www.biodicon.com

Biological Diversity and Conservation

e -ISSN 1308-8084, ISSN 1308-5301

Research article
https://doi:10.46309/biodicon.2026.2060160
19/4 (2026) 392-401

Phytochemical profile and biological activities of *Vinca soneri* Koyuncu methanol extract

Gülderen YILMAZ1[*] [1], Gülnur Ekşi BONA [2], Nuraniye ERUYGUR [3], Abdulselam ERTAŞ [4],
Mehmet BONA5, Şevket ALP [6]
ORCID: 0000-0002-6569-4766; 0000-0002-6869-8703; 0000-0002-4674-7009; 0000-0002-2193-8386;
000-0003-1656-2641; 0000-0002-9552-4848 ·

[1] Department of Pharmaceutical Botany, Faculty of Pharmacy, Tokat Gaziosmanpasa University, 60250, Tokat, Türkiye
[2] Department of Pharmaceutical Botany, Faculty of Pharmacy, İstanbul University-Cerrahpaşa, İstanbul, Türkiye
3 Department of Pharmacognosy, Faculty of Pharmacy, Selcuk University, 42250, Konya, Türkiye
[4] Department of Pharmacognosy, Faculty of Pharmacy, Dicle University, 21280 Diyarbakır, Türkiye
5 Department of Botany, Faculty of Science, İstanbul University, İstanbul, Türkiye
[6] Faculty of Agriculture, Department of Landscape Architecture, Yüzüncü Yıl University, Van, Türkiye

Abstract

Purpose: In the present study, methanol extract was prepared from the aerial parts of *Vinca soneri* and has been chemically characterized by LC-MS/MS analyses.

Method: *V. soneri* was collected from Erzincan, the aerial parts were dried in the shade and then powdered. The powdered material was extracted with methanol twice at room temperature, and the extract was evaporated by rotary evaporator at 40°C under vacuum.

Findings: Notably, the content of some secondary metabolites, namely phenolic acids (quinic acid, protocatechuic acid, chlorogenic acid, protocatechuic aldehyde, rosmarinic acid and caffeic acids), flavonoids (rutin, quercetin, isoquercitrin, hesperidin, acacetin, and luteolin), flavonoid glycosides (nicotiflorin), have been determined. Furthermore, the extracts were tested for their antioxidant capabilities (DPPH, and ABTS radical scavenging assays) and enzyme inhibitory properties against cholinesterase, tyrosinase, elastase, and collagenase enzymes.

Conclusion: Our findings present data for chemico-biological characteristics of *V. soneri* and give a scientific foundation for the development of nutraceuticals and food supplements.

Keywords: *Vinca soneri*; antioxidants; enzyme inhibitory properties; LC-MS/MS.

---------- * ----------

Vinca soneri l. metanol ekstresinin fitokimyasal profili ve biyolojik aktiviteleri

Özet

Amaç: Bu çalışmada, *Vinca soneri* Koyuncu bitkisinin toprak üstü kısımlarından metanol ekstresi hazırlanmış ve LC-MS/MS analizleri ile kimyasal karakterizasyonu yapılmıştır.

Metod: *V. soneri* örnekleri Erzincan'dan toplanmış; toprak üstü kısımları gölgede kurutulup toz haline getirilmiştir. Toz halindeki materyal oda sıcaklığında iki kez metanol ile ekstrakte edilmiş ve elde edilen ekstreler, vakum altında ve 40°C'de döner buharlaştırıcı (rotary evaporatör) kullanılarak uçurulmuştur.

Bulgular: Çalışmada, başta fenolik asitler (kinik asit, protokateşuik asit, klorojenik asit, protokateşuik aldehit, rozmarinik asit ve kafeik asit), flavonoidler (rutin, kuersetin, izokuersetrin, hesperidin, akasetin ve luteolin) ve flavonoid glikozitleri (nikotiflorin) olmak üzere çeşitli ikincil metabolitlerin içeriği belirlenmiştir. Ayrıca ekstrelerin antioksidan kapasiteleri (DPPH ve ABTS radikal süpürme testleri) ile kolinesteraz, tirozinaz, elastaz ve kolajenaz enzimlerine karşı inhibitör özellikleri incelenmiştir.

Sonuç: Elde edilen bulgular, *V. soneri* bitkisinin kimyasal ve biyolojik özelliklerine dair detaylı veri sunmakta ve nutrasötikler ile gıda takviyelerinin geliştirilmesi için bilimsel bir temel oluşturmaktadır.

Anahtar kelimeler: *Vinca soneri;* antioksidanlar; enzim inhibitör özellikleri; LC-MS/MS.

[*] *Corresponding author*: Tel.: +905363665967; Fax.: +905363665967; E-mail: gulderen_yilmaz@yahoo.com
All published content is licensed under **CC BY 4.0**; Received: 12.10.2026; Published: 15.12.2026; BioDiCon.ID: 1256-121026

1. Introduction

For centuries, medicinal plants have played an essential role in promoting human health and treating diseases. Various cultures have relied on these plants as traditional remedies for a broad range of health conditions. Their medicinal effects are largely attributed to their complex chemical composition, which includes numerous bioactive compounds with pharmacological activities. Beyond their traditional applications, medicinal plants have also contributed significantly to the discovery and development of many modern therapeutic drugs [1,2]. Approximately 66.66% of commercial medicines introduced to the global market each year are isolated from or developed using natural resources. Recent evidence suggests that nearly one-quarter of pharmaceutical drugs prescribed and marketed worldwide are derived from or associated with plant-based sources for the management of various health conditions. Plants continue to represent a rich and significant source of secondary metabolites, many of which exhibit therapeutic potential and can be used in the treatment of a wide range of diseases [3,4].

Apocynaceae is a significant family of angiosperms, commonly referred to as the dogbane family of flowering plants. It is a large and diverse family that includes approximately 5,000 species distributed across around 415 genera [5,6]. The family is predominantly distributed throughout tropical and subtropical regions worldwide, although certain species also occur in temperate areas [6,7]. Members of the Apocynaceae family include trees, shrubs, and herbaceous plants that are typically characterized by the presence of milky latex. Their leaves are simple and generally arranged oppositely or in whorls. The flowers are often large, brightly coloured, and mildly fragrant, with five twisted lobes. The fruits commonly develop as paired structures [8,9]. Some members of the family are valued as sources of timber, while many others are cultivated for ornamental purposes. In addition to their medicinal uses, Apocynaceae species have a variety of other applications, including as sources of dyes, fodder, food, perfumes, poisons and timber [6,9].

Most species belonging to the Apocynaceae family are rich in alkaloids and are recognized for their considerable therapeutic potential [6]. Phytochemical investigations have reported the presence of various bioactive constituents in Apocynaceae plants, including alkaloids, flavonoids, glycosides, lactones, phenolic compounds, steroids, and triterpenoids [4,10]. These bioactive compounds are associated with a wide range of pharmacological activities, including antibacterial, anticancer, antifungal, anti-inflammatory, antimalarial, antioxidant, antiviral, and cytotoxic effects [6], Furthermore, members of the Apocynaceae family have been widely used in traditional and ethnomedicinal practices for the management of various ectoparasitic infections, fever, health conditions, including diabetes, gastrointestinal problems, malaria, pain, and skin disorders [4,9].

The genus *Vinca* L., commonly known as the periwinkles, consists of species primarily native to northwestern Africa, southwestern and central Asia, and temperate regions of Europe. Members of this genus are generally characterized as creeping, evergreen or deciduous, perennial subshrubs. The genus comprises of seven recognized species: *V. difformis* Pouret, *V. erecta* Regel & Schmalh, *V. herbacea* Waldst. & Kit., *V. ispartensis* Koyuncu & Ekşi, *V. major L.*, *V. minor* L., and *V. soneri* Koyuncu. Of these, the latter five species are reported to be distributed in Turkey [11-14]. *Vinca* species have been extensively investigated for their medicinal potential due to their high content of biologically active alkaloids [15,16]. These naturally occurring compounds are produced and accumulated in the aerial parts of *Vinca* plants, where they are believed to contribute to the plants' defense mechanisms against herbivores and pathogens [16]. Along with flavonoid glycosides and tannins, monoterpene indole alkaloids (MIAs) represent the major group of bioactive secondary metabolites found in *Vinca* species [13]

V. soneri is an erect, unbranched perennial subshrub growing up to 50 cm from a woody rootstock, lacking trailing shoots. Its leaves are opposite, deciduous, and nearly stemless to shortly petiolate. The leaf blades are ovate-elliptic, smooth and hairless margins, and a lower surface that is puberulent only along the veins. Solitary, large flowers emerge from the leaf axils. The calyx with linear, glabrous lobes. The funnel-shaped corolla is blue to pale blue. Stamens are enclosed within the corolla tube, attached near its midpoint. A slender style extends just below the height of the anthers, ending in a capitate, hair-tipped stigma. The plant produces follicles, containing tuberculate seeds. It flowers in May and June on dry, stony slopes [11]

Traditionally utilized in folk medicine for their antidiabetic, hypotensive, and sedative properties, Vinca species have attracted significant pharmaceutical interest as a rich source of bioactive compounds aimed at enhancing cerebral metabolism, supporting brain function, and treating circulatory disorders [17, 18].

When we search the literature for the importance of *Vinca* species in respect to their phytochemical compositions and biological activities, we can see that, more than 60 indole alkaloids have been identified in *V. minor*, contributing to the continued scientific interest in the genus. Several natural sources have been reported to contain compounds capable of inhibiting acetylcholinesterase (AChE) and butyrylcholinesterase (BuChE) enzymes. Due to their structurally diverse and complex nitrogen-containing frameworks, alkaloids are considered as promising bioactive compounds for the development of potential therapeutic agents for Alzheimer's disease [13]. *V. minor is* regarded as one of the most important natural source of vincamine, an alkaloid recognized for its beneficial effects on cellular function [16-18. Vincamine has been reported to modulate cerebral circulation and neuronal homeostasis and to exhibit antihypoxic and neuroprotective activities. It has been used in the prevention and management of cerebrovascular insufficiency and related disorders, primarily due to its ability to enhance cerebral blood flow, glucose utilization and oxygen consumption [17]. Currently, alkaloids derived from *Vinca* species are among the most widely utilized chemotherapeutic agents in the

treatment of hematological and lymphatic malignancies and represent an important class of anticancer compounds [18. In addition to their antineoplastic activity, the indole alkaloids present in the plant have been reported to exhibit hypoglycemic effects, suggesting their potential therapeutic application in the management of diabetes mellius [19].

Several medicinal preparations have been developed from *Vinca* species, including devincan, vinblastine, vincapan, and vincristine. These compounds have been used in the management of conditions such as cerebral vascular spasms, hypertension, neurogenic tachycardia, and other autonomic nervous system disorders. In addition to these therapeutic applications, several of these alkaloid-derived medicines possess significant antitumor activity and have been incorporated into the treatment of malignancies, including cancers of the lung and breast, acute leukemia, and lymphogranulomatosis [19]. In addition to alkaloids, *Vinca* species contain several other important groups of natural compounds, including amino acids, carotenoids, flavonoids, and phenolic acids [17]. Phenolic compounds have attracted considerable attention due to their potential antioxidant properties, while flavonoids have been investigated for their anti-inflammatory and antimicrobial activities [15,20]. Extracts of *Vinca* species have demonstrated notable antioxidant effects and an ability to inhibit lipid peroxidation, suggesting potential applications in the management of cardiovascular and neurodegenerative disorders. Furthermore, numerous studies have reported the antibacterial and antifungal activities of ethanolic extracts obtained from *Vinca* species [20].

Based on these literature data, the objective of the present study was the development of a Liquid Chromatography coupled to Mass Spectrometry (LC-MS/MS) analytical method for the quantitative evaluation of the main bioactive compounds of *V. soneri* methanol extract belonging to different chemical classes, such as phenolic acids, flavonoids, and their glycosides. The total phenolic content (TPC) and total flavonoid content (TFC) have also been determined. Moreover, the antioxidant and enzyme inhibitory properties were evaluated. In particular, the antioxidant activity was assessed through antiradical (DPPH and ABTS) assays. On the other hand, the inhibitory activity was tested on different enzymes: acetylcholinesterase (ACh, EC3.1.1.7), butyrylcholinesterase (BuCh, EC 3.1.1.8), tyrosinase (1.14.18.1), elastase (EC 3.4.21.37), and collagenase (EC 3.4.24.3). Finally, statistical studies such as Pearson's correlation and partial least square analysis were used to investigate the link between TPC, TFC, and biological activities, as well as to assess the contribution of various phytochemicals to these activities.

2. Materials and methods

2.1. Plant material

Specimens of *V. soneri* were collected in 2019 from roadside slopes at an altitude of 1400 m in the Kemaliye district of Erzincan. The specimens were identified by the authors using the Flora of Turkey and the East Aegean Islands and by comparing the plant material with a reference specimen (accession number 31230) housed in the Ankara University Herbarium (AEF). The aerial parts of the plant were air-dried in the shade and ground into a powder.

2.2. Preparation of extract

30 g of the powdered material was extracted twice with 250 ml of methanol at room temperature and evaporated under vacuum at 40°C (Buchi R-100, Switzerland). The powdered material was extracted with methanol twice at room temperature, and they were evaporated (Buchi R-100, Swiss) at 40°C under vacuum. The yield of methanol extract of *V. soneri* was 14.13 % (g/g).

2.3. Total Phenolic and Flavonoid Content

The total phenolic and flavonoid content of the extracts was determined as previously described [20]. Gallic acid (GAE) for phenolics and quercetin (QE) for flavonoids were employed as standards to explain the findings.

2.4. Antioxidant activities

The antioxidant potential of the methanol extract of *V. soneri* was tested using a antiradical (DPPH and ABTS assays, following the methods published by Eruygur et al. [22]. BHT and α-TOC were the reference molecules for the DPPH and ABTS assays, respectively. All tests were conducted in triplicate and results are expressed as Mean ± standard deviation.

2.5. Enzyme Inhibitory Properties

The key enzyme inhibition activity of extracts against acetylcholinesterase (AChE, EC3.1.1.7), butyrylcholinesterase (BuChE, EC 3.1.1.8), tyrosinase (1.14.18.1), elastase (EC 3.4.21.37), and collagenase (EC 3.4.24.3) was measured using the protocols published previously [22,23]. Galantamine was used as an inhibitor for AChE and BuChE, kojic acid for tyrosinase, oleanolic acid for elastase, and epicatechin gallate for collagenase activity assays. To provide comparison with inhibitors, IC_{50} values were also given (this is the extract concentration required for inhibiting

50% of the enzyme in the inhibitory assays). All experiments were conducted in triplicate and results are expressed as mg standard equivalent per gram of dry extract.

2.6. Statistical Analysis

All quantitative analyses were done in triplicate (n = 3), and findings were reported as means ± standard deviation (Mean ± SD). Three replicates were used to determine bioactivities. The statistical analysis was performed using Graphpad Prism software (version 9.0.0). Analysis of variance (ANOVA) was used to determine whether there were significant differences between the extracts, with a probability value of 5%.

3. Results

1.1. Phytochemical investigation of V. soneri

GC–MS analysis of the methanolic extract of *V. soneri* given in Table 1 revealed a predominance of terpenoid- and steroid-like constituents, with squalene (5058.91), stigmasterol (1713.45), β-sitosterol (1580.97), 3-acetyl lupeol (1189.70), and α-amyrin (1104.19) showing the highest relative abundances. As shown in Table 2, the complementary LC–MS/MS analysis demonstrated that the extract also contained substantial levels of phenolic constituents, particularly quinic acid (8.939 mg/g extract), rutin (1.731 mg/g), hesperidin (1.581 mg/g), chlorogenic acid (0.704 mg/g), and protocatechuic acid (0.390 mg/g). Together, these findings indicate that the methanolic extract possesses a chemically diverse profile comprising triterpenoids, phytosterols, phenolic acids, and flavonoids.

Table 1. Terpenoid-steroid content of methanol extract of *V. soneri* by GC-MS

Compound	RT[a]	Molecularion-m/z (relativeintensity %) (m/z)[b]	Three major fragment ions m/z (relative intensity %)			*V. soneri*
Sclareolide	13.009	250.38 (1.1)	123(100)	235(39.1)	206(21.6)	ND
Sclareol	15.405	308.51 (2.0)	109(100)	191(44.6)	257(18)	ND
Ferruginol	17.091	286.46 (95.7)	271(100)	189(63.5)	201(44.4)	ND
Cryptanol	17.638	316 (100)	205(24.9)	219(22.7)	301(19.8)	ND
6,7-Dehydroroyleanone	18.821	314.19 (1.1)	298(100)	283(41.8)	265(8.7)	ND
Suginal	19.728	314.43 (2.8)	299(100)	300(20.8)	281(4)	5058,91
9,10-Dihydro-7,8-dimethyl-2-(1-methylethyl) phenanthren-3-ol	20.437	266.15 (48)	251(100)	252(19.4)	203(6.8)	ND
Sugiol	21.628	300.44 (69)	285(100)	217(37.5)	243(25.2)	ND
Inuroyleanone	21.996	346.28 (100)	331(45.9)	261(17.7)	245(2.3)	ND
12-Demethylmulticauline	22.646	264.15 (91.1)	249(100)	234(17.3)	216(16.6)	ND
7α-Hydroxy-β-sitosterol	27.700	430.71 (2.5)	394(100)	135(75.7)	143(69.9)	ND
Salvigenin	28.311	328.09 (100)	313(99.5)	299(27.1)	282(25.3)	ND
Stigmasterol	30.052	412.36 (100)	255(87.1)	271(66)	300(47.6)	1713,45
β-Sitosterol	30.795	414.72 (100)	396(58)	303(53.2)	329(51)	1580,97
Sinensetin	31.343	372.37 (19.2)	357(100)	341(20.6)	313(6.4)	ND
Lupenone	31.592	424.37 (36.0)	205(100)	313(27.7)	218(805.2)	ND
α-Amyrin	31.944	426.73 (8.4)	218(100)	189(21.6)	203(21.2)	1104,19
Lupeol	31.944	426.38 (38.9)	218(463.5)	189(100)	203(98.2)	ND
3-Acetyl lupeol	33.513	468.40 (22.35)	189(100)	121(71.4)	203(35.1)	1188,70
1α,21α-Dihydroxy-2-3-(1',1'-dimethyl-dioxymethylene)urs-9(11),12-diene	37.636	512.39 (100)	421(19.3)	343(17)	271(17)	ND
Uvaol	37.800	442.73 (1.1)	203(100)	204(16.6)	234(11)	ND
Betulin	38.269	442.73 (11.1)	203(1224.7)	189(100)	411(26.9)	ND
Pyxinol	39.160	476.74 (0.62)	143(100)	400(13.9)	191(9.7)	ND
Lup-(20)29-ene-2α-hydroxy-3β- acetate	39.467	484 (5.5)	416(100)	273(68.6)	189(44.5)	ND
Betulin 3β,28β-diacetate	41.236	526.80 (1.6)	189(100)	466(47.1)	203(39.5)	ND
21α-Hydroxy,2α,3β-diacetoxy urs-9(11),12-diene	43.145	540.38 (100)	405(48.1)	271(43.7)	420(22.1)	ND

[a]RT: Retention time; [b]Mother ion(m/z): Molecular ions of the standard compounds (m/z ratio); N.D: Not detected

Table 2. Identification and quantification of phenolic compounds of *V. soneri* by LC-MS/MS

NO	Analytes	Parent Ion (m/z)[a]	MS^2 (Collision Energy)[b]	Quantification (mg analyte/g extract)
1	Quinic acid	190.8	93.0	8.939
2	Fumaric acid	115.2	40.9	ND
3	Aconitic acid	172.8	129.0	ND
4	Gallic acid	168.8	79.0	ND
5	Epigallocatechin	304.8	219.0	ND
6	Protocatechuic acid	152.8	108.0	0.390
7	Catechin	288.8	203.1	ND
8	Gentisic acid	152.8	109.0	ND
9	Chlorogenic acid	353.0	85.0	0.704
10	Protocatechuic aldehyde	137.2	92.0	0.017
11	Tannic acid	182.8	78.0	ND
12	Epigallocatechingallate	457.0	305.1	ND
13	1,5-Dicaffeoylquinic acid	515.0	191.0	ND
14	4-OH Benzoic acid	137,2	65.0	ND
15	Epicatechin	289.0	203.0	ND
16	Vanilic acid	166.8	108.0	ND
17	Caffeic acid	179.0	134.0	0.016
18	Syringic acid	196.8	166.9	ND
19	Vanillin	153.1	125.0	ND
20	Syringic aldehyde	181.0	151.1	ND
21	Daidzin	417.1	199.0	ND
22	Epicatechingallate	441.0	289.0	ND
23	Piceid	391.0	135/106.9	ND
24	*p*-Coumaricacid	163.0	93.0	ND
25	Ferulic acid-D3-IS[d]	196.2	152.1	IS
26	Ferulic acid	192.8	149.0	ND
27	Sinapic acid	222.8	193.0	ND
28	Coumarin	146.9	103.1	ND
29	Salicylic acid	137.2	65.0	ND
30	Cynaroside	447.0	284.0	ND
31	Miquelianin	477.0	150.9	ND
32	Rutin-D3-IS[d]	612.2	304.1	IS
33	Rutin	608.9	301.0	1.731
34	isoquercitrin	463.0	271.0	0.128
35	Hesperidin	611.2	449.0	1.581
36	*o*-Coumaric acid	162.8	93.0	ND
37	Genistin	431.0	239.0	ND
38	Rosmarinic acid	359.0	197.0	0.252
39	Ellagic acid	301.0	284.0	ND
40	Cosmosiin	431.0	269.0	ND
41	Quercitrin	447.0	301.0	ND
42	Astragalin	447.0	255.0	ND
43	Nicotiflorin	592.9	255.0/284.0	0.298
44	Fisetin	285.0	163.0	ND
45	Daidzein	253.0	223.0	ND
46	Quercetin-D3-IS[d]	304.0	275.9	IS
47	Quercetin	301.0	272.9	0.016
48	Naringenin	270.9	119.0	ND
49	Hesperetin	301.0	136.0/286.0	ND
50	Luteolin	284.8	151.0/175.0	0.006
51	Genistein	269.0	135.0	ND
52	Kaempferol	285.0	239.0	ND
53	Apigenin	268.8	151.0/149.0	ND
54	Amentoflavone	537.0	417.0	ND
55	Chrysin	252.8	145.0/119.0	ND
56	Acacetin	283.0	239.0	0.023

[a]Parent ion (*m/z):* Molecular ions of the standard compounds (mass to charge ratio), [b]MS^2(CE): MRM fragments for the related molecular ions (CE refers to related collision energies of the fragment ions),[c]Values in *m*g/g (w/w) of plant ethanol extract,[d]IS: Internal standard, N.D: not detected

1.2. Biological activity of V. soneri extracts

1.2.1. Antioxidant activity

The methanolic extract of *V.* contained measurable levels of total phenolic compounds and flavonoids, with values of 26.19 ± 0.40 µg pyrocatechol equivalents (PEs)/mg extract and 21.30 ± 0.44 µg quercetin equivalents (QEs)/mg extract, respectively. The relatively high flavonoid content in relation to the total phenolic content indicates that flavonoids constitute an important proportion of the phenolic constituents of the extract. This finding is consistent with the LC–MS/MS profile, which identified flavonoid compounds such as rutin and hesperidin, together with phenolic acids including quinic acid, chlorogenic acid, and protocatechuic acid.

The antioxidant activity of the *V. soneri* extract was evaluated using DPPH and ABTS radical-scavenging assays. The extract exhibited IC_{50} values of 1023 ± 1.48 µg/mL in the DPPH assay and 634.6 ± 0.75 µg/mL in the ABTS assay (Table 3). Since lower IC_{50} values indicate stronger radical-scavenging capacity, the extract showed a lower antioxidant activity than the reference antioxidants butylated hydroxytoluene (BHT) and α-tocopherol (α-TOC). BHT displayed IC50 values of 51.72 ± 1.54 µg/mL and 15.87 ± 0.87 µg/mL in the DPPH and ABTS assays, respectively, whereas α-TOC showed stronger activity, with IC50 values of 15.83 ± 0.44 µg/mL for DPPH and 8.45 ± 0.22 µg/mL for ABTS.

Notably, the extract showed greater scavenging activity in the ABTS assay than in the DPPH assay, as indicated by its lower ABTS IC_{50} value. This difference may reflect variations in the sensitivity and reaction mechanisms of the two radicals toward the phytochemicals present in the extract. The antioxidant effect of *V. soneri* may be associated with the combined contribution of phenolic acids and flavonoids, particularly chlorogenic acid, protocatechuic acid, rutin, and hesperidin. Although the extract was less potent than the synthetic and natural reference antioxidants, its detectable radical-scavenging activity, together with its phenolic and flavonoid contents, supports the potential of *V. soneri* as a natural source of antioxidant phytochemicals.

The stronger ABTS activity relative to DPPH activity may indicate that the compounds present in the *V. soneri* extract interact more effectively with the ABTS radical system. The antioxidant response is likely attributable to the combined action of phenolic acids and flavonoids rather than to a single compound. Overall, the results suggest that *V. soneri* is a source of phenolic and flavonoid constituents with detectable antioxidant properties, although its radical-scavenging activity is lower than that of BHT and α-tocopherol and may be less pronounced than that reported for other certain *Vinca* species.

Table 3. Total phenol and flavonoid content, and antioxidant activities of *V. soneri* methanol extract

Samples	**Total phenolic (µg PEs/mg)[b]**	**Total flavonoids (µg QEs/mg)[c]**	**Antioxidant activity (IC_{50} µg/mL)**	
			DPPH scavenging activity	**ABTS scavenging activity**
V. soneri	26,19±0.40	21,30±0.44	1023 ± 1.48	634.6 ± 0.75
BHT	-	-	51.72±1.54	15.87±0.87
α-TOC	-	-	15.83±0.44	8.45±0.22

a: Values expressed are means ± S.D. of three parallel measurements and values were calculated according to negative control. Values with different letters in the same column were significantly different ($p < 0.05$)

b: GAEs. Gallic acid equivalents ($y=0.0413x + 0.0440$ gallic acid ($r^2 = 0.9958$))

c: QEs. quercetin equivalents ($y=0.0362x + 0.0172$ quercetin ($r^2 = 0.9975$)).

1.2.2. Enzyme inhibitory activity

V. demonstrated selective enzyme inhibitory activity, with the strongest effect observed against BChE (75.84 ± 2.27%). This response was markedly higher than its inhibition of AChE (20.54 ± 0.37%), tyrosinase (27.51 ± 4.61%), and elastase (15.55 ± 0.09%) (Table 4). Although the BChE inhibition was lower than that of galanthamine (80.27 ± 1.09%), it indicates a substantial and selective anti-BChE potential of the extract under the tested conditions. In contrast, the relatively low AChE inhibition suggests that the extract may preferentially target BChE rather than exert balanced cholinesterase inhibition.

The tyrosinase inhibition of *V. soneri* was moderate (27.51 ± 4.61%) and considerably lower than that of kojic acid (88.43 ± 1.48%). Similarly, elastase inhibition was weak (15.55 ± 0.09%) relative to the positive control oleanolic acid (59.98 ± 1.06%). No collagenase inhibitory value was recorded for *V. soneri* under the tested conditions, whereas epicatechin gallate showed strong collagenase inhibition (86.01 ± 1.32%). Thus, compared with its BChE activity, the extract showed limited potential as an inhibitor of enzymes associated with melanogenesis and extracellular matrix degradation.

Table 4. Enzyme inhibitory activities of *V. soneri* methanol extract and reference compounds[a]

Samples	AChE	BChE	Tyrosinase	Elastase	Collagenase
V. soneri	20.54 ± 0.37	75.84 ± 2.27	27.51 ± 4.61	15.55 ± 0.09	NA
Galanthamine[b]	85.22 ± 1.78	80.27 ± 1.09	-	-	-
Kojic acid[b]	-	-	88.43 ± 1.48	-	-
Oleanolic acid[b]	-	-	-	59.98 ± 1.06	-
Epicatechin gallate[b]	-	-	-	-	86.01 ± 1.32

a: Values are expressed as the mean ± standard deviation of three parallel measurements and values were calculated according to negative control (50 µg/mL).; b: Standard compound; NA: not active

4. Discussion

This phytochemical profile is broadly consistent with previous phytochemical investigations of *Vinca* species. Earlier studies have established that, in addition to their characteristic monoterpenoid indole alkaloids, *Vinca* plants contain phenolic acids, flavonoids, iridoids, and other non-alkaloidal metabolites. Chlorogenic acid, caffeic acid derivatives, rutin, quercetin-related flavonoids, and related phenolics have been reported in *V. minor, V. major, V. herbacea*, and *V. difformis*. In particular, *V. difformis* leaves have been reported to be rich in quinic acid and chlorogenic acid, supporting the prominence of these compounds in the present extract (Table 5) [16,24].

The abundance of stigmasterol, β-sitosterol, α-amyrin, and lupeol derivatives further indicates an active terpenoid and sterol metabolism in *V. soneri*. Although many earlier studies of this genus have focused primarily on vincamine and related indole alkaloids, metabolomic profiling has shown that *V. soneri* also has a distinct non-alkaloid metabolic composition and contains intermediates associated with terpenoid metabolism. Therefore, the present results expand the phytochemical characterization of *Vinca* species by demonstrating that its methanolic extract is not only a source of phenolic antioxidants but also of potentially bioactive phytosterols and pentacyclic triterpenoids [24].

Previous comparative studies of *Vinca* leaf extracts support the presence of interspecific variation in phenolic composition and antioxidant capacity. In hydroalcoholic leaf extracts, *V. herbacea* showed the highest total phenolic content and antioxidant activity, whereas *V. major* had the highest flavonoid content; *V. minor* was reported to contain relatively lower phenolic and flavonoid levels than these species. This pattern is broadly consistent with the moderate antioxidant activity observed for the present *V. soneri* extract [16].

Direct numerical comparison with previous studies should, however, be made cautiously since the reported values depend strongly on the plant species, extraction solvent, geographic origin, phenolic standard, expression units, and antioxidant assay used. The cited comparative study assessed hydroalcoholic leaf extracts using rutin-equivalent antioxidant capacity, CUPRAC, and lipid-peroxidation assays, whereas the present study used methanolic extract and DPPH/ABTS IC_{50} measurements. Therefore, variation between the present results and earlier *Vinca* reports may reflect methodological differences as well as genuine differences in phytochemical composition among species [16].

Enzyme inhibitory activity findings are broadly consistent with previous reports on *Vinca* species. An earlier study of alkaloid extracts from *V. minor* and *V. major* reported strong *in vitro* anticholinesterase activity, supporting the view that *Vinca* species are a relevant source of cholinesterase-inhibiting alkaloids. The earlier work identified vallesiachotamine and isovallesiachotamine in the aerial parts of *V. minor*, indicating that indole alkaloids may contribute to the cholinesterase-related activity observed in the present extract. However, direct numerical comparison is not appropriate because the previous study examined alkaloid-enriched extracts, whereas the present results represent the tested *V. minor* extract and are expressed as percentage inhibition [15].

Overall, the present findings are consistent with previous phytochemical studies indicating that *Vinca* species contain substantial amounts of phenolic acids and flavonoids, with chlorogenic acid and rutin appearing repeatedly across several species. The high quinic acid concentration in the present *V. soneri* extract is particularly comparable to *V. difformis*, whose leaf extracts were also characterized by abundant quinic and chlorogenic acids. In contrast, the predominance of squalene, stigmasterol, β-sitosterol, α-amyrin, and 3-acetyl lupeol in the GC–MS profile highlights a terpenoid–steroid fraction that is less frequently emphasized in comparative *Vinca* phytochemical studies, which have commonly focused on indole alkaloids and polar phenolic constituents. These differences likely reflect variation in species, plant material, solvent polarity, extraction procedure, environmental conditions, and analytical platform.

The preferential BChE inhibition observed here is similar to phytochemical investigation of *V. minor*, in which isolated monoterpene indole alkaloids were evaluated against AChE and BChE. One isolated compound showed potent and selective human BChE inhibition, with an IC50 value of 0.65 ± 0.16 µM. Although this activity cannot be equated directly with that of the crude extract, it provides a plausible phytochemical basis for the relatively high BChE inhibition observed in the present study. The lower activity of the crude extract compared with galanthamine may reflect lower concentrations of active alkaloids, antagonistic interactions among extract constituents, or differences in enzyme source and assay conditions [13].

Table 5. A comparison table of *V. soneri* with former studies on *Vinca* species

***Vinca* species**	**Plant material/ method**	**Major reported constituents**	**Comparison with the present *V. soneri* methanolic extract**
V. soneri (present study)	Methanolic extract; GC–MS and LC–MS/MS	GC–MS: squalene, stigmasterol, β-sitosterol, 3-acetyl lupeol, and α-amyrin. LC–MS/MS: quinic acid, rutin, hesperidin, chlorogenic acid, and protocatechuic acid.	Demonstrates a mixed profile of phytosterols and pentacyclic triterpenoids together with phenolic acids and flavonoids.
V. minor	Leaf extracts; HPLC-based phytochemical profiling	Chlorogenic acid was abundant; rutin, quercetin, quercitrin, and several phenolic acids were also detected. Alkaloids, particularly vincamine, were prominent in *V. minor*.	Supports the detection of chlorogenic acid, rutin, and protocatechuic acid in the present extract. However, the present GC–MS results additionally emphasize non-alkaloidal terpenoid–steroid constituents [16]
V. herbacea	Leaf extracts; HPLC-based phenolic and flavonoid profiling	High chlorogenic acid levels and particularly high rutin content; quercetin and quercitrin were also identified.	The occurrence of rutin and chlorogenic acid is consistent with the present profile, although quinic acid was the dominant phenolic constituent in the present *V. soneri* extract [16]
V. major	Leaf extracts; phenolic, flavonoid, and alkaloid profiling.	Chlorogenic acid was detected at high levels across extracts; *V. major* showed high total phenolic and flavonoid contents.	Reinforces chlorogenic acid as a recurrent phenolic constituent within the genus. The present results extend this pattern by identifying hesperidin and quantifying quinic acid as the predominant phenolic compound [16]
V. difformis	Methanolic extracts of leaves, flowers, and roots; LC-MS/MS	Twenty-one polyphenols were identified. Leaves were especially rich in quinic acid, chlorogenic acid, caffeoylquinic acid derivatives, and robinin; rutin, quercetin, kaempferol, catechin, and several phenolic acids were also reported.	This extract shows the closest phenolic similarity to the present extract, particularly the predominance of quinic acid and the presence of chlorogenic acid and rutin. Differences in absolute concentrations may be attributable to species, plant organ, geographic origin, and extraction or analytical conditions [25]

5. Conclusions

In conclusion, *V. soneri* exhibited selective enzyme inhibitory activity, with a pronounced inhibitory effect against BChE (75.84 ± 2.27%) and comparatively weak activity against AChE, tyrosinase, and elastase. The absence of detectable collagenase inhibition further suggests limited anti-aging enzyme inhibitory potential under the tested conditions. The strong BChE inhibition indicates that *V. soneri* may be a promising source of bioactive constituents, particularly alkaloids, with potential relevance to cholinesterase-targeted applications. Further phytochemical characterization, isolation of active compounds, and IC_{50}-based enzyme assays are required to identify the constituents responsible for this activity and confirm their selectivity and potency.

Artificial Intelligence Statement
(X) This article did not use artificial intelligence.
( ) This article does use artificial intelligence.

Funding: No Funding Received

Conflicts of interest: No Conflict of Interest

Author contributions: All authors contributed to the study conception and design. All authors read and approved the final manuscript.

Ethical statement: -

Data Availability Statement (Please see the Data Availability Policy section for details.)
(X) Option A (Public Repository): "The research data supporting this study are publicly available in [Name of Repository: e.g., Zenodo, Figshare, Dryad] with the permanent DOI link [URL/DOI]."

( ) Option B (Upon Request): "The raw data supporting the findings of this study are available from the corresponding author [Author Initials] upon reasonable request and within ethical boundaries."
( ) Option C (Third-Party Data): "The data used in this study were obtained from [Name of Institution/Source] and are subject to third-party restrictions regarding redistribution."
( ) Option D (No Data): "No new data were created or analyzed in this study. Data sharing is not applicable to this article."

References

[1] Shukla, S. K. (2023). Conservation of medicinal plants: challenges and opportunities. *Journal of Medicinal Botany*, 7, 5–10.

[2] Bona, G. E., & Bona, M. (2026). Impact of cultivation and domestication of medicinal plants on genetic and phytochemical diversity. In *Genetic Diversity in Medicinal Plants: Challenges, Threats, and Future Applications* (pp. 239–268). Springer Nature Singapore.

[3] Al-Saeedi, A. H., Al-Ghafri, M. T. H., & Hossain, M. A. (2017). Brine shrimp toxicity of various polarities leaves and fruits crude fractions of *Ziziphus jujuba* native to oman and their antimicrobial potency. *Sustainable Chemistry and Pharmacy*, 5, 122–126. https://doi.org/10.1016/j.scp.2017.03.003

[4] Yadav, K., & Joshi, J. (2026). biological activity of phytochemicals extracted from medicinal plants of apocynaceae family. *Materials Today: Proceedings*, 127, 88–100. https://doi.org/10.1016/j.matpr.2024.04.003.

[5] Endress, M. E., Liede-Schumann, S., & Meve, U. (2014). An updated classification for Apocynaceae. *Phytotaxa,* 159(3), 175–194. https://doi.org/10.11646/phytotaxa.159.3.2.

[6] Patil, R. H., Patil, M. P., & Maheshwari, V. L. (2023). *Apocynaceae plants: ethnobotany, phytochemistry, Bioactivity and Biotechnological Advances. Springer.* https://doi.org/10.1007/978-981-99-4985-4Abouzeid, S., Hijazin, T., Lewerenz, L., Hansch, R., & Selmar, D. (2019). The genuine localization of indole alkaloids in *Vinca minor* and *Catharanthus roseus*. *Phytochemistry*, 168, 112110. https://doi.org/10.1016/j.phytochem.2019.112110

[7] Mahmood, T., Meer, F., Munir, F., Nazar, N., & Naveed, I. (2011). Genetic diversity of selected apocynaceae species based on chloroplast gene rps11. *Journal of Medicinal Plants Research*, 5(17), 4382–4387.

[8] Wiart, C. (2006). *Medicinal plants of Asia and the Pacific*. CRC Press. https://doi.org/10.1201/9781420016338.

[9] Wong, S. K., Lim, Y. Y., & Chan, E. W. (2013). Botany, uses, phytochemistry and pharmacology of selected apocynaceae species: a review. *Pharmacognosy Communications*, 3(3), 2–11. https://doi.org/10.5530/pc.2013.3.2.

[10] Ekalu, A., Ayo, R. G. O., James, H. D., & Hamisu, I. (2019). A mini-review on the phytochemistry and biological activities of selected Apocynaceae plants. Journal of Medicinal Plants Research, 13(18), 442–455.

[11] Koyuncu, M. (2012). A new species of *Vinca* (Apocynaceae) from eastern Anatolia, Turkey. *Turkish Journal of Botany*, 36(3), 247–251. https://doi.org/10.3906/bot-1104-12.

[12] Koyuncu, M., Ekşi, G., & Özkan, A. M. G. (2015). *Vinca ispartensis* (Apocynaceae), a new species from Turkey. *Annales Botanici Fennici*, 52(5–6), 340–344. https://doi.org/10.5735/085.052.0507.

[13] Vrabec, R., Drašar, P., Opletal, L., Kosturko, Š., Blunden, G., & Cahlíková, L. (2025). Alkaloids from the genus *Vinca* L. (Apocynaceae): a comprehensive biological and structural review. *Phytochemistry Reviews*, 24(5), 3665–3735. https://doi.org/10.1007/s11101-024-09950-8.

[14] Jungová, M., Čepková, P. H., Müllerová, V. J., & Svoboda, P. (2026). Population genetic structure and cultural Lineages of *Vinca minor* L. across Europe. *Biodiversity and Conservation*, 35(12), 294. https://doi.org/10.1007/s10531-026-03501-x

[15] Bahadori, F., Topçu, G., Boğa, M., Türkekul, A., Kolak, U., & Kartal, M. (2012). Indole alkaloids from *Vinca major* and *V. minor* growing in Turkey. *Natural Product Communications*, 7(6), 731–734. https://doi.org/10.1177/1934578X1200700612.

[16] Ciorîță, A., Zăgrean-Tuza, C., Moț, A. C., Carpa, R., & Pârvu, M. (2021). The phytochemical analysis of *Vinca* L. *Species Leaf Extracts is Correlated with the Antioxidant, Antibacterial, and Antitumor Effects*. *Molecules,* 26(10), 3040. https://doi.org/10.3390/molecules26103040

[17] Neculai, A. M., Stanciu, G., & Mititelu, M. (2023). Determination of active ingredients, mineral composition and antioxidant properties of hydroalcoholic macerates of *Vinca minor* L. plant from the dobrogea area. *Molecules*, 28(15), 5667. https://doi.org/10.3390/molecules28155667.

[18] Farahanikia, B., Akbarzadeh, T., Jahangirzadeh, A., Yassa, N., Ardekani, M. R. S., Mirnezami, T., Hadjiakhoondi, A., & Khanavi, M. (2011). Phytochemical investigation of *Vinca minor* cultivated in *Iran. Iranian Journal of Pharmaceutical Research*, 10(4), 777–785.

[19] Cheryatova, Y. S. (2021, March). Actual aspects of anatomical research of medicinal plant material of *Vinca minor* L. IOP *Conference Series: Earth and Environmental Science,* 723(2), 022036. IOP Publishing. https://doi.org/10.1088/1755-1315/723/2/022036

[20] Grujić, S. M., Radojević, I. D., Vasić, S. M., Čomić, L. R., & Topuzović, M. D. (2014). Antimicrobial activity and some phytochemical analysis of two extracts *Vinca minor* L. *Kragujevac Journal of Science*, 36, 145–154.

[21] Clarke, G., Ting, K. N., Wiart, C., & Fry, J. (2013). High correlation of 2, 2-diphenyl-1-picrylhydrazyl (dpph) radical scavenging, ferric reducing activity potential and total phenolics content indicates redundancy in use of all three assays to screen for antioxidant activity of extracts of plants from the malaysian rainforest. *Antioxidants*, 2(1), 1–10. https://doi.org/10.3390/antiox2010001

[22] Eruygur, N., & Ayaz, F. (2021). Investigation of acetylcholinesterase, butyrylcholinesterase, α-glucosidase, α-amylase, and tyrosinase inhibition and antioxidant activity of methanol and water extracts from aerial parts of *Phlomis lycia D. DON. International Journal of Phytocosmetics and Natural Ingredients*, 8(1), 3. https://doi.org/10.15171/ijpni.2021.03.

[23] Fidan, H. S., Kilinc, F. M., Yilmaz, M. A., Akdeniz, M., Yener, I., Firat, M., Onay, A., Kolak, U., & Ertas, A. (2021). Comparison of chemical and biological properties of in vivo and in vitro samples of *Salvia siirtica* Kahraman, Celep & Dogan extracts prepared with different solvents. *South African Journal of Botany*, 142, 421–429. https://doi.org/10.1016/j.sajb.2021.07.009

[24] Chen, Q., Lu, X., Guo, X., Guo, Q., & Li, D. (2017). Metabolomics characterization of two Apocynaceae plants, *Catharanthus roseus* and *Vinca minor*, using GC-MS and LC-MS methods in combination. *Molecules*, 22(6), 997. https://doi.org/10.3390/molecules22060997.

[25] Foddai, M., Maldini, M., Addis, R., Petretto, G. L., Chessa, M., & Pintore, G. (2017). Profiling of the bioactive compounds in flowers, leaves and roots of *Vinca sardoa*. *Natural Product Communications*, 12(6), 925–928. https://doi.org/10.1177/1934578X1701200625