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Phytochemical characterization of Himalayan barberry (*Berberis lycium*) leaves

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ABSTRACT

Berberis lycium Royle, commonly known as Himalayan barberry, is an important medicinal shrub traditionally used in the treatment of various ailments. The present study investigates the phytochemical composition of *B lycium* leaves using Gas Chromatography-Mass Spectrometry (GC-MS). Leaf samples collected from Solan district, Himachal Pradesh, were subjected to Soxhlet extraction using solvents of varying polarity: acetone, ethyl acetate and methanol. GC-MS profiling revealed a diverse phytochemical spectrum comprising polyketides, terpenoids, fatty acids, hydrocarbons, phenolics, phytosterols, vitamins and lipids. Ethyl acetate extract was rich in nonacosan-10-ol, phytol derivatives and tocopherols, while acetone extract predominantly contained γ-sitosterol, phenolics and hydrocarbons. Methanol extract exhibited high levels of polyketides, phytol, phytosterols and fatty acid derivatives. Several compounds such as phenols, alkaloids, flavonoids, lipids and lignans were documented, some of which are reported for the first time from *B lycium* leaves. The presence of these biologically active constituents highlights the therapeutic potential of the species and underscores its value for further pharmacological, biochemical and isolation studies.

Keywords: *Berberis lycium*; GC-MS; phytochemical analysis; leaf extract; bioactive compounds; phenolics; terpenoids; phytosterols

INTRODUCTION

Since ancient times, medicinal plants have been employed in traditional medical systems and the vast majority of people worldwide still rely on plants to treat a variety of diseases. Additionally, a range of plant-derived phytochemicals and their various parts are being studied for the treatment of many ailments, such as diabetes, cancer and many others. An estimated 70-80 per cent of people on the globe use medicinal plants to treat a variety of health issues (Ahmad et al 2024). Berberis is a large genus of evergreen and deciduous shrubs belonging to the family Berberidaceae, commonly known as barberry and is distributed across temperate and subtropical regions of the world. According to the Plant List this genus includes 628 species worldwide.

Berberis lycium Royle (Plate 1), one of the members of Berberidaceae family, is native to the Himalayan area, particularly Nepal, although it may also be found worldwide, in temperate and subtropical temperatures with the exception of Australia. John Forbes Royle gave a description of *B lycium* in 1837 (Parra et al 2018). It is a highly valuable medicinal plant. In Hindi, this plant is known as Kashmal or Kasmal and in English as Indian barberry. It is a highly valuable medicinal plant that has been used for a very long time in conventional medicine (Ali et al 2015) and possesses broad spectrum antimicrobial activities against many pathogens (Parra et al 2018). It is a spiny shrub that grows to an average height of 2-4 metres, with lanceolate leaves arranged alternately on the stem. It bears yellow flowers in corymbose racemes and produces ovoid berries (Ahmed et al 2017). It is a source of many biologically active compounds. Phytochemicals of this plant include berbamine, berberine, jhelumine, palmatine, sindamine, punjabine, alkaloids, phenols, tannin, flavonoids, maleic acid, ascorbic acid, terpenoids, fats and resins (Anjum et al 2023). Singh and Gupta (2018) investigated antifungal activity of root, flower and fruit extract in different solvents (aqueous, ethanolic, Dimethyl formamide, propanol-2 and n-hexane) of *B lycium* against three fungal pathogens *Aspergillus niger*, *A fumigatus* and *A cuboida*. Their results revealed that ethanolic fruit extract had significant antifungal activity than other extracts.

The objective of the present study was to assess the phytochemical composition of *B lycium* by analysing extracts prepared using solvents of different polarities. The biologically active constituents in each extract were identified and characterized using Gas Chromatography-Mass Spectrometry (GC-MS). This study also provides a comprehensive profile of compounds that may be utilized in future research owing to their pharmacological properties.

MATERIAL and METHODS

Preparation of extract

The plant leaves were collected from Solan district, Himachal Pradesh, in the month of October. The samples were shade-dried and then ground into a fine powder. Soxhlet extraction was carried out using a thimble containing approximately 20 g of the powdered leaf material. Acetone, ethyl acetate and methanol were used as extraction solvents. Fig 1 illustrates the chromatograms of GC-MS of ethyl acetate leaf extract, acetone extract, methanol leaf extract of Himalayan barberry.

Phytochemical characterization

A GCMS system with an AOC-20i+s autosampler and a capillary column (HP-5MS, 30 m × 0.25 mm, 0.25 µm film thickness) was used to analyse the phytochemical components of the plant extract. Helium was used as the carrier gas at a constant flow rate of 1.0 ml/min. The injector temperature was set at 280°C and the column oven was initially maintained at 70°C for five minutes. A 1 µl sample was injected in splitless mode. After that, the oven's temperature was set to rise at a rate of 5°C per minute until 310°C, where it was maintained for ten minutes. The ion source and interface temperatures were kept at 230°C and 280°C respectively. With a scan range of m/z 50-700, the mass spectrometer was run in electron ionisation (EI) mode at 70 eV. The solvent cut time was set at 4.5 minutes and the whole run length was roughly 63 minutes. Spectral similarity indexes were used to compare the mass spectra of the compounds with the NIST libraries.

RESULTS

Phytochemical compounds identified and their molecular formula, weight, retention time, area percentage are listed in the tables separately for each solvent.

A wide range of bioactive substances from several phytochemical groups were identified by GC-MS analysis of ethyl acetate leaf extract (Table 1).

Thirty four compounds, including polyketides, terpenoids, hydrocarbons, phenols, fatty acids, lipids and phytosterols, were found. Nonacosan-10-ol (30.05%), a lipid, was the most prevalent component and it was followed by 2-hexadecen-1-ol, 3,7,11,15-tetramethyl- (phytol acetate; 8.13%), dl-α-tocopherol (vitamin E, 7.66%) and quinic acid (7.10%). Phytol (5.22%), tricosyl acetate (4.46%), γ-sitosterol (4.01%) and pentacosane (4.06%) were other phytochemicals that add to the pharmacological relevance of the plant. Additionally, some compounds including 1,2-epoxyoctadecane (1.68%), n-hexadecanoic acid (1.65%) and neophytadiene (2.63%) were also found, suggesting the presence of terpenoid and fatty acid derivatives with possible bioactivity. Overall, the extract had a high concentration of hydrocarbons and lipid-based compounds; its aromatic and antioxidant profile was enhanced by other compounds such as o-cymene, γ-terpinene, thymol and 2,4-di-tert-butylphenol. The retention periods varied from 7.59 to 60.59 minutes, indicating a broad range of compound polarity. The phytochemical richness of *B lycium* is shown by this chemical diversity, highlighting its potential as a valuable source of natural antioxidants, antimicrobials.

A comprehensive chemical profile comprising 23 bioactive chemicals from several chemical classes, such as alkanes, hydrocarbons, fatty acid derivatives, lipids, terpenes and phenolic compounds, was identified by GC-MS analysis of acetone extract (Table 2).

The most prevalent components were nonacosan-10-ol (7.34%), γ-sitosterol (8.30%) and 2,4-di-tert-butylphenol (9.38%). Tetradecane (4.57%), neophytadiene (3.82%), heptadecane (3.80%), 7,9-di-tert-butyl-1-oxaspiro (4,5)deca-6,9-diene-2,8-dione (3.26%) and eicosane (2.94%) are other significant chemicals that contribute to the pharmacological potential of the plant. Dodecane, hexadecane, phytol, and vitamin E are also important chemicals found in the extract contribute to its bioactivity The retention time, which varied from 14.14 to 55.50 minutes, showed that chemicals with different polarity and volatility were present. The plant's vast phytochemical diversity is highlighted by the prevalence of alkanes and

Plate 1. *Berberis lycium* a. Flowering stage, b. Leaves

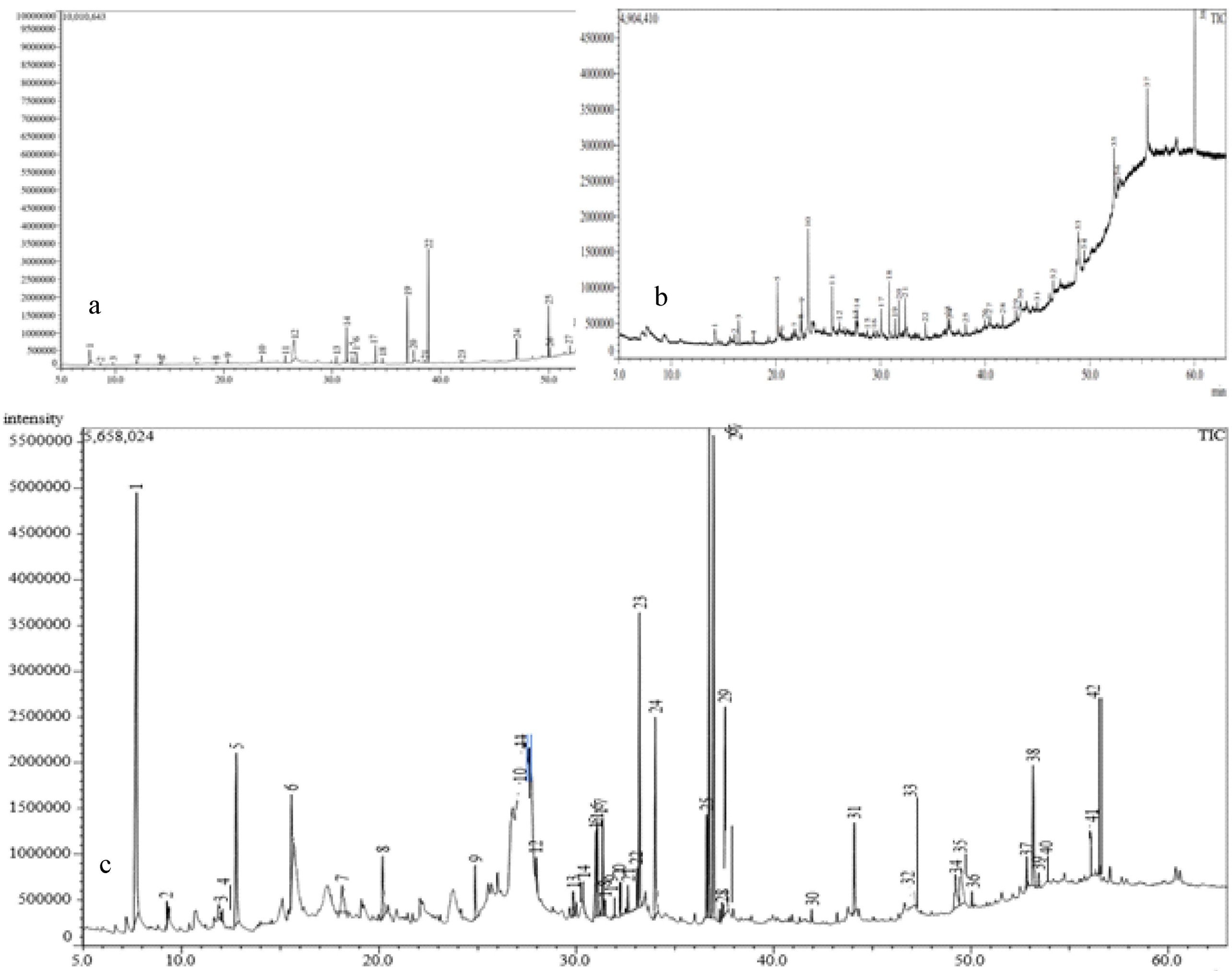

Fig 1. Chromatogram of GC-MS of Himalayan barberry a. Ethyl acetate leaf extract b. Acetone leaf extract c. Methanol leaf extract

hydrocarbons as well as the presence of phenolic and lipidic compounds.

A variety of bioactive substances, such as polyketides, amino acid derivatives, phenolics, terpenes, fatty acids and lipids, were found in the methanol extract accordance to the GC-MS analysis (Table 3).

2H-pyran-2,6(3H)-dione, which belongs to the polyketide class, was the most prevalent compound found (retention time 7.706 min, area 16.62%). Phytol (9.37%), 9,12,15-octadecatrienoic acid, methyl ester (Z,Z,Z) (9.33%), α-linolenic acid (6.01%), n-hexadecanoic acid (4.84%) and γ-sitosterol (5.56%) were among the significant compounds found. Butylsyringone (2.98%), dl-

Table 1. Phytochemicals present in the ethyl acetate extract of Himalayan barberry

Compound	Category	Molecular formula	Molecular mass	Retention time	Area (%)
2H-Pyran-2,6(3H)-dione	Polyketides	$C_5H_4O_3$	112	7.595	1.92
o-Cymene	Monoterpenoid	$C_{10}H_{14}$	134	8.636	0.12
γ-Terpinene	Monoterpene	$C_{10}H_{16}$	136	9.785	0.15
1-Dodecene	Hydrocarbon	$C_{12}H_{24}$	168	14.290	0.19
Thymol	Monoterpenoids	$C_{10}H_{14}O$	150	17.513	0.19
Phenol, 2-methoxy-3-(2-propenyl)	Phenol	$C_{10}H_{12}O_2$	164	19.285	0.52
2,4-Di-tert-butylphenol	Phenol	$C_{14}H_{22}O$	206	23.506	0.46
1-Pentadecene	Hydrocarbons	$C_{15}H_{30}$	210	25.663	0.53
Quinic acid	Cyclitol	$C_7H_{12}O_6$	192	26.513	7.10
1-Octadecene	Hydrocarbons	$C_{18}H_{36}$	252	30.386	0.53
Neophytadiene	Terpenoid	$C_{20}H_{38}$	278	31.336	2.63
n-Hexadecanoic	Fatty acid	$C_{16}H_{32}O_2$	256	34.008	1.65
1-Heptadecene	Hydrocarbons	$C_{17}H_{34}$	238	34.651	0.41
Phytol	Diterpene	$C_{2}0H_{40}O$	296	36.941	5.22
9,12,15-Octadecatrienoic acid	Fatty acid	$C_{18}H_{30}O_2$	278	37.512	1.26
1-Hexacosene	Hydrocarbons	$C_{26}H_{52}$	364	38.546	0.16
2-Hexadecen-1-ol,3,7,11,15-tetramethyl-, acetate	Phytol acetate	$C_{22}H_{42}O_2$	338	38.881	8.13
3,7,11,15-Tetramethylhexadec-2-en-1-yl acetate	Terpenoids	$C_{22}H_{42}O_2$	338	41.938	0.16
Heptacosane	Hydrocarbons	$C_{27}H_{56}$	380	47.034	1.58
Pentacosane	Hydrocarbons	$C_{25}H_{52}$	352	49.973	4.06
Tetracosan-10-ol	Fatty acid derivative	$C_{24}H_{50}O$	354	50.051	0.66
Octacosanal	Lipid	$C_{28}H_{56}O$	408	51.964	0.66
Pentacosane	Alkane	$C_{25}H_{52}$	352	52.725	1.94
Nonacosan-10-ol	Lipids	$C_{29}H_{60}O$	424	52.848	30.05
dl-α-Tocopherol	Vitamin E	$C_{29}H_{50}O_2$	430	53.175	7.66
Phytyl stearate	Fatty acid	$C_{38}H_{74}O_2$	562	53.439	0.77
Tricosyl acetate	Fatty acid ester	$C_{25}H_{50}O_2$	382	54.265	4.46
Triacontanal	Fatty acid derivative	$C_{30}H_{60}O$	436	54.801	0.70
1-Heptacosanol	Fatty alcohol	$C_{27}H_{56}O$	396	55.795	0.71
1,2-Epoxyoctadecane	Fatty acid derivative	$C_{18}H_{36}O$	268	56.031	1.68
γ-Sitosterol	Phytosterol	$C_{29}H_{50}O$	414	56.168	4.01
Oxirane, hexadecyl	Fatty acid derivative	$C_{18}H_{36}O$	268		
Clionasterol acetate	Phytosterol	$C_{31}H_{52}O_2$	456	58.301	1.05
Hexadecanoic acid, 3,7,11,15-tetramethyl-2-hexadecenyl ester, [R-[R*,R*-(E)]]	Lipid	$C_{36}H_{70}O_2$	534	60.591	0.67

α-tocopherol (2.85%), hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl) ethyl ester (2.13%) and methyl syringate (2.02%) were other significant components. A complex mixture of phytochemicals with possible biological significance was found in moderate levels, including 5-hydroxymethylfurfural (2.24%), dl-corydine (2.66%) and 9,12,15-octadecatrienoic acid, 2,3-dihydroxypropyl ester (3.02%). Trace amounts of minor chemicals were found, including L-proline 1-methyl, methyl ester, neophytadiene, sesamin, phenol, and 4-ethenyl-2,6-dimethoxy.

Table 2. Phytochemicals present in the acetone extract of Himalayan barberry

Compound	Category	Molecular formula	Molecular mass	Retention time	Area (%)
Dodecane	Alkane	$C_{12}H_{26}$	170	14.143	3.05
2,4-Dimethylundecane	Alkane	$C_{13}H_{28}$	184	16.067	1.07
2,6,11 Trimethyldodecane	Alkane	$C_{15}H_{32}$	212	16.447	2.85
Hexadecane	Alkane	$C_{16}H_{34}$	226	17.853	0.71
Tetradecane	Alkane	$C_{14}H_{30}$	198	20.133	4.57
Heneicosane	Alkane	$C_{21}H_{44}$	296	20.534	0.51
Eicosane	Alkane	$C_{20}H_{42}$	282	22.479	2.94
2,4-Di-tert-butylphenol	Phenol	$C_{14}H_{22}O$	206	23.081	9.38
Heptadecane	Hydrocarbon	$C_{17}H_{36}$	240	25.379	3.80
3-Methylheptadecane	Hydrocarbon	$C_{18}H_{38}$	254	29.391	0.32
Neophytadiene	Sesquiterpenoid	$C_{20}H_{38}$	278	30.836	3.82
Phthalic acid, tetradecyl trans-dec-3-enyl ester	Fatty acid derivatives	$C_{32}H_{52}O_4$	500	31.373	1.49
7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione	Flavonoid	$C_{17}H_{24}O_3$	276	32.346	3.26
Phytol	Terpene	$C_{20}H_{40}O$	296	36.447	1.25
Triacontane, 1-iodo	Alkyl halide	$C_{30}H_{61}I$	148	41.699	0.88
Hexadecanoic acid, (2,2-dimethyl-1,3-dioxolan-4-yl) methyl ester	Fatty acid ester	$C_{22}H_{42}O_4$	370	42.947	0.93
Dotriacontane, 1-iodo	Alkyl halide	$C_{32}H_{65}I$	576	43.360	0.50
Hexatriacontane	Hydrocarbon	$C_{36}H_{74}$	506	44.980	0.53
Tetrapentacontane	Hydrocarbon	$C_{54}H_{110}$	758	46.525	1.20
Hexadecanoic acid, eicosyl ester	Fatty acid	$C_{36}H_{72}O_2$	536	46.525	0.93
2,6,10,14-Tetramethyloctadecane	Hydrocarbon	$C_{22}H_{46}$	310	49.456	1.12
Nonacosan-10-ol	Lipid	$C_{29}H_{60}O$	424	52.308	7.34
Vitamin E	Vitamin	$C_{29}H_{50}O_2$	430	52.661	1.59
γ-Sitosterol	Lipid	$C_{29}H_{50}O$	414	55.503	8.30

DISCUSSION

GC-MS profiling of *B lycium* leaves revealed a significant degree of phytochemical variation in solvent extracts of ethyl acetate, acetone and methanol. Nonacosan-10-ol, phytol derivatives, tocopherols and phenolic antioxidants were predominated in the ethyl acetate extract. The acetone extract was rich in γ-sitosterol, phenolics and hydrocarbons. Phytol, phytosterols, fatty acids (derivatives of linolenic acid) and polyketides (2H-pyran-2,6-dione) were abundantly present in the methanol extract. On the whole, the chemical composition was affected by the polarity of the solvent and the metabolites that were found showed significant biological properties such as antifungal, antibacterial, anti-cancerous, anti-inflammatory, insecticidal, antiviral, antimalarial and antioxidant properties (Table 4) which make this plant economically important.

The effectiveness of *B lycium* in treating a variety of diseases has drawn attention, which has led researchers to embark on a number of experiments that aim at its pharmacological effects. This plant has historically been used to treat many diseases such as diarrhoea, intestinal colic, jaundice, piles, internal wounds, ophthalmia, rheumatism, and diabetes (Anjum et al 2023). According to experimental studies performed, *B lycium* was reported to have antibacterial, antihyperlipidemic, antidiabetic, anti-inflammatory, anticancer, antiviral and anthelminthic properties (Ahmad et al 2024). These diverse biological properties

Table 3. Phytochemicals present in the methanol extract of Himalayan barberry

Compound	Category	Molecular formula	Molecular mass	Retention time	Area (%)
2H-Pyran-2,6(3H)-dione	Polyketides	$C_5H_4O_3$	112	7.706	16.62
L-Proline 1-methyl-, methylester	Proline derivative	$C_7H_{13}NO_2$	143	9.231	0.47
Methylpyrrole-2-carboxylate	Organic acids	$C_6H_7NO_2$	124	11.858	0.64
Butanedioicacid, hydroxy-, dimethyl ester (Malic acid)	Dicaboxylic acid	$C_6H_{10}O_5$	162	12.025	0.67
5-Hydroxymethylfurfural (HMF)	Furan	$C_6H_6O_3$	126	15.577	2.24
L-Proline, 5-oxo-, methyl ester (Pyroglutamic acid)	Amino acid derivative	$C_6H_9NO_3$	143	20.207	1.91
Phenol, 4-ethenyl-2,6-dimethoxy	Methoxyphenols	$C_{10}H_{12}O_3$	180	24.888	1.35
Cyclopentanol, 1,2-dimethyl-3-(1-methylethenyl)-, [1R-(1.alpha.,2.alpha.,3.alpha.)]	Terpene	$C_{10}H_{18}O$	154	27.225	0.23
Benzoic acid, 4-hydroxy-3,5-dimethoxy-, hydrazide	Phenol	$C_9H_{12}N_2O_4$	212	29.828	0.53
1-Acetyl-2,2,6,6-tetramethyl-4-acetyloxypiperidyne	Alkaloid	$C_{13}H_{23}NO_3$	241	30.384	0.51
Butylsyringone	Phenolic	$C_{12}H_{16}O_4$	224	31.000	2.98
Benzoic acid, 4-hydroxy-3,5-dimethoxy-, methyl ester (Methyl syringate)	Phenolic	$C_{10}H_{12}O_5$	212	31.057	2.02
Neophytadiene	Terpene	$C_{20}H_{38}$	278	31.332	1.93
Hexahydrofarnesyl acetone, 6,10,14-Trimethyl-2-pentadecanone	Sesquiterpene ketone	$C_{18}H_{36}O$	268	31.448	0.32
7,10,13-Hexadecatrienoic acid, methyl ester	Fatty acid	$C_{17}H_{28}O_2$	264	32.609	0.49
7-Hexadecenoic acid, methyl ester	Fatty acid	$C_{17}H_{32}O_2$	268	33.110	0.72
n-Hexadecanoic acid	Palmitic acid	$C_{16}H_{32}O_2$	256	34.036	4.84
9,12-Octadecadienoic acid (Z,Z)-, methyl ester	Methyl linoleate	$C_{19}H_{34}O_2$	294	36.608	1.76
9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)	Methyl linolenate	$C_{19}H_{32}O_2$	292	36.730	9.33
Phytol	Diterpene	$C_{20}H_{40}O$	296	36.946	9.37
9,12,15-Octadecatrienoic acid, (Z,Z,Z)	α-linolenic acid	$C_{18}H_{30}O_2$	278	37.537	6.01
2-Hexadecen-1-ol, 3,7,11,15-tetramethyl-, acetate, [R-[R*,R*-(E)]]	Phytol acetate	$C_{22}H_{42}O_2$	338	41.935	0.17
Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl) ethyl ester	Lipid	$C_{19}H_{38}O_4$	330	44.079	2.13
9,12-Octadecadienoic acid (Z,Z)-, 2,3-dihydroxypropyl ester	Linoleoyl glycerol	$C_{21}H_{38}O_4$	354	46.900	0.62
9,12,15-Octadecatrienoic acid, 2,3-dihydroxypropyl ester, (Z,Z,Z)	Fatty acid	$C_{21}H_{36}O_4$	352	47.027	3.02
α-Tocospiro B	Terpenoid	$C_{29}H_{50}O_4$	462	49.183	1.66
dl-Corydine	Benzylisoquinoline (Alkaloid)	$C_{20}H_{23}NO_4$	341	49.461	2.66
Nonacosan-10-ol	Lipid	$C_{29}H_{60}O$	424	52.825	0.55
dl-α-Tocopherol	Poyterpene	$C_{29}H_{50}O_2$	430	53.172	2.85
Phytyl stearate	Terpenoids	$C_{38}H_{74}O_2$	562	53.442	0.25
Sesamin	Lignan	$C_{20}H_{18}O_6$	354	53.827	0.70
γ-Sitosterol	Lipids	$C_{29}H_{50}O$	424	56.177	5.56

Table 4. Compounds present in Himalayan barberry reported to have biological activities

Compound name	Biological activity	Reference
γ-Sitosterol	Anti-inflammatory, anti-cancer, cytotoxic, antihyperlipidemic, antidiabetic; treats ulcers, bronchitis, diabetes, heart diseases	Naikwadi et al (2022), Sonia and Singh (2019)
Sesamin	Antioxidant, anti-inflammatory, anticancer	Zhang et al (2022)
Phytyl stearate	Found in plant wax	Garcés et al (2023)
dl-α-Tocopherol	Antioxidant	Serbinova et al (1991)
Nonacosan-10-ol	Component of tubular wax aggregates; also found in cuticular waxes of Pinaceae	Matas et al (2003), Dommisse et al (2007)
dl-Corydine	Inhibits growth of tumour cells	Konda et al (1990)
α-Tocospiro B	Antioxidant	Chen et al (2007)
Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl) ethyl ester	Anti-inflammatory, haemolytic; pesticidal, antioxidant	Tyagi and Agarwal (2017), Mohamed et al (2024)
2-Hexadecen-1-ol, 3,7,11,15-tetramethyl- acetate, [R-[R*, R*-(E)]]	Antibacterial	Thejashree and Naika (2023)
9,12,15-Octadecatrienoic acid, (Z,Z,Z)-	Antimicrobial, anticancer, hepatoprotective, anti-inflammatory	Banu and Nagarajan (2013)
Phytol	Antioxidant, anti-inflmmatory, antimicrobial	Ashoka and Shivanna (2022)
9,12,15-Octadecatrienoic acid, methyl ester, (Z,Z,Z)	Antioxidant, anti-inflammatory, antibacterial, antifungal, anticancer	Mohamed et al (2015)
n-Hexadecanoic acid	Antimicrobial, antioxidant, hypocholesterolemic, nematicidal, pesticidal	Vedhanayaki and Ramkumar (2019)
Hexahydrofarnesyl acetone, 6,10,14-Trimethyl-2-pentadecanone	Antibacterial, anti-inflammatory, anticancer	Avoseh et al (2021)
Neophytadiene	Analgesic, antioxidant, antimicrobial, anticancer, antimalarial, insecticidal, neuroprotective	Rajeswaran and Rajan (2025)
1-Acetyl-2,2,6,6-tetramethyl-4-acetyloxypiperidyne	Antimicrobial	Li et al (2015)
5-Hydroxymethylfurfural	Antioxidant, antiproliferative, cytotoxic	Zhao et al (2013)
2H-Pyran-2,6(3H)-dione	Antiallergic	Garst et al (1988)
Hexadecane	Antibacterial	Rouis-Soussi et al (2014)
Tetradecane	Antibacterial, antifungal	Naeim et al (2020)
Heneicosane	Antimicrobial	Vanitha et al (2020)
Vitamin E	Antioxidant	Brigelius-Flohé (2006)
o-Cymene	Insecticidal, insect repellent	Feng et al (2021)
γ-Terpinene	Antioxidant	Guo et al (2021)
Thymol	Antibacterial, antifungal	Marchese et al (2016)
Quinic acid	Antioxidant, antidiabetic, anticancer, antimicrobial, antiviral, antinociceptive, analgesic	Benali et al (2024)
2-Hexadecen-1-ol,3,7,11,15-tetramethyl-, acetate	Antibacterial	Thejashree and Naika (2023)
Heptacosane	Antioxidant, antibacterial, antimalarial, antitumor, antidermatophytic	Kuiate et al (2006)

of this plant are attributed to the presence of numerous phytocompounds.

Many studies were reported on the phytochemical characterization of root, flower and fruit by HPLC and qualitative analysis but very few on the leaf; therefore, this study has significance of documenting phytochemical compounds of leaves through GC-MS analysis for the first time.

Studies conducted on the phytochemical analysis of root confirmed the presence of steroids, alkaloids, flavonoids, tannins, terpenoids, anthoquinonine, proteins and carbohydrates (Mughal et al 2022) and through HPLC analysis presence of phenolic compounds (chlorogenic acid, quercetin, berberine, mandellic acid, rutin and hydroxy benzoic acid) were also confirmed (Nazir et al 2021).

GC-MS analysis of root, flower and fruit (methanolic extracts) were done by Gupta and Singh (2018) and they revealed the presence of some biologically active compounds, such as 3-benzyl-1,2-dihydronaphthalene, N-(4-biphenylyl) benzamide, n-phenylbenzanilide etc. Stigmasterol was reported to be present in the root extract of *B lycium* by Sharma et al (2019) and also present in the leaves, in the current study.

Alkaloids, phenols, saponins, tannins, flavonoids, carbohydrates, terpenoids, steroids and glycosides were all found in *B lycium* leaves according to qualitative phytochemical examination and HPLC results have shown the presence of quercetin, gallic acid, ferulic acid and caffeic acid (Landry et al 2021).

In the current study, phenols (butylsyringone, benzoic acid, 4-hydroxy-3,5-dimethoxy-, methyl ester, 2,4-di-tert-butylphenol), alkaloids (dl-corydine, 1-acetyl-2,2,6,6-tetramethyl-4-acetyloxypiperidyne), flavonoid (7,9-di-tert-butyl-1-oxaspiro(4,5) deca-6,9-diene-2,8-dione), terpenoids, lipids, vitamin, steroids, lipids and lignan etc are documented.

This study offers the first GC-MS-based phytochemical profiling of *B lycium* leaves. A number of compounds found in this analysis are being reported for the first time from this species and their biological activities are still mostly unknown. These results highlight the need for additional research, especially with regard to the isolation, structural characterisation and pharmacological evaluation of these newly identified constituents in order to better understand their therapeutic potential.

CONCLUSION

This study investigates the presence of diversity of bioactive compounds with many of them reported to have biological properties according to the literature surveyed. Future investigations need to focus on in-depth mechanistic assessments that describe the molecular mechanisms by which *B lycium* exerts its effects, emphasising specific objectives for therapeutic development.

To assess its effectiveness and safety in humans, especially for its antidiabetic, anticancer and antiviral properties, carefully planned clinical trials are also required. To ensure consistency in therapeutic efficacy and safety, standardised extracts and formulations must be prepared. Using advanced techniques, further isolation and characterisation of the distinct phytochemicals found in this plant will bring insight into the particular compounds that are responsible of its pharmacological actions. Choosing the optimum growing techniques and plant traits for medicinal application can be facilitated by investigating the genetic and environmental factors influencing the phytochemical content and therapeutic properties of *B lycium*.

Despite the plant's widespread traditional use, only little research has investigated the chemical profile of leaves, rendering phytochemical characterisation essential. Determining the bioactive compounds affirms its ethnobotanical significance and establishes a scientific foundation for its medicinal properties. Additionally, this kind of characterisation aids in the selection of efficient compounds for focused pharmacological research. Further study on compound isolation, mechanism-of-action and the development of innovative medicinal formulations will be rendered feasible through the results presented here.

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