Original Article KYMJ / 2026;1(1): 34-39
DOI: https://doi.org/10.66251/ncn4fs46
The content of this journal is licensed under a Creative Commons Attribution-Non Commercial 4.0 International License,

Evaluation of the *Linden Tree* (*Tilia* spp.) as a Value-Added Product in the Cosmetics, Health, and Food Industries

Musa Karadağ[1(ID)], Kadir Sinan Aslan[1(ID)]

[1]Iğdır University Technical Sciences Vocational School, Iğdır, Türkiye
[2]Dicle University, Science Faculty, Department of Biology, Diyarbakir, Türkiye,

Received: 03.03.2026. Accepted:13.04.2026 Publication:26.04.2026

ABSTRACT

Objective: Linden (Tilia spp.) is an important plant resource with a wide range of uses, from traditional medicine to modern industrial applications, due to its phytochemical content rich in phenolic compounds, flavonoids, essential oils, and mucilage. In recent years, the increasing demand for natural and functional ingredients has brought linden to the forefront as a strategic raw material for the development of value-added products in the cosmetic, health, and food industries. In this context, it is of great importance to reveal the biological activity potential of linden using scientific methods.

Methods: In this study, the phenolic and flavonoid composition of linden extracts was examined in detail using HPLC-DAD analysis. According to the analysis results, the presence of biologically active compounds such as ascorbic acid, gallic acid, protocatechuic acid, catechin, p-coumaric acid, ferulic acid, rutin, naringin, and quercetin was detected.

Results: The chromatographic data obtained show that linden has a phytochemical profile with a multi-component and strong antioxidant capacity. When HPLC-DAD results were evaluated, it was observed that ascorbic acid and gallic acid eluted at high intensity at early retention times, while ferulic acid, rutin, and naringin were identified as dominant compounds in the middle retention region. Flavonoids such as quercetin, which exhibit delayed elution, represent the phenolic fraction with low to medium polarity. The co-occurrence of these compounds and their synergistic effects support the free radical scavenging, anti-inflammatory, and cell-protective properties of linden extracts, offering potential benefits particularly for preventing oxidative stress-based skin aging and chronic diseases.

Conclusion: The phytochemical profile and biological activity data presented indicate that linden is a suitable plant raw material for anti-aging soothing formulations in cosmetic products, herbal teas in the health sector, functional supplements, and antioxidant-rich functional products in the food industry. In this context, evaluating linden as standardized extracts can significantly contribute to the development of natural, reliable, sustainable, and value-added products.

Keywords: *Tilia* spp., phenolic compounds, functional food, phytocosmetics, value-added products

Corresponding Author's information: Musa Karadağ Iğdır University Technical Sciences Vocational School, Iğdır, Türkiye. e-mail: dengemusa@hotmail.com. Telephone Number: +9053594226
Suggested citation: Karadağ M, Aslan KS. Evaluatıon of the *Lınden Tree* (*Tilia* spp.) as a Value-Added Product in the Cosmetıcs, Health, and Food Industries. KYJM, 2026;1(1): 34-39.

DOI: https://doi.org/10.66251/ncn4fs46

INTRODUCTION

Due to increasing awareness of healthy living, concerns about synthetic additives, and the spread of sustainable production approaches, interest in naturally derived bioactive compounds has increased significantly in recent years. In this context, medicinal and aromatic plants are considered strategic raw materials for the development of functional and value-added products in the cosmetics, health, and food industries. Plant extracts with antioxidant, anti-inflammatory, and antimicrobial properties are used, especially in preservative and supportive product formulations. Linden (*Tilia spp*.) is an important medicinal plant widely found in the flora of Europe and Anatolia and has been used in traditional medicine for many year[1].The flower, leaf, and bark parts of the plant are valued in folk medicine for their soothing, diaphoretic, and mildly sedative effects on different morphological parts of the plant. Current scientific studies show that beyond this traditional use, linden has high potential for modern industrial applications due to its rich phytochemical content[2,3]. The functional properties of the plant extracts largely stem from the phenolic and flavonoid compounds they contain. The results of the HPLC-DAD analysis used in this study show that biologically active compounds such as ascorbic acid, gallic acid, protocatechuic acid, catechin, p-coumaric acid, ferulic acid, rutin, naringin, and quercetin are present in linden extracts. These compounds play a significant role in reducing oxidative stress with strong free radical scavenging effects and contribute to preventing cellular damage. Phenolic acids and flavonoids have a protective effect against reactive oxygen species, which play a role in skin aging, inflammation, and the development of chronic diseases. Compounds found in lemons, such as ferulic acid, rutin, and quercetin, are known to be valuable for cosmetic applications, particularly for supporting skin barrier function by reducing oxidative damage caused by UV rays[4]. Similarly, the antioxidant and antimicrobial activities of flavonoids such as naringin and catechin support the use of lemon in health functional food products. In this context, the detailed elucidation of the phytochemical composition of linden (*Tilia spp*.) and its correlation with biological activities is of great importance in terms of value-added product development processes. This study addresses the potential of linden to be evaluated in the cosmetic, health, and food sectors based on HPLC-DAD data; and aims to provide a scientific framework for the integration of natural, reliable, and sustainable plant-based raw materials into industrial applications.

DOI: https://doi.org/10.66251/ncn4fs46

The significance of this study lies in the scientific demonstration that the linden (*Tilia spp*.) plant, due to its rich phenolic and flavonoid content, holds value not only for traditional uses but also for modern industrial applications. The bioactive compounds identified via HPLC-DAD analysis support the potential for use in cosmetic, health, and functional food products due to their antioxidant, anti-inflammatory, and antimicrobial properties. The findings provide a solid scientific foundation for integrating natural, reliable, and sustainable plant sources into industrial product development processes.

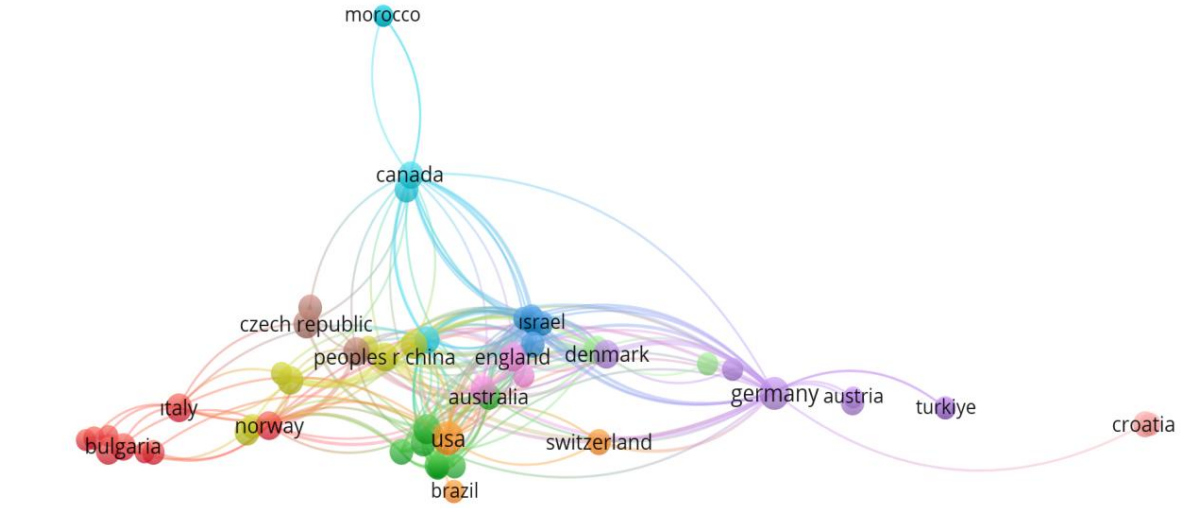


Figure 1. Countries Using Linden (Tilia spp.) Plants in Cosmetics, Food, and Health (webofsience)

Linden (Tilia spp.) extracts stand out as a valuable raw material for cosmetic and dermocosmetic products due to their rich content of phenolic and flavonoid compounds. Compounds such as ferulic acid, rutin, quercetin, and naringin, identified by HPLC-DAD analysis, exhibit antioxidant effects on the skin, reducing oxidative damage caused by free radicals and contributing to delaying the signs of aging5. Furthermore, the anti-inflammatory and soothing properties of linden extracts make them an effective natural ingredient in the care of sensitive, irritated skin. In cosmetic formulations, linden can be integrated into products such as anti-aging creams, face masks, toners, and serums. Thanks to its phenolic and flavonoid profile, it both supports skin barrier function and increases moisture retention capacity5,6. In addition, the increasing consumer demand for

DOI: https://doi.org/10.66251/ncn4fs46

natural herbal ingredients supports the use of linden extracts as a sustainable and reliable alternative in dermocosmetic products7. In this context, linden is a strategic raw material in functional and value-added product development strategies in the cosmetics and dermocosmetic sectors.

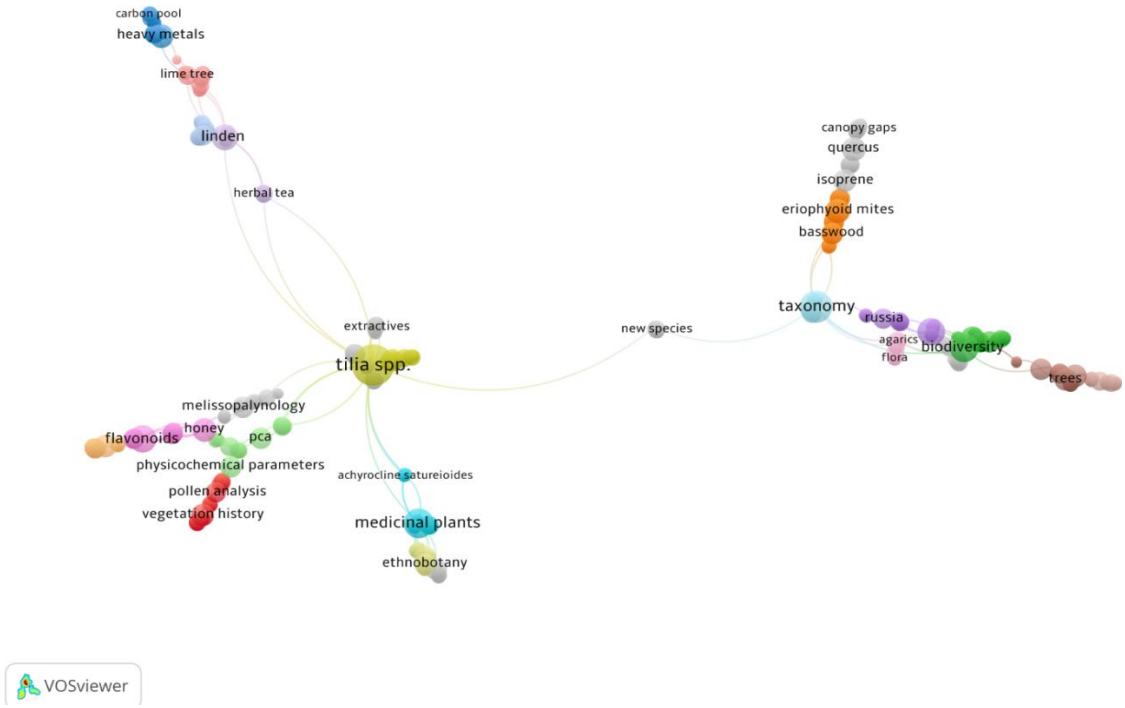


Figure 2. Keywords Used in Studies on the Linden (Tilia spp.) Plant in the Cosmetics, Food, and Health Fields (Web of Science)

Linden (***Tilia spp***.) has significant potential for the development of functional products in the food sector due to its rich phytochemical profile in terms of phenolic and flavonoid compounds. Compounds such as ascorbic acid, gallic acid, ferulic acid, rutin, naringin, and quercetin, identified by HPLC-DAD analyses, exhibit strong antioxidant and antimicrobial properties, enhancing the oxidative stability of food products[5,8]. These properties support the use of linden in functional beverages, herbal teas, smoothies, and natural flavoring formulations. Furthermore, phenolic compounds enhance the biological value of food products, providing a health-promoting function. Linden extracts can be considered a strategic raw material to meet the increasing consumer demand for natural and plant-based functional ingredients. Components with antioxidant capacity and biological activity can delay oxidative deterioration in functional foods while also contributing to supporting the immune system and reducing the risk of chronic diseases[9]. In this context, linden stands out as a sustainable and reliable source in the food sector for the development of

functional products that both support consumer health and create added value.

METHODS

Plant Material and Extraction

The linden (*Tilia spp.*) flowers used in this study were harvested from trees growing on the Şehit Bülent Yurtseven Campus of Iğdır University. After cleaning the collected plant material from foreign matter, it was brought to the Iğdır University Research Laboratory Application and Research Center (ALUM) and dried in the shade, protected from direct sunlight. After the drying process was completed, the plant material was ground to homogenize it. For the extraction of phenolic compounds, 40 g of the ground sample was used; a solvent system consisting of a mixture of ethanol (96%) and pure water (80:20, v/v) was preferred to ensure the effective dissolution of bioactive compounds. Accordingly, 320 mL of ethanol and 80 mL of pure water were used in the extraction process[10]. The extraction process was carried out with the help of an ultrasonic bath, and the obtained extracts were filtered with filter paper.

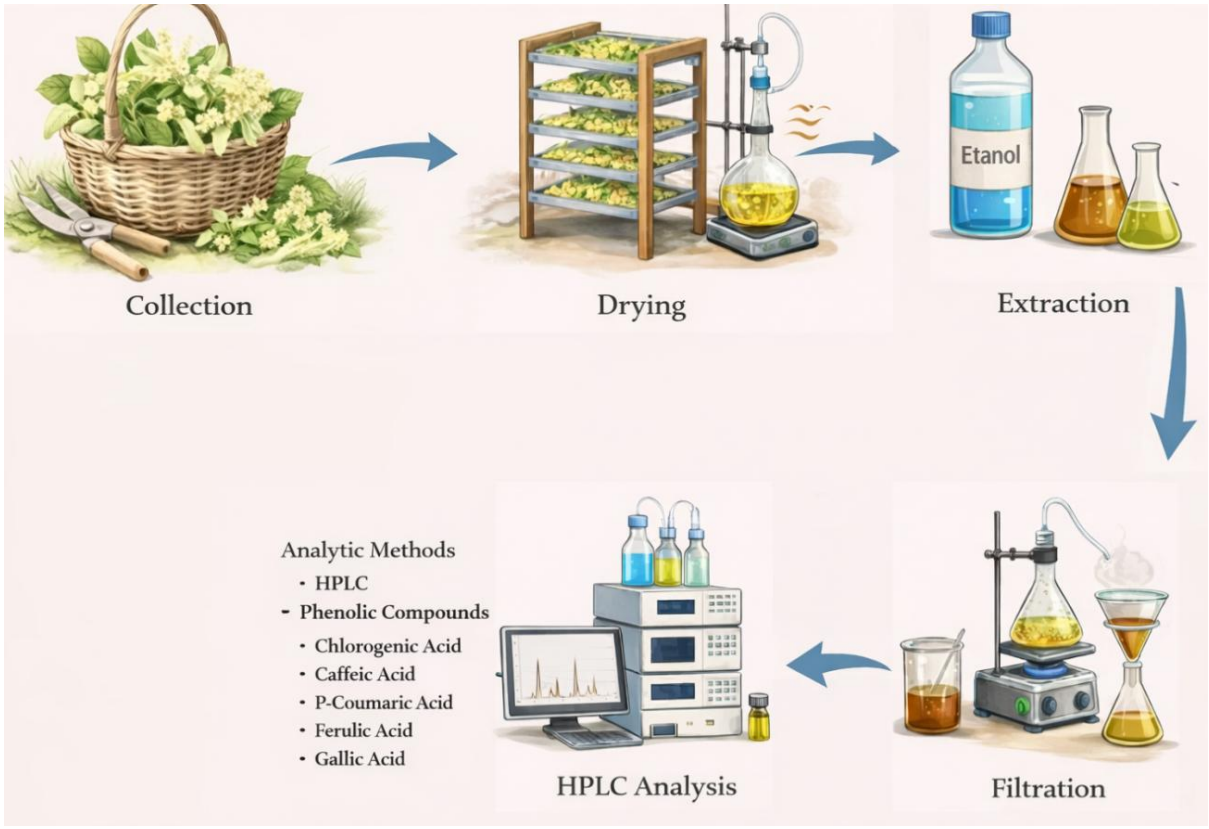


Figure 3. Lime Tree (*Tilia spp.*) Analysis Stages Diagram

DOI: https://doi.org/10.66251/ncn4fs46

Prior to analysis, the extracts were passed through a membrane filter with a pore diameter of 0.45 µm to completely remove particulate matter; the resulting extracts were stored in a refrigerator at +4 °C until analysis to maintain the stability of the bioactive compounds

HPLC-DAD Analysis Conditions

Analysis of phenolic and flavonoid compounds was performed using a reverse-phase high-performance liquid chromatography (HPLC) system and a diode array detector (DAD). Separation was achieved on a C18 column (250 × 4.6 mm, 5 µm). Mobile phase A was defined as pure water containing 0.1% formic acid, and mobile phase B as acetonitrile, and a gradient elution program was applied. The flow rate was set to 1.0 mL/min, and the injection volume to 20 µL. Detection was performed at wavelengths of 280–300 nm for phenolic acids and 340–370 nm for flavonoids[10].

Identification of Compounds

Identification of phenolic and flavonoid compounds in linden (*Tilia spp*.) extracts was performed using high-performance liquid chromatography-diode array detector (HPLC-DAD). During the analysis, extracts were separated on a C18 reversed-phase column, and gradient elution of formic acid-water with acetonitrile was applied as the mobile phase. Detection wavelengths were selected as 280–300 nm for phenolic acids and 340–370 nm for flavonoids. Individual compounds were identified by comparing the retention times and UV spectra of the peaks with commercial standards; this approach allows for reliable determination of both polyphenol class compounds and flavonoid diversity[11]. In the identification process, hydrophilic phenolic acids such as ascorbic acid, gallic acid, and protocatechic acid were observed in the early retention times; In the medium retention zones, flavonoid and phenolic compounds such as catechin, ferulic acid, rutin, and naringin were predominantly eluted, while flavonols such as quercetin, which showed later retention, represented the low-to-medium polar fraction. The co-existence of these compounds supports the high antioxidant capacity of linden extracts and also strengthens their potential for use in functional food, dermocosmetic, and health products. Analytical results provide a reliable basis for the preparation of standard linden extracts in value-added product development processes[12].

RESULTS

HPLC-DAD analyses revealed the presence of numerous phenolic acids and flavonoid compounds in linden (*Tilia spp*.) extracts, primarily ascorbic acid, gallic acid, protocatechyl acid, catechin, p-coumaric acid, ferulic acid, rutin, naringin, neohesperidin, and quercetin. The elution of ascorbic acid

DOI: https://doi.org/10.66251/ncn4fs46

and gallic acid during early retention times indicates that this extract contains a hydrophilic fraction with strong antioxidant capacity. These compounds are known to play a critical role in reducing oxidative stress, particularly through their free radical scavenging properties[3,13]. The obtained chromatographic profile reveals that linden has a multi-component phytochemical structure and contains biologically active components in different polarity ranges.

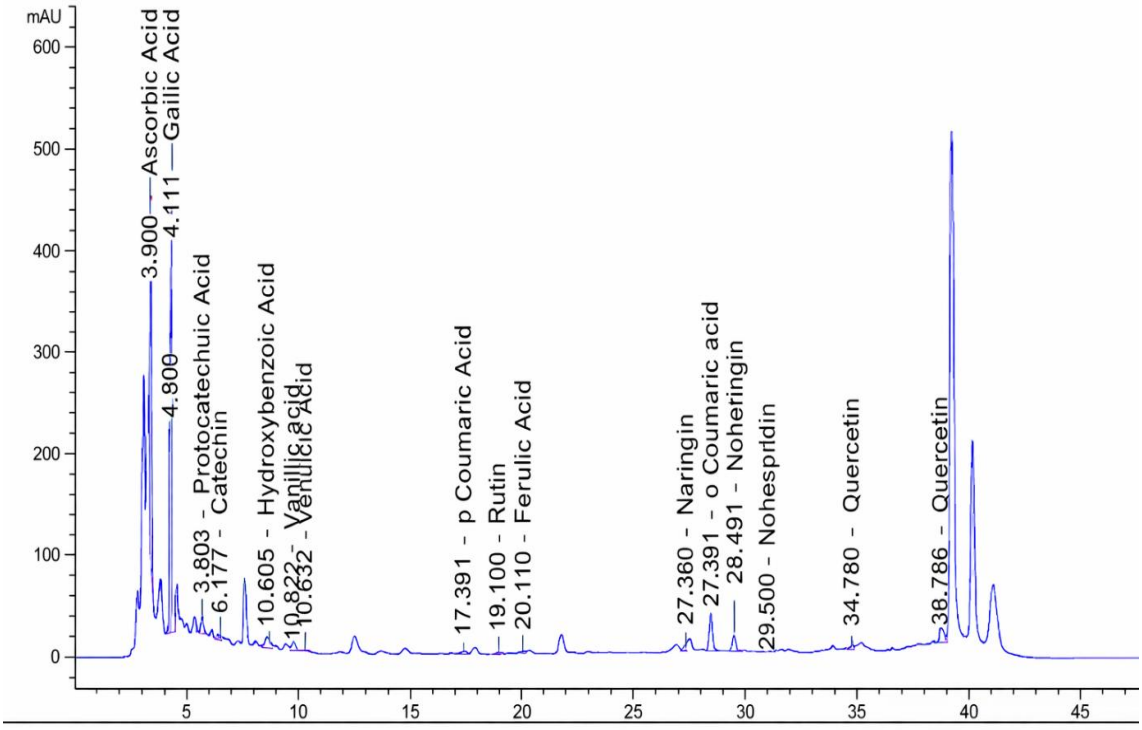


Figure 4. Lime Tree (*Tilia spp.*) Phenolic and Flavonoid Chromatogram HPLC-DAD

The chromatogram shows that numerous phenolic acids and flavonoid compounds were successfully separated from the linden (*Tilia spp.*) extract by HPLC-DAD analysis. The high-intensity peaks of ascorbic acid (approximately 3.9 min) and gallic acid (approximately 4.4 min) during the early retention times indicate that the extract contains a hydrophilic fraction with strong antioxidant capacity. Following this, phenolic acids such as protocatechylic acid, hydroxybenzoic acid, and vanillic acid were observed to elute in the low-to-medium retention regions. While peaks for p-coumaric acid, rutin, and ferulic acid became prominent in the middle region, intense signals from flavonoids such as naringin, neohesperidin, and quercetin were observed in the later retention times. The quercetin peak, observed particularly at approximately 38.7 minutes, suggests that the extract is rich in low-to-medium polar flavonols. This multi-

DOI: https://doi.org/10.66251/ncn4fs46

component chromatographic profile reveals that linden possesses a broad phenolic spectrum and that its antioxidant, anti-inflammatory, and cell-protective potential extends to both hydrophilic and lipophilic fractions, supporting the plant's potential as a potent phytochemical source for value-added product development in the cosmetic, health, and functional food sectors.

Table 1: Phenolic and flavonoid compounds of linden (*Tilia spp*.) ethanol extract determined by HPLC.

RetTime [Min]	Type	Area (MAU·S)	Amt/ Area	Amount [NG/UL]	Name
3.390	VB	1.42314e-2	1.42314e-2	28.26913	Ascorbic acid
4.311	VV	2149.25586	6.46920e-2	139.03965	Gallic Acid
5.733	VB	165.18214	4.97556e-2	5.84547	Protocatechuic acid
6.417	BV	56.12614	4.97556e-2	2.79259	Catechin
8.603	VV	213.06624	4.16574e-2	8.87579	Hydroxybenzoic acid
9.722	VB	162.17264	2.48759e-2	4.03419	Vanillic acid
10.320	BB	19.58216	3.03617e-2	5.94548e-1	Gentisic acid
17.391	VV	81.93633	6.79718e-3	5.56936e-1	p-Coumaric acid
19.010	BV	45.09513	3.77560e-2	1.70261	Rutin
20.110	VV	73.18573	2.97224e-2	2.17525	Ferulik acid
27.360	BV	57.60483	5.12304e-2	2.95112	Naringin
28.431	VB	256.04654	3.15119e-2	8.06852	o-Coumaric acid
29.500	BV	82.51116	8.03505e-2	6.62981	Neohesperidin
30.936	BV	4.32998	1.13797e-2	4.92740e-2	Coumarin
32.399	-	-	-	-	Resveratrol
34.780	BV	68.78664	2.70474e-2	1.86050	Quercetin
35.462	-	-	-	-	trans-Cinnamic acid
36.732	-	-	-	-	Hesperidin
38.786	BV	330.88345	1.02193e-1	33.81408	Alizarin
40.769	-	-	-	-	Flavon

DISCUSSION

As shown in Table 1, analysis of HPLC-DAD data reveals that numerous phenolic acid and flavonoid compounds were separated and quantitatively determined in linden (Tilia spp.) extract at different retention times. In particular, gallic acid (Rt: 4.31 min; 139.04 ng/µL) was one of the compounds detected in the highest amounts, highlighting the extract's strong hydrophilic antioxidant character. This is followed by early elution of phenolic acids such as ascorbic acid (28.27 ng/µL) and protocatechic acid, supporting linden's oxidative stress suppressive potential. Catechin, p-coumaric acid, rutin, and ferulic acid, identified in the medium retention zones, stand out as compounds that enhance the functional diversity of the extract and are associated with antioxidant, anti-inflammatory, and skin-protective effects. Naringin, neohesperidin, and quercetin, which exhibit later elution, represent the flavonoid-dominant fraction; the presence of quercetin in particular strengthens the biological value of linden in health and cosmetic applications. Furthermore, alizarin (33.81 ng/µL), detected

DOI: https://doi.org/10.66251/ncn4fs46

in the late retention period, demonstrates the wide variety of secondary metabolites in the extract. This quantitative and qualitative distribution reveals that linden extracts possess high biological activity potential in both hydrophilic and low-to-medium polar fractions, offering a strong phytochemical profile for value-added product development. Compounds such as catechin, ferulic acid, rutin, and naringin, detected in the medium retention zones, represent key phenolic and flavonoid groups supporting the functional potential of linden extracts. The literature indicates that these compounds exhibit antioxidant, anti-inflammatory, and antimicrobial activities; It is also reported to support skin barrier functions by reducing UV-induced oxidative damage[4,5]. In this respect, linden extracts have high potential for use as anti-aging soothing active ingredients, especially in cosmetic and dermocosmetic formulations. In addition, the presence of rutin and ferulic acid together contributes to the increase in antioxidant capacity through a synergistic effect, strengthening the industrial value of the extract. Quercetin and other low-to-medium polar flavonoids, identified at later retention times, are important components that complement the biological activity of linden extracts. Quercetin's strong antioxidant, anti-inflammatory, and cell-protective properties demonstrate that linden is a phytochemical source suitable not only as a traditional herbal tea but also for use in functional food health support products[8,14]. These results are consistent with the rich phenolic profiles of Tilia species reported in the literature[15-17], revealing that their evaluation in the form of standardized extracts provides a scientific basis for value-added product development processes.

The findings of this study clearly demonstrate that the linden (Tilia spp.) plant possesses a composition rich in phenolic compounds. Analyses have identified the presence of phenolic and flavonoid compounds, particularly ascorbic acid, gallic acid, ferulic acid, rutin, naringin, and quercetin. These compounds are the primary reason for the plant’s strong antioxidant properties. Phenolic compounds neutralize free radicals, thereby reducing cellular damage and limiting the effects of oxidative stress. The high concentration of compounds such as gallic acid and ascorbic acid indicates that linden possesses a strong hydrophilic antioxidant capacity. Additionally, moderately polar compounds like ferulic acid, rutin, and naringin enhance the plant’s biological activity by providing both antioxidant and anti-inflammatory effects. Flavonoids such as quercetin, on the other hand, stand out for their cell-protective effects and constitute

DOI: https://doi.org/10.66251/ncn4fs46

complementary elements of the phenolic profile.

The presence of these compounds together creates a synergistic effect, further enhancing Linden's biological value. The results obtained support the use of plants rich in phenolic compounds as natural active ingredients in cosmetic and dermocosmetic products. In this context, plants like linden possess significant potential, particularly in the development of anti-aging and skin-protective products, thanks to their phenolic compound content.

CONCLUSIONS

The phenolic and flavonoid profile of Tilia spp. species revealed by HPLC-DAD analysis clearly demonstrates the potential of these species to be transformed into value-added products in the cosmetic, health, and food industries. The presence of biologically active compounds such as ascorbic acid, gallic acid, ferulic acid, rutin, naringin, and quercetin demonstrates that the extracts of this plant exhibit strong antioxidant properties and cell protection activities. The data obtained show that Tilia spp. can be used not only traditionally as an herbal tea but also to develop value-added products in standardized extract form. Its diverse biological activities make it a strategic plant for transforming into functional value-added products in the cosmetics, dermo-cosmetic, and health food sectors, but key factors to consider in industrial applications are standardization, active ingredient stability, and sustainable raw material supply. Future studies on the standardization, bioavailability, and clinical efficacy of Tilia spp. extracts will make significant contributions, both scientifically and industrially, to the development of value-added products.

According to data from the study, plants particularly linden (Tilia spp.) offer potent antioxidant, anti-inflammatory, and cell-protective effects due to their rich phenolic and flavonoid content. These biological activities are leading to the increasing preference for plant extracts in cosmetic formulations designed for anti-aging, soothing, and skin barrier-strengthening purposes. Along with the growing demand for natural and sustainable ingredients, plants will emerge in the future not merely as alternatives but as strategic and indispensable raw materials in the cosmetic industry.

Acknowledgment

I would like to express my gratitude to the YIP0723I08 project for providing financial support during the research and preparation of the data presented in this article.

Conflict of Interests

The authors declare that there is no conflict of interest in the study.

Financial Disclosure

The authors declare that they have received no financial support for the study.

Ethical Approval

This study was conducted using the human podocyte cell line, which is a commercially available cell line. There are no primary culture cell lines derived from human or animal tissues involved in this research. Therefore, there is no requirement for Ethics Committee or Institutional Review Board approval for this study.

REFERENCES

1. Yazar MK, Yazar M. The importance of Linden (Tilia spp.) in agroforestry practices in Rize province. Biological Diversity and Conservation, 2025;18(3):307-320. https://doi.org/10.46309/biodicon.2025.1654861
2. Varbanova E, Georgieva D, Stefanova V. Quantification of the Total and Extractable Content of Micro-and Trace Elements in Linden Blossom and Infusions—The Impact of Urban Pollution on Health Risk for Samples from Plovdiv, Bulgaria. Environments, 2024;11(12):274. https://doi.org/10.3390/environments11120274
3. Pavlović T, Dimkić I, Andrić S, et al. Linden tea from Serbia–an insight into the phenolic profile, radical scavenging and antimicrobial activities. Industrial Crops and Products, 2020;154:112639. https://doi.org/10.1016/j.indcrop.2020.112639
4. Jomova K, Raptova R, Alomar SY, et al. Reactive oxygen species, toxicity, oxidative stress, and antioxidants: chronic diseases and aging. Archives of toxicology, 2023;97(10):2499-2574. https://doi.org/10.1007/s00204-023-03562-9
5. Karadag M, Baran A, Güneş Z. Production of value-added cosmetic products from cold-pressed Helianthus annuus L. oil and pulp. Advances in Biology & Earth Sciences, 2024;9:35-39. https://doi.org/10.62476/abes9s35
6. Sen AK, Sen DB, Maheshwari R A. Extraction, isolation, and quantitative determination of flavonoids by HPLC. In: Sen S, Chakraborty R. editors. Herbal Medicine in India: Indigenous Knowledge, Practice, Innovation and its Value Singapore: Springer. 2019. p. 303-336. https://doi.org/10.1007/978-981-13-7248-3_21
7. Karadağ M, Omarova, S. Use of Prunus armeniaca L. seed oil and pulp in health and cosmetic products. Adv Biol Earth Sci, 2024;9(1):105-10. https://doi.org/10.62476/abess105
8. Omoba OS, Obafaye RO, Salawu SO, et al. (2015). HPLC-DAD phenolic characterization and antioxidant activities of ripe and unripe sweet orange peels. Antioxidants, 2015;4(3):498-512. https://doi.org/10.3390/antiox4030498
9. Adefegha SA. Functional foods and nutraceuticals as dietary intervention in chronic diseases; novel perspectives for health promotion and disease prevention. Journal of dietary supplements, 2018;15(6): 977-1009. https://doi.org/10.1080/19390211.2017.1401573
10. Karadağ M, Güneş Z, Çelik S. Chemical Composition of Essential Oil Obtained from Rosemary (Rosmarinus officinalis L.) Plant Grown in Igdir and its Use in

Cosmetics. Journal of Agriculture, 2025;8(1):53-64. https://doi.org/10.46876/ja.1652589

11. Karadağ M. Phenolic Compound Profile of Mentha arvensis L. (Plain Mint) Samples. Turkish Journal of Technical Sciences and Innovation 2025;1(1):12-23. https://izlik.org/JA89XK84ET
12. Karadağ M. Phenolic compounds of Rumex acetosella L. collected from two different regions of Iğdır province (Türkiye). Journal of Agriculture, 2024;7(2):253-260. https://doi.org/10.46876/ja.1597526
13. Yayalacı Y, Celik I, Batı B. Hepatoprotective and antioxidant activity of linden (Tilia platyphyllos L.) infusion against ethanol-induced oxidative stress in rats. The Journal of Membrane Biology, 2014;247(2):181-188. doi 10.1007/s00232-013-9622-z
14. De Simone M, De Feo R, Choucha A, et al. Enhancing sleep quality: Assessing the efficacy of a fixed combination of Linden, Hawthorn, Vitamin B1, and Melatonin. Medical Sciences, 2023;12(1), 2. https://doi.org/10.3390/medsci12010002
15. Zhou YJ, Ren Q, Shen YB. Comprehensive review of Tilia L.: phytochemical profiles, edible value, therapeutic potentials, and ecological significance. Food Med. Homol, 2025;2:9420035. https://doi.org/10.26599/FMH.2025.9420035
16. Parcheta M, Świsłocka R, Orzechowska S, et al. Recent developments in effective antioxidants: The structure and antioxidant properties. Materials, 2021;14(8):1984. https://doi.org/10.3390/ma14081984
17. Paliwal L, Ambwani S. Unveiling the Sleep-immunity nexus: Plant bioresources for ameliorating consequences of Sleep deprivation. The Journal of Phytopharmacology, 2024;13(4), 307-313. doi: 10.31254/phyto.2024.13406