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Original Article

GC-MS, FT-IR, and ICP-MS Analysis of Bioactive Compounds in the Methanolic Leaves Extract of *Thalictrum foliolosum*

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ABSTRACT

Background: There are many therapeutic effects of medicinal plants that are used in treating and preventing a variety of diseases. Recently medicinal plants contain many bioactive compounds which are playing an important role in the health sector. The use of herbal medicine is based on the fact that herbal medicines are safe without any ill effects on human health and are easily accessible at minimum cost. However, there is an urgent need to assure the quality and efficacy of the product. **Objectives:** The main objective of current study directed to characterize possible the phytochemical compounds and mineral elements present in the methanolic leaves extract of the *Thalictrum foliolosum* plant by using GC-MS, FTIR, and ICP-MS analysis to ensure quality of this medicinally important herb and for a better understanding of its pharmacological claim. **Materials and Methods:** *Thalictrum foliolosum* was collected in July and August from the Hatu peak at an elevation of 3400 m in the Shimla district of Himachal Pradesh, India. The fine powder of the plant leaf was extracted with methanol at room temperature for 8 hr. The chemical analysis of bioactive compounds of *Thalictrum foliolosum* has been evaluated using GC-MS, FTIR and ICP-MS. **Results:** GC-MS analysis disclosed the presence of 48 compounds which shows various medicinal activities. The major phytoconstituents were Octacosanol (22.37%), Diethyl Phthalate (22.32%), Hexanoic acid, 2-ethyl-, ethyl ester (6.14%), n-Hexadecanoic acid (4.11%) and many more which exhibited antioxidant, antidiabetic, antimicrobial, anti-inflammatory and anticancer activities. The compounds found in the extract were compared with mass spectra from the National Institute of Standards and Technology (NIST). The crude extract was analyzed in a spectrometer Perkin Elmer Spectrum 400 and characteristic peaks were recorded indicating various functional groups such as phenol, alkanes, alcohol, amides, and amines are present. The ICP-MS technique was simultaneously used to trace the mineral element and the result revealed the presence of important micronutrients including manganese (1,770.517 ppb), ferrous (22,604.753ppb), zinc (4,322.423 ppb), chromium (491.231), copper (7,048.321ppb) and potassium (450,067.837ppb). These mineral element acts as cofactors for more than 3000 enzymes that regulate various metabolic pathways in the living system. Hence our study provides a huge platform to screen out these bioactive compounds and mineral elements which are used to treat various lethal and lifestyle diseases. **Conclusion:** The current study reveals that the methanolic leaves extract of *Thalictrum foliolosum* contains various phytoconstituents which were responsible for various biological activities. The relative concentration of bioactive compounds and mineral elements is reasonable and can be considered for medical purposes.

Keywords: FTRI, GC-MS, ICP-MS, Medicinal plants, Secondary metabolites.

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INTRODUCTION

Thalictrum foliolosum DC (Ranunculaceae) is a perennial medicinal herb, commonly known as "Mamira" having high medicinal potential. It is the native temperate Himalayan region of China and India.[1] Root extract was used by indigenous people for the treatment of jaundice, dyspepsia, and skin allergy. Traditional uses of its leaves include tonic, purgative, anti-periodic, diuretic, febrifuge, and stomachic.[2] The therapeutic effect of medicinal plants has become a wide issue drawing an influence on world health. Medicinal plants are played a crucial role in the maintenance of the healthcare system all over the world. The quantitative analysis shows the presence of alkaloids, phenols, flavonoids, saponins, and tannins, which have therapeutic effects and are used from ancient times in treating and preventing a variety of diseases and increase body immunity of the body.[3]

Herbal drugs are increasingly being tested for quality by using metabolomics as an integrated and versatile approach. The metabolomics study helps in the proper understanding, characterization, and identification of bioactive compounds present in plant samples. The Researchers show more curiosity

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to explore the intricate compositions of bioactive compounds and to check their potential ability to cure diseases on large scale. After the scientific revolution, the research on plant-formulated medicine has gone up which accompanied the evolution of the pharmaceutical industry. It is our pressing priority to pull out nature's power to oppose proliferating diseases like diabetes, cancer, skin diseases, and viral disease like COVID-19.[4]

The knowledge of bioactive components and mineral elements of plants is essential for defining the efficacy of the plant to cure ailments and helps in apprehending their therapeutic action. The chemical components of plants are moderately related to nutritional and medical properties. In this study, the mineral elements are traced by using the ICP-MS (Inductively Coupled Plasma Mass Spectroscopy) technique. As GC-MS (Gas Chromatography-Mass Spectrometry), FTIR (Fourier Transform Infrared), and ICP-MS (Inductively Coupled Plasma Mass Spectroscopy) techniques are used in our research to determine phytochemicals present in the plant extract. On the basis of specific wavelength, FTIR fingerprints provide information about the presence of the specific functional group. Multiple phytochemicals can also be identified with the help of diagnostic functional group patterns. Various compounds such as alcohols, alkaloids, nitro compounds, organic acids, steroids, esters, and long-chain hydrocarbons were detected by using GC-MS method. The use of herbal medicine is based on the fact that herbal medicines are safe without any ill effects on human health and are easily accessible at minimum cost. However, there is an urgent need to assure the quality and efficacy of the product.

MATERIALS AND METHODS

Plant Collection

Thalictrum foliolosum was collected in July and August from the Hatu peak at an elevation of 3400 m in Shimla district of Himachal Pradesh, India. Identification was done by comprising authentic species present in the herbarium of the Botanical Survey of India (BSI), Dehradun under accession No. 467.

Plant extracts preparation

The fresh plant parts were washed with running water to eliminate all contaminants. The plant parts were, then in shade on a dry paper towel at room temperature and fine powder was made. Methanol (95%) solvent was used to prepare the extract of the plants. The maceration procedure was followed for extraction in which the methanol was poured into a flask on the 5gm coarse plant powder until all the plant material was dissolved in the solvent. The entire solvent extract was evaporated for dryness with a rotary flash evaporator in methanol (95%) under diminished pressure. The dried plant extracts obtained after rotary evaporation was stored in sterilized air-tight bottles free from contamination at -4°C. Finally, quantitative and qualitative studies were carried out using standard methods.

GC-MS analysis

The detection of phytoconstituents present in *T. foliolosum* was done by GC-MS analysis. Shimadzu Triple Quadrupole GCMS-TQ8050 NX Gas Chromatography mass spectrometer with helium as carrier gas at a constant flow rate of 60 mL/min was used for the analysis with a length of 30 M, and a diameter of 0.25 mm column. The column flow rate was 0.91 mL/min, the linear velocity was 34.9cm/sec, the flow of pressure was 53.3kpa, and an injector of temperature 230°C was used for analysis. The oven temp. was programmed from 70°C to 310°C for 10 min. A 0.5µL fraction of the sample with a split ratio of 5:0 was injected. The in-built library search function was used for the quantitative analysis of the sample. Based on retention time, peak area, and mass spectra, the compound in the sample was recognized by the National Institute of Standards and Technology (NIST).[5] The plant sample prepared in methanol was injected once. A standard for internal use was Eicosane.

FTIR

The spectrometer Perkin Elmer Spectrum 400 was used to obtain the FTIR spectrum of the bioactive compound found in the plant sample. A very small quantity of dried powder extract plant was required for analysis which was converted into small tablets by mixing with potassium bromide and pressure was applied to make a thin film for analysis. The range of the absorbance spectrum was 400 to 4000 cm^{-1}. In order to determine chemical bonds and functional groups in the sample, the spectral data were compared to references.[6]

ICP-MS

Instrumentation

ICP-MS is a powerful technique to analyze multiple mineral and heavy metal elements present in plant extract with high accuracy. ICP-MS instrument (Thermos Scientific iCAPRQ) equipped with quadrupoles and composed of a double spray chamber, a glass nebulizer, and an automatic sampler was used to investigate the samples. The spectral interference was minimized by using helium gas. Instrument details are mentioned in Table 1.

Sample preparation

The first step in the analysis process was sample digestion. For the digestion 200mg of dried plant sample was frozen and acid digestion of the sample was done by using Aqua-Regia then 20% nitric acid (50 mL) was added. This mixture was heated at 70-85°C for about 48 hr. The digested sample was diluted and filtered by using a micro filter and the filtrate was allowed to cool. The digested sample was further analyzed with the iCAPRQ ICP-MS instrument. The calibration curves were made using a standard solution. An internal standardization process is used to compensate for variations in instrument operating conditions or matrix effects that might impact the analytic signal.

The instrument was tuned for its standard operation using a tuning solution before starting the analysis. After standardizing the parameters during tuning, the instrument was set for the elemental analysis in the samples.

Internal standard for ICP-MS

The internal standard has similar properties and behaves in the same manner as the analyte. As the mass and ionization potential of the element were determined significantly in ICP-MS, therefore ideal internal standard should have mass and ionization potential similar to the sample analyzed.[7,8] The most commonly used internal standard in ICP-MS included germanium, scandium, lithium, rhodium, rhenium, tellurium, and iridium. A wide series of elements were analyzed by using a combination of internal standard.

Table 1: Instrument details used in ICP-MS analysis.

Instrument	Thermos Scientific iCAPRQ ICP-MS
RF power	400 W to 1600W
Nebulizer	Borosilicate glass
Nebulizer flow rate	400 µL/min
Spray chamber	Quartz, cyclonic
Sampling depth	0-15 mm
Quadrupole Mass analyzer (Frequency)	2MHz
Interface	High matrix
Digitally Controlled Plasma Gas Flows	3
Temperature	2°C

RESULTS

GC-MS screening result

The identification of various bioactive compound present was determined by GC-MS analysis (Figure 1). Fifty-two compounds were detected in the methanolic leaves extract of the plant. The Major compounds with their retention time, peak area, percentage of peak area, molecular formula, and medicinal potential were shown in Tables 2 and 3. Major compound present in *T. foliolosum* were Octacosanol (22.37%), Diethyl Phthalate (22.32%), Carbaril (6.14%), n-Hexadecanoic acid (4.11%), 5-Hydroxymethylfurfural (3.13%), Stigmast-5-en-3-ol, oleate/beta-Sitosterol (3.92%), 2(3H)-Furanone, 5-hexyldihydro (2.25%), 9,12,15-Octadecatrienoic acid, (Z,Z,Z) (2.04%), 9,12-Octadecadienoic acid (2.03%), 9-Octadecenamide, (Z) (1.75%), n-Capric acid isopropyl ester (1.60%), Oxirane, hexadecyl (1.35%), Dibutyl phthalate (1.09%), Cyclotetradecane (0.77%),7-Hexadecenal, (Z) (0.68%), and Pentadecanal (0.66%). All these bioactive compounds having medicinal potential like antioxidant, anti-inflammatory, anti-diabetic, anti-fungal, anti-microbial, anti-cancerous, anti-hypoxia, anti-parkinson's, anti-viral, hypocholesterolemic, analgesic, anxiolytic, and sedative effect.

FTIR analysis

The FTIR analysis revealed the presence of various functional groups like C-H, O-H, C=C, N-H, S=O, and N =C =S (Figure 2). The functional group was identified by matching the frequency range with reference of Sigma-Aldrich table. The absorption peak at 3930.54 cm^{-1}, 3551.32 cm^{-1}, 3474.41 cm^{-1}, and 3235.95 cm^{-1} is corresponding to O-H stretching which confirmed the presence of an alcohol functional group. The absorption band at 2852.98 cm^{-1}

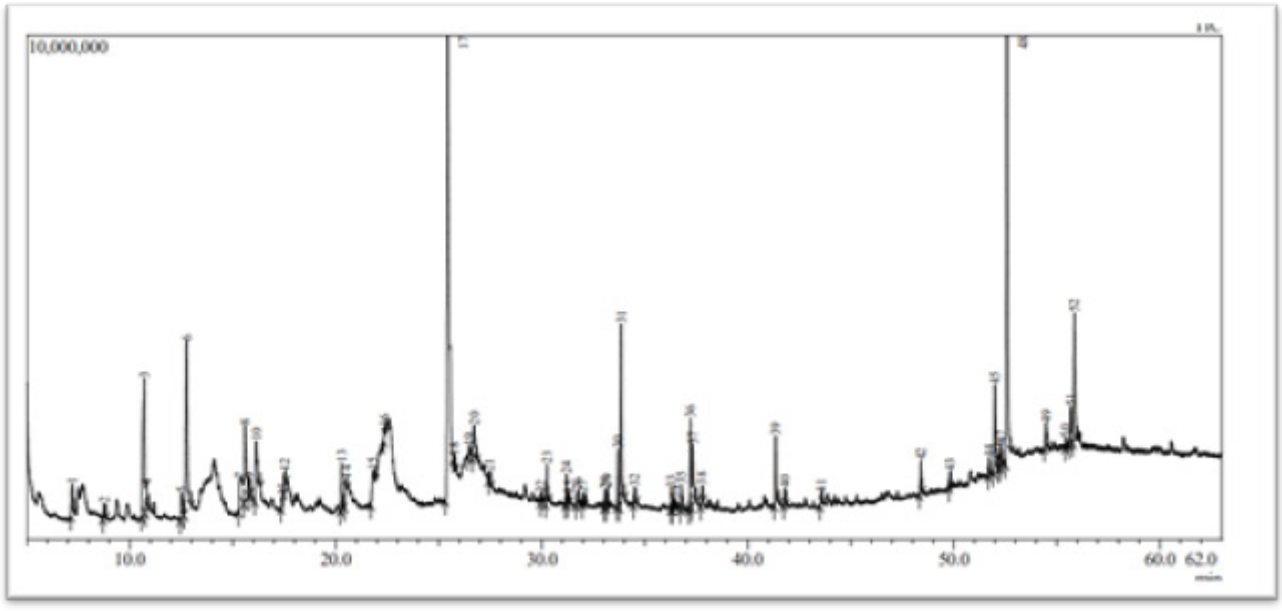


Figure 1: GC–MS chromatogram of methanolic root extract of *Thalictrum foliolosum*.

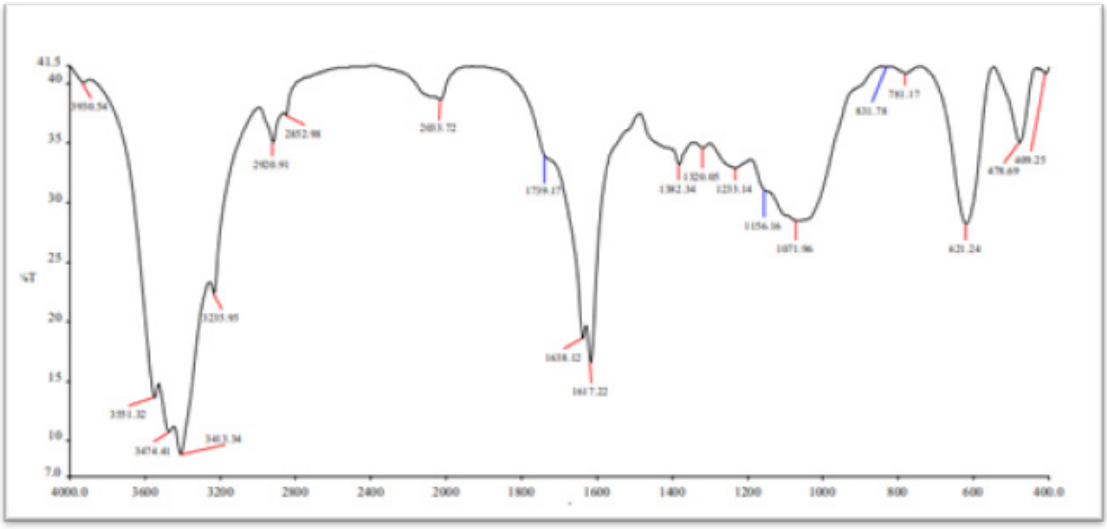


Figure 2: FTIR spectrum of methanolic root extract of *Thalictrum foliolosum*.

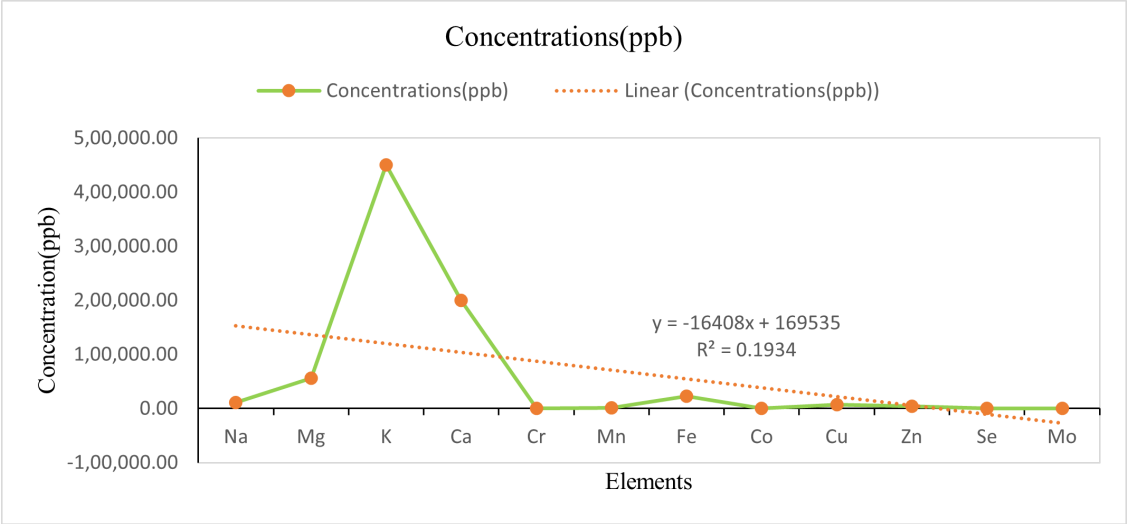


Figure 3: Calibration curve of ICP-MS analyzed mineral elements.

is O-H, N-H, and C-H stretching which revealed the presence of carboxylic acid, alcohol, amine salt, and alkane. 2852.98 cm^{-1}, 2033.72 cm^{-1}, 1739.17 cm^{-1}, 1638.12 cm^{-1}, 1617.22 cm^{-1}, 1382.34 cm^{-1}, 1320.05 cm^{-1}, 1233.14 cm^{-1}, 1156.16 cm^{-1}, 1071.96 cm^{-1}, 831.78 cm^{-1},781.17 cm^{-1}, 621.24 cm^{-1}, 478.69 cm^{-1}, 409.25 cm^{-1} indicates the presence of cyclic alkane, conjugated alkene, amine, aldehyde, sulphate, sulfonyl chloride, alcohol, phenol, sulfone, aromatic amine, and α, β unsaturated ester (Table 4).

ICP-MS analysis

Inorganic mineral elements play important role in regulating various biological functions of the body. Twelve biological essential elements such as Na, Mg, K, Ca, Cr, Mn, Fe, Co, Zn, Se, and Mo were identified through ICP-MS analysis that were present in different concentrations (Table 5 and Figure 3). Potassium (K^+) was present in higher concentrations followed by Calcium (Ca^{2+}) and Magnesium (Mg^{2+}).

DISCUSSION

The leaves extract of the *Thalictrum foliolosum* was analyzed to expose the pharmaceutical important bioactive constituents. The GC-MS analysis total of 52 compounds was obtained at a specific Retention Time (RT). The Peak area in the chromatogram showed the presence of essential compounds. The mass/ charge ratio helped to separate the compounds at a particular Retention Time (RT). The phthalate ester like Diethyl Phthalate at RT 25.431 with peak area 22.32%, and Dibutyl phthalate with RT 33.695 at peak area 1.09% were observed. These phthalate esters were known to exhibit anti-bacterial, and anti-cancerous.[37,38] The presence of long-chain fatty acids like 9,12,15-Octadecatrienoic acid, (Z, Z, Z) at RT 37.32 with peak area (2.04%), and 9,12-Octadecadienoic acid at RT 37.213 With peak area (2.03%) were confirmed which exhibited hepatoprotective, anti-histaminic, anti-acne,5-αreductase inhibitor, anti-androgenic, anti-arthritic, and anti-coronary activity.[39] The phytosterol Stigmast-5-en-3-ol,

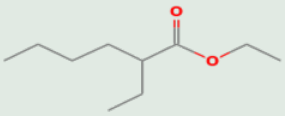
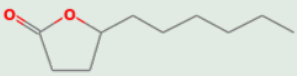
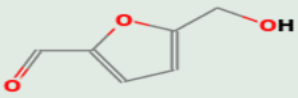
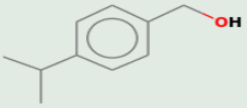
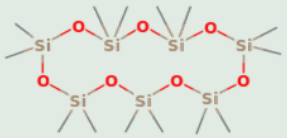
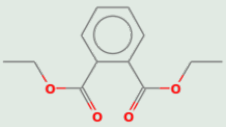
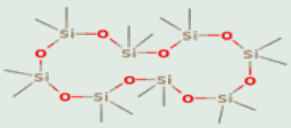
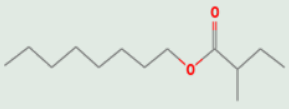
Table 2: GC-MS analysis of methanolic root extract of *Thalictrum foliolosum*.

Sl. No.	RT	Name of the compound	Molecular Formula	Peak Area	% Peak Area	M.W
1	12.753	Hexanoic acid, 2-ethyl-, ethyl ester	$C_{10}H_{20}O_2$	19965432	6.14	172
2	15.347	2(3H)-Furanone, 5-hexyldihydro	$C_{10}H_{18}O_2$	7308814	2.25	170
3	15.596	5-Hydroxymethylfurfural	$C_6H_6O_3$	10166686	3.13	126
4	17.400	2-Pentadecanone, 6,10,14-trimethyl	$C_{18}H_{36}O$	574956	0.18	268
5	17.518	p-Cymen-2-ol	$C_{10}H_{14}O$	1173170	0.36	150
6	20.287	Cyclotetradecane	$C_{14}H_{28}$	2500225	0.77	196
7	20.513	Pentadecane	$C_{15}H_{32}$	1459156	0.45	212
8	22.363	Cycloheptasiloxane, tetradecamethyl	$C_{14}H_{42}O_7Si_7$	461365	0.14	518
9	25.431	Diethyl Phthalate	$C_{12}H_{14}O_4$	72531584	22.32	222
10	26.460	Cyclooctasiloxane, hexadecamethyl	$C_{16}H_{48}O_8Si_8$	1838955	0.57	592
11	26.722	Butanoic acid, 2-methyl-, octyl ester	$C_{13}H_{26}O_2$	5202600	1.60	214
12	27.452	8-Petadecanone	$C_{15}H_{30}O$	686860	0.21	226
13	30.257	1-Hexadecanol	$C_{22}H_{46}O$	2079943	0.64	326
14	33.695	Dibutyl phthalate	$C_{16}H_{22}O_4$	3550302	1.09	278
15	33.857	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	13343628	4.11	256
16	34.504	Behenic alcohol	$C_{22}H_{46}O$	1060139	0.33	326
17	36.436	9,11-Octadecadienoic acid, methyl ester, (E,E)-	$C_{19}H_{34}O_2$	616949	0.19	294
18	37.213	9,12-Octadecadienoic acid (Z,Z)-	$C_{18}H_{32}O_2$	6605835	2.03	280
19	37.325	9,12,15-Octadecatrienoic acid, (Z,Z,Z)	$C_{18}H_{30}O_2$	6613688	2.04	278
20	41.349	9-Octadecenamide, (Z)	$C_{18}H_{35}NO$	5679148	1.75	281
21	43.558	1-Hexacosanol	$C_{26}H_{54}O$	810229	0.25	382
22	48.404	7-Hexadecenal, (Z)	$C_{16}H_{30}O$	2211829	0.68	238
23	52.193	Hydrastine	$C_{21}H_{21}NO_6$	1386918	0.43	383
24	52.298	10-Nonadecanone	$C_{19}H_{38}O$	1766694	0.54	282
25	52.584	Octacosanol	$C_{28}H_{58}O$	72693983	22.37	410
26	54.496	Pentadecanal	$C_{15}H_{30}O$	2157006	0.66	226
27	55.685	Oxirane, hexadecyl	$C_{18}H_{36}O$	4374487	1.35	268
28	55.865	Stigmast-5-en-3-ol, oleate	$C_{47}H_{82}O_2$	12738343	3.92	678

oleate/beta-Sitosterol was observed whose anti-diabetic, antioxidant, anti-inflammatory, and anti-cancerous property was evaluated by Iyer *et al.*, (2012).[40] Zhou *et al.*, (2022)[41] proved that Octacosanol has anti-parkison's disease, Anti-hypoxia, anti-glycation and anti-inflammatory effects. Rouis-Soussi *et al.*, (2014).[42] evaluate anti-microbial and anti-fungal activity of alkane hydrocarbon. Bennett *et al.*, (2019)[43] exhibited that Behenic alcohol Inhibited HSV-1 and HSV-2 viruses. Moreover, many other compounds like 1- Hexacosanol, 7-Hexadecenal, Hydrastine, 10-Nonadecanone, and Oxirane, hexadecyl were detected in our investigation.

The inorganic mineral elements are essentially required by our body for various biological functions.[44] Sodium is the principal cation of extracellular fluid and helps to balance fluids and electrolytes which in turn help to regulate blood pressure. Magnesium regulates the function of more than 3000 enzymes and helps in the formation of DNA, RNA, and ATP. Mg is an essential bivalent cation that regulates the biochemical functioning of various metabolic pathways.[45] Potassium an important cation of intracellular fluid, acts as an anti-cancerous and anti-calcification activity. It helps to improve bone density and also acts as an insulin-sensitizing molecule.[46] Calcium helps in muscle contraction and conduction of nerve impulses. Its active conversion of prothrombin into thrombin. Chromium plays an important in lipid metabolism and activates the action of insulin because the glucose-tolerant factor contains it as an active ingredient.[47-49] Manganese cofactor of many enzymes like

Table 3: Structure of phytochemicals from NIST library and their medicinal potential.

Name of the compound	Structure	Medicinal property of compound
Hexanoic acid, 2-ethyl-, ethyl ester		Anti-fungal.[9]
2(3H)-Furanone, 5-hexyldihydro		Anti-microbial, Preservative, Antioxidant activity.[10]
5-Hydroxymethylfurfural		Antioxidation anti-inflammatory and anti-tumor activities, also produces Nephrotoxicity.[11]
2-Pentadecanone, 6,10,14-trimethyl		Anti-microbiaal, and Anti-bacterial activities.[12]
p-Cymen-2-ol		Anti-bacterial Antioxidant, Anti-cancer, and Anti-fungal activities.[13]
Cyclotetradecane		Anti-bacterial, and Anti-fungal activity.[14]
Pentadecane		Anti-microbial and antioxidant activity.[15]
Cycloheptasiloxane, tetradecamethyl		Anti-fungal activity.[16]
Diethyl Phthalate		Anti-microbial activity.[17]
Cyclooctasiloxane, hexadecamethyl		Anti-funal, Anti-bacterial, Anti-fouling, and Anti-cancer activities, Immunomodulatory.[18]
Butanoic acid, 2-methyl-, octyl ester		Anti-inflammatory, Anxiolytic activity, Antioxidant activity, Anti-depressant, Analgesic and Sedative effect.[19]
8-Pentadecanone		Hepatotoxic, Demyelination, Conjunctivitis.[20]
1-Hexadecanol		Antioxidant, Anti-microbial activity.[21]

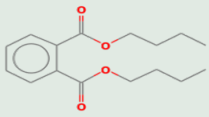
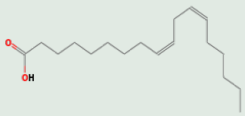
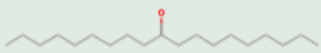
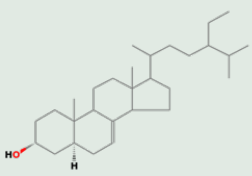
Name of the compound	Structure	Medicinal property of compound
Dibutyl phthalate		Anti-microbial, Anti-cancer activity.[22]
n-Hexadecanoic acid		Anti-fungal, Antioxidant, Anti- inflammatory, Anti-microbial activity Hypocholesterolemic.[23]
Behenic alcohol		Inhibit HSV-1 and HSV-2 viruses.[24]
9,11-Octadecadienoic acid, methyl ester, (E,E)-		Anti-cancerous, Anti-anthergonic activity.[25]
9,12-Octadecadienoic acid (Z, Z)-		Hepatoprotective, Anti-histaminic, Hypocholesterolemic, Anti-eczemic activity.[26]
9,12,15-Octadecatrienoic acid, (Z, Z,Z)		Anti-inflammatory, Hypocholesterolemic, Anti-cancer, Anti-eczemic, Hepatoprotective, Nematicide, Insectifuge, Anti-histaminic, Antiacne, 5-Alpha Reductase inhibitor, Anti-androgenic, Anti-arthritic, Anti-coronary activity.[27]
9-Octadecenamide, (Z)		Hypolipidemic effect, Anti-inflammatory, Analgesic.[28]
1-Hexacosanol		Analgesic effect, Antioxidant, Anti-inflammatory, and Anti-bacterial activity.[29]
7-Hexadecenal, (Z)		Anti-viral activity, organic fertilizer.[30]
Hydrastine		Anti-cancer activity.[31]
10-Nonadecanone		Anti-tumor activity, Anti-microbial activity.[32]
Octacosanol		Antioxidant, Anti-hypoxia, Anti-inflammatory effect, Anti-tumor activity, Anti-glycation, Anti-diabetes, Anti-Parkinson's disease, Protect cardiovascular, Reduce hyperlipidemia.[33]
Pentadecanal		Anti-microbial, Anti-bioflim activity.[34]
Oxirane, hexadecyl		Anti-microbial activity.[35]
Stigmast-5-en-3-ol, oleate		Anti-diabetic activity, Anti-cancer, Antioxidant, Anti-microbial, Sedative, Analgesic effect, Anti-inflammatory activity, Hepatoprotetcive effect, Wound healing effect, and Hypolipidemic effect.[36]

Table 4: FTIR peak assignment of analysed fraction compared with standard chart.

Sl. No.	Peak Frequency cm^{-1}	Reference Frequency Rang cm^{-1}	Functional group	Intensity of functional group	Compound class
1.	3930.54	3700-3584	O-H Stretch	Medium, Sharpe	Alcohol
2.	3551.32	3550-3200	O-H Stretch	Medium, Sharpe	Alcohol
3.	3474.41	3550-3200	O-H Stretch	Strong, Broad	Alcohol
4.	3413.34	3550-3200	O-H Stretch	Strong, Broad	Alcohol
5.	3235.95	3550-3200	O-H Stretch	Strong, Broad	Alcohol
6.	2920.91	3300-2500, 3200-2700, 3000-2800, 3000-2840	O-H Stretch, N-H Stretch, C-H Stretch	Strong, Broad, weak, Broad, Medium, Strong, Broad	Carboxylic acid, Alcohol, Amine salt, Alkane
7.	2852.98	3300-2500, 3200-2700, 3000-2800, 3000-2840	O-H Stretch, N-H Stretch, C-H Stretch	Strong, Broad, weak, Broad, Medium, Strong, Broad	Carboxylic acid, Alcohol, Amine salt, Alkane.
8.	2033.72	2140-1990	N=C =S Stretch	Strong, Broad	Isothiocyanate.
9.	1739.17	1730-1715	C =O Stretch	Strong	α, β Unsaturated ester.
10.	1638.12	1650-1566, 1650-1600, 1650-1580	C=C Stretch, N-H Bending	Medium	Cyclic alkane, Conjugated alkene, amine.
11.	1617.22	1620-1610	C=C Stretch	Strong, Medium	α, β Unsaturated ketones.
12.	1382.34	1390-1380, 1385-1380, 1410-1380, 1420-1330, 1390-1310	C-H Bending, S=O Stretch, O-H bending	Medium, Strong, Medium	Aldehyde, Alkane, Sulphate, Sulfonyl chloride, Alcohol, Phenol.
13.	1320.05	1350-1300, 1342-1266	S=O Stretching, C-N Stretching	Strong, Strong	Sulfone, Aromatic amine
14.	1233.14	1310-1250, 1275-1200, 1250-1020	C-O Stretching, C-N Bending	Strong, Medium	Alkyl aryl ether, Amine, Aromatic ester.
15.	1156.16	1205-1124	C-O Stretching	Strong	Tertiary alcohol.
16.	1071.96	1085-1050	C-O Stretching	Strong	Primary alcohol.
17.	831.78	840-790	C=C Bending	Medium	Alkene.
18.	781.17	750 ± 20	C-H Bending	Strong	Monosubstituted.
19.	621.24	600-500	C-I Stretching	Strong	Halocompound.
20.	478.69	-	--	--	-
21.	409.25	-	--	--	-

Table 5: Inorganic elements present in *Thalictrum foliolosum* detected by ICP-MS.

Sl. No.	Element	Concentration(ppb)	Concentration RSD (%)	Property
1.	Sodium	11,229.067	1.2	Blood pressure regulation, Maintains electrolytes and fluid.
2.	Magnesium	56,320.941	0.6	ATP synthesis, Cofactor for metabolic pathways.
3.	Potassium	450,067.837	1.5	Anti-cancerous, Anti-calcification, Improve bone density and heart health.
4.	Calcium	200,223.819	1.5	An important constituent of bone and teeth, help in muscle contraction, conduction of nerve impulses, convert prothrombin into thrombin.
5.	Chromium	491.231	0.7	Activates insulin action.
6.	Manganese	1,770.517	1.0	Regulates glycoprotein and proteoglycan synthesis.
7.	Iron	22,604.753	1.1	An integral part of haemoglobin, synthesis and packing of neurotransmitter.
8.	Cobalt	16.273	7.1	An integral part of Vitamin B_{12}.
9.	Copper	7,048.321	2.1	Constituent of cytochrome c oxides, Help in iron absorption.
10.	Zinc	4,322.423	1.2	Regulates metabolism of macronutrients.
11.	Selenium	469.153	11.7	Regulates the action of glutathione peroxidase and thioredoxin reductase.
12.	Molybdenum	7.395	5.0	Cofactor for metalloenzymes.

phosphohydrolase, hydrolase, decarboxylase, and transferase. These are enzymes of the urea cycle and pyruvate metabolism. It regulates proteoglycan and glycoprotein synthesis.

Iron is an essential component of haemoglobin, myoglobin, and cytochrome oxidase also helps in the myelination of the spinal cord, and the synthesis and packing of neurotransmitters so it, directly and indirectly, helps in brain functioning. Copper element helps in the incorporation of iron into hemoglobinn. Copper is an essential microelement for the neurologic system as it helps in myelin sheet formation in the nervous system.[50] Cobalt is an integral part of Vitamin B_{12}. Zinc is an important cofactor for various enzymes like carbonic anhydrase, DNA RNA polymerase, alkaline phosphatase, and glutamic dehydrogenase. All these enzymes manifested the cellular pathway of metabolism of macronutrients, protein synthesis, tissue repair, and cell replication.[51] It is also an integral constituent of plasma and insulin. Selenium is the most essential element which defends against free radical oxidative damage to living things by destroying H_2O_2. It shows a synergistic antioxidant effect with Vitamin E. Molybdenum is involved in cellular metabolism and in utilizing iron by activating various metalloenzymes like xanthine and aldehyde oxides.

CONCLUSION

The current study reveals that the methanolic leaves extract of *Thalictrum foliolosum* has different biological active phytoconstituents. This information may help many pharmaceutical companies to manufacture innovative organic drugs for society. The relative concentration of bioactive compounds and mineral elements is reasonable and can be considered for medical purposes.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

GC-MS: Gas Chromatography-Mass Spectrometry; **FTIR:** Fourier Transform Infrared; **ICP-MS:** Inductively Coupled Plasma Mass Spectroscopy; **B. S. I.**: Botanical Survey of India; **RT:** Retention Time; ***T. foliolosum:*** *Thalictrum foliolosum*; **NIST:** National Institute of Standards and Technology; **CSIR:** Council of Scientific and Industrial Research.

SUMMARY

In this research paper, active phytoconstituents of the leaf plant extract of Thalictrum foliolosum is identified through the GC-MS, FT-IR, and ICP-MS analysis, which exhibits different pharmacological properties This information may help many pharmaceutical companies to manufacture innovative organic drugs for society. The relative concentration of bioactive compounds and mineral elements is reasonable and can be considered for medical purposes. Also, it may be proved useful in the field of pharmacy in the preparation of novel herbal drugs.

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