A.M. (2023). Chemical composition and antioxidant activity of ethanol extracts obtained from lavender (*Lavandula angustifolia* Mill.). *Phillipine Journal of Science*, 152(3), 861–870.

Mykhailenko, O., Hurina, V., Herbina, N., Muslii, Y., Ivanauskas, L., Vladymyrova, I., Lytkin, D., Gudzinskas, Z., Severina, H., Ruban, O., & Georgiyants, V. (2025). Phenolic compounds and pharmacological potential of *Lavandula angustifolia* extracts for the treatment of neurodegenerative diseases. *Plants*, 14, 289. https://doi.org/10.3390/plants14020289

Nikšić, H., Kovač-Bešović, E., Makarević, E., Durić, K., Kusturica, J., & Muratovic, S. (2017). Antiproliferative, antimicrobial, and antioxidant activity of *Lavandula angustifolia* Mill. essential oil. *Journal of Health Sciences*, 7(1), 35–43. https://doi.org/10.17532/jhsci.2017.412

Perović, A.B., Karabegović, I.T., Krstić, M.S., Veličković, A.V., Avramović, J.M., Danilović, B.R., & Veljkovic, V.B. (2024). Novel hydrodistillation and steam distillation methods of essential oil recovery from lavender: A comprehensive review. *Industrial Crops and Products*, 211, 118244. https://doi.org/j.indcrop.2024.118244

Pinto, T., Aires, A., Cosme, F., Bacelar, E., Morais, M.C., Oliveira, I., Ferreira-Cardoso, J., Anjos, R., Vilela, A., & Gonçalves, B. (2021). Bioactive (Poly)phenols, volatile compounds from vegetables, medicinal and aromatic plants. *Foods*, 10, 106. https://doi.org/10.3390/foods10010106

Popoviciu, D.R., & Panaitescu, L. (2021). Essential oils and total phenolic content correlated with anatomical features in *Lavandula angustifolia* Mill. organs. *Annals of the University of Craiova*, 26(17), 135–140. https://doi.org/10.52846/bhfe.26.2021.21

Prieto, P., Pineda, M., & Aguilar, M. (1999). Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of vitamin E. *Analytical Biochemistry*, 269(2), 337–341. https://doi.org/10.1006/abio.1999.4019

Radulescu, C., Stihi, C., Ilie, M., Lazurcă, D., Cruia, R., Olaru, O.T., Bute, O.C., Dulama, I.D., Stirbescu, R.M., Teodorescu, S., & Florescu, M. (2017). Characterization of phenolics in *Lavandula angustifolia*. *Analytical Letters,* 50(17), 1–13. http://dx.doi.org/10.1080/00032719.2016.1264409

Raibhar, K., Dawda, H., & Mukundan, U. (2015). Polyphenols: methods of extraction. *Scientific Reviews and Chemical Communications*, 5(1), 1–6.

Rao, M.J., & Zheng, B. (2025). The Role of polyphenols in abiotic stress tolerance and their antioxidant properties to scavenge reactive oxygen species and free radicals. *Antioxidants*, 14, 74. https://doi.org/10.3390/antiox14010074

Robu, S., Aprotosaie, A.C., Miron, A., Cioancă, O., Stănescu, U., & Hăncianu, M. (2012). *In vitro* antioxidant activity of ethanolic extracts from some *Lavandula* species cultivated in Romania. *Farmacia*, 60(3), 394–401.

Saad, A.M., Mohammed, D.M., Alkafaas, S.S., Ghosh, S., Negm, S.H., Salem, H.M., Fahmy, M.A., Semary, H.E., Ibrahim, E.H., AbuQamar, S.F., El-Tarabily, K.A., & El-Saadony, M.T. (2025). Dietary polyphenols and human health: sources, biological activities, nutritional and immunological aspects, and bioavailability – a comprehensive review. *Frontiers in Immunology*, 16, 1653378. https://doi.org/10.3389/fimmu.2025.1653378

Sánchez-Moreno, C., Larrauri, A., & Saura-Calixto, F. (1998). A procedure to measure the antioxidant efficiency of polyphenols. *Journal of the Science of Food and Agriculture*, 76, 2, 270–276. https://doi.org/10.1002/(SICI)1097-0010(199802)76:2<270::AID-JSFA945>3.0.CO;2-9

Shafii, Z. A., Basri, M., Malek, E. A., & Ismail, M. (2017). Phytochemical and antioxidant properties of *Manilkara zapota* (L.) P royal fruit extracts and its formulations for cosmeceutical application. *Asian Journal of Plant Science and Research*, 7(3), 29–41.

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagent. *American Journal of Enology and Viticulture*, 16(3), 144–158.

Slavov, A.M., Karneva, K.B., Vasileva, I.N., Denev, P.N., Denkova, R.S., Shikov, V.T., Manolova, M.N., Lazarova, Y.L., & Ivanova, V.N. (2018). Valorization of lavender waste – obtaining and characteristics of polyphenol rich extracts. *Food Science and Applied Biotechnology*, 1(1), 11–18. https://doi.org/10.30721/fsab2018.vl.il

Slimani, Ch., Sqalli, H., Rais, Ch., Farah, A., Lazraq, A., El Ghadraoui, L., Belmalha, S., & Echchgadda, G. (2022). Chemical composition and evaluation of biological effects of essential oil and aqueous extract of *Lavandula angustifolia* L. *Notulae Scientia Biologicae,* 14(1), 11172. https://doi.org/10.15835/nsb14111172

Soni, U., Brar, S., & Gauttam, V.K. (2015). Effect of seasonal variation on secondary metabolites of medicinal plants. *International Journal of Pharmaceutical Sciences and Research*, 6(9), 3654–3662. http://dx.doi.org/10.13040/IJPSR.0975-8232.6(9).3564-62

Stagos, D., Portesis, N., Spanou, C., Mossialos, D., Aligiannis, N., Chaita, E., Panagoulis, C., Reri, E., Skaltosounis, L., Tsatsakis, A.M., & Kouretas, D. (2012). Correlation of total phenolic content with antioxidant and antibacterial activity of 24 extracts from Greek domestic Lamiaceae species. *Food and Chemical Toxicology*, 50(11), 4115–4124. https://doi.org/10.1016/j.fct.2012.08.033

Staveckienė, J., Kulaitienė, J., Levickienė, D., Vaitkevičienė, N., & Vaštakaite-Kairienė, V. (2023). The effect of ripening stages on the accumulation of polyphenols and antioxidant activity of the fruit extracts of *Solanum* species. Plants, 12(14), 2672. https://doi.org/10.3390/plants12142672

Svydenko, L., Vergun, O., Ivanisova, E., Korablova, O., & Fatrcová Šramková, K. (2022). Polyphenol compounds and antioxidant activity of *Salvia officinalis* L. and *Salvia sclarea* L. *Agrobiodiversity for Improving Nutrition, Health and Life Quality,* 2, 139–148. https://doi.org/10.15414/ainhlq.2022.0015

Talić, S., Odak, I., Boras, M.M., Smoljan, A., & Bevanda, A.M. (2023). Essential oil and extracts from *Lavandula angustifolia* Mill. cultivated in Bosnia and Herzegovina: antioxidant activity and acetylcholinesterase inhibition. *International Journal of Plant Based Pharmaceuticals*, 3(1), 95–103. https://doi.org/doi.org/10.29228/ijpbp.21

Untea, A., Lupu, A., Saracila, M., & Panaite, T. (2018). Comparison of ABTS, DPPH, phosphomolybdenum assays for estimating antioxidant activity and phenolic compounds in five different plant extracts. *Bulletin UASVM Animal Science and Biotechnologies*, 75(2), 110–114. https://doi.org/10.15835/buasvmcn-asb:2018.0009

Wierdak-Nurzyńska, R., & Zawislak, G. (2016). Chemical composition and antioxidant activity of lavender (*Lavandula angustifolia* Mill.) aboveground parts. *Acta Scientiarum Polonorum Hortorum Cultus*, 15(5), 225–241.

Xu, L., & Wang, X. (2025). A comprehensive review of phenolic compounds in horticultural plants. *International Journal of Molecular Sciences*, 26(12), 5767. https://doi.org/10.3390/ijms26125767

Yu, M., Gouvinhas, I., Rocha, J., & Barros, A.I.R.N.A. (2021). Phytochemical and antioxidant analysis of medicinal and food plants towards bioactive food and pharmaceutical resources. *Scientific Reports*, 11, 10041. https://doi.org/10.1038/s41598-021-89437-4