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# Volatile Phytochemicals of *Sterculia foetida* Leaf Detected through GC-MS and their Associated Biological Properties Divulged through Meta-analysis

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***Abstract***: *Sterculia foetida* is commonly called as wild Indian almond belonging to the family Malvaceae. In present study analysed leaf samples from 8 different sources from south Gujarat region to detect the volatile phytochemicals through in nontargeted gas-chromatography mass-spectrometry (GC-MS). In total, 38 volatile phytochemical compounds were detected in *S. foetida* leaves. Based on the relative area percentage, Lupeol, Squalene, dl-α-Tocopherol, ß-Amyrin and D-Friedoolean-14-en-3-ol were top 5 having respective area percentage of 17.16, 11.39, 11.35, 10.12 and 8.11. These were followed by another important ones namely Phytol, Sitosterol, Neophytadiene, 24-Noroleana-3,12-diene and Stigmasterol. Furthermore, compounds like ß-Tocopherol, Campesterol, γ-Tocopherol, and d-Tocopherol with important biological activities were also detected. The meta-analysis for corroboration of biological activities revealed that most represented biological properties were antioxidant, antibacterial, anti-inflammatory, and anti-microbial by 14, 9, 8 and 6 compounds. Furthermore, although represented by a smaller number of compounds, were anti-diabetic, antifungal (4 compounds each), analgesic, antidepressant (3 compounds), anti-allergic, anti-pyretic, anti-ulcer (2 compounds), anti-cancer, anti-tumour, antispasmodic, anti-aging, anti-HIV-1 and other various biological properties (1 compound each). Thus, *S. foetida* leaf is a store house of array of important chemical compounds and their derivatives with important biological activities.

***Keywords***: *Sterculia foetida*, GC-MS, Volatile phytochemical, Biological activity

Plants have been used as source of food and medicine since ancient time. Plants are rich source of bioactive compound. Plant bioactive substances are currently the focus of a lot of research. Numerous phytochemicals, usually referred to as secondary metabolites, are found in plants. Due to their individual, additive, or synergistic effects on health, phytochemicals are helpful in the treatment of some illnesses (Jana et al., 2023). *Sterculia foetida* L is a large, straight, deciduous tree (Orwa et al., 2009) and found from Eastern tropical Africa to North Australia, through Malaysia, Burma, Bangladesh, India, Sri Lanka and Malaccas. It has been reported from West Bengal, Bihar, Orrisa, Andhra Pradesh, Maharashtra, Tamil Nadu and Kerala in India (Sharma and Sanjappa 1993, Mujumdar et al., 2000). The fruits, seeds and leaves of *S. foetida* have been conventionally known for its many therapeutic purpose (Jafri et al., 2019). Its seeds are roasted and eaten like chestnuts. Gray coloured wood is used in making rough packing cases. Gum is used in the medicine. The bark yields fibre. The leaves of this plant are used as herbal medicine as aperient and diuretic (Chopra et al., 1992, Mujumdar et al., 2000). A gum that resembles 'gum tragacanth' is obtained from the trunk and branches and is used for bookbinding and similar purposes. *S. foetida* leaves contain up to 2.66% calcium and are also a good source of protein and phosphorus, meeting nutritional requirements of ruminants (Orwa et al., 2009). Seeds and bark of *S. foetida* possess a vast array of biologically active compounds which are chemically diverse and structurally complex (Amuthavalli and Ramesh 2021, Alam et al., 2021, Jana et al., 2023). The medicinal plants are widely used in traditional medicine to prevent and treat various diseases. The phytoconstituents present in the various part of the plant can be exhibit anti-cancer, anti-tumour, anti-diabetic, antispasmodic, anti-inflammatory, anti-oxidant and antibacterial activities (Nanadagopalan et al., 2015). The study was conducted to unveil the various phytochemicals of *S. foetida* from south Gujarat region.

## MATERIAL AND METHODS

The leaf samples of *S. foetida* were collected from distantly located eight different locations in winter and summer from south Gujarat. The samples of winter and summer were pooled and 2 samples were drawn from each season and phytochemicals were detected through GC-MS partly following Murugesan et al. (2013) and Sukhadiya et al. (2021) as under:

One gm of the powdered sample was extracted using Hexene: Acetone (1:1) solvent in centrifuge tube and after 72 hrs of incubation the homogenate centrifuged for 20 min. at 3500 rpm and supernatant was collected. Pinch of activated charcoal was added to treat chlorophyll content. 2 ml of supernatant was collected in pre cleaned glass test tube and

evaporated using cold nitrogen air drier. After drying 2 ml ACN solution was added to test tube, vortex for 2-3 min and sonicate for 2 min. The content was then filtered using injection and disk filter in to 2 ml glass sampling vile. Reading was taken in GC-MS (Thermo make trace GC ultra – ITQ 900). The GC-MS analysis was carried out on Thermo make Trace GC-ULTRA-ITQ 900 with fused silica capillary column (Rx-1-5MS) of 30 m length, 0.25 internal diameter and 0.25 µm film thickness. The injection volume was 1µl and the total run time of the sample was 33.00 minutes.

## RESULTS AND DISCUSSION

Non-targeted gas-chromatography mass-spectrometry (GC-MS) analysis of *S. foetida* leaves from different locations of south Gujarat region revealed array of total 38 volatile phytochemical compounds (Fig. 1). Amongst 38 compounds, lupeol, squalene, dl-α-Tocopherol, ß-Amyrin and D-Friedoolean-14-en-3-ol were top 5 with respective area percentage of 17.16, 11.39, 11.35, 10.12 and 8.11. These were followed by another important ones namely phytol, sitosterol, neophytadiene, 24-Noroleana-3, 12-diene and stigmasterol. Furthermore, compounds like ß-Tocopherol, Campesterol, γ-Tocopherol, and d-Tocopherol were also detected in *S. foetida* leaf in this study. Jana et al. (2023) reported 34 phytoconstituents through GC-MS from methanol extract of *Sterculia foetida* (bark). Amuthavalli and Ramesh (2021) reported 13 bioactive compounds were identified through GC-MS analysis of seed powder of *S. foetida.* Alam et al. (2021) identified 29 compounds through GC-MS analysis from methanolic extract of *S. foetida* seeds. Siswadi and Saragih (2021) identified fifteen compounds from stem bark, twenty-one compounds from leaves and fourteen compounds from seeds of *Sterculia quadrifida.* The *S. foetida* volatile phytochemicals identified in the study have been corroborated with available literature. It is found that many of the compounds detected in *S. foetida*, in present study are reported in other plant species and have one or the other beneficial biological properties/activities (Table 1). The diversity of these phytochemicals underscores their potential for therapeutic, nutraceutical and agro-industrial applications, as corroborated by their reported biological activities in other plant species. Further meta-analysis done from the corroboration of biological properties (Fig. 2a & b) revealed that as highest number of phytochemical

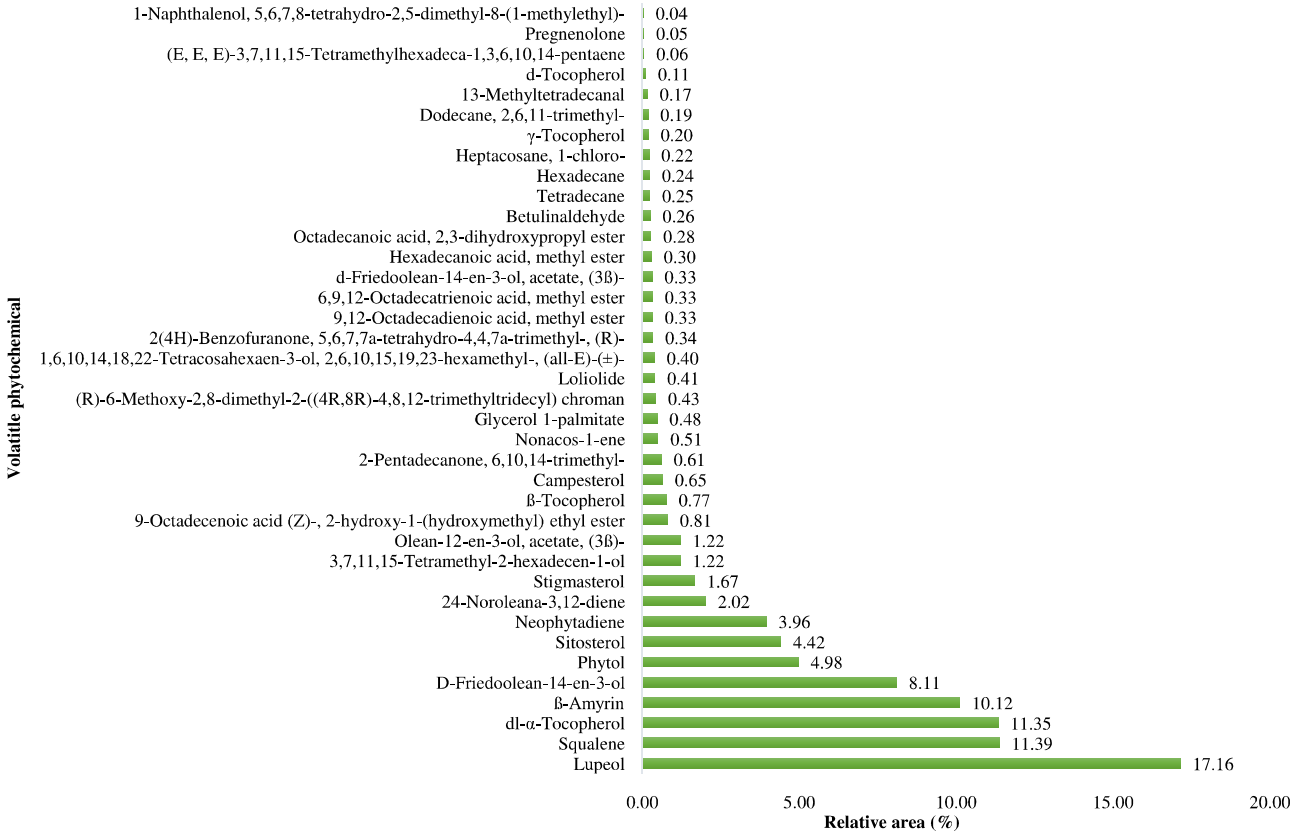


**Fig. 1.** Phytochemicals compounds and their relative percentage in *S. foetida* leaf detected through nontargeted gas-chromatography mass-spectrometry (GC-MS)

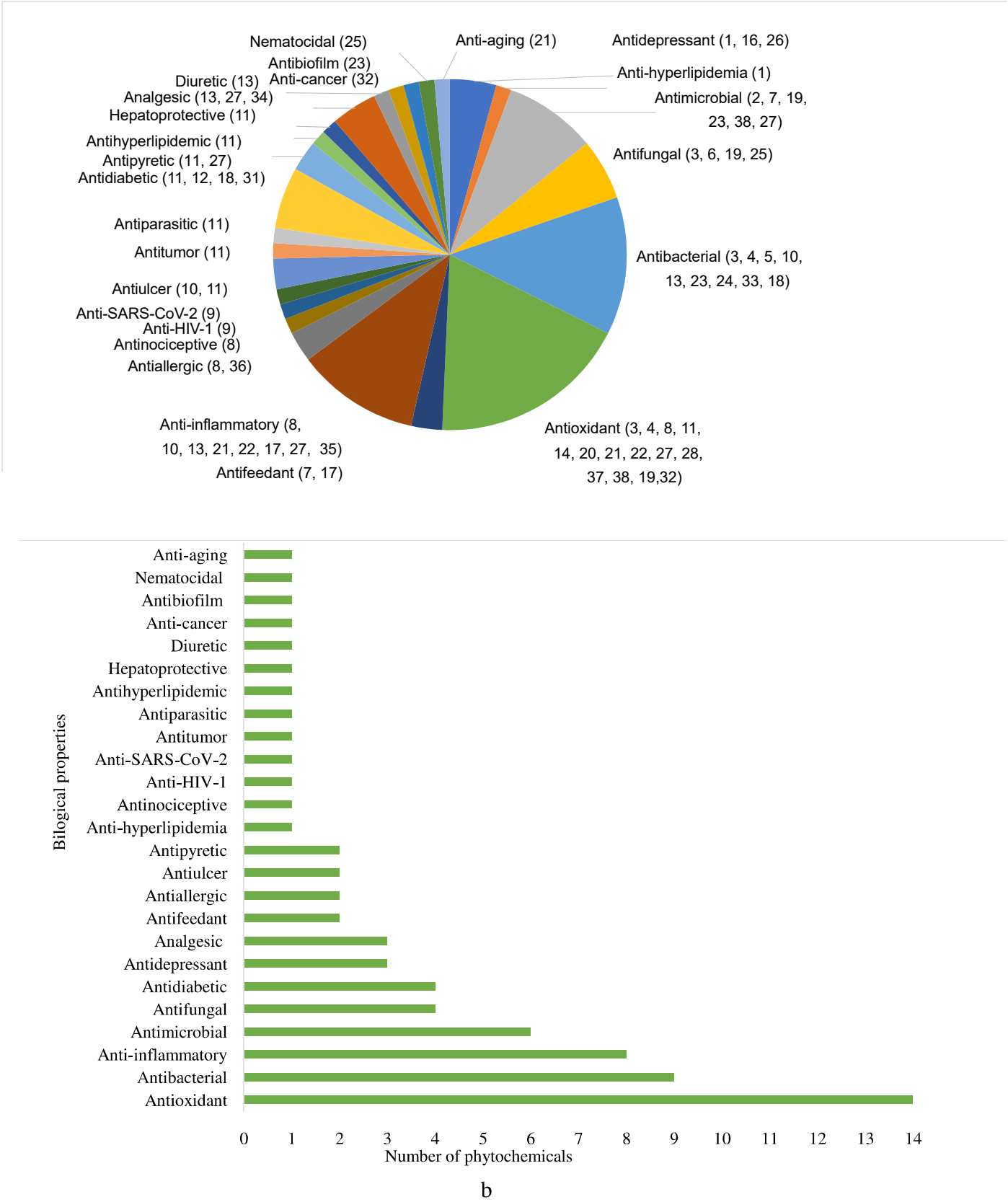


**Fig. 2**. a) biological activities and phytochemicals associated (for compound name, refer Sl. No., column 1, Table 1) and b) number of compounds exhibiting particular biological activity

**Table 1.** Phytochemicals compounds of *S. foetida* leaf detected in present study and their corroboration for biological activities with available literature

| Compound | Chemical nature/class and biological activity | Reports in other species | Reference |
|---|---|---|---|
| Dodecane, 2,6,11-trimethyl- | Branched alkane; antidepressant and anti-hyperlipidemia | *Taxus chinensis var. mairei* | Wei and Yin (2019) |
| 2(4H)-Benzofuranone, 5,6,7,7a-tetrahydro-4,4,7a-trimethyl-, (R)- | A cyclic ester; antimicrobial activity, flavor and fragrance agents | *Premna paucinervis, Alstonia scholaris* | Francis et al. (2021) Swamy et al. (2019) |
| Hexadecane | Alkane hydrocarbon; plant epicuticular wax, antifungal, antibacterial and antioxidant | *Tapinanthus bangwensis* | Atewolara-Odule and Oladosu (2016) |
| 13-Methyltetradecanal | Fatty aldehyde; antioxidant and antibacterial | *Celtis australis* | Badoni et al. (2010) |
| 2-Pentadecanone, 6,10,14-trimethyl- | Methyl ketone; antibacterial activity against gram $^{+ve}$ and gram$^{-ve}$ bacteria | *Funtumia africana* | Amos-Tautua et al. (2020) |
| Hexadecanoic acid, methyl ester | Fatty acid ester; antifungal agent | *Annona muricata* Linn. | Abubacker and Deepalakshmi (2013) |
| 9,12-Octadecadienoic acid, methyl ester | Antifeedant and antimicrobial | *Azadiachta indica* | Khanday and Sharma (2021) |
| 6,9,12-Octadecatrienoic acid, methyl ester | γ-Linolenic acid ester; antinociceptive, antioxidant activities, anti-inflammatory and antiallergic | *Livistona australis* | El-Hawary et al. (2022) |
| Glycerol 1-palmitate | Monoglyceride; anti-HIV-1 and anti-SARS-CoV-2 | *Jatropha curcas* | De Sousa Ferrão and Janeque (2023) |
| Heptacosane, 1-chloro- | Chlorinated alkane; anti-inflammatory, antibacterial and antiulcergenic | *Syzygium cumini* | Kumar et al. (2009) |
| Octadecanoic acid, 2,3-dihydroxypropyl ester | Glyceryl monostearate; antioxidant, antitumour, anti-inflammatory, antiparasitic, antiulcer, antimicrobial, antidiabetic, antipyretic, antihyperlipidemic and hepatoprotective | *Manilkara bidentata* | Powder-George and Mohammed (2018) |
| 9-Octadecenoic acid (Z)-, 2-hydroxy-1-(hydroxymethyl) ethyl ester | Glyceryl monooleate; antidiabetic | *Nauclea latifolia* | Mgbeje and Abu (2020) |
| (R)-6-Methoxy-2,8-dimethyl-2-((4R,8R)-4,8,12-trimethyltridecyl) chroman | Tocotrienol isomer; antibacterial, anti-inflammatory, analgesic, diuretic | *Rhus coriaria* | Hamad et al. (2024) |
| Nonacos-1-ene | Alkene Hydrocarbon; antioxidant | *Anthocleista Djalonensis* | Ogunboyeo et al. (2022) |
| Campesterol | Phytosterol, associated with cholesterol lowering and cancer prevention | *Strychnos innocua* | Uttu et al. (2023) |
| Stigmasterol | Phytosterol; antidepressant | *Aegle marmelos* | Ghosh et al. (2022) |
| 1-Naphthalenol, 5,6,7,8-tetrahydro-2,5-dimethyl-8-(1-methylethyl)- | Sesquiterpenoid; antifeedant, anti-inflammatory and antioxidant | *Ardisia solanacea Roxb.* | Anjum et al. (2019) |
| Pregnenolone | Steroid precursor; antidiabetic and antibacterial | *Lansium parasiticum* | Mutiah et al. (2024) |
| (E, E, E)-3,7,11,15-Tetramethylhexadeca-1,3,6,10,14-pentaene | Polyene; antimicrobial, antifungal and antioxidant | *Paulownia fortunei, Cosmostigma cordatum* | Ferdosi et al. (2021), Das et al. (2022) |
| d-Tocopherol | Vitamin E isomer; antioxidant | *Ficus carica* | Konyalıoglu et al. (2005) |
| ß-Tocopherol | Vitamin E isomer; antibacterial, anti-inflammatory, skin tightening and anti-aging, therapeutic agents against SARS-CoV-2 | *Plukenetia volubilis L, Moringa oleifera* | Wang et al. (2018) Siddiqui et al. (2022) |
| γ-Tocopherol | Vitamin E isomer; anti-inflammatory and antioxidants | *Moringa oleifera* | Sanchez-Machado et al. (2006) |
| 24-Noroleana-3,12-diene | Triterpenoid; antibacterial, antibiofilm and antimicrobial | *Swietenia macrophylla, Boswellia carterii* | Man et al. (2022), Damour et al. (2025) |
| Betulinaldehyde | Triterpenoid; antibacterial | *Zizyphus rugosa* | Shoeb et al. (2005) |
| Tetradecane | Antimicrobial, antifungal and nematocidal | *Mangifera indica* | Velumani and Selvi (2019) |
| Loliolide | Antidepressant, | *Mondia whitei* | Neergaard et al. (2010) |

***Cont...***

**Table 1.** Phytochemicals compounds of *S. foetida* leaf detected in present study and their corroboration for biological activities with available literature

| Compound | Chemical nature/class and biological activity | Reports in other species | Reference |
|---|---|---|---|
| Neophytadiene | Sesquiterpenoids; anti-inflammatory agent, a plant metabolite and an algal metabolite. analgesic, antipyretic, antimicrobial, and antioxidant | *A. pannosum, G. tenax, Plectranthus amboinicus, Eupatorium odoratum, M. dubia* | Aadesariya et al. (2017), Swamy et al. (2017), Raman et al. (2012), Malek et al. (2023) |
| 3,7,11,15-Tetramethyl-2-hexadecen-1-ol | Acyclic diterpene alcohol; antioxidant and antibacterial | *Moringa oleifera* | Suganandam et al. (2022) |
| Phytol | A constituent of chlorophyll, after fermentation converted to phytanic acid and stored in fats. | *M. dubia, G. pubescens Aegle marmelos* | Murugesan et al. (2013), Hamid et al. (2016) Hossain et al. (2013), Malek et al. (2023) |
| Squalene | (Triterpene) Monoxygenases inhibitor, antioxidant, antibacterial, cancer preventive, immune−stimulant and anti−tumour | *Strobilanthes glutinosus, Senna tora, M. dubia* | Aziz et al. (2022), Duke (1992), Beulah et al. (2018), Kabila et al. (2022), Malek et al. (2023) |
| 1,6,10,14,18,22-Tetracosahexaen-3-ol, 2,6,10,15,19,23-hexamethyl-, (all-E)-(±)- | Polyisoprenoid alcohol; antidiabetics | *Cordia myxa L., Syzygium cumini, Syzygium malaccense, and Antidesma bunius* | Zubair et al. (2025) |
| dl-α-Tocopherol | Vitamin E analog; anti-cancer, Antioxidant | *Sarcopoterium spinosum L., M. dubia, Prunus armeniaca, P. persica, P. domestica, Malus domestica* | Bozkurt Sarikaya and Kayalar (2014), Malek et al. (2023), Wojdyto et al. (2022) |
| Sitosterol | Phytosterol; antibacterial | *Odontonema strictum* | Luhata and Usuki (2021) |
| D-Friedoolean-14-en-3-ol | Pentacyclic triterpenoid; analgesic | *Osyris lanceolata* | Yeboah and Majinda (2013) |
| Lupeol | Triterpenoid; anti-inflammatory | *Quercus obtusata* | Sánchez-Burgos (2015) |
| ß-Amyrin | Triterpenoid; anti-allergic | *Anchientia salutaris var. martiana* | Di Stasi et al. (1999) |
| d-Friedoolean-14-en-3-ol, acetate, (3ß)- | Acetylated triterpenoid; antioxidant | *Clitoria ternatea* | Nurcholis et al. (2023) |
| Olean-12-en-3-ol, acetate, (3ß)- | β-Amyrin acetate; anti-microbial and antioxidant | *Ficus religiosa L., Ficus semicordata Buch.- Ham. ex Sm.* | Babu et al. (2023) |

compounds are associated with antioxidant property of 14 compounds (Fig. 2a & b). This was followed by antibacterial activity and anti- by 9 and 8 compounds. Antimicrobial activity associated with 6 compounds, whereas antidiabetic and antifungal activities linked to 4 compounds

Antidepressant (1, 16, 26) and analgesic (13, 27, 34) activities were associated with 3 compounds each. Antipyretic (11, 27), antifeedant (7, 17), antiulcer (10, 11) and antiallergic (8, 36) activities involved 2 compounds. Additionally, antinociceptive (8), anti-aging (21), anti-cancer (32), antihyperlipidemic (11), hepatoprotective (11), antitumor (11), antiparasitic (11), diuretic (13), anti-HIV-1 (9), anti-SARS-CoV-2 (9), antibiofilm (23), nematocidal (25) and anti-hyperlipidemia (1) is ascribed to one compound (Fig. 2a & b). Further, meta-analysis pinned out that detected 38 chemical compounds detected in *S. foetida* leaf exhibit 26 different types of biologically beneficial properties (Fig. 2b) which have also been reported from plant species.

## CONCLUSION

Total 38 of biologically active compound were reported from *S. foetida* leaves collected from various locations from South Gujarat. The non-volatile compounds findings through GCMS analysis inferred that *S. foetida* leaves has beneficial biological active phytochemicals which may be beneficial to human and animals. Meta-analysis revealed that as many as 26 different types of biologically beneficial properties are exhibited by these detected compounds. Out these14 antioxidant, 9 antibacterial, 8 inflammatory, 6 antimicrobial and 3 each exhibit antidiabetic and antifungal properties, apart from important ones like anti-cancer, anti-HIV-1, anti-SARS-CoV-2, antitumor activities *etc.*, though possessed by a smaller number of compounds. Thus, *S. foetida* leaf is a store house of array of chemical compounds and their derivatives with important biological activities which need to be isolated for further improvement.

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**AUTHOR'S CONTRIBUTION**

M.L. Sukhadiya: sample collection, laboratory analysis, data arrangement and manuscript draft preparation; N. S. Thakur: research conceptualization, sample collection, data interpretation, table and figure construction, reviewing and editing manuscript; Susheel Singh: GC-MS sample analysis and identification of phytochemicals; R.P. Gunaga: research conceptualization, data interpretation, sampling and statistical procedures; S.K. Sinha: laboratory work and data tabulation; V.R. Patel: interpretation of data, laboratory analysis, methodological inputs.

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