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Exploring the phytochemicals of *Bombax ceiba* (L.) flower extract using GC-MS: An updated study

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Abstract
Background: *Bombax ceiba* (L.) is known by herbal medicine due to its rich chemical constituents and remarkable ethnomedicinal and pharmacological properties.
Aim: In this study, the phytochemical composition of the *B. ceiba* flower was described by GC-MS analysis of its petroleum ether and ethanol extracts.
Results: The petroleum ether extract contained eight phytoconstituents, with two major compounds, 6-Octen-1-ol, 3,7-dimethyl-, formate at the highest concentration of 50.89% and Triacontane at 15.40%. The ethanol extract revealed the presence of twenty phytoconstituents, among which 5-Hydroxymethylfurfural (39.04%), Pentadecanoic acid (11.55%), and 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-(10.22%) were the most dominant. Phytochemicals isolated in both extracts displayed remarkable biological activities, such as antioxidant, anti-inflammatory, antimicrobial, anticancer, and hepatoprotective activities.
Conclusion: The findings establish that *B. ceiba* flower extracts possess tremendous potential for therapeutics and industries, thus forming a strong basis for further pharmacological studies.

Keywords: *Bombax ceiba*, GC-MS analysis, petroleum ether, and ethanol extract

1. Introduction
It is believed that 80% of the global population, primarily in developing nations, remains dependent on herbal remedies for healthcare. People residing in villages or rural areas with limited access to healthcare facilities continue to utilize their expertise and knowledge of various plant items for the treatment of diverse diseases [1]. *Bombax ceiba* (L.) plays a significant role in the herbal system of medicine, with a broad array of chemical constituents, and combines ethnomedicinal and pharmacological properties. *B. ceiba* is the family belonging to Bombacaceae, also commonly identified as Semal, Simbal, Simul, Indian Kapok, Indian Bombax, or red silk cotton tree, found in temperate Asia, tropical Asia, Australia, and Africa. The tree is very common in dry areas and also in moist deciduous forests and river areas. On deep sandy loams or well-drained soils, it grows very well, particularly in valleys [2]. The chemical constituents of *B. ceiba* reports have shown the presence of glycosides and tannins in roots, stems, and leaves. Some alkaloids are identified in the stem and roots, and proteins are identified. Stem bark and root contain mangiferin, luped, and β-sitosterol. The root bark has 3 naphthalene derivatives related to gossypol (toxic principle of cotton seed) and is called 'semi gossypol'. The flowers contain β-sitosterol, traces of essential oil, Kaempferol, and quercetin. Gums yield arabinose, galactose, galacturonic acid, and rhamnose on hydrolysis [3]. The ethnobotanical survey of *B. ceiba* has reported various diseases likewise; inflammation, microbial infections, algesia, hepatotoxicity, hypertension, angiogenesis, HIV, fever, catarrhal affection, dysentery, ulceration of the bladder, acne, piles, gynecological disorders, and urinary infections. The roots and flowers of this plant are regarded as having diuretic, laxative, tonic, and restorative properties. The leaves are reported in treatment of skin eruptions. The tender bark is used as famine food. The tender bark is demulcent, emetic and tonic. The aqueous extract of tender bark is mixed with curd to check blood-dysentery [4]. In another study, it was demonstrated that *B. ceiba* has potential anti-helicobacter pylori activity. It has been revealed in a recent study that the plant possesses strong anti-inflammatory, immunomodulatory, antioxidant, antineoplastic, hypotensive, anticancer, hypolipidemic, and antihyperglycemic activities [5]. Previous pharmacological studies have reported that *B. ceiba* exhibits hepatoprotective [6-8], antioxidant [9-14], immunomodulatory [12], antimicrobial [10, 15, 16],

antiproliferative [9,17], antiangiogenic [18], hypoglycemic [19], hypolipidemic [20], hypotension [19], anti-obesity [15], anti-inflammatory, and anthelmintic [21]. Previous and current studies have extensively explored the phytochemical and pharmacological properties of B. ceiba, revealing its therapeutic potential in traditional and modern medicine. However, additional research is essential to uncover the full scope of its bioactive phytoconstituents and their mechanisms of action have yet to be investigated more extensively. Thus, the present study focused on extending knowledge regarding phytoconstituents of *B. ceiba* by using GC-MS analysis.

2. Materials and Methods

Chemicals

Petroleum ether (Merck), ethanol (Merck)

Collection of *B. ceiba* flower

Samples of *Bombax ceiba* flowers have been collected from Gandhamardhan Hills, Odisha; one specimen is being sent to Shree Ram College, Rampur, Sonepur, and Odisha for confirmation from botanist S.K. Barpanda, along with the voucher specimen number TPC/COL/22/020.

Extraction of the samples

The flowers were washed with distilled water and shade-dried at room temperature until dry. The sample after drying was coarsely ground using a mechanical grinder. Then, 100 g of powdered sample was treated with hot continuous extraction (Soxhlet extraction), by petroleum ether at 40-60 °C, followed by ethanol at 60-70 °C as solvents. Extracts were filtered using Whatman filter paper, and the solutions were concentrated with the use of a rotary evaporator.

GC-MS analysis

The methanolic extract of *Bombax ceiba* was analyzed using a Thermo Scientific TSQ 8000 Gas Chromatograph-Mass Spectrometer (GC-MS). The gas chromatography system featured Split/Splitless injectors, a Programmed Temperature Vaporizing (PTV) intake, and sustained a column temperature of 400 °C, alongside a TRACE 1300 GC and an auto-sampler for automated processing. Approximately 1 µl of the extract was injected via a micro-syringe, and the analytical cycle lasted for 31.08 minutes, using helium as the carrier gas at a constant flow rate of 1 ml/min, with the ion source temperature maintained at 350 °C. All noted components comprised names, chemical formulae, and molecular weights, derived from data obtained from the NIST library [22].

3. Results and Discussion

GC-MS analysis of petroleum ether extract of *B. ceiba* flower has possessed 8 phytoconstituents, among these, two compounds showed the highest percentages namely 6-Octen-1-ol, 3,7-dimethyl-, formate (50.89), and Triacontane (15.40), and the rest of the compounds were γ-Sitosterol (9.97), Tetratriacontane (9.11), 1-(+)-Ascorbic acid 2,6-dihexadecanoate (7.28), n-Hexadecanoic acid (3.70), Hexatriacontane (2.04), Eicosane (1.61) (Table 1). Ethanol extract of *B. ceiba* flower revealed 20 phytoconstituents. Three compounds had highest percentages namely; 5-Hydroxymethylfurfural (39.04), Pentadecanoic acid (11.55), 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl- (10.22), and rest compounds were, 9,12-Octadecadienoic acid (Z, Z)-(8.76), Tetradecanoic acid (4.20), Erythritol (4.03), Scopoletin (3.84), Desulphosinigrin (2.97), Glycerin (2.83), Octadecanoic acid (2.21), Hexadecanoic acid, ethyl ester (2.02), α-D-Glucopyranoside, O-α-D-glucopyranosyl-(1. fwdarw.3)-β-D-fructofuranosyl (1.86), 9,12-Octadecadienoic acid, ethyl ester (1.26), Diethyl phthalate (1.13), 1H-2-Indenone, 2,4,5,6,7,7a-hexahydro-3-(1-methylethyl)-7a-methyl (1.10), Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-(0.76), Hexadecanoic acid, methyl ester (0.63), Dibutyl phthalate (0.58), Phytol (0.55), 9,12-Octadecadienoic acid (Z, Z)-, methyl ester (0.46) (Table 2). The chromatograms are presented in Figures 1 and 3, while the chemical structures of the identified compounds are illustrated in Figures 2 and 4, respectively.

The compound with the highest concentration in the petroleum ether extract 6-Octen-1-ol, 3,7-dimethyl-, formate showed flavoring and fragrance, Antitumor, antibacterial, and antifungal activity [23]. Whereas, the alkane compound Triacontane has possessed Antibacterial, antidiabetic, and antitumor activities [24]. Additionally, γ-Sitosterol, a steroid compound showed various pharmacological properties, including anti-cancerous, antihyperglycemic, hepatoprotective, and antidiabetic effects [25]. The long-chain alkane compound, Tetratriacontane was found to possess antibacterial and antifungal activity [26]. 1-(+)-Ascorbic acid 2,6-dihexadecanoate exhibited a wide range of biological activities, including Antioxidant, anti-scorbutic, anti-inflammatory, anti-antinociceptive, anti-mutagenic, and wound healing properties [27]. In the ethanolic extract, the major compound 5-Hydroxymethylfurfural was identified as having antioxidant activity. The saturated fatty acid pentadecanoic acid possessed antimicrobial, antioxidant, and antibacterial properties as well as application as a lubricant, and adhesive agent [28, 29]. Another significant compound, 4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-revealed antibacterial activity [30].

Table 1: GC-MS analysis of petroleum ether extract of *B ceiba* Flower

SI. No.	RT	Name of the compound	Nature of Compound	Molecular formula	Molecular weight	Peak area %	Biological activity
1	5.43	6-Octen-1-ol, 3,7-dimethyl-, formate	Carboxylic ester	$C_{11}H_{20}O_2$	184.28	50.89	Antitumor, antibacterial, antifungal, flavoring, and fragrance [23].
2	13.92	n-Hexadecanoic acid	Palmitic acid ester	$C_{16}H_{32}O_2$	256.42	3.70	Antioxidant, hypocholesterolemic, nematicide, Anti-androgenic, Hemolytic, Pesticide, Lubricant [31]. Antifungal, Antioxidant, Hypocholesterolemic Nematicide, Anti-androgenic Flavour, Haemolytic 5-Alphareductase Inhibitor, Potent Antimicrobial Agent, Antimalarial and Antifungal [26].
3	13.97	1-(+)-Ascorbic acid 2,6-dihexadecanoate	Fatty acid ester	$C_{38}H_{68}O_8$	652.90	7.28	Antioxidant, anti-scorbutic, anti-inflammatory, anti-antinociceptive, anti-mutagenic, wound healing property [27].
4	18.69	Eicosane	Alkane	$C_{20}H_{42}$	282.55	1.61	Antifungal, antibacterial, antitumor, cytotoxic [22].
5	20.42	Triacontane	Alkane	$C_{30}H_{62}$	422.82	15.40	Antibacterial, antidiabetic, and antitumor activities [24].
6	21.47	Hexatriacontane	Alkane	$C_{36}H_{74}$	506.97	2.04	Radical scavenger [26].
7	22.75	Tetratriacontane	Long chain alkane	$C_{34}H_{70}$	478.92	9.11	Antibacterial and antifungal activity [26].
8	23.89	γ-Sitosterol	Steroid	$C_{29}H_{50}O$	414.71	9.97	Anti-cancerous, antihyperglycemic activity, hepatoprotective, and antidiabetic drug [25].

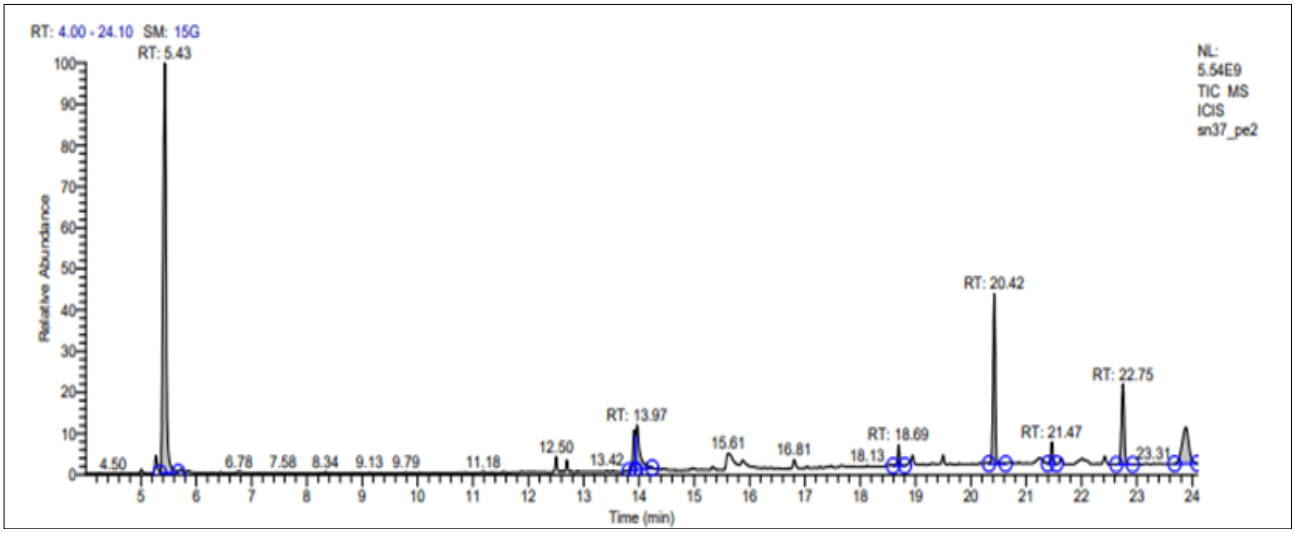

Fig 1: GC-MS chromatogram of the petroleum ether extracts of *Bombax ceiba* flowers

Table 2: GC-MS analysis of ethanol extract of *B ceiba* Flower

SI. No.	RT	Name of the compound	Nature of compound	M.F.	M.W. (g/mol)	Peak area %	Biological activity
1	4.60	4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-	Dihydropyranones	$C_6H_8O_4$	144.12	10.22	Antibacterial [30].
2	5.00	Glycerin	Simple polyol	$C_3H_8O_3$	92.09	2.83	A potent osmotic dehydrating agent with additional effects on brain metabolism, decreases intracranial pressure (Reye's syndrome, stroke, encephalitis, meningitis, pseudotumor cerebri, central nervous system tumor, and space-occupying lesions), glaucoma [22].
3	5.46	Erythritol	Natural sugar alcohol	$C_4H_{10}O_4$	122.12	4.03	Not reported
4	5.79	5-Hydroxymethylfurfural	Organic compound	$C_6H_6O_3$	126.11	39.04	Antioxidant activity. [32]
5	8.66	Benzene, 1-(1,5-dimethyl-4-hexenyl)-4-methyl-	Aromatic monoterpenoid	$C_{15}H_{22}$	202.33	0.76	Skincare products Anti-inflammatory Anticancer, Antioxidant activity [33].
6	9.91	Diethyl phthalate	Phthalate ester	$C_{12}H_{14}O_4$	222.23	1.13	Estrogenic activity, Antimicrobial, Plasticizer, Antioxidant activity [26].
7	11.80	α-D-Glucopyranoside, O-α-D-glucopyranosyl-(1. fwdarw.3)-β-D-fructofuranosyl	-	$C_{18}H_{32}O_{16}$	504.44	1.86	Preservatives [34].
8	11.88	Tetradecanoic acid	Saturated fatty acid	$C_{14}H_{28}O_2$	228.37	4.20	Antioxidant, Nematicidal, Hypocholesterolemic, Anticancer activity [26].
9	12.17	Desulphosinigrin	-	$C_{10}H_{17}NO_6S$	279.31	2.97	Anticancer activity [35].
10	13.55	Hexadecanoic acid, methyl ester	Fatty acid methyl ester	$C_{17}H_{34}O_2$	270.45	0.63	Not reported
11	13.88	Dibutyl phthalate	Benzoic acid ester	$C_{16}H_{22}O_4$	278.34	0.58	Antimicrobial, Antifouling activity [36].
12	14.00	Pentadecanoic acid	Saturated fatty acid	$C_{15}H_{30}O_2$	242.39	11.55	Antimicrobial, Antioxidant, Antibacterial activity [29]. Lubricants, Adhesive agents [28].
13	14.23	Hexadecanoic acid, ethyl ester	Fatty acid ester	$C_{18}H_{36}O_2$	284.47	2.02	Antimicrobial, Antioxidant activity [29]. Antioxidant, Hemolytic, Hypocholesterolemic, Flavor, Nematicide, Anti-androgenic activity [31].
14	14.33	Scopoletin	Phenolic coumarin	$C_{10}H_8O_4$	192.16	3.84	Scopoletin plays an important role in treating various diseases such as Alzheimer's disease, anxiety, cancer, depression, epilepsy, esophagitis, diabetes, gastric ulcer, hypertension, hyperuricemia, inflammation, obesity, rheumatoid arthritis, thyroid, tuberculosis, tumor [37].
15	14.48	1H-2-Indenone, 2,4,5,6,7,7a-hexahydro-3-(1-methyl ethyl)-7a-methyl	-	$C_{13}H_{20}O$	192.29	1.10	Hepatoprotective, Herbicide, HIV-RT-inhibitor, Histamine inhibitor, Hypercholesterolemic activity [38].
16	15.19	9,12-Octadecadienoic acid (Z, Z)-, methyl ester	Fatty ester	$C_{19}H_{34}O_2$	294.47	0.46	Not reported
17	15.38	Phytol	Acyclic diterpenoid	$C_{20}H_{40}O$	296.53	0.55	Antimicrobial, Anti-inflammatory, anti-cancer, Diuretic, Antifungal against S. typhi, resistant gonorrhea, joint dislocation, headache, hernia, stimulant, and antimalarial activity [39].
18	15.62	9,12-Octadecadienoic acid (Z, Z)-	Saturated fatty acid	$C_{18}H_{32}O_2$	280.44	8.76	Not reported
19	15.81	9,12-Octadecadienoic acid, ethyl ester	Polyunsaturated fatty acid	$C_{20}H_{36}O_2$	308.49	1.26	Hepatoprotective, antihistaminic, hypocholesterolemic, anti-eczemic activity [31].
20	15.87	Octadecanoic acid	Saturated fatty acid	$C_{18}H_{36}O_2$	284.47	2.21	Antimicrobial activity, dietary supplements, softening agent, surfactant [22]. Antifungal, Antitumor, Antibacterial activity [39].

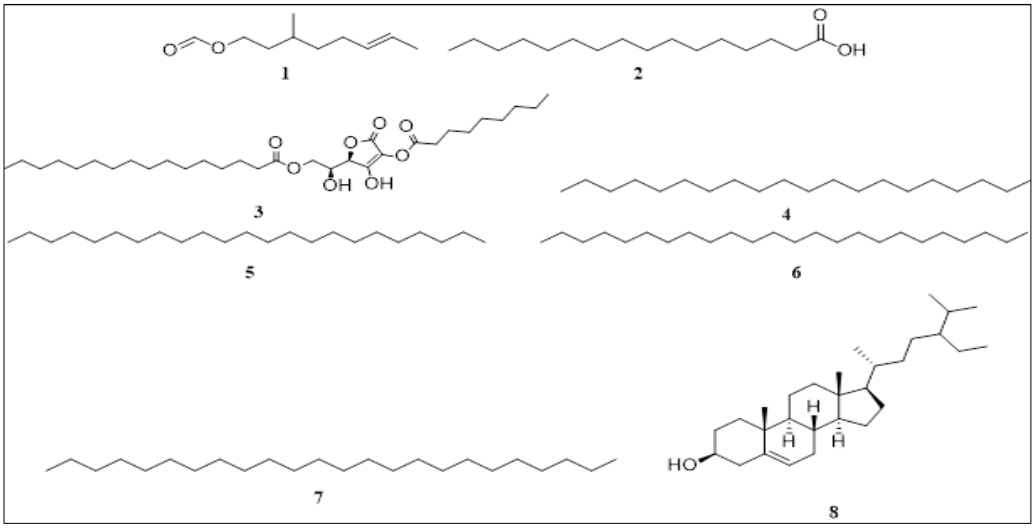

Fig 2: Structure of the compounds from GC-MS analysis of petroleum ether extract of *B. ceiba* flower

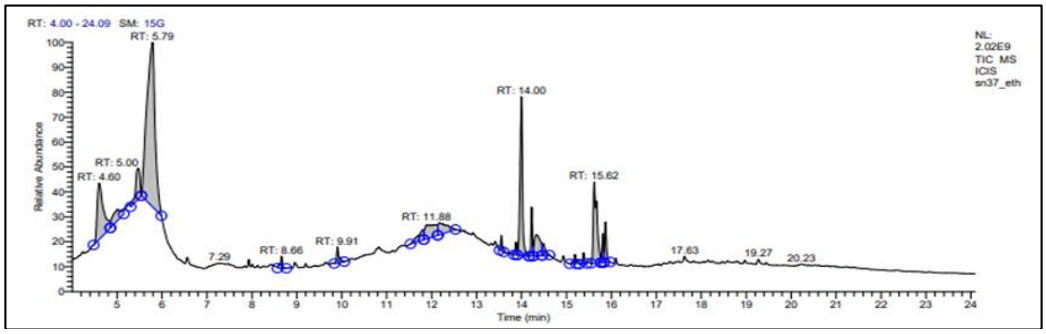

Fig 3: GC-MS chromatogram of the ethanol extract of *Bombax ceiba* flower

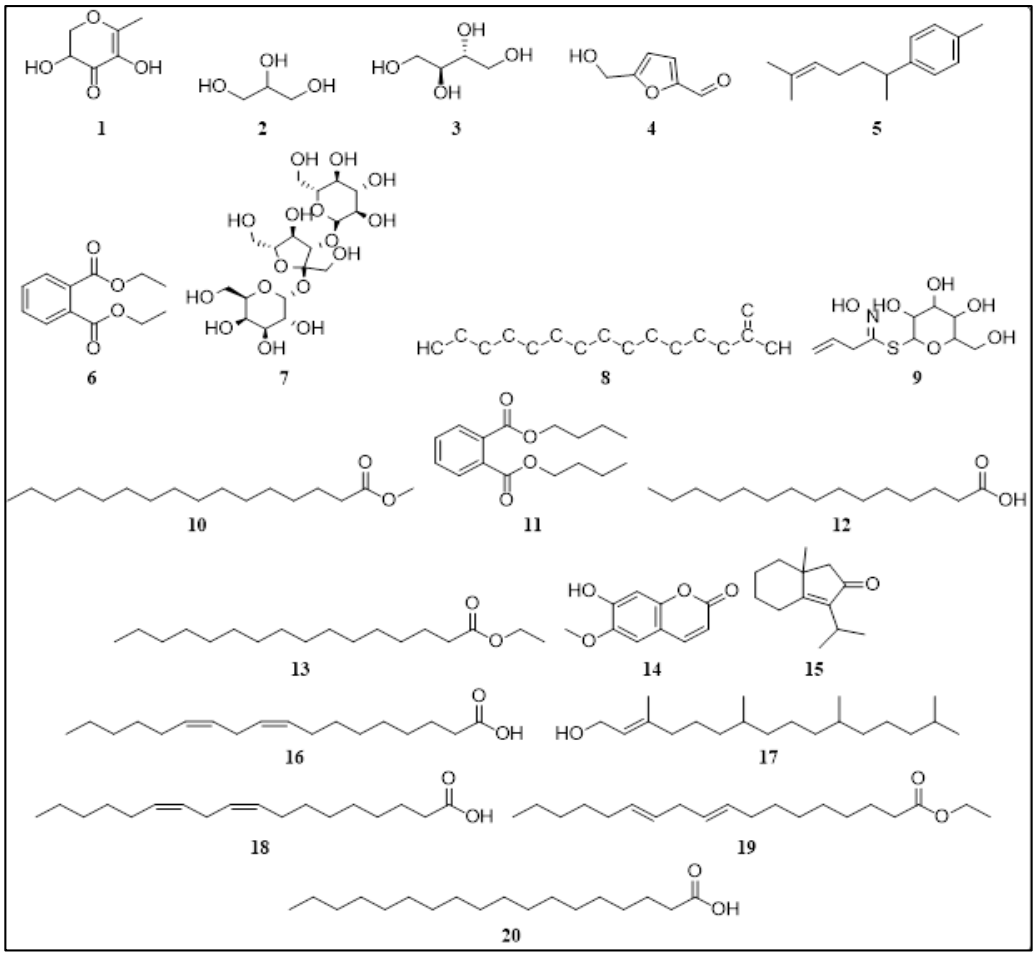

Fig 4: Structure of the compounds from GC-MS analysis of ethanol extract of *B. ceiba* flower

Conclusion

The presence of these phytoconstituents suggests the bioactive potential of *B. ceiba* flower extracts. The petroleum ether and ethanol extract demonstrated the presence of terpenoids, hydrocarbons, fatty acids, esters, and phenolics. These findings indicate the potential therapeutic and industrial applications of the identified compounds and provide a foundation for further pharmacological studies.

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Conflict of Interest

No conflict of interest

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