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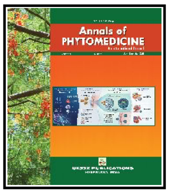

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Comparative phytochemical profiling and functional evaluation of exudate gums from selected farm grown tree species

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Abstract

The present study conducted a comparative phytochemical profiling and functional evaluation of exudate gums from four farm grown tree species: *Moringa oleifera* Lam.; *Lannea coromandelica* (Houtt.) Merr.; *Albizia lebbeck* (L.) Benth. and *Samanea saman* (Jacq.) Merr. Gums were obtained through controlled bark incisions and purified using a combination of hydration, filtration, ethanol precipitation and centrifugation. Physicochemical analysis revealed significant interspecific variation. *M. oleifera* gums exhibited superior hot water solubility (92.5%) and the lowest ash content (1%) indicating high purity. *L. coromandelica* gums recorded the highest chlorophyll content (0.61 mg/g), while *M. oleifera* showed the highest vitamin C concentration (220 mg/100 g). All gums were mildly acidic (pH 4.4 to 5.8) and displayed no detectable peroxide values, suggesting oxidative stability. Biochemical assessment showed varied levels of total nitrogen (0.52 to 0.80%), minerals (Ca: 385.16 to 1024.41 mg/100 g; Fe: 0.31 to 9.97 mg/100 g; K: 240.25 to 943.26 mg/100 g), tannins (0.95-2.10%) and phytic acid (0.34-2.95%). Gas chromatography-mass spectrometry (GC-MS) profiling identified a diverse range of bioactive compounds across species, including furanones, fatty acids (*e.g,* palmitic acid, oleic acid), siloxanes, esters, and pharmacologically significant molecules such as didemnin B (*M. oleifera*) and squalene (*L. coromandelica*). The results highlight the gums rich and species specific phytochemical composition, underscoring their strong potential as sustainable, multifunctional resources for applications in pharmaceutical, cosmetic, food and chemical industries.

1. Introduction

Natural exudate gums constitute a remarkable class of plant derived biopolymers that have long been valued for their diverse functional, nutritional and industrial applications (Anderson and Morrison, 1990). These complex polysaccharide rich materials are secreted by several tree species in response to mechanical injury, environmental stress or pathogenic attack and they serve as protective agents that seal wounds and prevent desiccation. In recent years, the demand for naturally sourced, biodegradable and safe hydrocolloids have increased substantially across the food, pharmaceutical, cosmetic and textile industries. This has renewed scientific interest in the systematic exploration, characterization and valorization of gums obtained from farm grown tree species, particularly those distributed in tropical and subtropical regions (Panda, 2010). India harbours significant gums and resin yielding flora, many of which remain unexploited despite their ecological abundance and potential economic value. Among these, M. *oleifera*, *L. coromandelica*, *A. lebbeck* and *S. saman* are noteworthy agroforestry species widely adopted in the farming system across the southern states. These tree species exudate gums although traditionally used in indigenous systems for food stabilization, medicine and artisanal applications have received limited scientific attention with respect to their phytochemical composition, physicochemical quality attributes and industrial relevance. Variations in gums properties among species and even within species were strongly influenced by tapping method, environmental conditions, age of the tree and post harvest handling techniques (Ali *et al*., 2009; Chaplin, 2003).

M. oleifera is a fast growing, drought tolerant deciduous tree widely cultivated in India for its highly nutritious leaves, pods and seeds. It produces a pale colored exudate gums and is valued for its medicinal, nutritional and pharmaceutical importance. *L. coromandelica* is a medium to large deciduous tree commonly found in dry deciduous forests and farmlands of peninsular India. The tree exudes a reddish brown gums and is traditionally used for medicinal purposes, timber and rural utilities. *A. lebbeck* is a large, spreading, nitrogen fixing deciduous tree widely planted in agroforestry systems and along roadsides. It yields a natural exudate gums and is valued for its soil improving ability, medicinal properties, and shade. *S. saman* is a large, fast growing tree with a wide umbrella shaped crown, commonly grown as a shade and avenue tree. It produces a polysaccharide rich exudate gums and is important for fodder, timber and agroforestry applications.

The process of gums tapping involves controlled incision of the bark to stimulate exudation, a technique that plays a crucial role in determining both the yield and quality of the gums produced.

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Standardized tapping protocols are essential to minimize tree damage and to obtain a consistent exudate profile suitable for subsequent purification and biochemical assessments. Once collected, raw exudate gums require systematic extraction, hydration, filtration and precipitation to isolate the polysaccharide fractions and remove extraneous materials such as bark debris, resins, chlorophyll pigments and phenolic compounds. These steps were crucial for producing chemically stable, high purity gums samples appropriate for analytical characterization (Mirhosseini and Amid, 2012). Recent advancements in analytical platforms particularly gas chromatography-mass spectrometry (GC-MS) have enabled detailed profiling of the biochemical constituents of plant gums (Hussain *et al*., 2008). Such analyses provide insights into the presence of monosaccharides, organic acids, fatty acid derivatives, volatile components and bioactive compounds that contribute to the functional properties and potential industrial utility of each gums sample. Complementary assessments of pH, ash content, vitamin content, solubility behavior and mineral composition further enhance understanding of the physicochemical attributes governing gums quality.

The exudate gums obtained from *M. oleifera, L. coromandelica, A. lebbeck and S. saman* possess several pharmaceutically important properties owing to their rich phytochemical composition. These gums are predominantly composed of complex polysaccharides along with associated phenolic compounds, flavonoids, tannins and trace proteins, which collectively contribute to their antioxidant, anti-inflammatory and antimicrobial activities. The presence of bioactive polysaccharides imparts immunomodulatory and wound healing properties, while phenolic constituents enhance free radical scavenging potential. Functionally, these natural gums exhibit excellent binding, emulsifying, thickening and stabilizing properties making them suitable as pharmaceutical excipients in tablet formulation, suspensions and controlled drug delivery systems. Additionally, their biocompatibility, biodegradability, non-toxicity and mucoadhesive nature support their use in sustained release formulations and topical preparations. Collectively, the exudate gums from these farm grown tree species represent promising natural materials with both therapeutic relevance and excipient potential for pharmaceutical and nutraceutical applications.

Given the growing interest raising awareness on natural biopolymers and the relative scarcity of comparative phytochemical studies on gums from farm grown tree species the present investigation aims to: (i) standardize the purification procedures for gums obtained from *M. oleifera*, *L. coromandelica*, *A. lebbeck* and *S. saman*; (ii) evaluate their physicochemical and biochemical characteristics and (iii) identify major chemical constituents through GC-MS analysis. The outcomes of our study generated valuable information on the industrial applicability, nutritional potential and biochemical richness of these species, thereby supporting their sustainable utilization in agro forestry based livelihoods and bioresource industries.

2. Materials and Methods

2.1 Authentication of plant material

The plant species *Moringa oleifera* Lam., *Lannea coromandelica* (Houtt.) Merr., *Albizia lebbeck* (L.) Benth. and *Samanea saman* (Jacq.) Merr. were authenticated by the Botanical Survey of India (BSI), Coimbatore, Tamil Nadu, India and the corresponding voucher specimens were deposited under the numbers BSI/SRC/5/23/2025-26/Tech./860, BSI/SRC/5/23/2025-26/Tech./861, BSI/SRC/5/23/2025-26/Tech./862 and BSI/SRC/5/23/2025-26/Tech./863.

2.2 Background and rationale of the study

Exudate gums from tree species are natural biopolymers widely used in the pharmaceutical and food industries due to their biodegradability and functional versatility. Farm grown trees provide a sustainable and eco-friendly source of these gums while supporting rural livelihoods. The phytochemical composition of exudate gums influences their functional properties such as antioxidant activity, emulsification and binding capacity. A comparative understanding of these properties among different farm-grown tree species is essential for identifying suitable gums for specific applications. Hence, the present study focuses on the comparative phytochemical profiling and functional evaluation of exudate gums from selected farm grown tree species.

2.3 Extraction and tapping of gums

Gums were collected from selected species of farm grown trees using a traditional tapping method similar to techniques described in earlier botanical studies. The tapping process began by making a careful incision into the outer bark with a small axe or knife. After that, gently loosen the bark by sliding the tool underneath and peeling it back, creating a horizontal wound about 4.0 to 8.0 centimeters wide. Over time, the tree began to exude gums due to that incision. The first harvest took place roughly four weeks after the initial cut. Following that, we found we could collect fresh gums every three days around 30 to 40 gram gums harvested each time. The exudates themselves formed in narrow strips about 2.0 to 2.5 centimeters wide. We carefully collected this material and stored it in a clean, dry container for further analysis.

2.4 Extraction and purification of exudate gums

Exudate gums were collected from farm grown *Moringa oleifera* Lam. (Oddanchatram, Dindigul district and Saravanampatti, Coimbatore district), *Lannea coromandelica* (Houtt.) Merr. (Nagapattinam district), *Albizia lebbeck* (L.) Benth. and *Samanea saman* (Jacq.) Merr. (Forest College and Research Institute, Mettupalayam), Tamil Nadu, India. Mature trees were selected and controlled incisions were made on the bark to induce gum exudation. The collected raw gums were soaked in distilled water for three days with intermittent stirring, followed by filtration through a muslin cloth to remove insoluble impurities. The filtrate was dried in a hot air oven to obtain a solid residue, which was finely powdered and subjected to ethanol precipitation to purify the gums. The resulting suspension was centrifuged to separate the precipitated gums from the supernatant, and both fractions were collected for further analysis (Figures 1-4).

2.5 Polysaccharide extraction

Polysaccharides from different tree gums were extracted using a systematic purification procedure. Twenty grams of powdered gums was first mixed with 200 ml of cold distilled water to form slurry. This slurry was slowly added to 800 ml of boiling distilled water and heated for 20 min in a water bath with continuous stirring to obtain a clear solution. The solution was allowed to stand overnight to enable the settling of proteins and fibrous impurities. The following day, the mixture was centrifuged at 5000 rpm for 20 min to remove residual solids. The clear supernatant was carefully collected and added with constant stirring to twice its volume of absolute ethanol resulting in polysaccharide precipitation. The precipitate was recovered by pressing through a cheese cloth. It was then washed sequentially with absolute ethanol, diethyl ether and petroleum ether to remove impurities and aid drying. The purified polysaccharide thus obtained was used for subsequent chemical characterization. Identification of constituent sugars was carried out using gas chromatography-mass spectrometry (GC-MS)

Figure 1: Gums collection from the *M. oleifera* tree and gums powder.

Figure 2: Gums collection from the *L. coromandelica* tree and gums powder.

Figure 3: Gums collection from *A. lebbeck* tree and gums powder.

Figure 4: Gums collection from *S. saman* tree and gums powder.

2.6 Solubility analysis

The solubility of the purified gums was evaluated using selected common solvents, namely water, acetone, chloroform and ethanol. In each assessment one gram of the gums sample was mixed with 50 ml of the respective solvent and left undisturbed overnight. After the incubation period the extent of dissolution was determined and solubility was expressed as the percentage of gums dissolved in each solvent.

2.7 pH measurement

The pH of the gums was determined using a glass electrode pH meter on a 1% (w/v) aqueous dispersion prepared by shaking the sample in water for five min. After calibration at neutral pH under ambient conditions (28°C) the electrode was immersed in the solution and the stabilized pH value was recorded.

2.8 Ash content determination

Ash content, which reflects the inorganic mineral fraction of the gums was estimated using a standard dry ashing procedure. Ten grams of dried gums were weighed into a clean, preweighed crucible and initially charred over an open flame for about 30 min to remove moisture and partially decompose organic matter. The crucible was then placed in a muffle furnace at 550°C for 4 h to ensure complete incineration of organic constituents. After cooling in a desiccator to room temperature, the crucible was reweighed and the mass of the remaining residue was used to calculate the ash content as a percentage of the original sample (Formula 1).

$$\text{Ash content (\%)} = \frac{(\text{Weight of crucible with ash} - \text{Weight of empty crucible})}{(\text{Weight of crucible with sample} - \text{Weight of empty crucible})} \times 100 \quad \text{... (1)}$$

2.9 Total chlorophyll

Chlorophyll content was determined by extracting pigments from 1 g of sample with 80% acetone and clarifying the extract by centrifugation at 5000 rpm for 5 min. The combined extract was made up to 100 ml and absorbance was measured at 645 and 663 nm using 80% acetone as the blank. The amount of total chlorophyll in the sample was calculated using the formula 2:

$$\text{Total chlorophyll} = 20.2\,(A645) + 8.02\,(A663) \times \frac{V}{1000 \times W} \quad \text{... (2)}$$

where,

V = Final volume of the extract;

W = weight of the sample:

The values are expressed as mg chlorophyll/g sample.

2.10 Vitamin C

Vitamin C was determined by the 2, 6-dichlorophenol-indophenol dye method (Ruck, 1963). This titrimetric method is widely used for ascorbic acid determination in plant materials.

2.11 Percentage yield of purified gums

The dried and purified gums obtained after precipitation was accurately weighed and the percentage yield was calculated by relating the weight of the purified gums to the initial weight of the crude dried exudate.

2.12 GC-MS analysis

Chemical characterization was performed using a GC-MS system (GC Clarus 500, PerkinElmer) equipped with an auto sampler at Tamil Nadu Agricultural University, Coimbatore. Separation was achieved on an elite-1 fused silica capillary column under electron impact ionization (70 eV) with helium as the carrier gas. The injector and ion source temperatures were maintained at 250°C and 280°C, respectively, while the oven temperature was programmed from 110°C to 280°C with a final isothermal hold. Mass spectra were recorded over a range of 40 to 450 Da with a total run time of 34 min and compounds were identified by comparison with the NIST mass spectral library.

3. Results

The results of the solubility of four important farm grown trees in different solvents are given in Table 1.

Table 1: Solubility (%) of gums collected from different farm grown tree species

Solvent	*Albizia lebbeck*	*Samanea saman*	*Lannea coromandelica*	*Moringa oleifera*
Hot water	80%	88%	80.2%	92.5%
Cold water	75%	83.5%	74.5%	90%
Ethanol	38%	32.5%	14.6%	26%
Acetone	33.6%	22.9%	28.8%	32.4%

* Mean value of three samples

Among the gums samples, *M. oleifera* gums is more soluble (92.5%) in hot water when compared with all other gums samples and *A. lebbeck* recorded the least solubility of 80%. Among the different solvents used for solubility studies, hot water showed more solubility capacity than other solvents.

3.1 Physical parameters of gums collected from various gums yielding tree species

The following physical parameters of the collected gums were assessed using standard methodology, and the results of the assessment are given in Table 2.

Table 2: Physical parameters of gums collected from various gums yielding tree species

Solvent	*A. lebbeck*	*S. saman*	*L. coromandelica*	*M. oleifera*
pH	5.5	4.4	4.7	5.8
Ash content (%)	14	2	4	1
Total chlorophyll (mg/ g)	0.12 ± 0.001	0.13 ± 0.001	0.61 ± 0.02	0.1 ± 0.001
Vitamin C (mg/100 g)	195 ± 0.25	175 ± 0.20	189 ± 0.20	220 ± 0.30

* Mean value of three samples

The pH of all the gums samples tested registered under acidic category. Comparing the pH of all the exudate gums samples the *M. oleifera* sample recorded a maximum pH of 5.5, followed by *A. lebbeck* and the minimum pH value was recorded by *S. saman*. *A.*

lebbeck gums sample registered a maximum ash content of 14% and *M. oleifera* gums registered a minimum ash content value of 1%. The total chlorophyll content of the gums samples was estimated using a spectrophotometer. *L. coromandelica* gums recorded the maximum total chlorophyll content of 0.61 mg/ g, followed by *S. saman* (0.13 mg/ g). The gums sample of *M. oleifera* recorded a minimum total chlorophyll content of 0.1 mg/ g. Vitamin C is an antioxidant that helps protect cells against the effects of free radicals. Vitamin C analysis among the different gums samples showed that *M. oleifera* registered the highest amount of vitamin C of 220 mg/100 g when compared to all other samples, followed by *A. lebbeck* and *S. saman*, which registered with a minimu m vitamin C.

3.2 Biochemical properties of gums samples

The following biochemical properties were quantified in gums collected from different farm grown tree species, *viz., M. oleifera, L. coromandelica, A. lebbeck* and *S. saman* (Table 3).

Table 3: Biochemical properties of exudate gums from *M. oleifera, L. coromandelica, A. lebbeck* and *S. saman*

S. No.	Chemical components	*M. oleifera*	*L. coromandelica*	*A. lebbeck*	*S. saman*
1	Acidity as H_2SO_4 (%)	2.83	2.35	1.41	1.81
2	Total nitrogen (%)	0.67	0.52	0.80	0.61
3	Peroxide value (meq/kg)	Below detective limits	Below detective limits	Below detective limits	Below detective limits
4	Calcium (mg/100 g)	385.16	1024.41	567.09	418.14
5	Iron (mg/100 g)	2.80	0.31	9.97	0.70
6	Potassium (mg/100 g)	240.25	294.91	943.26	453.60
7	Tannin (%)	2.1	1.88	0.95	1.32
8	Phytic acid (%)	0.34	0.51	2.95	1.85

* Mean values of three samples

Acidity as sulphuric acid is used to determine the volatile acid of the sample and it was found to be lower, falling in the range of 1.41 to 2.83%. The peroxide value was found below detectable levels in all four gums indicating that there is no possibility of rancidity. The different concentrations of total nitrogen, calcium, iron and potassium is shown in Table 3. The total nitrogen content was in the range of 0.52 to 0.80%, calcium in the range of 385.16 to 1024.16%, iron between 0.31 to 9.97% and potassium in the range of 240.25 to 943.26%. The concentration of the different elements was found to be in a considerable range. The tannin content was found to be higher in moringa gums (2.1%) and lower in *A. lebbeck* (0.95%). Tannin content can be used as one of the biochemical parameters to check the quality of the gums. The highest phytic acid content was observed in *A. lebbeck* gums (2.95%), followed by *S. saman* (1.85%). Tannins and phytic acid have been reported to have anticancer, antiathero-sclerotic, anti-inflammatory and antihepatoxic properties.

3.3 Characterization of biochemical constituents through GC-MS

From the GC-MS spectrum (Figure 5) it is evident that *M. oleifera, L. coromandelica, A. lebbeck and S. saman* gums consist of a number of dominant peaks which denote the chemical compounds present in the four gums samples. The concentrations of active constituents of the gums samples, associated retention time, probability, compound name, chemical formula, area and molecular weight of the compounds were identified from the spectrum.

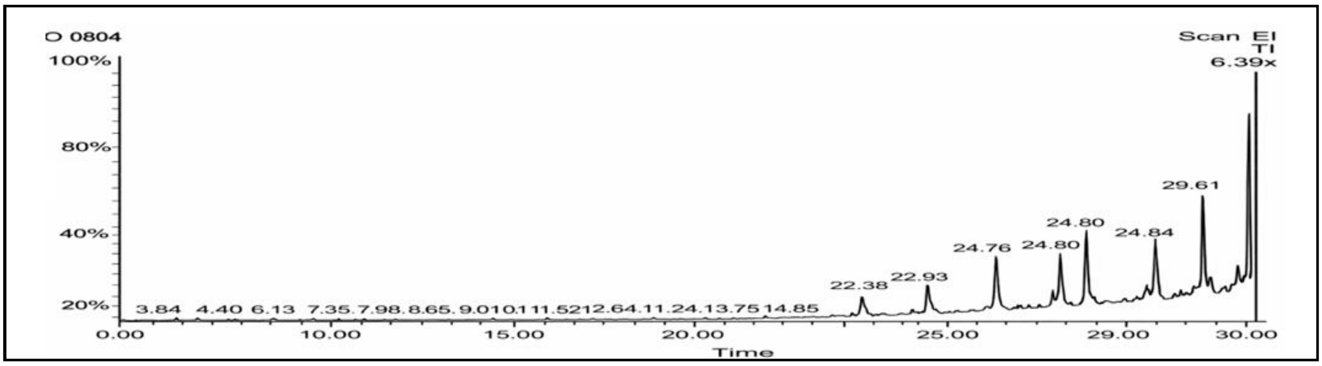


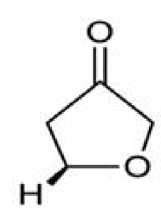
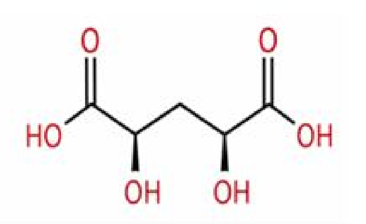
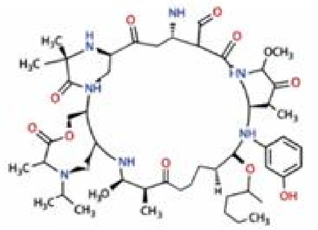
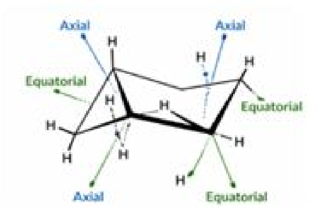
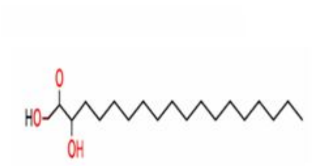
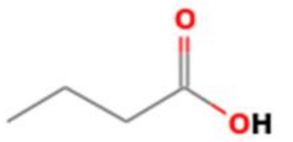
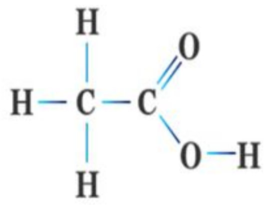
Figure 5: Biochemical constituents identified in the gums extract of *M. oleifera* through GC-MS.

GC-MS analysis of *M. oleifera* gums identified numerous bioactive compounds including 2(5H)-furanone, succinic ac and lauric acids provide antioxidant, anti-inflammatory and antimicrobial benefits for use in cosmetics and soaps. Acetic and butanoic acids support roles in food preservation and chemical synthesis. Various esters and ethers within the gums serve as emulsifiers, stabilizers and conditioning agents in personal care products. This diverse phytochemical profile confirms *M. oleifera* gums as a versatile natural resource with applications across pharmaceutical, cosmetic, food and industrial sectors (Tables 4 and 5).

Table 4: Key characteristics of compounds identified from GC-MS analysis of *M. oleifera* gums

Compound name	Molecular formula	Molecular weight	Uses
2(5H) - Furanone	$C_4H_4O_2$	84.07 g/mol	Pharmaceutical industries
Betanedioic acid	$C_4H_6O_4$	118.088 g/mol	Food, Chemical, Leather and Textile industries
Didemnin B	$C_{57}H_{89}N_7O_{15}$	1112.35 g/mol	Pharmaceutical industries
Cyclohexane	C_6H_{12}	84.16 g/mol	Used as a solvent, oil extractant, paint and varnish remover and in solid fuels
Hexadecanoic acid	$C_{16}H_{32}O_2$	256.42 g/mol	Antioxidant, antimicrobial and anti-inflammatory activities
Butanoic acid	$C_4H_8O_2$	88.10 g/mol	Artificial flavourings, as a food additive, varnish. Used in the manufacture of perfume, flavourings, pharmaceuticals and disinfectants.
Acetic acid	$C_4H_4O_2$	60.05 g/mol	Printing industry, Textile industry, medical and food industries
Dodecanoic acid	$C_{12}H_{24}O_2$	200.31 g/mol	Soaps and cosmetics, saponification of various oils

Table 5: Structures of identified compounds from *M. olifera* gums

 2(5H) - Furanone	 Betanedioic acid	 Didemnin B	 Cyclohexane
 Hexadecanoic acid	 Butanoic acid	 Acetic acid	 Dodecanoic acid

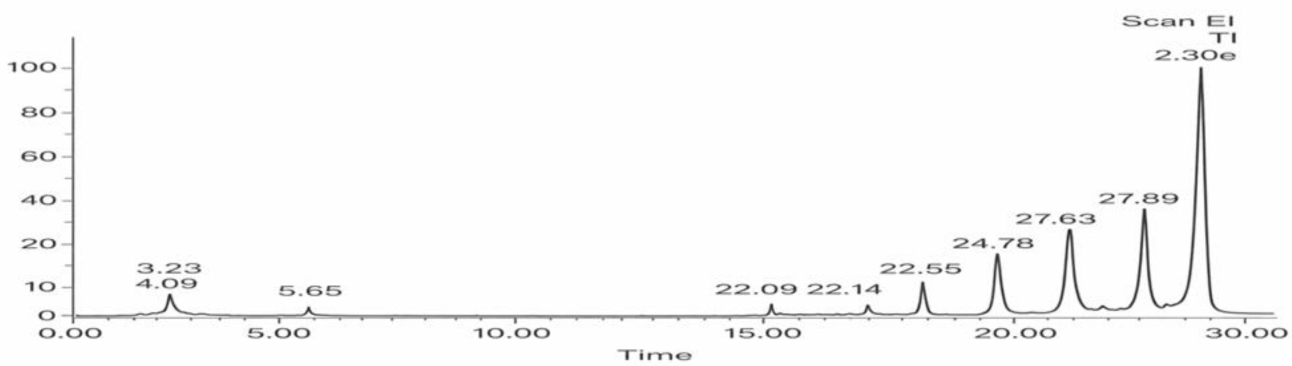


Figure 6: Biochemical constituents identified in the gums extract of *L. coromandelica* using GC-MS.

GC-MS analysis of *L. coromandelica* gums revealed a range of bioactive compounds, including oleic acid derivatives, squalene, delphinidin cation and 1,25-dihydroxyvitamin D3. Squalene offers antioxidant, chemo preventive and moisturizing properties, supporting cosmeceutical uses. Delphinidin cation provides anti-inflammatory and antioxidant benefits valuable for nutraceuticals. Oleic acid and its esters contribute to cardiovascular health and serve as emollients in soaps and cosmetics. Compounds such as dibutyl phthalate and heptacosane indicate industrial applications as plasticizers, thickeners and adhesive additives. This phytochemical diversity positions *L. coromandelica* gums as a versatile biomaterial for pharmaceutical, cosmetic, food and chemical industries, promoting sustainable utilization (Tables 6 and 7, Figure 6).

GC-MS analysis of *A. lebbeck* gums identified a range of bioactive compounds including various siloxanes, 2-myristynoyl pantetheine, 17-pentatriacontene and butanoic acid. The siloxane derivatives such as cyclotrisiloxane-hexamethyl, function as natural emollients and conditioners offering cosmetic applications as alternatives to synthetic silicones. Compounds like 2-myristynoyl pantetheine and 17-pentatriacontene provide anti-inflammatory and antimicrobial properties supporting the gums traditional medicinal uses. Butanoic acid contributes to flavouring and pharmaceutical applications, while fatty acid esters and phenolic derivatives indicate utility as thickeners and adhesive additives. This diverse phytochemical profile establishes *A. lebbeck* gums as a sustainable, multifunctional resource for pharmaceutical, cosmetic and industrial sectors (Tables 8 and 9, Figure 7).

Table 6: Characteristics of suggested compounds identified from GC-MS of *L. coromandelica* gums

Compound name	Molecular formula	Molecular weight	Uses
9-octadecenoic acid (Z)-hexyl ester	$C_{24}H_{46}O_2$	366.60 g/mol	Textile screen ink industry and the graphics arts industries
Ethylbenzene	C_8H_{10}	106.17 g/mol	Inks, pesticides and paints
Hexadecane1-bis (dodecyloxy)	$C_{40}H_{82}O_2$	595.08 g/mol	Radio labeling
O-xylene, 2-pyrrolidinone	C_4H_7NO	85.10 g/mol	Petrochemical and plastics industries as a solvent
1-methyl-, dibutyl phthalate	$C_{16}H_{22}O_4$	278.35 g/mol	Plasticizer in nitrocellulose lacquers, elastomers, explosives, nail polish and solid rocket propellants
Milnacipran	$C_{15}H_{22}N_2O$	246.35 g/mol	To treat fibromyalgia
Delphinidin	$C_{15}H_{11}ClO_7$	338.69 g/mol	Antioxidant
Oleic acid	$C_{18}H_{34}O_2$	282.5 g/mol	Preventing heart disease and reducing cholesterol
3-hydroxypropyl ester	$C_{21}H_{40}O_3$	340.5 g/mol	Resin coatings for food cans
Heptacosane	$C_{27}H_{56}$	380.7 g/mol	Soap and food additives

Table 7: Structures of identified compounds from *L. coromandelica* gums

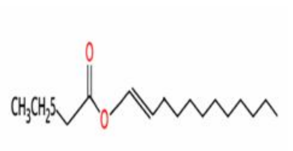
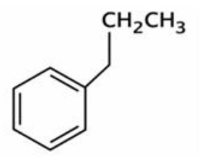
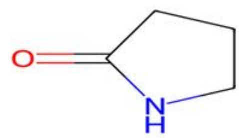
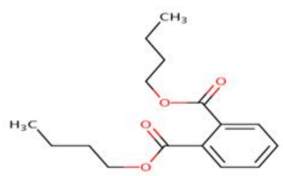
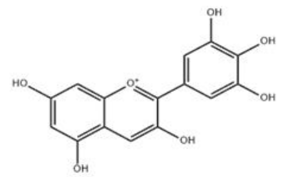
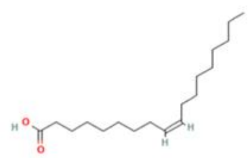
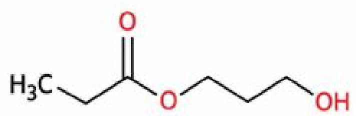
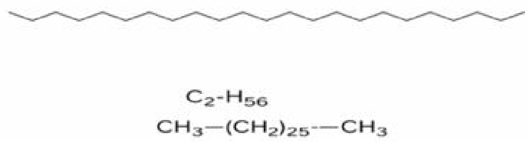
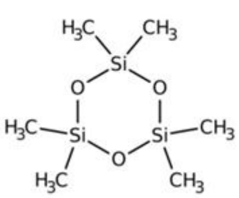
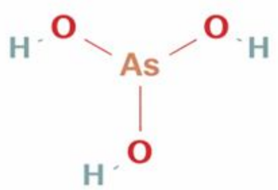
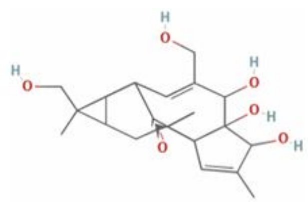
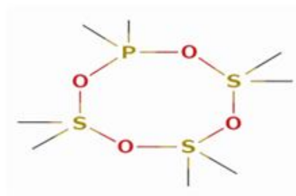
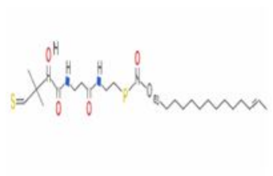
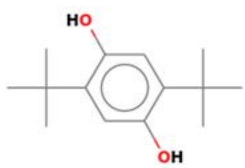
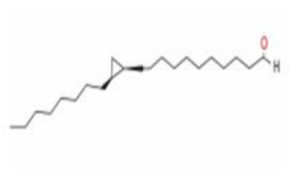
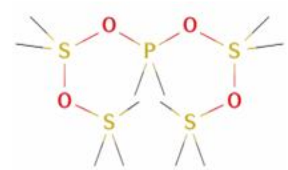
 **9-octadecenoic acid (Z) – hexyl ester**	 **Ethylbenzene**	 **Hexadecane 1-bis (dodecyloxy)**	 **O-xylene, 2-Pyrrolidinone**
 **1-methyl-, Dibutyl phthalate**	 **Milnacipran**	 **Delphinidin**	 **Oleic acid**
 **3-hydroxypropyl ester**		 **Heptacosane**	

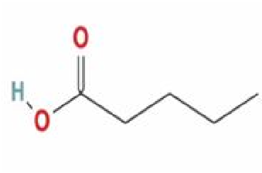
Figure 7: GC-MS profile illustrating the biochemical constituents present in the gums extract of *A. lebbeck*.

Table 8: Characteristics of suggested compounds identified from GC-MS of *A. lebbeck* gums

Compound name	Molecular formula	Molecular weight	Uses
Cyclotrisiloxane -hexamethyl	$C_6H_{18}O_3Si_3$	222.46 g/mol	Used as a lubricant, solvent and intermediate in organic synthesis. Conditioning agent, emollient
Arsenous acid	AsH_3O_3	125.944 g/mol	Used as a herbicide, pesticide and rodenticide.
Methanocyclopenta [a]cyclopropa [e]cyclodecen-11 one	$C_{20}H_{28}O_6$	364.4 g/mol	Pharmaceutical industries
Cyclotetrasiloxane -octamethyl	$C_8H_{24}O_4Si_4$	296.61 g/mol	used in the cosmetics industries
1,4-Benzenediol 2,6-bis(1,1-dimethylethyl)	$C_{14}H_{22}O_2$	222.32 g/mol	used for the isolation of impurities in preparative separation
2-Myristynoyl pantetheine	$C_{25}H_{44}N_2O_5S$	484.7 g/mol	Anti-inflammatory activity
Cyclopropanedodecanoic acid 2-octyl-, methyl ester	$C_{20}H_{38}O_2$	310.5 g/mol	Pharmaceutical industries
Cyclopentasiloxane-decamethyl	$C_{10}H_{30}O_5Si_5$	370.77 g/mol	Polymers, laboratory chemicals, cosmetics, personal care products, textile treatment products and dyes.
Butanoic acid	$C_4H_8O_2$	88.11 g/mol	Food additive varnishes industries, cosmetics, pharmaceuticals and disinfectants.
Dasycarpidan-1-methanol	$C_{20}H_{26}N_2O_2$	326.4 g/mol	Pharmaceutical and cosmetic industries
7,8-Epoxylanostan-11-ol 3-acetoxy	$C_{32}H_{54}O_4$	502.8 g/mol	Antimicrobial and anti-inflammatory effects
Cyclopropanebutanoic acid	$C_{11}H_{20}O_2$	184.27 g/mol	Therapeutic and industrial applications
17-Pentatriacontene	$C_{35}H_{70}$	490.9 g/mol	Anti-inflammatory, anticancer, antibacterial and antiarthritic properties

Table 9: Structures of identified compounds from *A. lebbeck* gums

 **Cyclotrisiloxane-hexamethyl**	 **Arsenous acid**	 **Methanocyclopenta [a] cyclo propa [e] cyclodecen-11 one**	 **Cyclotetrasiloxane-octamethyl**
 **2-Myristynoyl pantetheine**	 **1,4-Benzenediol 2,6-bis(1,1-dimethylethyl)**	 **Cyclopropane dodecanoic acid 2-octyl-, methyl ester**	 **Cyclopentasiloxane-decamethyl**



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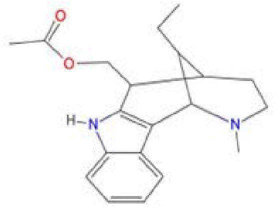
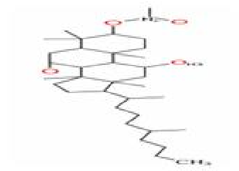
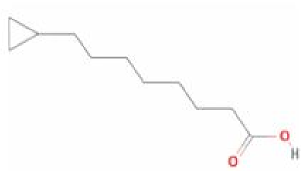


Dasycarpidan-1 -methanol



7,8-Epoxylanostan-11-ol 3-acetoxy



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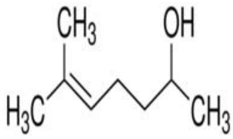


17-Pentatriacontene

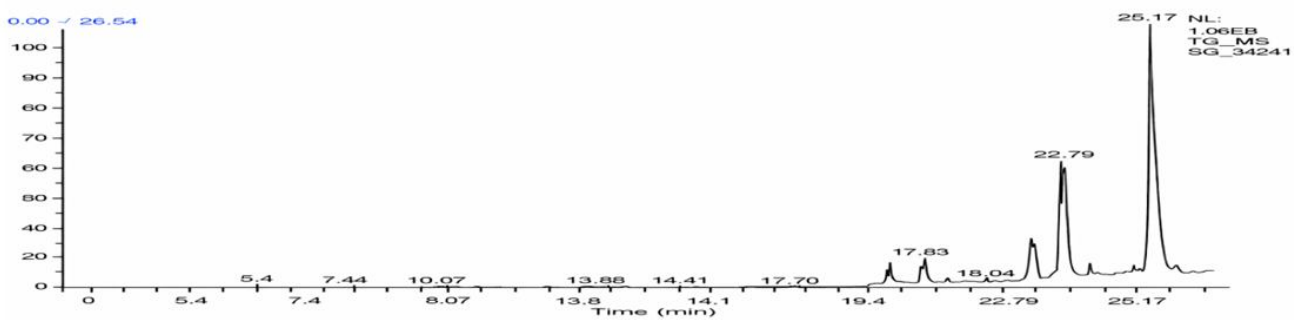


Figure 8: GC-MS characterization of biochemical constituents detected in the gums extract of *S. saman*.

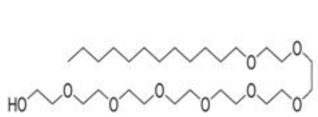
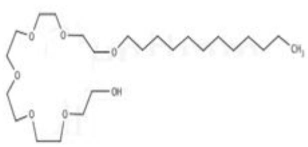
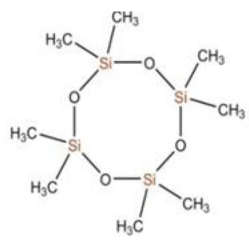
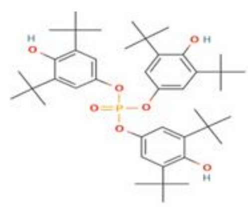
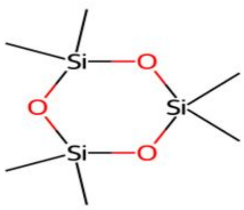
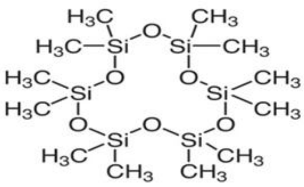
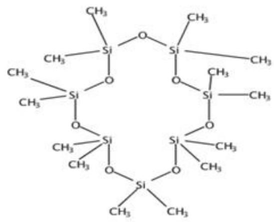
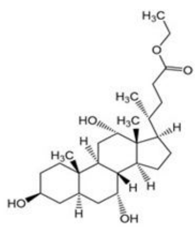
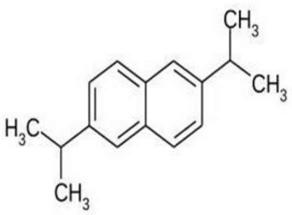
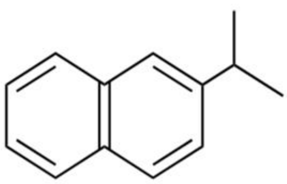
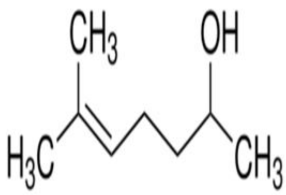
GC-MS analysis of *S. saman* gums revealed a rich profile of functional compounds including multiple cyclosiloxanes, glycol ethers, 2-undecenal and bioactive agents like 17-pentatriacontene. Cyclosiloxanes serve as natural emollients and conditioning agents, positioning the gums as a sustainable alternative to synthetic silicones in cosmetics. Fragrance contributing compounds such as 2-undecenal enhance its value in perfumery. Anti-inflammatory and antimicrobial activities suggested by 17-pentatriacontene and ethyl iso-allocholate support pharmaceutical potential. Additionally, glycol ethers and fatty acid esters enable industrial uses as thickeners, softeners, and adhesive additives. This diverse phytochemical portfolio affirms *S. saman* gums as a versatile, renewable resource for cosmetic, pharmaceutical and industrial applications (Tables 10 and 11, Figure 8).

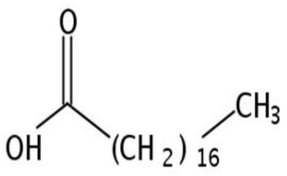
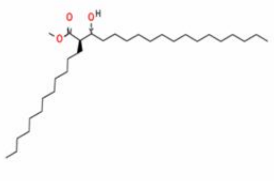
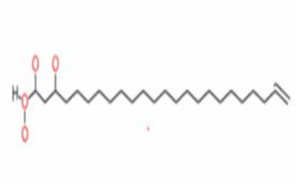
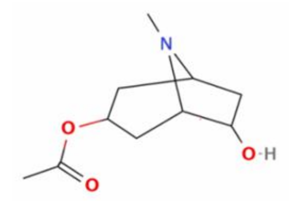
Table 10: Characteristics of suggested compounds identified from GC-MS of *S. saman* gums

Compound name	Molecular formula	Molecular weight	Uses
Octaethylene glycol monododecyl ether	$C_{28}H_{58}O_9$	538.8	*Used* in the production of detergents
Hexaethylene glycol monododecyl ether	$C_{26}H_{54}O_8$	494.7	Stabilizer in the biodegradable polymers and as a dispersant in the synthesis of nanocomposites
Cyclotetrasiloxane- octamethyl	$C_8H_{24}O_4Si_4$	296.61	Emollient for cosmetics, hair care products, skin care products, antiperspirants and deodorants
1,4-Benzenediol 2,6-bis(1,1-dim-ethylethyl)-4,4',4''-Phosphate	$C_{42}H_{63}O_7P$	710.9	*I*nhibitor, an antioxidant and as an intermediate chemical in the synthesis of dyes, motor fuels, and oils.
Cyclotrisiloxane-hexamethyl	$C_6H_{18}O_3Si_3$	222.46	Use as a lubricant, solvent and intermediate in organic synthesis
Cyclohexasiloxane-dodecamethyl	$C_{12}H_{36}O_6Si_6$	444.92	Hair/skin care products, antiperspirants and deodorants
2-Undecenal	$C_{11}H_{20}O$	168.28	Cosmetic industries

Cycloheptasiloxane-tetradecamethyl	$C_{14}H_{42}O_7Si_7$	519.07	Use as a film forming agent, lubricant, solvent and intermediate in organic synthesis
Ethyl iso-allocholate	$C_{26}H_{44}O_5$	436.6	Folk remedies in the form of decoctions and infusions to treat bacterial infections
1,3-diisopropylnaphthalene	$C_{16}H_{20}$	212.33	Manufacturing of carbonless copy paper, fuels and solvents
2,6-Diisopropylnaphthalene	$C_{16}H_{20}$	212.33	Used as solvents, pharmaceutical preparations, and as a chemical intermediate
17-Pentatriacontene	$C_{35}H_{70}$	490.9	Anti-inflammatory, anticancer, antibacterial, and antiarthritic properties
Octadecanoic acid	$C_{18}H_{36}O_2$	284.5	Hardening soaps, softening plastics and making cosmetics, candles and plastics
Methyl 3-hydroxy-2-tetradecy-loctadecanoate	$C_{33}H_{66}O_3$	510.9	Pharmaceutical and textile industries
22-Tricosenoic acid	$C_{23}H_{44}O_2$	352.6	Plant metabolite, a human metabolite and a Daphnia magna metabolite
3-Acetoxy – 6 - hydroxytropane	$C_{10}H_{17}NO_3$	199.25	Used as anticholinergic drugs

Table 11: Structures of identified compounds from *S. saman* gums

 Octaethylene glycol monododecyl ether	 Hexaethylene glycol monododecyl ether	 Cyclotetrasiloxane-octamethyl	 1,4-Benzenediol 2,6-bis (1,1-dimethylethyl) -4,4,4-Phosphate
 Cyclotrisiloxane -hexamethyl	 Cyclohexasiloxane-dodecamethyl	 Cycloheptasiloxane-tetradecamethyl	 2-Undecenal
 Ethyl iso-allocholate	 1,3-diisopropylnaphthalene	 2,6-Diisopropylnaphthalene	 17-Pentatriacontene

 Octadecanoic acid	 Methyl 3-hydroxy-2-tetradecyloctadecanoate	 22-Tricosenoic acid	 3-Acetoxy - 6 - hydroxytropane

4. Discussion

4.1 Functional properties and industrial implications

The superior hot water solubility of *M. oleifera* gums (92.5%) surpasses many commercially available gums and suggests excellent hydration capacity, making it suitable for pharmaceutical syrups, beverage stabilizers and food thickeners (Williams and Phillips, 2009). The significantly lower solubility in organic solvents confirms effective purification, removing non-polar contaminants while preserving the hydrophilic polysaccharide structure essential for hydrocolloid functionality (Mirhosseini and Amid, 2012).

The mildly acidic pH (4.4-5.8) observed across all gums is characteristic of plant exudates containing uronic acid residues in their polysaccharide backbone (Verbeken *et al*., 2003). This pH range must be considered in formulation design particularly for pharmaceutical applications where acid labile drugs require neutral or alkaline environments. However, this acidity may be advantageous in food systems requiring microbial stability or in topical formulations where slight acidity benefits skin health (Imeson, 2010).

The exceptionally low ash content of *M. oleifera* gums (1%) indicates high purity, meeting quality standards for pharmaceutical excipients where mineral impurities can interfere with drug stability and bioavailability (Anderson and Morrison, 1990). In contrast, the higher ash content in *A. lebbeck* gums (14%) suggests greater mineral content, which could be either advantageous for mineral supplementation or disadvantageous for certain purity sensitive applications.

4.2 Nutritional and therapeutic potential

The remarkable chlorophyll content in *L. coromandelica* gums (0.61 mg/ g) is unusual for exudate gums and may be attributed to specific metabolic pathways or collection from younger bark tissues. While chlorophyll may limit applications in colourless products, it offers significant benefits as a natural antioxidant and anti-inflammatory agent (Ferruzzi and Blakeslee, 2007). Chlorophyll derivatives have demonstrated chemopreventive properties against various cancers, suggesting potential therapeutic applications (Chernomorsky *et al*., 1999).

The presence of chlorophyll in an exudate gums is a noteworthy and rare occurrence, which suggests specific pharmaceutical applications distinct from conventional gums. In pharmaceutical formulations, chlorophyll is valued for its wound-healing promotion, deodorising properties and potential in photodynamic therapy. The inherent presence of chlorophyll in *L. coromandelica* gums could be leveraged to develop medicated dressings or topical gels that harness its tissue regenerative and anti-inflammatory effects directly without the need for a synthetic additive. This natural integration within a polysac charide matrix may enhance stability and controlled release in wound care products. Furthermore, chlorophyll's role in mitigating internal odours and supporting detoxification processes indicates its potential in oral gastrointestinal therapeutics, where the gums could act as both a bioactive carrier and an active ingredient.

The substantial vitamin C content across all gums particularly in *M. oleifera* (220 mg/100 g) enhances their nutraceutical value. Vitamin C (ascorbic acid) functions as a potent water-soluble antioxidant that can synergise with other phytochemicals in the gums to provide enhanced oxidative protection (Carr and Frei, 1999). This combination suggests potential applications in functional foods, dietary supplements, and natural preservative systems. The absence of detectable peroxide values in all gums indicates excellent oxidative stability-a critical factor for commercial applications requiring extended shelf-life. This stability likely results from the synergistic action of endogenous antioxidants, including vitamin C, tannins and other phytochemicals identified through GC-MS analysis (Shahidi and Zhong, 2005).

4.3 Mineral composition and health implications

The exceptional calcium content in *L. coromandelica* gums (1024.41 mg/100 g) positions it as a promising natural calcium source for food fortification particularly relevant given widespread calcium deficiency in various populations households. The high iron content in *A. lebbeck* gums (9.97 mg/100 g) combined with its substantial potassium levels (943.26 mg/100 g) suggests applications in nutritional supplements targeting anaemia and electrolyte balance. The presence of antinutritional factors, tannins and phytic acid requires balanced interpretation. While excessive levels can impair mineral absorption, moderate concentrations offer significant health benefits. The high tannin content in *M. oleifera* gums (2.10%) contributes antioxidant, antimicrobial and anti-inflammatory properties (Serrano *et al*., 2009). Phytic acid in *A. lebbeck* gums (2.95%) functions as an antioxidant and has demonstrated chemo preventive potential against colon cancer through multiple mechanisms including mineral chelation and modulation of cell signaling pathways (Graf and Eaton, 1990).

4.4 Bioactive compounds and therapeutic applications

The GC-MS analysis reveals a rich phytochemical diversity with significant therapeutic implications. The identification of didemnin B in *M. oleifera* gums is particularly noteworthy as this compound is a potent antiviral and antitumor depsipeptide originally isolated from marine tunicates (Rinehart *et al*., 1981). Its presence in a terrestrial plant source opens new avenues for the sustainable production of this valuable compound. *L. coromandelica* gums contains several compounds with established health benefits: Oleic acid, a cardioprotective monounsaturated fatty acid; Squalene, a superior skin moisturizer with demonstrated chemopreventive properties and delphinidin, an anthocyanidin with potent antioxidant and anti-inflammatory activities (Prior and Wu, 2006). This combination suggests applications in cardiovascular health products, skincare formulations and anti-inflammatory supplements. The prevalence of siloxane derivatives in both *A. lebbeck* and *S. saman* gums is significant for cosmetic applications. These compounds, typically synthesized for use as emollients and conditioners occur naturally in these gums, offering sustainable alternatives to synthetic silicones in natural and organic cosmetic formulations (Baki, 2022). 17-pentatriacontene, identified in both *A. lebbeck* and *S. saman* gums has demonstrated anti-inflammatory, anticancer, antibacterial and antiarthritic properties in previous studies. Similarly, 2-myristoyl pantetheine in *A. lebbeck* gums shows anti-inflammatory activity supporting traditional uses of this gums in inflammatory conditions.

4.5 Species specific compounds, benefits and recommendations

Based on the comprehensive analysis each gums exhibits unique properties suggesting specific applications:

- ***M. oleifera* gums:** Superior solubility, low ash content, rich in vitamin C and tannins contains didemnin B. Recommended for: Pharmaceutical formulations requiring high clarity and solubility, antioxidant supplements and natural preservative systems.
- ***L. coromandelica* gums:** High chlorophyll and calcium content contains oleic acid and squalene. Recommended for: Calcium fortified foods, green colored natural products, skincare formulations and cardiovascular health supplements.
- ***A. lebbeck* gums:** High protein, iron and potassium content rich in siloxanes and anti-inflammatory compounds. Recommended for: Emulsification applications, mineral supplements, natural cosmetic ingredients and anti-inflammatory formulations.
- ***S. saman* gums:** Contains diverse siloxanes and bioactive compounds. Recommended for: Cosmetic applications requiring emollient properties, adhesive formulations and pharmaceutical preparations with specific compound requirements.

4.6 Sustainability and economic implications

The cultivation of these tree species in agroforestry systems offers environmental benefits including soil conservation, carbon sequestration and biodiversity preservation. The sustainable harvesting of exudate gums provides additional economic returns without necessitating tree felling, aligning with principles of sustainable forest management and circular bioeconomy (Panda, 2010). The valorization of these underutilized gums can contribute to rural livelihood enhancement while promoting conservation of indigenous tree species.

4.7 Limitations and way forward

While the present study offers a comprehensive characterization of the selected plant exudate gums, several aspects merit further investigation. First, detailed toxicological evaluations of the identified bioactive compounds are essential, particularly for those exhibiting established or predicted pharmacological activities. Second, systematic *in vitro* and *in vivo* studies are required to validate the therapeutic potential inferred from the phytochemical profiles. Third, optimization of extraction and purification protocols should be undertaken to enhance yield, reproducibility, and feasibility for large scale commercial applications. Additionally, investigations into possible synergistic or antagonistic interactions among the constituent compounds are necessary to better understand their combined biological effects. Stability studies under diverse storage and processing conditions are also crucial to assess shelf-life and functional integrity. Furthermore, the development of targeted formulations based on the identified bioactivities would facilitate translational and industrial applications.

5. Conclusion

Among the four gums samples, *viz., M. oleifera, L. coromandelica, A. lebbeck and S. saman*, *M. oleifera* gums showed more solubility (92.5%) in hot water when compared with other gums samples. Among the different solvents used for solubility studies hot water showed more solubilizing capacity than other solvents. Biochemical constituents of different gums samples were identified through gas chromatography and mass spectrometry. The identified components can be used as raw materials and find applications in pharmaceutical industries, soap and cosmetics industries, varnish industries, thickening agents, additives to adhesives and softening agents. Specifically all four gums yielding tree species have high potential of yielding more number of phytochemicals with a variety of applications in the field of pharmaceutical industries.

Acknowledgements

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Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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