Research Article

Phytochemical Profiling of Leaf, Stem, and Tuber Parts of Solena amplexicaulis (Lam.) Gandhi Using GC-MS

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1. Introduction

Herbal plants are valuable gift of nature for mankind and they are the source of a variety of phytochemicals which are utilized for human and animal diets also. It is capable of synthesizing an overwhelming variety of low molecular weight organic compounds called secondary metabolites, usually with unique and complex structures. The medicinal actions of plants unique to particular plant species or groups are consistent with the concept that the combination of secondary products in a particular plant is taxonomically distinct [1]. It states that around 85–90% of the world’s population consumes traditional herbal medicines [2]. In recent decades, studies on phytochemical constituents of medicinal plant and its pharmacological activities have received wide attention [3–6]. WHO has emphasized the need to ensure the quality of medicinal plant products using modern techniques with the application of suitable standards. Many modern methods are adapted for identification and quantification of active principle compounds in plant materials. Of them, gas chromatography-mass spectrometry (GC-MS) has become firmly established as a key technological platform for secondary metabolite profiling in both plant and nonplant species [7, 8].

The plant species Solena amplexicaulis is commonly called creeping cucumber and belongs to the family Cucurbitaceae distributed very seldom in the dry deciduous forest and scrub jungles of Tamil Nadu [9]. The medicinal uses of this species are multifaceted. The local healers of Tamil Nadu and Andhra Pradesh are prescribing this species for many ailments owing to its effective healing property [10]. The traditional healers are prescribing the tubers, leaves, and seeds of this species for various ailments like spermatorrhoea, thermogenics, diuretics, haemorrhoids, and invigorating and it is a very good appetizer and cardiotonic [11]. The whole plant is a potential source of natural antioxidant [12, 13], antidiabetic [10], and antibacterial agent [14] also. As the leaves have good anti-inflammatory activity, it is recommended for inflammation, skin lesions, and skin diseases [15]. Crude leaf juice is used to cure jaundice [16]. Unripe fruits are eaten raw to strengthen the body [17]. The decoction of the root is taken orally to cure stomachache [18]. As the reproductive parts like...
2. Materials and Methods

2.1. Collection, Identification and Preparation of Plant Materials. The leaf, stem, and tuber parts of *S. amplexicaulis* were collected separately from the thorny scrub jungles of Madukkarai, Coimbatore District, Tamil Nadu, India. The authenticity of the plant was confirmed in Botanical Survey of India, Southern Regional Centre, Coimbatore, by referring to the deposited specimen (Voucher specimen number: CPS 313). They were washed thoroughly in tap water, shade-dried, and then homogenized to fine powder and stored in air tight bottles.

2.2. Preparation of Extract. 50 g of powdered leaf, stem, and tuber parts of *S. amplexicaulis* was separately extracted with 250 mL methanol at the temperature between 60 and 65°C for 24 h by using soxhlet extractor. The solvent was evaporated by rotary vacuum evaporator to obtain viscous semisolids masses. This semidry methanolic crude extract was subjected to GC-MS analysis.

2.3. GC-MS Analysis. GC-MS analysis was carried out on a 5975C Agilent equipped with a DB-5ms Agilent fused silica capillary column (30 × 0.25 mm ID; film thickness: 0.25 μm), operating in electron impact mode at 70 eV. Pure helium (99.999%) was used as carrier gas at a constant flow of 1 mL/min and an injection volume of 1 μL was employed (split ratio is 10:1). Mass transfer line and injector temperature were set at 230 and 250°C, respectively. The oven temperature was programmed from 70 (isothermal for 3 min) to 300°C (isothermal for 9 min) at the rate of 10°C/min. Total GC running time was 34 min and the MS detection was completed within 35 min.

By GC-MS, the compounds were separated and then they were eluted from the column and made enter into the detector which was capable of creating an electronic signal. Then they were processed by the computer for generating chromatogram. Then the compound entered into the electron ionization (mass spectroscopy) detector, where they were bombarded with a stream of electrons causing them to break apart into fragments. These fragments were actually charged ions with certain mass. The m/z (mass/charge) ratio obtained was calibrated from the graph, called the mass spectrum, and is the fingerprint of the molecule.

2.4. Identification of the Compounds. To identify the compounds, the extract was assigned for comparison of their retention indices and mass spectra fragmentation patterns with those stored on the computer library and also with the published literature. National Institute of Standards and Technology library sources were also used for matching the identified compounds from the plant materials [19, 20].

3. Results

The gas chromatograms of leaf, stem, and tuber parts of *S. amplexicaulis* confirmed the presence of various interesting compounds with different retention times as illustrated in Figures 1, 2, and 3. These compounds were identified through mass spectrometry attached with GC. The identified compounds and their retention time, molecular formula, molecular weight, peak area (%), structure, category of the compound, and activities related with medicinal uses are given in Tables 1, 2, and 3 for leaf, stem, and tuber, respectively. The compound prediction is based on Dr. Duke's Phytochemical and Ethnobotanical Databases. Six compounds were detected in the methanolic leaf extract of *S. amplexicaulis*. Among them, the most prevailing major compounds were phytol, a diterpene (peak area: 38.24%) (Figure 4(a)), carane, a terpene (peak area: 18.76%) (Figure 4(b)), and a flavonoid (peak area: 11.97%) (Figure 4(c)).
| S. number | Name of the compound | RT | Molecular formula | Molecular weight | Peak area % | Structure  | Category of the compound | Activity * |
|-----------|----------------------|----|-------------------|------------------|-------------|------------|--------------------------|------------|
| 1         | Hexahydropyridine, 1-methyl-4-[4,5-dihydroxyphenyl]- | 6.761 | C12H17NO2 | 207.12 | 10.75 | ![Aromatic piperidine](image) | Aromatic piperidine | No activity reported |
| 2         | 1-Octanamine         | 11.990 | C8H19N | 129.24 | 16.16 | ![Aliphatic amine](image) | Aliphatic amine | No activity reported |
| 3         | 1-Tetradecanamine    | 12.091 | C14H31N | 213.40 | 10.24 | ![Aliphatic amine](image) | Aliphatic amine | No activity reported |
| 4         | Carane               | 16.317 | C10H18 | 138.24 | 18.76 | ![Terpene](image) | Terpene | Antifeedant, antioxidant |
| 5         | Pentane-2,4-dione, 3-(1-adamantyl) | 16.753 | C15H22O2 | 234.33 | 5.85 | ![Aliphatic diketone](image) | Aliphatic diketone | No activity reported |
| 6         | Phytol               | 18.990 | C20H40O | 296.53 | 38.24 | ![Diterpene](image) | Diterpene | Anticancer, antioxidant, anti-inflammatory, diuretic, antitumor, chemopreventive, antimicrobial, use in vaccine formulations |

* Source: Dr. Duke's Phytochemical and Ethnobotanical Databases (online database).
| S. number | Name of the compound | RT | Molecular formula | Molecular weight | Peak area % | Structure | Category of the compound | Activity* |
|-----------|----------------------|----|------------------|------------------|-------------|-----------|--------------------------|-----------|
| 1         | 1,3-Cyclopentanedione | 3.929 | C₅H₆O₂           | 98.09            | 4.47        | ![Cyclic diketone](image) | Cyclic diketone | No activity reported |
| 2         | Undecane             | 6.718 | C₁₁H₂₄           | 156.30           | 3.92        | ![Alkane](image)         | Alkane     | Antimicrobial agents, transducer for immunosensor and its method of production, carcinogens, enzyme inhibitors, solvents |
| 3         | 1,2,4-Triazino[5,6-E][1,2,4]-triazine-3,6-dione, hexahydro- | 7.633 | C₄H₈N₆O₂         | 172.14           | 0.36        | ![Triazine](image)      | Triazine   | No activity reported |
| 4         | 4-Hydroxyphenyl 3-nitrobenzoate | 10.218 | C₁₃H₉N₂O₅ | 259.21 | 0.52 | ![Aromatic nitro compound](image) | Aromatic nitro compound | No activity reported |
| 5         | Taurolidine          | 10.261 | C₇H₁₆N₄O₄S₂      | 284.35           | 0.17        | ![Taurine amino acid derivative](image) | Taurine amino acid derivative | Antimicrobial, anti-lipopolysaccharide, anti-tumor properties, anti-infective agents, antineoplastic agents |
| S. number | Name of the compound | RT   | Molecular formula | Molecular weight | Peak area % | Structure | Category of the compound | Activity*   |
|-----------|----------------------|------|-------------------|------------------|-------------|----------|-------------------------|------------|
| 6         | 4-(4-Ethoxyphenyl) but-3-en-2-one | 12.033 | C_{12}H_{14}O_{2} | 190.24          | 56.90       | Aliphatic acid | No activity reported |
| 7         | Trehalose            | 12.469 | C_{12}H_{22}O_{11} | 342.29          | 11.49       | Sucrose   | Treat amyloidosis (prevent the deposition of amyloid protein in the body) |
| 8         | d-Glycero-d-tallo-heptose | 12.701 | C_{7}H_{14}O_{7}  | 210.18          | 1.68        | Aldo heptose | No activity reported |
| 9         | Benzaldehyde, 6-hydroxy-4-methoxy-2,3-dimethyl- | 13.442 | C_{9}H_{12}O_{3}  | 180.20          | 1.71        | Aromatic benzaldehyde | No activity reported |
| 10        | 9-Tetradecen-1-ol, acetate, (Z)- | 16.303 | C_{9}H_{30}O_{2}  | 254.40          | 1.40        | Aliphatic ester | No activity reported |
| S. number | Name of the compound | RT   | Molecular formula | Molecular weight | Peak area % | Structure | Category of the compound | Activity* |
|-----------|----------------------|------|-------------------|------------------|-------------|----------|--------------------------|-----------|
| 11        | Hexadecanoic acid, methyl ester | 17.174 | C_{17}H_{34}O_{2} | 270.45           | 6.52        | Linoleic acid ester      | Anti-inflammatory, hypocholesterolemic, cancer preventive, hepatoprotective, nematicide, insectifuge, antihistaminic, antieczemic, antiacne, alpha reductase inhibitor, antiandrogenic, antiarthritic, anticoronary |
| 12        | 1-Methyl-3-ethyladamantane | 17.581 | C_{13}H_{22}     | 178.31           | 1.37        | Bicyclic alkane          | No activity reported |
| 13        | 9-Octadecenoic acid (Z)-, methyl ester | 18.844 | C_{19}H_{36}O_{2} | 296.48           | 6.76        | Linoleic acid ester      | Anti-inflammatory, antiandrogenic cancer preventive, dermatitigenic hypocholesterolemic, 5-alpha reductase inhibitor, anemiagenic, insectifuge |
| 14        | Benzaldehyde, 2-nitro-, diaminomet hylidenhydrazone | 18.975 | C_{8}H_{9}N_{5}O_{2} | 207.18           | 1.42        | Nitrogen | Antimicrobial |
| 15        | Heptadecanoic acid, 10-methyl-, methyl ester | 19.077 | C_{19}H_{38}O_{2} | 298.50           | 1.29        | Fatty ester              | No activity reported |

* Source: Dr. Duke’s Phytochemical and Ethnobotanical Databases (online database).
| S. number | Name of the compound                        | RT    | Molecular formula | Molecular weight | Peak area % | Structure | Category of the compound | Activity*                                                                 |
|----------|--------------------------------------------|-------|-------------------|------------------|-------------|-----------|--------------------------|--------------------------------------------------------------------------|
| 1        | Dodecanoic acid                            | 13.776| C₁₂H₂₅O₂          | 200.31           | 2.40        | HO        | Fatty acids              | No activity reported                                                     |
| 2        | Tetradecanoic acid                         | 16.071| C₁₄H₂₈O₂          | 228.37           | 0.95        | OH        | Myristic acid            | Antioxidant, cancer preventive, nematicide, hypocholesterolemic, lubricant |
| 3        | 1,2-Benzenedicarboxylic acid, bis(2-methylpropyl) ester | 17.189| C₆H₁₂O₄          | 278.34           | 0.74        | OH        | Phthalic ester           | Used in preparation of perfumes and cosmetics, plasticized vinyl seats on furniture, cars, and clothing including jackets, raincoats, and boots and used in textiles, as dyestuffs, cosmetics, and glass making |
| 4        | Pentadecanoic acid, 14-methyl-, methyl ester | 17.842| C₁₇H₃₄O₂          | 270.45           | 4.61        | OH        | Fatty ester              | No activity reported                                                     |
| 5        | n-Hexadecanoic acid                        | 18.176| C₁₆H₃₂O₂          | 256.42           | 21.75       | CH₃       | Palmitic acid            | Antioxidant, hypocholesterolemic, nematicide, pesticide, lubricant, hemolytic inhibitor, antiandrogenic |
| 6        | Cystodytin                                 | 18.510| C₂₂H₉O₃N₃        | 373.78           | 1.58        |         | Aromatic alkaloid        | Antiproliferative activity in human tumor cell lines                     |
| 7        | 1-Decanol, 2-hexyl-                        | 18.583| C₁₆H₃₁O        | 242.44           | 1.21        |           | Aliphatic alcohols       | Antimicrobial                                                            |
| 8        | 10,13-Octadecadienoic acid, methyl ester   | 19.469| C₁₈H₃₉O₂          | 294.47           | 4.72        |           | Linoleic acid esters     | Anti-inflammatory, hypocholesterolemic, cancer preventive, hepatoprotective, nematicide, insectifuge, antieczemic, anticancer, antiarthritic, insectifuge, antihistaminic, anticoronary  |
| S. number | Name of the compound | RT  | Molecular formula | Molecular weight | Peak area % | Structure | Category of the compound | Activity* |
|-----------|----------------------|-----|-------------------|------------------|-------------|-----------|-------------------------|----------|
| 9         | trans-13-Octadecenoic acid, methyl ester | 19.527 | C_{19}H_{36}O_{2} | 296.48 | 3.55 | ![Structure](image) | Linoleic acid esters | Anti-inflammatory, antiandrogenic, cancer preventive, dermatitigenic, irritant, antikukotriene—D4, hypcholesterolemic, 5-alpha reductase inhibitor, anemigenic, insectifuge, flavor |
| 10        | 9,12-Octadecadienoic acid (Z,Z)- | 19.817 | C_{18}H_{32}O_{2} | 280.44 | 9.35 | ![Structure](image) | Linolenic acid | Anti-inflammatory, hypcholesterolemic, cancer preventive, insectifuge, antiarthritic, hepatoprotective, antiandrogenic, nematicide, antihistaminic, antieczemic |
| 11        | 9,17-Octadecadienal, (Z)- | 19.876 | C_{18}H_{32}O | 264.44 | 21.77 | ![Structure](image) | Unsaturated aldehyde | Antimicrobial |
| 12        | Phthalic acid, di(2-propylnpentyl) ester | 23.201 | C_{24}H_{38}O_{4} | 390.55 | 9.48 | ![Structure](image) | Dicarboxylic acid ester | Oral toxicity during pregnancy and sucking in the Long-Evans Rat |
| 13        | Anthracene, 9-ethyl-9,10-dihydro-10-t-butyl | 25.699 | C_{20}H_{34} | 264.40 | 1.26 | ![Structure](image) | Hydrocarbons | No activity reported |
| S. number | Name of the compound | RT  | Molecular formula | Molecular weight | Peak area % | Structure | Category of the compound | Activity* |
|-----------|----------------------|-----|-------------------|------------------|-------------|-----------|--------------------------|----------|
| 14        | 4-Dehydroxy-N-(4,5-  | 32.148 | C₁₆H₁₄N₂O₄ | 298.29 | 6.72 | Tyramine derivative | No activity reported |
|           | methylenedioxy-2-nitrobenzylidene) tyramine |     |                   |                  |             |           |                          |          |

* Source: Dr. Duke’s Phytochemical and Ethnobotanical Databases (online database).
Figure 4: (a) Mass spectrum of carane. (b) Mass spectrum of phytol. (c) Mass spectrum of 4-(4-ethoxyphenyl) but-3-en-2-one. (d) Mass spectrum of trehalose. (e) Mass spectrum of n-hexadecanoic acid. (f) Mass spectrum of 9,17-octadecadienal, (Z)-.
(Figure 4(b)), and 1-octanamine, an aliphatic amine (peak area: 16.16%). The methanolic stem extract of *S. amplexicaulis* showed the presence of fifteen different organic compounds. The major phytochemical compounds among them were 4-(4-ethoxyphenyl) but-3-en-2-one, an aliphatic acid (peak area: 56.90%) (Figure 4(c)), trehalose, succrose (peak area: 11.49%) (Figure 4(d)), hexadecanoic acid, methyl ester, a linoleic acid ester (peak area: 6.52%), and 9-octadecenoic acid (Z)-, methyl ester, another linoleic acid ester (peak area: 6.76%). Fourteen compounds were identified in the methanolic tuber extract. In this account, 9,17-octadecadienal (Z)-, an unsaturated aldehyde (peak area: 21.77%) (Figure 4(e)), n-hexadecanoic acid, a palmitic acid (peak area: 21.75%) (Figure 4(f)), phthalic acid, di(2-propylpentyl) ester, a dicarboxylic acid ester (peak area: 9.48%), and 9,12-octadecadienoic acid (Z,Z)-, a linolenic acid (peak area: 9.35%) were the major phytochemicals on the basis of quantity.

### 4. Discussion

The gas chromatogram shows that the relative concentrations of various compounds are getting eluted as a function of retention time. The height of the peaks indicates the relative concentrations of the compounds present in the plant. The mass spectrometer analyzes of the compounds eluted at different times to identify the nature and structure of the compounds. The large compound fragments into small compounds give rise to appearance of peaks at different m/z ratios. These mass spectra are fingerprint of that compound which can be identified from the data library.

Generally, the reliability of medicinal plant for its usage is evaluated by correlating the phytochemical compounds with their biological activities [21]. In the present study, the GC-MS analysis of the methanolic extracts of leaf, stem, and tuber parts of *S. amplexicaulis* altogether showed the presence of 35 compounds. In this account, the leaf extract contained six compounds among them, phytol (38.24%) is having anti-cancer, antioxidant, anti-inflammatory, antitumor, antimicrobial, diuretic, and chemopreventive properties and used in vaccine formulations [22, 23]. The other compound, carane (18.76%) is having antifeedant and antioxidant properties [24, 25]. The methanolic stem and tuber extracts showed the presence of greater number of 14 and 15 compounds, respectively. The six phytoconstituents, namely, undecane, taurodine, trehalose, hexadecanoic acid methyl ester, 9-octadecenoic acid (Z)-, methyl ester, and benzyaldehyde, 2-nitro-, dianinomethyl hydienhydrazone in stem extracts have possessed medicinal properties [26]. Undecane, an alkane, is an antimicrobial agent, used as carcinogen [27, 28]. Similarly, the other compound, taurodine, a taurine amino acid derivative, has antimicrobial, antilipopolysaccharidal, and antitumor properties [29, 30]. The sucrose compound, trehalose, is used for the treatment of amyloidosis [31]. The linoleic acid esters present in the stem, hexadecanoic acid methyl ester, are reported to have anti-inflammatory, cancer preventive, hepatoprotective, antiarthritic, and anticoronyary properties. The other linoleic acid ester, 9-octadecenoic acid (Z)-, methyl ester, is also having anti-inflammatory, antiandrogenic, and anemiogenic properties [32]. The nitrogen compound, benzyaldehyde, 2-nitro-, dianinomethyl hydienhydrazone, is known to have the property of curing infectious diseases by its antimicrobial activity. In the tuber extracts, the compounds identified, namely, 10,13-octadecadienoic acid methyl ester, trans-13-octadecenoic acid, methyl ester, and 9,12-octadecadienoic acid (Z,Z)-, are possessed with anti-inflammatory and cancer preventive characters. The two compounds, namely, tetradecanoic acid and n-hexadecanoic acid, are antioxidants. The phthalic acid, 1,2-benzenedicarboxylic acid, bis(2-methylpropyl) ester, is used in the preparation of perfumes and cosmetics. The unsaturated alcohol compound, 9,17-octadecadienal, (Z)-, is reported to have antimicrobial property [33]. The study species *S. amplexicaulis* is endowed with various medicinal properties maybe due to the presence of all these compounds described. In a similar fashion, certain traditional medicinal plant species of Cucurbitaceae have been analyzed phytochemically by using GC-MS and suggested for drug preparation after succeeding in clinical trials [34, 35]. The therapeutic properties of the other compounds in all the three parts of *S. amplexicaulis* were not yet reported.

Our investigation through the present study revealed that the species *S. amplexicaulis* is a reliable source of bioactive compounds like fatty acid esters, alcohols, hydrocarbons, alkanes, amines, terpenes, and sugars that justify the traditional usage of this species [16–18] by the local healers in Coimbatore and Tirupur districts of Tamil Nadu, India, for various ailments. As GC-MS is the first step towards understanding the nature of active principles [36, 37], further investigation in this species is suggested for the development of novel drugs.

### Conflict of Interests

The authors declare that they have no conflict of interests regarding the publication of this paper.

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