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GCMS-based phytochemical profiling and in vitro pharmacological activities of plant *Alangium salviifolium* (L.f) Wang

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Abstract

Background There is an urge for traditional herbal remedies as an alternative to modern medicine in treating several diseases. A significant number of modern pharmaceutical drugs are based on or derived from medicinal plants or their extracts. These drugs derived from the plant origin have various antimicrobial, antioxidant, anticancer, anti-inflammatory activities. *Alangium salviifolium* belongs to Cornaceae family and is well known for its medicinal properties. The present study was carried out to evaluate the antibacterial, antioxidant effect and possible bioactive components present in the chloroform, acetone, ethanol, methanol and aqueous extract of *Alangium salviifolium* leaves.

Methodology Dried leaves of *Alangium salviifolium* were subjected to serial solvent extraction using increasing polarity of solvents, i.e., chloroform, acetone, methanol, ethanol, and distilled water. Crude extracts were further tested for qualitative analysis of phytochemicals using standard procedure, while GCMS analysis was performed to identify the probable phytocompounds. Antibacterial activity was performed against bacterial pathogens using agar well method, whereas antioxidant activity was performed using in vitro PM, DPPH and FRAP assays.

Results Phytochemical analysis of the extracts revealed the presence of key phytochemical classes. Using gas chromatography-mass spectrometry, several high and low molecular weight chemical compound kinds were discovered. These chemical substances are regarded as having significant biological and pharmacological effects. All crude extracts had considerable and comparable in vitro antioxidant and antibacterial properties.

Conclusions According to the findings of this study, *Alangium salviifolium* leaves are a rich source of phytoconstituents that are crucial in stopping the advancement of numerous disorders.

Keywords TPC, TFC, GC–MS, FTIR, Antioxidant activity, Antibacterial activity, Phytochemical screening

Background

Numerous metabolites that are more useful in the field of medicine are naturally produced by plants. More than 80% of the world's population, according to the World Health Organization (WHO), relies on traditional medicine for their primary healthcare requirements [1]. 21,000 plants are known to be used as medicines worldwide, according to the WHO [2]. As plants are the primary source of medicines in Siddha, Unani, and Ayurveda systems of medicine, India has a rich cultural history of ancient medicines [3]. Many of the chemicals produced by these medicinal plants have been shown to have therapeutic benefits [4]. More research works on

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ethnopharmacognosy were increased due to the result of the emergence of negative effects and microbial resistance to the chemically synthesized medications [5].

Secondary metabolites including tannins, steroids, phenolic compounds, and alkaloids, sometimes known as phytochemicals or phytocompounds, are what give plants their therapeutic potential. Some plant secondary metabolites with medicinal promise include morphine, vincristine, vinblastine, taxol and quinine [6]. Due to fewer side effects as compared to synthetic pharmaceutical chemicals, these phytochemicals have recently gained importance throughout the world and are used in the pharmaceutical industry for the drug development and treatment of major diseases like asthma, arthritis, cancer, and diabetes [7, 8]. These medicines have different antimicrobial, antioxidant, anticancer, and anti-inflammatory effects because they are derived from plants [9]. Antioxidants are substances that slow down or stop oxidative reactions that catalyze free radicals. The presence of phenolic substances such as flavonoids, phenolic acids, tannins, and phenolic diterpenes [10, 11] is primarily responsible for the antioxidant activity of plant products. Plants are protected from oxidative assault by antioxidants like BHT (Butylated Hydroxy-Toluene) and BHA (Butylated Hydroxy-Anisol), which bind oxidative damage to metallic ions, break down peroxides, or destroy free radicals [12]. According to Lobo et al. [13] and the rise in pathogen antimicrobial resistance, infectious diseases account for almost 50% of all deaths [14]. As a need of the hour researchers have created new, efficient antibacterial medications from natural phytochemicals [15, 16] demonstrated the potential of numerous herbs as sources of pharmaceuticals with lower toxicity. By screening a wide range of plant groups, the search for new antibacterial compounds continues. Higher plants are a possible source of novel antibiotic prototypes, according to research on the antibacterial activity of plant extracts and plant products [17, 18]. There is a need for more research into traditional health systems because certain traditional medicines have already developed substances that are effective against bacteria strains that are resistant to antibiotics [19, 20].

Alangium salviifolium, also known as sage leaved alangium or ankola, was chosen for the current study. It is a member of the Cornaceae family, which is indigenous to China, India, Bangladesh, and the Philippines [21]. This family of plants often grows in arid or hotter climates. It is used to treat a variety of illnesses. According to numerous studies [22–25], it is widely used as a treatment for skin conditions, leprosy, asthma, epilepsy, hepatitis, scabies, and as an antidote for snake and dog bites. According to numerous studies [26–28], roots can be used to cure diarrhea, paralysis, piles, and vomiting. Although *Alangium salviifolium* leaves are a storehouse of many nutrients and bioactive chemicals, the systematic analysis of these leaves is still not sufficient in terms of the specific biological activity of their chemical constituents. The potential benefits of *A. salviifolium* for treating different medical issues should be further investigated. Thus, the objective of the current study was to identify the phytochemical components, antioxidant, and antibacterial properties of various solvent extracts of *A. salviifolium* leaves. Additionally, utilizing GC–MS and FTIR analysis, the bioactive elements of the extracts and the functional groups of the compounds were also found.

Methods

Collection of plant material

The plant *Alangium salviifolium* (L.f) Wang's leaves were collected in the month of February 2022 in Ankola, Uttar Kannada District, Karnataka, India. Dr. K. Kotresha, Professor, Department of Botany, Karnatak Science College, Dharwad, Fresh plant leaves were gathered, cleaned under running water, dried in the shade, and then blended to a coarse powder. For future use, the powder was kept in sealed containers.

Solvent extraction

Alangium salviifolium dry leaves were coarsely pulverized, and then, serial solvent extractions were performed using a Soxhlet apparatus. In increasing order of polarity, the following solvents were used for the extraction: chloroform, acetone, methanol, ethanol, and distilled water. Using a Rota-evaporator, the extracts were further concentrated. The airtight containers used to hold the concentrated extracts were chilled until use.

Phytochemical analysis

The presence of various phytochemical components, including alkaloids, tannins, phenols, sterols, terpenoids, glycosides, saponins, flavonoids, and carbohydrates, were screened for in the crude extracts of *Alangium salviifolium* plant leaves using a standard procedure [29].

Total phenol content (TPC) estimation

Utilizing 1.5 ml of the Folin–Ciocalteu (FC) reagent and 7.5% sodium carbonate (Na_2CO_3) solution, the plant extract of known concentration, i.e., 1 mg/1 ml of respective solvent, was subjected to oxidation. The absorbance reading at 750 nm was obtained during an hour of incubation at room temperature. The experiment was performed in triplicate, and results were expressed as mean ± standard deviation. The quantity was determined using the calibration curve for gallic acid. Gallic

acid equivalent (GAE) mg/100 ml of sample was used to express the results [30].

Total flavonoid content (TFC) estimation

The 10% aluminum chloride ($AlCl_3$) and 1 M sodium acetate were combined with the known quantity of plant extract, i.e., 1 mg/1 ml of respective solvent. Following a 45-min incubation in the dark, the absorbance was measured at 415 nm. Using the Quercetin calibration curve, the quantity was determined. Quercetin equivalent (QE) mg/100 ml of sample was used to express the results [31]. The experiment was performed in triplicate, and results were expressed as mean ± standard deviation.

FTIR analysis

Utilizing a Perkin Elmer Spectrophotometer system, an FTIR study of *Alangium salviifolium* was carried out in order to identify the distinctive peaks between 400 and 4000 cm^{-1} and their functional groups. The FTIR's peak values were noted.

GC–MS profiling

The different solvent extracts of *A. salviifolium* were subjected to a GC–MS analysis with instrument model GCMS-QP 2010 Plus, Shimadzu). At an ionization voltage of 70 eV, injector temperature of 250 °C and injector mode was split with linear velocity 36.5 cm/s and pressure was 57.5 kPa. The instrument was run in electron impact mode. Approximately 1 µL of the sample was injected into mobile phase consisting of helium (99.9% purity) at a flow rate of 1 mL/min. The oven's temperature was first set to 60 °C for 2 min of isothermal operation before being raised to 100 °C at a rate of 10 °C per minute and then to 280 °C at a rate of 5 °C per minute for 9 min. The GC ran for 34 min in total. Comparing each component's average peak area to the total areas allowed us to determine the proportional percentage amount of each component. With the help of The National Institute of Standard and Technology-5 (NIST-5), a comparison was made between the spectra of the unknown component and the spectrum of the known components including the compound's name, chemical formula, molecular weight, and structure, which were identified.

In vitro antioxidant activity of *A. salviifolium's* leaves

Phosphomolybdenum assay

Using a standardized process, the phosphomolybdenum method was used to assess the antioxidant activity of the plant extracts [32] and ascorbic acid was used as reference standard. *Alangium salviifolium* extracts of concentration 1 mg/ml were added to each test tube separately along with 3 ml of distilled water and 1 ml of the phosphomolybdate (PM) reagent in varying concentrations ranging from 100 to 500µL. For 90 min, the tubes were incubated in a water bath at 95 °C. Following incubation, these tubes were cooled to room temperature, and the reaction mixture's absorbance was assessed at 695 nm.

2, 2 Diphenyl-2-picryl hydrazyl (DPPH) radical scavenging assay

A. salviifolium plant extracts were subjected to the Rice-Evans et al. [33] method for the DPPH radical scavenging assay. The known concentration of test samples (100 µg) was combined in various concentrations with 100 µl of a DPPH solution made in methanol (40 mM). The combination was incubated for 30 min at room temperature and in the dark to produce the desired color, which was measured at 517 nm along with ascorbic acid as a standard.

Each sample's DPPH scavenging activity was estimated using the formula below:

$$\text{Scavenging activity}(\%) \text{ of DPPH} = 100 \times \text{Ac} - \text{At}/\text{Ac}$$

where At is the absorbance of the test sample and Ac is the absorbance of the control reaction (100 µL of methanol plus 100 µL of DPPH solution).

Ferric ion reducing power (FRAP) assay

With a few minor modifications, the Oyaizu [34] method was used to assess the reducing power of ferric ions. The extracts of *A. salviifolium* (1 mg/ml) were pipetted into mixtures containing 2.5 ml of 0.2 M phosphate buffer, 2.5 ml (1% w/v) potassium ferricyanide, and various concentrations ranging from 100 to 500 µL. The mixture was then incubated at 50 °C for 20 min. After cooling the mixture, 2.5 ml of 10% w/v trichloroacetic acid and 0.5 ml of 0.1% w/v ferric chloride were added, and the combination was left at room temperature for 10 min to form a complex that was green in color. The absorbance was calculated using a spectrophotometer at 700 nm. The reference standard used was ascorbic acid.

Antibacterial activity

The antibacterial activity was screened using the agar well diffusion method [35] using *Pseudomonas aeruginosa* and *Staphylococcus aureus* cultures as the test organisms. 100µL of the uniformly diluted saline suspension were swabbed over the sterile agar plates. Along with the control drug Ciprofloxacin (30 µg), various concentrations of the extract (1 mg/ml) (30, 60, 90, and 120 µL/well) were added to the medium. The plates were incubated for 24 h at 37 °C. The diameter of the inhibition zones that formed around the wells after the incubation time was measured in millimeters.

Table 1 Preliminary phytochemical analysis of the leaves extract of *Alangium salviifolium*

Tests	Inference				
	Chloroform	Acetone	Ethanol	Methanol	Aqueous
1. Alkaloids	+	+	+	+	+
2. Flavonoids	+	+	+	+	+
3. Glycosides	−	−	+	−	+
4. Phenols	+	+	+	+	+
5. Lignin	+	+	+	−	+
6. Sterols	−	−	−	−	−
7. Saponins	−	−	−	−	+
8. Tannins	−	−	+	+	+
9.Terpenoids	−	−	−	−	−
10.Reducing sugar	+	−	+	−	−
11. Carbohydrate	+	−	+	+	+
12. Proteins and amino acids	−	−	−	−	−

'+' indicates Present; '−' indicates Absent

Statistical analysis

The experiments were performed in the triplicate, and the results were expressed as mean ± standard deviation using IBM SPSS Statistics 20.0.

Results

Plant chemical analysis

The qualitative phytochemical analysis of five different solvent extracts of *Alangium salviifolium* revealed the presence of flavonoids, reducing sugar, and carbohydrates in chloroform, acetone, methanol, ethanol, and distilled water; in addition, glycosides, saponins, and tannins were present in aqueous extract. All five extracts contained alkaloids and phenols. The other four extracts, with the exception of methanol, all included lignin The results of phytochemical analysis was shown in Table 1.

Total crude extraction

The phytochemical examination of *A. salviifolium* leaves revealed a significant amount of the plant secondary metabolites. Using the solvents chloroform, acetone, ethanol, methanol, and distilled water, the total yield of crude extracts from *A. salviifolium* leaves was determined to be 1.8%, 2.1%, 3.8%, 2.4%, and 2.8% (w/w), respectively.

Total phenol and flavonoid content

In terms of phenolic content, ethanol extract had the highest level (82.86 ± 0.04) mg/g GAE, followed by methanol extract (59.13 ± 0.02) mg/g GAE, acetone extract (47.61 ± 0.01) mg/g GAE, chloroform extract (12.51 ± 0.02) mg/g GAE, and aqueous extract (7.92 ± 0.02) mg/g GAE. In case of flavonoid content of all the extracts, chloroform extract had the highest amount of flavonoid content (71.86 ± 0.03) mg/g QE, followed by methanol extract (33.33 ± 0.05) mg/g QE, acetone extract (30.07 ± 0.04) mg/g QE, ethanol extract (16.3 ± 0.02) mg/g QE, and aqueous extract (5.04 ± 0.04) mg/g QE. Total phenolic and total flavonoid concentration in each extract showed a wide range of variance (Table 2).

Table 2 Total phenol and total flavonoid content from *A. salviifolium* (leaf extract)

Extract	Total phenolic content (mg)	Total flavonoid content (mg)
Chloroform	12.51 ± 0.029	71.86 ± 0.037
Acetone	47.61 ± 0.018	30.07 ± 0.046
Ethanol	82.86 ± 0.049	16.3 ± 0.012
Methanol	59.13 ± 0.021	33.33 ± 0.051
Aqueous	7.92 ± 0.020	5.04 ± 0.004

The results are expressed as Mean ± standard deviation

Fourier transform infrared spectroscopy analysis

The FTIR spectra of the all extracts revealed the presence of halogen and nitrogen compounds in common. The chloroform, acetone, and ethanol extracts revealed the presence of alkane and alcohol functional groups; the chloroform, acetone, methanol, and ethanol extracts revealed carbon dioxide and alkene groups; the chloroform extracts revealed the presence of aldehyde and ketone groups; the chloroform, methanol, and acetone extracts revealed amine groups; the acetone and ethanol extracts revealed esters groups; acetone, ethanol,

methanol, aqueous extract showed sulfoxide group; carboxylic acid group was found in methanol and aqueous extracts; vinyl ether was found in methanol and aqueous extract revealed sulfonyl chloride groups. The results of FTIR are shown in Tables 3, 4, 5, 6, and 7 (Additional file 1: Figs. S1–S6).

Table 3 FTIR Interpretation of compounds of leaf chloroform extract of *A. salviifolium*

Sl. no.	Frequency	Functional group	Bond strength	Nature of bond
1	2916.92	Alkane	C–H Stretching	Covalent bond
2	2849.04	Alkane	C–H Stretching	Covalent bond
3	2360.24	Carbon-di-oxide	O=C=O stretching	Covalent bond
4	1735.51	Aldehyde	C=O stretching	Neutral
5	1667.49	Conjugated ketone	C=O stretching	Neutral
6	1545.36	Nitro compound	N–O stretching	Covalent bond
7	1510.94	Nitro compound	N–O stretching	Covalent bond
8	1451.37	Alkane (methyl group)	C–H bending	Covalent bond
9	1375.46	Alcohol	O–H bending	Covalent bond
10	1157.46	Amine	C–N stretching	Basic
11	1121.29	Amine	C–N stretching	Basic
12	1036.56	Amine	C–N stretching	Basic
13	916.96	Alkene	C=C bending	Nonpolar
14	838.03	Halo compound	C–Cl stretching	Polar
15	796.52	Alkene	C=C bending	Nonpolar
16	731.49	Alkene	C=C bending	Nonpolar
17	669.30	Alkene	C=C bending	Nonpolar
18	595.74	Halo compound	C–Br stretching	Polar covalent bond
19	565.05	Halo compound	C–I stretching	Nonpolar
20	522.19	Halo compound	C–I stretching	Nonpolar

Table 4 FTIR Interpretation of compounds of leaf acetone extract of *A. salviifolium*

Sl. no.	Frequency	Functional group	Bond strength	Nature of bond
1	3348.98	Aliphatic 1°–amine	N–H stretching	Nonpolar
2	2921.48	Alkane	C–H stretching	Nonpolar
3	2851.67	Alkane	C–H stretching	Nonpolar
4	2358.39	Carbon dioxide	O=C=O stretching	Covalent bond
5	2338.99	Carbon dioxide	O=C=O stretching	Covalent bond
6	1735.95	Esters (δ-lactone)	C=O stretching	Polar covalent bond
7	1554.43	Nitro compound	N–O stretching	Covalent bond
8	1510.98	Nitro compound	N–O stretching	Covalent bond
9	1457.26	Alkane	C–H bending	Covalent bond
10	1376.13	Alcohol	O–H bending	Covalent bond
11	1163.83	Ester	C–O stretching	Polar covalent bond
12	1033.49	Sulfoxide	S=O stretching	Covalent bond
13	885.42	Alkene	C=C bending	Nonpolar
14	834.26	Alkene	C=C bending	Nonpolar
15	720.53	Alkene	C=C bending	Nonpolar
16	667.77	Alkene	C=C bending	Nonpolar
17	607.39	Halo compound	C–I stretching	Nonpolar
18	579.89	Halo compound	C–Cl stretching	Polar
19	521.74	Halo compound	C–I stretching	Nonpolar
20	504.55	Halo compound	C–I stretching	Nonpolar

Table 5 FTIR interpretation of compounds of leaf methanol extract of *A. salviifolium*

Sl. no.	Frequency	Functional group	Bond strength	Nature of bond
1	3262.95	Alkyne	C–H stretching	Nonpolar
2	2924.46	Amine salt	N–H stretching	Nonpolar
3	2360.71	Carbon dioxide	O=C=O stretching	Covalent bond
4	1603.96	Conjugated alkene	C=C stretching	Nonpolar
5	1511.84	Nitro compound	N–O stretching	Covalent bond
6	1432.41	Carboxylic acid	O–H bending	Covalent bond
7	1215.22	Vinyl ether	C–O stretching	Polar covalent bond
8	1034.24	Sulfoxide	S=O stretching	Covalent bond
9	871.67	1,2,4-Trisubstituted	C–H bending	Nonpolar covalent bond
10	842.51	Halo compound	C–Cl stretching	Polar
11	803.25	Alkene	C=C bending	Nonpolar
12	645.09	Alkene	C=C bending	Nonpolar
13	588.99	Halo compound	C–Br stretching	Polar covalent bond
14	562.54	Halo compound	C–Br stretching	Polar covalent bond
15	546.82	Halo compound	C–Br stretching	Polar covalent bond
16	520.47	Halo compound	C–Br stretching	Polar covalent bond
17	491.11	Halo compound	C–I stretching	Nonpolar

Table 6 FTIR Interpretation of compounds of leaf ethanol extract of *A. salviifolium*

Sl. no.	Frequency	Functional group	Bond strength	Nature of bond
1	3261.48	Alcohol	O–H stretching	Covalent bond
2	2921.73	Alkane	C–H stretching	Nonpolar covalent bond
3	2851.76	Alkane	C–H stretching	Nonpolar covalent bond
4	2363.57	Carbon di oxide	O=C=O stretching	Covalent bond
5	1650.10	*δ*-Lactam	C=O stretching	Polar
6	1604.99	Conjugated alkene	C=C stretching	Nonpolar
7	1512.11	Nitro compound	N–O stretching	Covalent bond
8	1455.11	Alkane	C–H bending	Nonpolar covalent bond
9	1194.75	Ester	C–O stretching	Polar covalent bond
10	1034.20	Sulfoxide	S=O stretching	Covalent bond
11	889.42	Alkene	C=C bending	Nonpolar
12	667.43	Alkene	C=C bending	Nonpolar
13	596.40	Halo compound	C–I stretching	Nonpolar
14	565.05	Halo compound	C–I stretching	Nonpolar
15	546.93	Halo compound	C–Br stretching	Polar covalent bond
16	516.77	Halo compound	C–Br stretching	Polar covalent bond
17	503.04	Halo compound	C–I stretching	Nonpolar

GC–MS analysis

The compounds from the GC–MS analysis of the chloroform, acetone, methanol, ethanol, and aqueous extracts of *A. salviifolium* leaves are shown in Tables 8, 9, 10, 11, and 12. In case of the chloroform extract, the compound Androst-5-ene-3, 17-diol, 17-methyl-, dipropan was found to be major compound, in case of acetone extract the compound Phytol was found to be major compound, for methanol extract the compound ethyl (dimethyl) isopropoxysilane seems to be major compound, in case of ethanol extract diethyl phthalate was found to be major compound, and for aqueous extract benzofuran, 2, 3-dihydro compound was found to be major compound. Overall, the GC–MS results of chloroform, acetone, ethanol, methanol, and aqueous extract showed the presence of 24, 53, 23, 31, and 6 compounds, respectively, and the results are shown in Tables 8, 9, 10, 11, and 12. Additional file 1: Figs.

Table 7 FTIR Interpretation of compounds of leaf aqueous extract of *A. salviifolium*

Sl. no.	Frequency	Functional group	Bond strength	Nature of bond
1	3281.10	Carboxylic acid	O–H stretching	Covalent bond
2	1556.67	Nitro compound	N–O stretching	Covalent bond
3	1405.05	Sulfonyl chloride	S=O stretching	Covalent bond
4	1039.62	Sulfoxide	S=O stretching	Covalent bond
5	550.72	Halo compound	C–Cl stretching	Polar
6	511.71	Halo compound	C–I stretching	Nonpolar

S7–S11 show the GCMS chromatogram for all the extracts.

A. salviifolium's antioxidant activity in vitro

Phosphomolybdenum (PM) assay

On comparison between the all extracts, i.e., for acetone, chloroform, ethanol, methanol, and aqueous extracts in the phosphomolybdenum (PM) assay, aqueous extract has shown the highest activity with higher absorbance, i.e., 0.991 ± 0.004 for 500 µg concentration, whereas standard ascorbic acid has shown 1.078 ± 0.003. The results of all test samples are shown in Table 13 and Additional file 1: Fig. S12.

Radical scavenging assay using 2, 2 diphenyl-2-picryl hydrazyl (DPPH)

In case of DPPH assay among the selected chloroform, acetone, ethanol, methanol, and aqueous extracts, aqueous extract has exhibited prominent activity with a higher percentage of inhibition, i.e., 84.892% and standard ascorbic acid shown around 86.271%. The study found that when aqueous extract was compared to regular ascorbic acid, it had the comparable antioxidant activity than the remaining extracts (Table 14).

Ferric ion reducing power (FRAP) assay

Using standard ascorbic acid, the ferric ion reducing power (FRAP) assay was carried out on extracts of acetone, chloroform, ethanol, methanol, and distilled water. According to the study's findings (Table 15, Additional file 1: Fig. S13), aqueous extract had the highest antioxidant activity with higher absorbance OD value when compared to the other four extracts.

Antibacterial activity of *Alangium salviifolium* leaves extract

Aqueous extract from the leaves of *A. salviifolium* had the greatest zone of inhibition against *Pseudomonas aeruginosa* and *Staphylococcus aureus* of all the leaf extracts tested for antibacterial activity. With a maximum inhibitory zone of 10 mm, leaf aqueous extract was found to be more effective to *Pseudomonas aeruginosa* than ethanol, acetone, and chloroform (5 mm) or methanol extract (3 mm). With a maximum inhibitory zone of 11 mm, *Staphylococcus aureus* was found to be more sensitive to the aqueous extract than to acetone, chloroform, ethanol, or methanol. Table 16 and Additional file 1: Figs. S14 and S15 display the measured zone of inhibition for leaf extracts produced from various solvents.

Discussion

Numerous chemicals found in plants that are known to be biologically active and to have a variety of pharmacological effects [36, 37]. These plant secondary metabolites include several important natural antioxidant sources that are safer and more efficient than synthetic antioxidants [38]. The most prevalent phenolic molecules that act as natural antioxidants in plants include ascorbic acid, carotenoids, and flavonoids [39].

The phytochemicals found in the plant *A. salviifolium* were extracted in the current study utilizing a variety of increasing polarity solvents, including chloroform, acetone, ethanol, methanol, and distilled water. Different phytochemical tests were used to identify the phytochemicals, which included the presence of reducing sugar, alkaloids, flavonoids, phenols, lignin, glycosides, and tannins. Plants use alkaloids, the majority of which have a severe bitter taste and are very toxic, to protect themselves from herbivory, pathogenic microbial attack, and invertebrate pests. Numerous studies on phenolic compounds have demonstrated the significance of these compounds in demonstrating biologically active properties like anti-inflammatory, antidiabetic, antioxidant, antibacterial, anticancer, etc. [38]. Because of this, the total phenolic and total flavonoid contents of various extracts of *A. salviifolium* leaves were determined, as well as their antioxidant potential by in vitro phosphomolybdenum, DPPH, and ferric ion reducing power (FRAP) assay methods. In the current investigation, chloroform extract (71.86 mg/g QE) and ethanol extract (82.86 mg/g GAE) were shown to have the greatest concentrations of total flavonoid and phenol, respectively. It can be expected that the biological activity of the leaves of *A.*

Table 8 Compound identified in the chloroform extract of *A. salviifolium* using GCMS

Sl. no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area	Compound nature	Uses
1	3-Dodecene, (E)-	$C_{12}H_{24}$	168.32	7.615	0.85		
2	3-Hexadecene, (Z)-	$C_{16}H_{32}$	224.42	10.323	2.46	Unsaturated hydrocarbons	
3	Phenol, 3,5-bis(1,1-dimethylethyl)-	$C_{14}H_{22}O$	206.32	11.945	8.77		
4	3-Hexadecene, (Z)-	$C_{16}H_{32}$	224.42	12.797	4.31	Unsaturated hydrocarbons	
5	2-Propenoic acid, octyl ester	$C_{11}H_{20}O_2$	184.27	13.992	0.72		
6	9-Eicosene, (E)-	$C_{20}H_{40}$	280.5	15.031	7.40	Alkene	Hypotensive effect, antimicrobial property
7	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	$C_{20}H_{40}O$	296.5	15.534	7.13	Terpene alcohol	Catechol-O-Methyl-Transfearse inhibitor, antimicrobial, anti-inflammatory
8	9-Eicosene, (E)-	$C_{20}H_{40}$	280.5	17.058	8.09	Alkene	Hypotensive effect, antimicrobial property
9	Phytol	$C_{20}H_{40}O$	296.5	18.259	6.29	Diterpene	Antimicrobial, Anti-inflammatory, antiallergic, Anticancer, Diuretic, anti-diabetic, Cytotoxicity, antiproliferative, cancer preventive
10	9-Tricosene, (Z)-	$C_{23}H_{46}$	322.6	18.907	9.13		
11	Pentane-2,4-dione, 3-(5-phenyl-2-furfurylidene	$C_{16}H_{14}O_3$	254.28	19.914	2.31		
12	1H-Cyclopenta[b]indol-3(2H)-one, 7-cyclohex	$C_{11}H_9NO$	171.19	20.014	3.83		
13	9-Tricosene, (Z)-	$C_{23}H_{46}$	322.6	20.606	6.69		
14	Dichloroacetic acid, heptadecyl ester	$C_{19}H_{36}Cl_2O_2$	367.4	23.631	2.37		
15	9-Tricosene, (Z)-	$C_{23}H_{46}$	322.6	25.093	1.56		
16	2-Methyl-Z-4-tetradecene	$C_{15}H_{30}$	210.40	25.973	1.75		Catechol-O-methyltransferase inhibitor
17	Vitamin E acetate	$C_{31}H_{52}O_3$	472.7	26.667	0.95	Ester of acetic acid and α-tocopherol	Antioxidants, stabilize membranes, affect eicosanoid signaling and cellular proliferation, and modulate immune responses
18	10,12-Octadecadienoic acid, 9-oxo-$$ (10E,12			27.421	0.87		
19	L-Ascorbic acid, 6-octadecanoate $$ L-Ascorbi	$C_{24}H_{42}O_7$	442.6	28.106	1.54		
20	Stigmasterol	$C_{29}H_{48}O$	412.7	28.403	14.10	Steroid	Anti-infammatory, antioxidant, antimicrobial, sedative activity, Anticancer, Diuretic, hypoglycemic and thyroid inhibiter, antiarthritic, antiasthama
21	Pregnan-20-one, 3-(acetyloxy)-17-hydroxy-, (3	$C_{23}H_{36}O_4$	376.5	29.247	1.62		
22	3-Cyclohexen-2-on-1-carboxylic acid, 1-methy	$C_8H_{12}O_2$	140.18	29.741	1.04	Esters	

Table 8 (continued)

Sl. no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area	Compound nature	Uses
23	Acetamide, 2-(3-methyl-2-oxo-2,3-dihydrobenz			31.819	0.87		
24	Androst-5-ene-3,17-diol, 17-methyl-, dipropan	$C_{19}H_{30}O_2$	290.4	33.859	5.34		

Table 9 Compound identified in the acetone extract of *A. salviifolium* using GCMS

Sl. no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area	Compound nature	Uses
1	2-Pentanone, 4-hydroxy-4-methyl-	$C_6H_{12}O_2$ or $(CH_3)_2C(OH)CH_2COCH_3$	116.16	3.145	6.81	Alcohol	Antifreeze and brake fluids
2	(3H) Indazole, 3,3-dimethyl-	$C_9H_{10}N_2$	146.19	4.835	1.22	Aromatic	
3	Oxetane, 2,2,4-trimethyl-	$C_6H_{12}O$	100.16	7.835	0.68		
4	3-Dimethylsilyloxytridecane	$C_{15}H_{33}OSi$	257.51	8.619	0.36		
5	9-Octadecene, (E)-	$C_{18}H_{36}$	252.5	12.797	4.28	Unsaturated fatty acid	
6	Benzene, (1-butylheptyl)-	$C_{16}H_{26}$	218.38	13.372	0.88	Aromatic	
7	Benzene, (1-propyloctyl)-	$C_{17}H_{28}$	232.4	13.501	0.47	Aromatic	
8	Cyclohexane, decyl-	$C_{16}H_{32}$	224.42	13.607	0.32		
9	Benzene, (1-ethylnonyl)-	$C_{17}H_{28}$	232.4	13.749	0.51		
10	Benzene, (1-methyldecyl)-	$C_{17}H_{28}$	232.4	14.167	0.70		
11	Benzene, (1-pentylheptyl)-	$C_{18}H_{30}$	246.4	14.430	0.36		
12	Benzene, (1-butyloctyl)-	$C_{18}H_{30}$	246.4	14.481	0.41		
13	Benzene, (1-propylnonyl)-	$C_{18}H_{30}$	246.4	14.620	0.54		
14	Benzeneacetic acid, 4-pentadecyl ester	$C_{23}H_{38}O_2$	346.54	14.874	1.50		
15	9-Eicosene, (E)-	$C_{20}H_{40}$	280.5	15.032	9.31	Alkene	Hypotensive effect, antimicrobial property
16	Benzene, (1-methylundecyl)-	$C_{18}H_{30}$	246.4	15.284	0.81		
17	Benzene, (1-pentyloctyl)-	$C_{19}H_{32}$	260.5	15.478	0.33		
18	9-Eicosyne	$C_{20}H_{38}$	278.5	15.540	1.46	Unsaturated hydrocarbon	
19	1,19-Eicosadiene	$C_{20}H_{38}$	278.5	15.793	0.36	Unsaturated hydrocarbon	
20	9-Heptadecanone	$C_{17}H_{34}O$	254.5	15.933	3.18		
21	Benzene, (1-methyldodecyl)-	$C_{19}H_{32}$	260.5	16.345	0.37		
22	1,2-Benzenedicarboxylic acid, butyl octyl ester	$C_{20}H_{30}O_4$	334.4	16.448	0.34	Dicarboxylic acid ester	Antimicrobial, antifouling
23	Heptadecanoic acid, heptadecyl ester	$C_{34}H_{68}O_2$	508.9	16.818	1.02	Fatty acid	Acidifier, acidulant, arachidonic acid inhibitor, inhibit production of uric acid
24	Phthalic acid, bis(7-methyloctyl) ester	$C_{26}H_{42}O_4$	418.6	16.929	1.02	Plasticizer compound	Antimicrobial antifouling
25	1-Nonadecene	$C_{19}H_{38}$	266.5	17.060	8.22	Unsaturated fatty acid	Antituberculosis, anticancer, antioxidant, antimicrobial, antifungal
26	n-Pentadecylcyclohexane	$C_{22}H_{42}$	294.6	17.884	1.12		Antitumor, neurodepressant, neurogenic
27	Phytol	$C_{20}H_{40}O$	296.5	18.261	21.70	Diterpene	Antimicrobial, anti-inflammatory, antiallergic, anticancer, Diuretic, antidiabetic, cytotoxicity, antiproliferative, cancer preventive
28	Tetracontane, 3,5,24-trimethyl-	$C_{43}H_{88}$	605.2	18.466	0.27		
29	Octadecane, 1-(ethenyloxy)-	$C_{20}H_{40}O$	296.5	18.675	0.41	Alkane	

Table 9 (continued)

Sl. no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area	Compound nature	Uses
30	1-Nonadecene	$C_{19}H_{38}$	266.5	18.910	5.50	Unsaturated fatty acid	Antituberculosis, anticancer, antioxidant, antimicrobial, antifungal
31	1,19-Eicosadiene	$C_{20}H_{38}$	278.5	19.703	1.19	Unsaturated hydrocarbon	
32	Tetrapentacontane, 1,54-dibromo-	$C_{54}H_{108}Br_2$	917.2	19.894	1.23	Hydrocarbon	
33	1-Pentacontanol	$C_{50}H_{102}O$	719.3	20.106	0.49		
34	1-Decanol, 2-hexyl-	$C_{16}H_{34}O$	242.44	20.396	1.03		Antimicrobial
35	1-Tricosene	$C_{23}H_{46}$	322.6	20.611	3.04	Alkene	Anticancer, anti-inflammatory
36	Tetrapentacontane, 1,54-dibromo-	$C_{54}H_{108}Br_2$	917.2	21.494	2.15	Hydrocarbon	
37	1-Octanol, 2-butyl-	$C_{12}H_{26}O$	186.33	21.695	0.29	Alcohol	Antimicrobial
38	Di-n-octyl phthalate	$C_{24}H_{38}O_4$	390.6	21.967	1.91	Plasticizer compound	Antimicrobial antifouling
39	Cyclooctacosane	$C_{28}H_{56}$	392.7	22.183	1.28	Saturated fatty acid	
40	Cyclononasiloxane, octadecamethyl-	$C_{18}H_{54}O_9Si_9$	667.4	22.840	0.32		Antimicrobial
41	17-Pentatriacontene	$C_{35}H_{70}$	490.9	22.979	2.41		Anti-inflammatory, anticancer, antibacterial, antiarthritic
42	Tetrapentacontane, 1,54-dibromo-	$C_{54}H_{108}Br_2$	917.2	23.178	0.38	Hydrocarbon	
43	Octadecane, 1,1′-[1,3-propanediylbis(oxy)] bis-	$C_{39}H_{80}O_2$	581.1	23.462	0.30		
44	Tetrapentacontane, 1,54-dibromo-	$C_{54}H_{108}Br_2$	917.2	23.648	0.40	Hydrocarbon	
45	2,6,10,14,18-Pentamethyl-2,6,10,14,18-eicosap	$C_{25}H_{52}$	352.7	23.975	0.60		
46	Trimethyl[4-(2-methyl-4-oxo-2-pentyl) phenoxy	$C_{15}H_{24}O_2Si$	264.43	24.234	0.27		
47	Tetrapentacontane, 1,54-dibromo-	$C_{54}H_{108}Br_2$	917.2	24.370	0.66	Hydrocarbon	
48	Dodecane, 1,12-dibromo-	$C_{12}H_{24}Br_2$	328.13	24.911	0.47		
49	1-Heptene, 1,3-diphenyl-1-(trimethylsilyloxy)-	$C_{22}H_{30}OSi$	338.6	25.131	0.39		
50	Pentatriacontane	$C_{35}H_{72}$	492.9	25.981	1.23		
51	Silicic acid, diethyl bis(trimethylsilyl) ester	$C_{10}H_{28}O_4Si_3$	296.58	26.695	0.51	Aliphatic esters	
52	Sulfurous acid, butyl undecyl ester	$C_{15}H_{32}O_3S$	292.5	28.115	0.99		
53	Stigmasterol	$C_{29}H_{48}O$	412.7	28.430	4.01	Steroid	Anti-infammatory, antioxidant, antimicrobial, sedative activity, anticancer, Diuretic, hypoglycemic and thyroid inhibiter, antiarthritic, antiasthama

Table 10 Compound identified in the methanol extract of *A. salviifolium* using GCMS

Sl.no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area	Compound nature	Uses
1	4-Propyl [1,3] oxathiane 3-oxide	$C_7H_{14}O_2S$	162.25	5.951	1.52		
2	Undecane	$C_{11}H_{24}$	156.31	6.297	1.24	Alkane	Lubricants and lubricant additives
3	Ethyl(dimethyl)isopropoxysilane	$C_7H_{18}OSi$	146.30	8.419	20.92		
4	2-Methoxy-4-vinylphenol	$C_9H_{10}O_2$	150.17	9.526	6.52	Phenolic	Antimicrobial, antioxidant, anti-inflammatory, analgesic, anti-germination
5	1-(3,6,6-Trimethyl-1,6,7,7a-tetrahydrocyclopen	$C_{13}H_{18}O_2$	206.28	10.575	1.26		
6	Alpha-L-rhamnopyranose	$C_6H_{12}O_5$	164.16	10.922	1.32		Antidote, antitumor, larvicide, antioxidant, anticancer
7	1,6-Anhydro-beta-D-glucopyranose (levoglucosan)	$C_6H_{10}O_5$	162.14	11.880	3.53	Carbohydrate	
8	7-Oxabicyclo[4.1.0] heptane, 1-methyl-4-(2-methyloxiranyl)-	$C_{10}H_{16}O_2$	168.23	13.115	1.87		
9	1-Hexadecanol	$C_{16}H_{34}O$	242.44	13.811	2.05	Alcohol	Antioxidant
10	5-Eicosene, (E)-	$C_{20}H_{40}$	280.5	15.021	1.56	Fatty acid	Antimicrobial and antifungal
11	7-Oxabicyclo[4.1.0] heptane, 1-methyl-4-(2-methyloxiranyl)-	$C_{10}H_{16}O_2$	168.23	15.162	2.90		
12	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	$C_{20}H_{40}O$	296.5	15.524	2.44	Terpene alcohol	Catechol-O-Methyl-Transfearse inhibitor, antimicrobial, anti-inflammatory
13	2-Pentadecanone, 6,10,14-trimethyl-	$C_{18}H_{36}O$	268.5	15.614	1.31		Hypocholesterolemic, antioxidant, and lubrication
14	Pentadecanoic acid, 14-methyl-, methyl ester	$C_{17}H_{34}O_2$	270.5	16.417	2.35	Fatty acid	biomarker for rheumatoid arthritis, antioxidant, antifungal, antimicrobial
15	alpha-D-Galactopyranose, 6-O-(trimethylsilyl)	$C_{17}H_{34}B_2O_6Si$	384.2	16.555	4.89		Antidote, anticancer
16	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	256.42	16.791	5.15	Carboxylic acid	Antioxidant, hypocholesterolemic nematicide, pesticide, lubricant, antibiotic, antiandrogenic, flavor, hemolytic, 5-alphareductase inhibitor, cosmetics
17	3-Imino-6-phenylimino-cyclohexa-1,4-diene	$C_{12}H_{10}N_2$	182.22	17.537	4.45		
18	Oxiraneundecanoic acid, 3-pentyl-, methyl ester	$C_{19}H_{36}O_3$	312.5	18.117	1.92	Ester	
19	Phytol	$C_{20}H_{40}O$	296.5	18.248	4.32	Diterpene	Antimicrobial, anti-inflammatory, anticancer, diuretic, cytotoxicity, antiproliferative, cancer preventive, diuretic

Table 10 (continued)

Sl.no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area	Compound nature	Uses
20	Z-7-Tetradecenal	$C_{14}H_{26}O$	210.36	18.507	1.30		Anti-inflammatory
21	Octadecanoic acid	$C_{18}H_{36}O_2$	284.5	18.677	1.45	Saturated fatty acid	Antifungal, antitumor activity, antibacterial, lubricants, inhibit production of uric acid
22	10-Formamido-10,11-dihydro-2,3-dimethoxydi			19.919	1.37		
23	1H-Cyclopenta[b]indol-3(2H)-one, 7-cyclohex			20.012	8.26		
24	Cyclohexane, decyl-	$C_{16}H_{32}$	224.42	20.978	1.13		
25	Hexanoic acid, 2-ethyl-, hexadecyl ester	$C_{24}H_{48}O_2$	368.6	21.277	1.58		
26	Dinonanoin monocaprylin	$C_{29}H_{54}O_6$	498.7	23.842	3.41		
27	Methyltris(trimethylsiloxy) silane	$C_{10}H_{30}O_3Si_4$	310.68	24.916	1.24	Organosilicon compound	
28	Trimethyl[4-(2-methyl-4-oxo-2-pentyl)phenoxy	$C_{15}H_{24}O_2Si$	264.43	25.961	1.12	Organosilane	Antioxidant, antibacteria1, anti-inflammatory
29	1,2-Bis(trimethylsilyl) benzene	$C_{12}H_{22}Si_2$	222.47	26.786	1.75	Aromatic hydrcarbon	
30	Trimethyl[4-(1,1,3,3,-tetramethylbutyl)phenoxy	$C_{17}H_{30}OSi$	278.5	27.258	1.07		
31	Ergosta-7,22-dien-3-ol, (3.beta.,22E)- $$ Ergos			28.420	4.82		

salviifolium may be caused by the presence of flavonoids and phenolic compounds in it based on the measurement of the total phenol and flavonoid content in them.

Based on the peak value ratio, the functional groups of the plant extracts are identified using the FTIR spectrum. Aldehyde, ketones, phenol, alkanes, alkenes, alcohol, aromatic, aliphatic amines, and amine compounds, as well as nitrogen and halogen compounds, were all confirmed to be present by FTIR analysis. For the examination of non-polar components and volatile essential oils, fatty acids, and lipids in the majority of medicinal plants, gas chromatography and mass spectroscopy (GCMS) investigations have become more and more helpful [40]. The existence of diverse bioactive components in all of the *A. salviifolium* extracts was confirmed by GC–MS analysis of the various solvent extracts used in the current study. Stigmasterol, (E)-9-Eicosene, 3, 7, 11, and 15-Tetramethyl-2-hexadecen-1-ol, Phytol were the main compounds identified in the chloroform extract; 9-Eicosene, 1-Nonadecene, 2- 4-hydroxy-4-methyl- Pentanone, and 9-Octadecene in acetone, whereas diethyl phthalate, di-(1-hexen-5-yl) ester phthalic acid in ethanol. Aqueous extract revealed the presence of 2,3-dihydro-Benzofuran and Squalene, as well as 7,1-cyclohex-1H-cyclopenta[b]indol-3(2H)-one, 2-Methoxy-4-vinylphenol, n-Hexadecanoic acid, alpha-D-Galactopyranose, 6-O-(trimethylsilyl) in methanol. Among the identified compounds, most of them are known to possess several biological activities such as stigmasterol was known to have anti-infammatory, antioxidant, antimicrobial, anticancer, antiarthritic, and antiasthama activity [41, 42]; (E)-9-Eicosene was known to have antimicrobial property [43]; 3,7,11,15-Tetramethyl-2-hexadecen-1-ol was known to have antimicrobial and anti-inflammatory property [44], and phytol was known to have antimicrobial, anti-inflammatory, antiallergic, anticancer, diuretic, antidiabetic, cytotoxicity, antiproliferative, cancer preventive properties [41, 45–47], 1-Nonadecene was proven to have antituberculosis, anticancer, antioxidant, antimicrobial and antifungal activities [48–50], and squalene was reported to have antibacterial, antioxidant, antitumor, cancer preventive and immunostimulant property [46, 51].

According to Neha et al. [52], an antioxidant is a chemical that can inhibit or block the oxidation of lipids or other molecules by avoiding the onset of oxidative chain reactions. As a result, it can stop or undo the harm that oxygen does to the body's cells. Natural antioxidants are more popular these days because of their potential to improve health and fend off diseases.

Table 11 Compound identified in the ethanol extract of *A. salviifolium* using GCMS

Sl.no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area	Compound nature	Uses
1	2-Propenoic acid, 3-ethoxy-, ethyl ester, (E)-	$C_7H_{12}O_3$	144.17	3.927	0.33		
2	Cyclohexanol, 4-methyl-1-(1-methylethyl)-	$C_{10}H_{20}O$	156.26	5.066	0.10		
3	Benzyl chloride $$ Benzene, (chloromethyl)- $$	C_7H_7Cl	126.58	5.372	0.29		
4	Propane, 1,1,3-triethoxy-	$C_9H_{20}O_3$	176.25	6.020	0.12	Alkane	Antibacterial
5	Propane, 1,1-diethoxy-2-methyl-	$C_8H_{18}O$	146.23	6.370	3.20		Flavoring agent, Antimalarial activity
6	Dodecane	$C_{12}H_{26}$	170.33	7.716	0.31		Activators of the heat-shock response signaling pathway, food additives, flavoring agents, lubricants, antifungal and antibacterial acitivity
7	Pentadecane	$C_{15}H_{32}$	212.41	10.419	0.37		Antibacterial
8	Pentadecane	$C_{15}H_{32}$	212.41	12.879	0.23		Antibacterial
9	Diethyl Phthalate	$C_{12}H_{14}O_4$	222.24	13.018	82.23		Antimicrobial, antioxidant, plasticizer, estrogenic
10	Phthalic acid, di-(1-hexen-5-yl) ester	$C_{20}H_{26}O_4$	330.4	13.249	4.47	Ester	Antifungal
11	Diethyl Phthalate	$C_{12}H_{14}O_4$	222.24	14.056	1.29		Antimicrobial, antioxidant, plasticizer, estrogenic
12	Phthalic acid, ethyl pentyl ester	$C_{15}H_{20}O_4$	264.32	14.594	0.28	Ester	
13	Pentadecane	$C_{15}H_{32}$	212.41	15.100	0.12		
14	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	$C_{20}H_{40}O$	296.5	15.539	0.16	Terpene alcohol	Catechol-O-Methyl-Transfearse inhibitor, antimicrobial, anti-inflammatory
15	2-Octylcyclopropene-1-heptanol	$C_{18}H_{34}O$	266.5	15.990	0.15	alcohol	Antibacterial activity
16	Acetamide, 2-(diethylamino)-N-(2,6-dimethylph	$C_{14}H_{23}ClN_2O$	270.80	16.493	2.36		Antiplasmodial activity
17	Hexadecane, 2,6,10,14-tetramethyl-	$C_{20}H_{42}$	282.5	17.105	0.14		Antifungal, antibacterial, antitumor, and cytotoxic effects
18	4-(3,5-Di-tert-butyl-4-hydroxyphenyl)butyl acrylate	$C_{21}H_{32}O_3$	332.5	17.320	0.12	Phenols	Antimicrobial
19	Phytol	$C_{20}H_{40}O$	296.5	18.266	1.71	Diterpene	Antimicrobial, anti-inflammatory, antiallergic, anticancer, diuretic, antidiabetic, cytotoxicity, anti-proliferative, cancer preventive
20	Acetic acid, trifluoro-, hexadecyl ester $$ Trifluoroacetoxy hexadecane	$C_{18}H_{33}F_3O_2$	338.4	20.104	0.11		
21	Benzyldiethyl-(2,6-xylylcarbamoylmethyl)-amm			22.021	1.61		

Table 11 (continued)

Sl.no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area	Compound nature	Uses
22	3-Butoxy-1,1,1,5,5,5-hexamethyl-3-(trimethylsiloxy	$C_{13}H_{36}O_4Si_4$	368.76	23.873	0.13		
23	3.beta-Acetoxy-bisnor-5-cholenamide	$C_{24}H_{37}NO_3$	387.6	28.448	0.17		B-galactosidase and β-glucuronidase inhibitor

Table 12 Compound identified in the aqueous extract of *A. salviifolium* using GCMS

Sl.no.	Compound name	Molecular formula	Molecular weight	Retention time	Peak area %	Compound nature	Uses
1	Benzofuran, 2,3-dihydro-	C_8H_8O	120.15	8.186	53.56	Heterocyclic aromatic	Anti-inflammatory and antifungal activity
2	2-Methoxy-4-vinylphenol	$C_9H_{10}O_2$	150.17	9.452	11.01		Antimicrobial, antioxidant, anti-inflammatory, analgesic, anti-germination
3	2-(2′,4′,4′,6′,6′,8′,8′-Heptamethyltetrasiloxan-2′-yl			11.548	6.44		
4	2-(3-Chloropropyl)-1,3-dioxolane	$C_6H_{11}ClO_2$	150.6	13.565	5.85		
5	Squalene	$C_{30}H_{50}$	410.7	23.954	17.84	Triterpene	Squalene-monooxygenase-inhibitor, chemo preventive, antibacterial, antioxidant, antitumor, cancer preventive, immunostimulant, lipoxygenase-inhibitor, Pesticide
6	Benzene,1-nitro-4-diphenylmethylazino-	$C_{20}H_{15}N_3O_2$	329.4	25.476	5.30		

Table 13 Phosphomolybdenum (PM) assay for *A. salviifolium* leaf extract

Concentration (µg/ml)	Standard ascorbic acid	Acetone	Chloroform	Ethanol	Methanol	Aqueous
100	0.347 ± 0.003	0.178 ± 0.009	0.139 ± 0.004	0.124 ± 0.001	0.291 ± 0.006	0.279 ± 0.004
200	0.513 ± 0.002	0.284 ± 0.004	0.244 ± 0.009	0.219 ± 0.006	0.375 ± 0.004	0.427 ± 0.004
300	0.681 ± 0.001	0.411 ± 0.002	0.398 ± 0.002	0.323 ± 0.004	0.526 ± 0.001	0.699 ± 0.002
400	0.887 ± 0.001	0.511 ± 0.005	0.429 ± 0.002	0.419 ± 0.006	0.717 ± 0.002	0.845 ± 0.002
500	1.078 ± 0.003	0.599 ± 0.007	0.523 ± 0.006	0.487 ± 0.003	0.871 ± 0.001	0.991 ± 0.004

The results are represented as mean ± standard deviation

In the current work, three assay methods—the Phosphomolybdenum (PM), DPPH, and ferric ion reducing power (FRAP) assay methods—were used to determine the antioxidant activity of *Alangium salviifolium* leaves extract. Different crude extracts of *Alangium salviifolium* leaves underwent PM, DPPH, and FRAP assays, and the results were compared to ascorbic acid standard. The phosphate-Mo (V) complex is a bluish green color, and its synthesis results in the reduction of molybdate ions, which is evaluated spectrophotometrically in the phosphomolybdenum test [32]. It is a method that is often used in laboratories to evaluate

Table 14 DPPH assay for *A. salviifolium* leaf extract

	Concentration (µg)	Percentage of inhibition	IC_{50} in µg
Standard ascorbic acid	10	86.271 ± 0.1016	5.788
Acetone	100	59.111 ± 0.2329	84.53
Chloroform	100	56.649 ± 0.3073	88.77
Ethanol	100	66.808 ± 0.4417	74.93
Methanol	100	76.703 ± 0.3206	65.49
Aqueous	100	84.492 ± 0.3556	58.89

The results are represented as mean ± standard deviation

Table 15 FRAP assay for *A. salviifolium* leaf extract

Concentration (µg/ml)	Ascorbic acid	Chloroform	Acetone	Ethanol	Methanol	Aqueous
100	0.566 ± 0.006	0.104 ± 0.003	0.146 ± 0.001	0.086 ± 0.004	0.198 ± 0.002	0.251 ± 0.003
200	1.012 ± 0.006	0.246 ± 0.003	0.254 ± 0.004	0.145 ± 0.004	0.245 ± 0.003	0.406 ± 0.001
300	1.432 ± 0.004	0.344 ± 0.004	0.463 ± 0.007	0.25 ± 0.002	0.485 ± 0.003	0.652 ± 0.001
400	1.735 ± 0.004	0.466 ± 0.004	0.564 ± 0.004	0.326 ± 0.004	0.556 ± 0.004	0.816 ± 0.004
500	1.987 ± 0.004	0.574 ± 0.002	0.762 ± 0.004	0.411 ± 0.004	0.605 ± 0.003	0.997 ± 0.002

The results are represented as mean ± standard deviation

Table 16 Zone of inhibition (in mm) for different solvent extracts of leaves of *A. salviifolium*

Type of extract	Inhibition zone (mm)							
	Pseudomonas aeruginosa				*Staphylococcus aureus*			
	30 µg	60 µg	90 µg	120 µg	30 µg	60 µg	90 µg	120 µg
Chloroform	3	4	5	5	1	2	4	5
Acetone	1	2	4	5	1	4	6	7
Methanol	0	1	3	3	0	1	2	2
Ethanol	1	3	4	5	1	2	2	3
Aqueous	5	1	9	10	5	9	10	11

the overall antioxidant activity of plant extracts. Aqueous extract had the highest activity in the current investigation (0.991 ± 0.004) (Table 13, Additional file 1: Fig. S12).

The assessed antioxidant's potential to scavenge free radicals is revealed by the decrease in DPPH solution absorbance during the reaction. *Alangium salviifolium* plant secondary metabolites such as alkaloids, flavonoids, tannins, phenols, and glycosides are abundant in the plant's crude extracts. By contributing a hydrogen molecule, each of these bioactive compounds has the ability to oxidize the DPPH solution [53]. Using chloroform, acetone, ethanol, methanol, and aqueous extract, the antioxidant activity of *Alangium salviifolium* was assessed in the current study and compared to that of conventional ascorbic acid. According to the results (IC_{50} value: 58.89 µg/ml) (Table 14), aqueous extract had the highest level of scavenging activity compared to all other extracts.

The ferric ion reducing power (FRAP) assay is a method that examines how antioxidants in an acidic media reduce ferric ion (Fe3+)-ligand complex to the strikingly blue ferrous (Fe2+) complex. According to this approach, absorption is inversely related to reducing potential; the greater the absorbance, the greater the antioxidants' capacity to reduce [54]. In the current analysis, aqueous extract was proven to be significant than chloroform, acetone, ethanol and methanol extracts in terms of antioxidant activity (0.997 ± 0.002) (Table 15, Additional file 1: Fig. S13). The investigated extracts' antioxidant activity varied greatly among the different solvent extracts, and the results concluded that on comparison among the tested extracts aqueous extract demonstrated a greater overall antioxidant capacity with noticeably superior

outcomes. According to research by Shravya et al. [1], the antioxidant activity of *Alangium salviifolium* leaves was found to be superior than that of the plant's roots. However, *Alangium salviifolium* leaf extract demonstrated significant antioxidant activity against the DPPH radical and was comparable to earlier findings for this plant, but there was no relationship between antioxidant activity and TPC for *Alangium salviifolium* leaves [55].

Over the past three decades, pharmaceutical companies have created a variety of innovative antibiotic treatments, but bacteria have grown more resistant to these medications. Plant extracts are a fantastic source of pathogen-fighting antibacterial compounds. They can therefore be utilized to treat a variety of infectious disorders brought on by virulent microorganisms. *Staphylococcus aureus* and *Pseudomonas aeruginosa* were used in this work to test the plant extract from *Alangium salviifolium* for antibacterial activity. In both test organisms (Zone of Inhibition-19 mm and 22 mm), aqueous extract stood out among the extracts for its strong antibacterial activity (Table 16, Additional file 1: Figs. S14 and S15). However, *Alangium salviifolium* stem bark and flower extract have been found in the past to have strong antibacterial activity against a variety of bacteria [56, 57]. Additionally, there are not many reports on the antibacterial properties of *Alangium salviifolium* leaf extract. The results of the current investigation make it abundantly evident that water extract proven to be have significant antibacterial activity, whereas acetone, chloroform, ethanol, and methanol have noticeable antibacterial properties. Our study's findings indicate that *Alangium salviifolium* leaves can act as a natural antioxidant to stop the onset and spread of a variety of ailments. To isolate and purify the plant chemicals for this antioxidant and antibacterial properties, more research is required.

Conclusions

In the present study, the plant *Alangium salviifolium* was selected and using phytochemical and GCMS analysis the different solvent extracts of the plant have shown the presence of several metabolites such as phenols and alkaloids, GC–MS analysis has shown the presence of several compounds which are having industry and medicinal applications. Among the different solvent extracts, ethanol and chloroform extract have shown the presence of highest phenolic and flavonoid content, respectively. Further, all selected extracts were screened for biological activities such as antioxidant and antibacterial activity. The results concluded that aqueous extract of plant *Alangium salviifolium* proven to be having potent properties in all performed assay. Hence, in future the molecular level of studies and animal model can be studied to understand its pathway studies.

Supplementary Information

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Additional file 1: Figure S1. *Alangium salviifolium* mature plant. **Figure S2**. FTIR Spectra of Leaf Chloroform extract of *A. salviifolium*. **Figure S3**. FTIR Spectra of Leaf Acetone extract of *A. salviifolium*. **Figure S4**. FTIR Spectra of Leaf Ethanol extract of *A. salviifolium*. **Figure S5**. FTIR Spectra of Leaf Methanol extract of *A. salviifolium*. **Figure S6**. FTIR Spectra of Leaf Aqueous extract of *A. salviifolium*. **Figure S7.** GC-MS chromatogram of Chloroform extract of *A. salviifolium* leaves. **Figure S8.** GC-MS chromatogram of Acetone extract of *A. salviifolium* leaves. **Figure S9.** GC-MS chromatogram of Ethanol extract of *A. salviifolium* leaves. **Figure S10.** GC-MS chromatogram of Methanol extract of *A. salviifolium* leaves. **Figure S11.** GC-MS chromatogram of Aqueous extract of *A. salviifolium* leaves. **Figure S12.** Graph for Phosphomolybdenum (PM) assay for *A. salviifolium* leaf extract. **Figure 13.** Graph for FRAP assay for *A. salviifolium* leaf extract. **Figure S14**. Anti-bacterial activity of Leaf extract of *A. salviifolium* against *S. aureus*; A: Chloroform extract; B: Acetone extract; C: Ethanol extract; D: Methanol extract; E: Aqueous extract; F: Control. **Figure S15.** Anti-bacterial activity of Leaf extract of A. salviifolium against P. aeroginosa; A: Chloroform extract; B: Acetone extract; C: Ethanol extract; D: Methanol extract; E: Aqueous extract; F: Control.

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Author contributions

All authors were involved in concept, design, and collection of data, interpretation, writing and critically revising the article. All authors approve final version of the article.

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Availability of data and materials

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Ethics approval and consent to participate

Not applicable because the present work doesn't involve any humans or animal study. The present study involves the plant materials and As per the guidelines of the university, the plant was identified and verified and its herbarium specimen (No BT was submitted to the Dept. of Botany, Karnataka Science College, Dharwad. The authenticate certificate for the plant identification was taken and uploaded in supplementary section.

Competing interests

The authors declare no competing interests.

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