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Phytochemical profile and GC-MS analysis of *Flacourtia jangomas* fruit for therapeutic applications

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Abstract. *Debnath P, Shill BR, Sarkar KK. 2025. Phytochemical profile and GC-MS analysis of* Flacourtia jangomas *fruit for therapeutic applications. Biodiversitas 26: 6140-6150.* The application of natural compounds and their structural analogs plays a pivotal role in modern pharmacotherapy. *Flacourtia jangomas*, a member of the Salicaceae family, is known for its traditional medicinal uses and pharmacological potential. The present study aimed to characterize the phytochemical constituents of hydroalcoholic whole-fruit extracts of *F. jangomas* through preliminary phytochemical screening and Gas Chromatography-Tandem Mass Spectrometry (GC-MS/MS). Qualitative analysis revealed the presence of alkaloids, carbohydrates, flavonoids, glycosides, saponins, and terpenoids. GC-MS/MS analysis identified 23 bioactive compounds, with Glycidyl Palmitate (30.92%) and 5-Hydroxymethylfurfural (13.92%) being the most abundant. Other compounds included 3-Methylthiophene-2-carboxamide (5.46%), (2R,6R)-2-Heptyl-6-Methylpiperidine (2.77%), Sebacic acid, isohexyl 2-naphthyl ester (1.72%), Sedoheptulosan (1.69%), 2(5H)-Furanon (1.53%), 1,2-Ethanediol, Dipropionate (1.27%), 2-Furancarboxylic Acid, Hydrazide (1.15%), and Trans-2-Methyl-4-N-Butylthiane, S,S-Dioxide (1.09%), and others in lower concentrations. A number of compounds identified in the sample through GC-MS/MS analysis have been previously reported to exhibit antioxidant properties. The presence of antioxidant, anti-inflammatory, and antidiabetic metabolites such as glycidyl palmitate, 5-hydroxymethylfurfural, eugenol, and coumarin supports its traditional medicinal uses. These results highlight the potential application of *F. jangomas* fruit extracts in the development of functional foods, nutraceuticals, and plant-based pharmaceuticals aimed at managing oxidative stress-related disorders, metabolic diseases, and chronic inflammatory conditions.

Keywords: Bioactive compounds, Flacourtiaceae, *Flacourtia jangomas*, GC-MS/MS, glycidyl palmitate

INTRODUCTION

Natural products have long been recognized as a prolific source of bioactive compounds with significant pharmacological potential, particularly due to their antioxidant properties and their roles in disease prevention and management. The search for biologically active metabolites from natural sources continues to be a cornerstone of drug discovery, with more than 200,000 structurally diverse and therapeutically relevant compounds isolated from plants to date (Dincheva et al. 2023; Gorlenko et al. 2024). Globally, approximately 80% of the population—especially in developing countries—relies on traditional and complementary medicine (T&CM) for primary healthcare because of its accessibility, cultural acceptance, and perceived efficacy (Miranda 2021; Hoenders et al. 2024). Correspondingly, the global medicinal herbs market, valued at USD 165.66 billion in 2022, is projected to reach USD 347.50 billion by 2030 (Data Bridge Market Research 2022).

Medicinal plants are rich sources of bioactive compounds—commonly termed phytochemicals—such as alkaloids, flavonoids, phenolics, terpenoids, glycosides, tannins, and saponins. These secondary metabolites exhibit a wide spectrum of pharmacological activities, including antioxidant, anti-inflammatory, antimicrobial, anticancer, and antidiabetic effects. Their therapeutic efficacy is often attributed to synergistic or additive interactions among multiple constituents, allowing simultaneous modulation of several biological targets while reducing adverse effects and drug resistance (Newman and Cragg 2020; Olivia et al. 2021). However, the phytochemical composition of plant extracts varies depending on species, plant part, geographic origin, seasonal conditions, and extraction technique. For example, marked variations in flavonoid levels in *Ginkgo biloba* and alkaloid content in *Catharanthus roseus* have been linked to such environmental and processing factors (Smith et al. 2021). Extraction methods, particularly hydroalcoholic extraction, can markedly influence the yield and diversity of recovered metabolites (Jurčević and Šamec 2024). Therefore, standardization and chemical profiling are critical for ensuring the quality, safety, and reproducibility of herbal preparations (Mukherjee 2019; Waksmundzka-Hajnos et al. 2022).

Oxidative stress, arising from excessive production of reactive oxygen species (ROS) and reactive nitrogen species (RNS), is a major contributor to cellular damage and chronic diseases such as cancer, cardiovascular and neurodegenerative disorders, diabetes, and inflammation. Although ROS and RNS play physiological roles in cell signaling and immune defense, their overproduction disrupts redox homeostasis by oxidizing lipids, proteins, and nucleic acids. The human body employs endogenous antioxidant enzymes to counteract these effects, yet dietary

antioxidants—particularly those derived from plants—offer additional protection. Phytochemicals such as polyphenols, flavonoids, alkaloids, and terpenoids act as potent antioxidants by scavenging free radicals, chelating pro-oxidant metal ions, inhibiting oxidizing enzymes, and activating the Nrf2-Keap1-ARE signaling pathway to enhance cellular defense mechanisms. Furthermore, many phytochemicals exert anti-inflammatory and cytoprotective effects and may be biotransformed by gut microbiota into metabolites with improved bioavailability and activity (Xiao et al. 2022; Myhrstad and Wolk 2023; Tumilaar et al. 2024).

Flacourtia jangomas (Lour.) Raeusch., commonly known as Indian coffee plum, belongs to the family Salicaceae and is a small, fruit-bearing tree widely distributed in tropical and subtropical regions of South and Southeast Asia, including Bangladesh, India, Nepal, Bhutan, Myanmar, and Sri Lanka. It thrives in moist deciduous forests, rural homesteads, and forest edges, exhibiting remarkable adaptability to diverse soil and climatic conditions (Kumar et al. 2024). Despite its ecological abundance and extensive use in traditional medicine, the species remains underutilized and scientifically underexplored. Ethnobotanical surveys report that *F. jangomas* has long been used in traditional healing systems for the treatment of fever, dysentery, toothache, and particularly metabolic disorders such as diabetes (Chowdhury et al. 2024). Its fruits are valued for their rich polyphenolic and flavonoid content, which contribute to their therapeutic and nutritional properties (Biswas et al. 2022). Phytochemical investigations have revealed that *F. jangomas* contains a wide spectrum of secondary metabolites, including flavonoids, phenolics, alkaloids, tannins, limonoids, and coumarins. Advanced analytical techniques such as GC-MS and HPLC have identified bioactive compounds such as limolin, ostruthin, hydnocarpic acid, and jangomolide, which are believed to contribute to the plant's pharmacological actions (Thamer and Thamer 2023; Pai and Shenoy 2023). However, limited research employing advanced tools like Gas Chromatography-Tandem Mass Spectrometry (GC-MS/MS) has been conducted to comprehensively elucidate its chemical composition and bioactive potential at the molecular level. Pharmacological studies have demonstrated that *F. jangomas* exhibits a wide range of biological activities. Methanolic extracts of the leaves and stems significantly lowered blood glucose levels and improved lipid profiles in streptozotocin-induced diabetic rats, producing effects comparable to glibenclamide (Singh and Singh 2010). The hepatoprotective properties of *F. jangomas* have also been established in vitro, where extracts reduced liver enzyme activity and oxidative stress in HepG2 cell models, indicating potential in managing hepatic disorders (Pai and Shenoy 2023). Additionally, the fruit and leaf extracts display potent antioxidant and antimicrobial properties, largely attributed to their high phenolic content. Studies have reported strong free radical scavenging activities and inhibitory effects against pathogens such as *Staphylococcus aureus* and *Escherichia coli* (Kumar et al. 2022). From an ecological standpoint, *F. jangomas* is a sustainable and readily available plant species, while from a pharmacological perspective, it presents a valuable candidate for natural product-based drug discovery. The present study therefore, aims to analyze the phytochemical composition of hydroalcoholic extracts of *F. jangomas* fruit using qualitative screening and GC-MS profiling to identify potential bioactive compounds contributing to its traditional therapeutic roles and its prospective use in managing oxidative stress and metabolic disorders.

MATERIALS AND METHODS

Collection and identification of plant

Fresh *Flacourtia jangomas* fruits (Figure 1) were collected from Rangamati, a district in the Chittagong Hill Tracts of southeastern Bangladesh, which is geographically located approximately between 22°27′N to 23°44′N latitude and 91°56′E to 92°33′E longitude. The fruits were identified and authenticated based on morphological characteristics by a taxonomist and scientific officer from the Department of Botany, Jahangirnagar University, Savar, Dhaka, Bangladesh. A voucher specimen (Accession No. JUH 10324) has been deposited in the Natural Products Research Laboratory, Department of Pharmacy, Comilla University, for future reference.

Preparation of plant material

At first, the fruit was washed with distilled water to remove dust. The dried fruit was macerated in 600 mL of 80% methanol for 21 days with occasional stirring to extract the phytochemicals (Naviglio et al. 2023). At a later stage, the mixture was filtered using a clean muslin fabric and Whatman No. 1 filter paper, respectively. Then the filtrate was condensed to produce a concentrated extract using a rotary evaporator (RE100-Pro DLAB USA) at 55°C. The percent yield of the extract was calculated and stored in the desiccator until it was subjected to further experimental procedures.

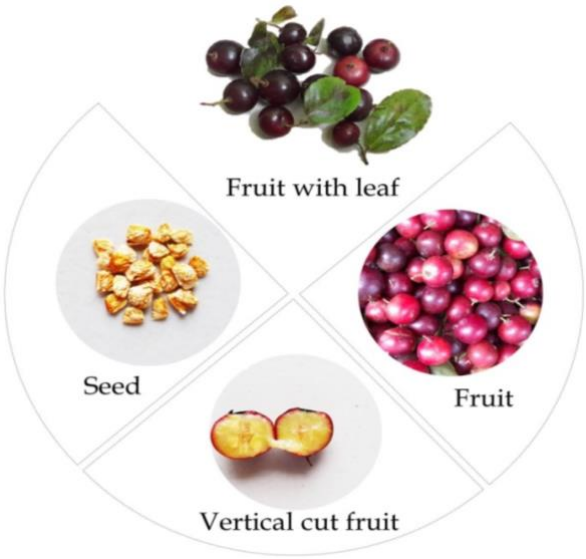

Figure 1. Photographic images of *Flacourtia jangomas* fruit, leaf and seed

Preliminary phytochemical screening

Phytochemical profiling of *F. jangomas* fruit extract was performed according to the previously described method for qualitatively identifying and verifying the phytochemicals found in the samples (Singh et al. 2022; Ouandaogo et al. 2023).

Gas Chromatography- Tandem Mass Spectrometry [GC-(MS/MS)] analysis

The hydroalcoholic extract of *F. jangomas* fruit was analyzed using Gas Chromatography Coupled with Tandem Mass Spectrometry (GC-MS/MS) for the identification of volatile and semi-volatile phytoconstituents. The analysis was carried out on Clarus® 690 gas chromatograph interfaced with a Clarus® SQ8C mass spectrometer (PerkinElmer, USA) equipped with an Elite-35 MS capillary column (30 m × 0.25 mm i.d. 0.25 µm film thickness), consisting of 35% diphenyl and 65% dimethylpolysiloxane stationary phase, which provides enhanced separation of polar and moderately polar compounds. A 1 µL aliquot of the extract was injected in splitless mode to maximize detection sensitivity, with ultrapure helium (99.999%) as the carrier gas at a constant flow rate of 1.0 mL/min. The oven temperature was initially set at 60°C, held for 0 min, then ramped at 5°C/min to 240°C and maintained for 4 min, for a total runtime of 40 min. The injector, ion source, and transfer line temperatures were maintained at 280°C, 200°C, and 280°C, respectively. Electron Ionization (EI) at 70 eV was used for ionization, and spectral data were recorded in full scan mode over a mass range of m/z 50-600. Peak identification was performed by comparing the acquired mass spectra with reference spectra in the NIST 2017 and Wiley libraries, applying a minimum match similarity index of 80% for tentative identification. This validated GC-MS/MS protocol allows for robust and reproducible identification of phytochemical constituents, in accordance with established analytical procedures used in natural product research (Willie et al. 2021).

RESULTS AND DISCUSSION

Preliminary phytochemical screening

The preliminary phytochemical screening of the ethanol extract of *F. jangomas* fruit revealed the presence of several important classes of secondary metabolites, including alkaloids, flavonoids, tannins, saponins, phenols, glycosides, and carbohydrates (Table 1). These phytochemicals are known to contribute to the medicinal properties of the plant and support its traditional uses in treating various ailments. Natural antioxidants like polyphenols and carotenoids have demonstrated significant anti-inflammatory, anticancer, antidiabetic, antiaging, and antiatherosclerotic attributed to their ability to neutralize free radicals and modulate oxidative stress pathways (Adouane et al. 2024). Alkaloids, another vital class of phytochemicals, possess diverse pharmacological actions, including anti-inflammatory, antimicrobial, anticancer, antidiabetic, and antihypertensive effects, mediated through interactions with various biological targets such as receptors and enzymes (Rajput et al. 2022). Carbohydrates, particularly oligosaccharides like GV-971 derived from marine algae, have shown promise in neuroprotection and have been approved in China for Alzheimer's treatment due to their ability to modulate gut microbiota and reduce neuroinflammation (Cao et al. 202). Glycosides are important for cardiovascular, immune, and neurological health and also exhibit antimicrobial activities, with compounds like salicin from willow bark traditionally used for fever and pain relief (Saxena et al. 2013; Yeasmin and Choi 2020). Flavonoids are known for their antioxidant and enzyme-inhibiting properties, targeting enzymes such as Xanthine Oxidase (XO), Phosphoinositide 3-kinase (PI3K), Lipoxygenase (LOX), and Cyclo-Oxygenase (COX), and are linked to the prevention and management of diseases like Alzheimer's, atherosclerosis, and cancer (Kumar and Pandey 2023). Phenolic compounds, potent secondary metabolites, offer therapeutic benefits including antidiabetic, antiobesity, anticancer, anti-inflammatory, and neuroprotective effects, owing to their strong antioxidant activities (Sun and Shahrajabian 2023).

Recent phytochemical studies on *F. jangomas* fruit extract have confirmed the presence of carbohydrates, alkaloids, glycosides, flavonoids, sterols, saponins, and total phenols, contributing to its reported antioxidant, antiarthritic, analgesic, and hypoglycemic activities (Pai and Shenoy 2021). These findings align with previous phytochemical studies of *F. jangomas*, which confirmed the richness of bioactive compounds contributing to its pharmacological potential (Ahmed et al. 2023). The diverse phytochemical profile supports further bioactivity-guided fractionation and advanced analytical studies such as GC-MS and FTIR to characterize the bioactive compounds more precisely. Overall, the preliminary screening confirms that *F. jangomas* fruit extract contains a complex mixture of phytoconstituents that justify its traditional medicinal applications and warrant further in vitro and in vivo pharmacological evaluations.

Table 1. Preliminary phytochemical analysis of *Flacourtia jangomas* fruit extract

Phytochemical class	Test method used	Observation
Alkaloids	Mayer's and Wagner's Tests	+
Carbohydrates	Molisch's Test	+
Flavonoids	Alkaline Reagent Test	+
Glycosides	Keller-Killiani Test	+
Phenols	Ferric Chloride Test	+
Proteins	Biuret Test	-
Resin	Copper acetate Test	-
Saponins	Frothing Test	+
Steroids	Liebermann-Burchard Test	-
Tannins	Ferric Chloride Test	+
Terpenoids	Salkowski Test	+

Note: +: Present, -: Absent

GC-MS/MS analysis

The hydroalcoholic fruit extract of *F. jangomas* was subjected to comprehensive chemical profiling using Gas Chromatography Coupled with Tandem Mass Spectrometry (GC-MS/MS) to identify its constituent bioactive compounds. The Total Ion Chromatogram (TIC), as illustrated in Figure 2, revealed the presence of 23 distinct phytochemical constituents based on their unique retention times and mass spectral fragmentation patterns. The detailed chromatographic and spectral characteristics of the identified compounds, including Retention Time (RT), relative abundance (% peak area), molecular ion peaks (m/z), molecular formulae, and reported biological activities, are tabulated in Table 2. GC-MS analysis revealed that the major bioactive constituents, as determined by Retention Time (RT) and relative peak area, were Glycidyl Palmitate (30.92%), 5-Hydroxymethylfurfural (13.92%), 3-Methylthiophene-2-carboxamide (5.46%), (2R,6R)-2-Heptyl-6-Methylpiperidine (2.77%), Sebacic acid, isohexyl 2-naphthyl ester (1.72%), Sedoheptulosan (1.69%), 2(5H)-Furanon (1.53%), 1,2-Ethanediol, Dipropionate (1.27%), 2-Furancarboxylic Acid, Hydrazide (1.15%), and Trans-2-Methyl-4-N-Butylthiane, S, S-Dioxide (1.09%) indicating their predominance in the extract composition. The chemical structures were predicted by analyzing the mass spectra, where fragmentation patterns generate peaks with various mass-to-charge (m/z) ratios. The predominant bioactive constituents based on peak intensity and area are highlighted in Figure 3. Compounds exhibiting reported antioxidant potential are depicted in Figure 4. Table 3 presents the reported bioactivities and mechanisms of the major bioactive compounds from *F. jangomas* fruit extract identified in this study. Moreover, biological activities of the identified compounds in this study were inferred from established phytochemical databases, notably Dr. Duke's Phytochemical and Ethnobotanical Databases (U.S. Department of Agriculture, Agricultural Research Service, 1992-2025), in addition to corroborating evidence from recent peer-reviewed literature.

Gas Chromatography coupled with Tandem Mass Spectrometry is an advanced analytical technique widely employed for the detection and quantification of trace-level compounds across a broad spectrum of chemical classes, including environmental contaminants, food residues, biological metabolites, and forensic substances. It combines the high separation efficiency of gas chromatography with the exceptional sensitivity and selectivity of tandem mass spectrometry, enabling accurate analysis even in complex sample matrices. Its robustness, reproducibility, and ability to analyze volatile and semi-volatile organic compounds make GC-MS/MS a cornerstone in analytical chemistry, particularly in regulatory, clinical, and research settings (David and Rostkowski 2020; Leary et al. 2023; Majhi et al. 2023).

The therapeutic use of medicinal plants in managing various human ailments is largely attributed to their diverse phytochemical constituents. GC-MS/MS is a highly sensitive and selective analytical technique capable of identifying and quantifying compounds present in trace amounts across a wide array of chemical classes (Leary et al. 2023). Its robustness, coupled with excellent resolution, sensitivity, and reproducibility, makes it a powerful tool in natural product research (Thamer and Thamer 2023). In the present study, GC-MS/MS spectral analysis was employed to characterize the bioactive compounds present in the hydroalcoholic fruit extract of *F. jangomas*. These identified compounds belonged to diverse phytochemical groups, including phenolics, aldehydes, esters, phytosterols, fatty acids, ketones, sesquiterpenoids, and terpenoids, which are known to contribute significantly to antioxidant and therapeutic efficacy.

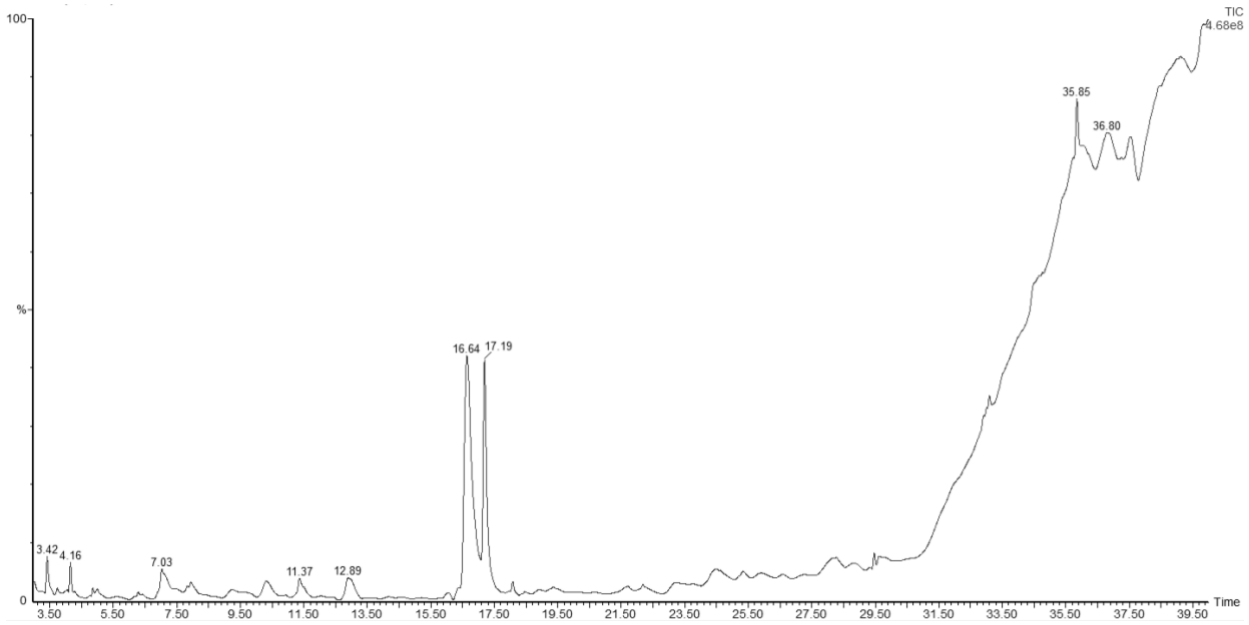

Figure 2. GC-MS/MS chromatogram of *Flacourtia jangomas* fruit extract

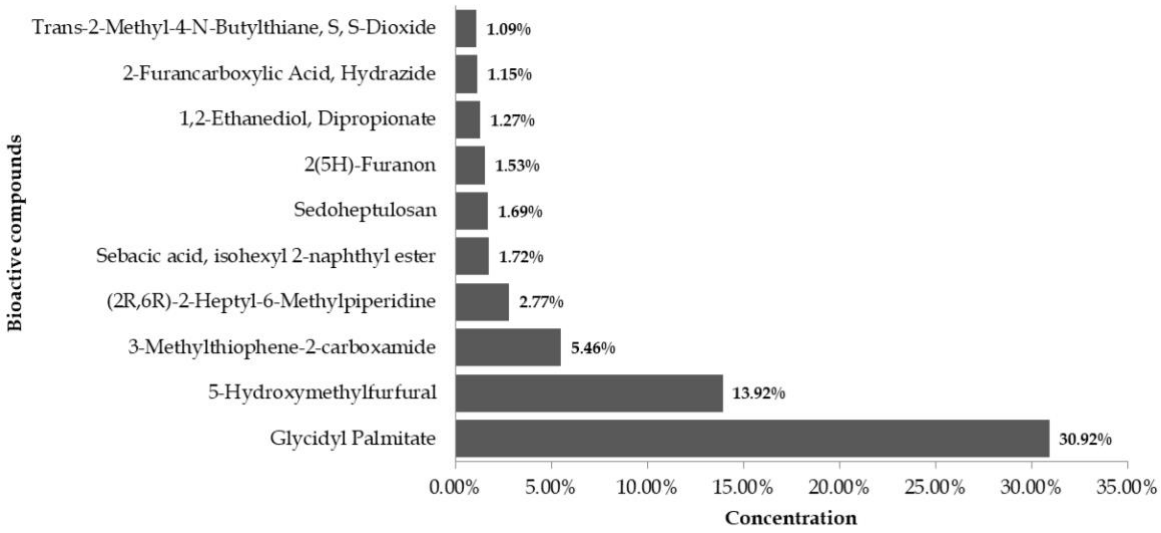

Figure 3. Major bioactive compounds identified in *Flacourtia jangomas* fruit extract

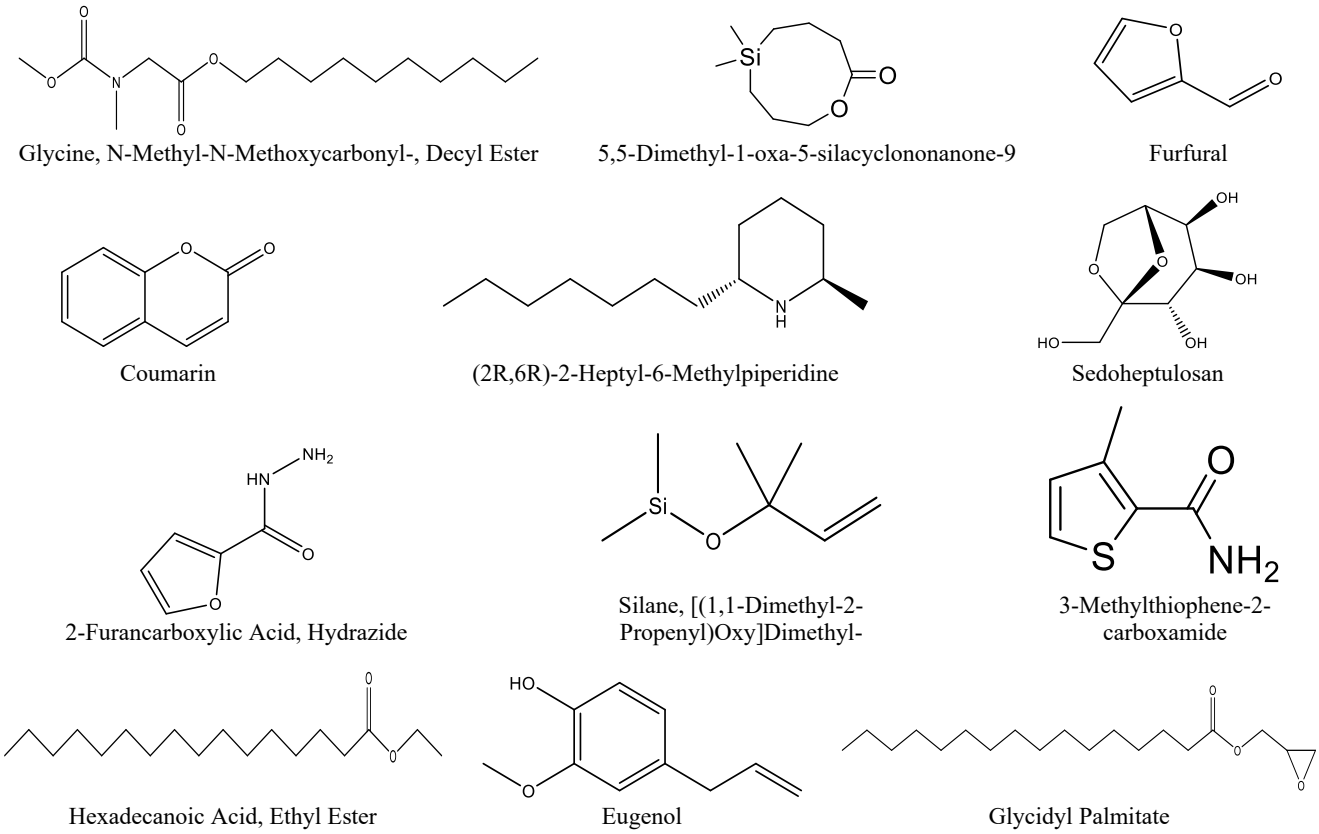

Figure 4. Reported antioxidant compounds identified in *Flacourtia jangomas* fruit extract by GC-MS/MS analysis

Table 2. Bioactive compounds identified in the *Flacourtia jangomas* fruit extract by GC-MS/MS analysis

Retention Time (RT)	% Area	Name of the compounds	Molecular weight (m/z)	Nature of compounds	Reported bioactivity	References
3.42	0.74	1-Propanol, 2-Methyl-2-[(2-Methyl-2-Propenyl)Oxy]-	144.21	Ether	Antibacterial	Too et al. 2020
3.74	0.09	Hexa-1,3,5-Triyne	74.08		Antifungal	Rabha et al. 2023
4.16	0.76	Glycine, N-Methyl-N-Methoxycarbonyl-, Decyl Ester	287.39	Amide ester	Neurotransmitter, anti-inflammatory, respiratory distress syndrome and asthma, anti-alopecic, anti-androgenic, antioxidant, hemolytic	Stachelska et al. 2025
4.86	0.25	Furfural	96.08	Aldehyde	Anti-tyrosinase and antimicrobial, Antioxidant, antibacterial, antidiabetic	Kang et al. 2019; Essien et al. 2021; Jilani and Olson 2023; Chen et al. 2025
5.00	0.38	1H-Imidazole-4-Methanol	98.1	Heterocyclic alcohol,	Antidiabetic	Sreelatha et al. 2020
6.29	0.45	1H-1,2,4-Triazole, 3-Ethyl-	97.12	Heterocyclic ethyl	Antidiabetic	Deswal et al. 2020
7.03	2.77	(2R,6R)-2-Heptyl-6-Methylpiperidine	197.36	Heterocyclic amine	Antimicrobial and antioxidant	Yıldız et al. 2023; Zala et al. 2023
7.95	1.53	2(5H)-Furanone	128.13	Cyclic ester	Antimicrobial	Khabibrakhmanova et al. 2023
9.25	1.09	Trans-2-Methyl-4-N-Butylthiane, S, S-Dioxide	204.33	Sulfonated thiane	Antimicrobial	Howe et al. 2018
10.32	1.27	1,2-Ethanediol, Dipropionate	174.19	Ester	Antibacterial	Tavman et al. 2010
11.37	1.15	2-Furancarboxylic Acid, Hydrazide	126.11	Hydrazide	Antioxidant, antibacterial, antiproliferative, immunosuppressant	Abouzayed et al. 2020
12.89	1.72	Sebacic acid, isohexyl 2-naphthyl ester	412.56	Ester	Antimicrobial, antifungal	Varenikov et al. 2020
16.64	13.92	5-Hydroxymethylfurfural	126.11	Cyclic aldehyde	Antioxidant, antimicrobial, antifungal, cytotoxic	Al-Baadani et al. 2024
17.19	5.46	3-Methylthiophene-2-carboxamide	141.19	Amide	Antioxidant, antimicrobial Anticancer	El-Rayyes et al. 2023; Metwally et al. 2023; Almatari et al. 2024
18.08	0.33	Eugenol	164.2	Phenol and ether	Antioxidant, antimicrobial, antifungal, anti-inflammatory	Hassanpour et al. 2020; Elbestawy et al. 2023; Kowalewska and Majewska-Smolarek 2023
19.36	0.85	5,5-Dimethyl-1-oxa-5-silacyclononanone-9	186.32	Carboxyl	Antioxidant, acetylcholinesterase inhibitor	Shen et al. 2023
22.18	0.72	Coumarin	146.14	Benzopyrone	Antifungal, antibacterial, antioxidants, anti-inflammatory	Mohammed and Ahamed 2022
24.46	1.69	Sedoheptulosan	192.17	Anhydro sugar	Antioxidant, antimicrobial, anticancer, anti-diabetic	Faisal et al. 2023
25.34	0.39	Silane, [(1,1-Dimethyl-2-Propenyl)Oxy]Dimethyl-	143.28	Silane	Anticancer, antioxidant, antiproliferative	Marques et al. 2021
26.58	0.23	4-Methoxy-6-Methyl-6,7-Dihydro-4h-Furo(3,2-C)Pyran	168.19	Furan and pyran	Not identified	-
29.47	0.13	Hexadecanoic Acid, Ethyl Ester	284.5	Ester	Antioxidant, anti-fibrinolytic, antimicrobial, alpha-reductase inhibitor	Starlin et al. 2019
33.10	0.42	6,8-Dodecadien-1-Ol (6Z,8E)	182.3	Unsaturated fatty alcohol.	antioxidant, anticancer, anti-inflammatory, and antimicrobial	Sowmiya et al. 2021
35.85	30.92	Glycidyl Palmitate	312.5	Ester	Antioxidant, antidiabetic, anticancer	Puspa et al. 2025

Table 3. Major phytochemicals from *Flacourtia jangomas* extract identified in this study with reported bioactivities and mechanisms

Compound	Biological activity	Mechanism of action	Reference
Glycidyl Palmitate	Antidiabetic potential (in silico), precursor of apoptosis-regulating LPA	Hydrolyzes into glycidol and palmitic acid, may modulate apoptosis via lysophosphatidic acid signaling	Puspa et al. 2025
5-Hydroxymethylfurfural (5-HMF)	Antioxidant, anti-inflammatory, neuroprotective	Scavenges ROS, inhibits NF-κB, MAPK, and Akt/mTOR pathways	Pagare et al. 2024
3-Methylthiophene-2-carboxamide	Antioxidant, antimicrobial	Thiophene ring enables ROS scavenging, amide group enhances microbial enzyme binding	Alsayari et al. 2023
(2R,6R)-2-Heptyl-6-Methylpiperidine	Potential neuroactive alkaloid mimic	Likely interacts with neuroreceptors or enzymatic systems, analog of solenopsin	Petrou et al. 2020
Sebacic acid, isohexyl 2-naphthyl ester	Antibacterial potential	Lipophilic esters may disrupt microbial membranes or enzymes	Mishra et al. 2019
Sedoheptulosan	Intermediate in sugar metabolism, anti-inflammatory potential	May regulate pathways in carbon metabolism, precursor of sedoheptulose-1,7-bisphosphate	Liu et al. 2023
2(5H)-Furanone	Antibacterial, anti-inflammatory	Inhibits quorum sensing and bacterial communication, enzyme interference	Khabibrakhmanova et al. 2023
1,2-Ethanediol, Dipropionate	Mild antimicrobial (diol esters)	Diol esters may interfere with microbial lipid membranes and cell wall integrity, leading to leakage of intracellular components	Tavman et al. 2010
2-Furancarboxylic Acid, Hydrazide	Antimicrobial (hydrazide analogs)	Forms hydrazone derivatives that inhibit microbial enzymes by reacting with essential carbonyl groups, leading to enzyme inactivation and microbial growth inhibition.	Kumar et al. 2021
Trans-2-Methyl-4-N-Butylthiane, S,S-Dioxide	Potential antimicrobial	Sulfone group disrupting microbial cell membranes	Naine et al. 2014

The identified bioactive compounds from the hydroalcoholic fruit extract of *F. jangomas* exhibit a range of biological activities. Among the 23 identified compounds, 11 (44.57% of the total peak area) have been reported to exhibit antioxidant activity (Figure 4), along with other pharmacological effects. Glycidyl palmitate (30.92%) is reported to exhibit multiple bioactivities. It demonstrates significant antidiabetic and anticancer properties. Additionally, glycidyl palmitate possesses antioxidant properties, which enable it to scavenge free radicals and protect cells from oxidative damage (Puspa et al. 2025). 5-Hydroxymethylfurfural (13.92%), commonly known as 5-HMF, demonstrates antioxidant properties and potential therapeutic roles in hypertension and sickle cell anemia (Pagare et al. 2024). 3-Methylthiophene-2-carboxamide (5.46%) has shown antioxidant and antibacterial potential in studies involving thiophene derivatives (Metwally et al. 2023). The piperidine compound (2R,6R)-2-heptyl-6-methylpiperidine shares structural features with (2R,6R)-hydroxynorketamine,a ketamine metabolite that has shown rapid-onset antidepressant effects in humans while avoiding dissociative side effects typically associated with ketamine—suggesting promising structure-activity parallels for mood-disorder therapeutics (Raja et al. 2024). Sebacic acid, isohexyl 2-naphthyl ester (1.72%), is associated with antimicrobial and anti-inflammatory potential due to its sebacic acid ester backbone (Varenikov et al. 2020).

Sedoheptulosan (1.69%) is a rare sugar with emerging interest due to its biological and therapeutic potential. Though it is primarily known as an intermediate in the pentose phosphate pathway, recent studies have explored its antioxidant, antimicrobial, anticancer, and antidiabetic properties (Yamamoto et al. 2022). The compound 2(5H)-furanon (1.53%) is a furanone derivative with established antibacterial and antifungal properties, particularly effective against biofilms (Khabibrakhmanova et al. 2023). 1,2-Ethanediol, dipropionate (1.27%) exhibits antibacterial effects (Tavman et al. 2010). 2-Furancarboxylic acid, hydrazide (1.15%), demonstrates antimicrobial properties and is being explored in pharmaceutical chemistry (Popiołek 2021; Mistry and Singh 2022). Trans-2-Methyl-4-N-butylthiane, S,S-dioxide (1.09%) is a sulfone derivative that has been reported to exhibit significant antimicrobial properties (Swargiary et al. 2023). The identified compounds, 5,5-Dimethyl-1-oxa-5-silacyclononanone-9 (0.85%), is a siloxane-related compound, and while siloxanes are widely used in pharmaceuticals and cosmetics, their specific bioactivity depends on structural context, with limited direct evidence for this derivative. Glycine, N-methyl-N-methoxycarbonyl-, decyl ester (0.76%) represents a modified amino acid ester and may possess antimicrobial or surface-active properties, though its precise biological activity is not well-documented. 1-Propanol, 2-methyl-2-[(2-methyl-2-propenyl)oxy]- (0.74%) is a branched ether alcohol, generally used in industrial or fragrance contexts, with minimal known pharmacological properties.

Coumarin (0.72%) is a well-documented phytochemical with antioxidant, anti-inflammatory, anticoagulant, and antimicrobial properties (Venugopala et al. 2013). 1H-1,2,4-triazole, 3-ethyl- (0.45%) belongs to a class of heterocyclic compounds with potent antifungal and antibacterial properties, commonly found in therapeutic agents (Abdelli et al. 2021). 6,8-Dodecadien-1-ol (6Z,8E) (0.42%) is a pheromone-related compound used in insect communication and may have potential in integrated pest management. Silane, [(1,1-dimethyl-2-propenyl)oxy]dimethyl (0.39%) is a silicon-based compound primarily known for its role in materials chemistry, with no confirmed biological activity. 1H-imidazole-4-methanol (0.38%) contains the imidazole ring, which is common in bioactive molecules and known for its antimicrobial and antifungal effects. Eugenol (0.33%), a major component of clove oil, possesses notable antioxidant, antimicrobial, antifungal, and anti-inflammatory properties. Its antioxidant activity stems from its ability to neutralize free radicals, while its antimicrobial and antifungal effects are due to membrane disruption and inhibition of microbial growth. Additionally, eugenol reduces inflammation by inhibiting pro-inflammatory mediators and enzymes (Hassanpour et al. 2020; Elbestawy et al. 2023; Kowalewska and Majewska-Smolarek 2023). Furfural (0.25%), a furan aldehyde, has been reported to possess antimicrobial and antioxidant properties but may also be cytotoxic at high concentrations. The compound 4-methoxy-6-methyl-6,7-dihydro-4H-furo(3,2-c)pyran (0.23%) is a furofuran derivative, a class known for moderate antioxidant and cytotoxic activities (Xu et al. 2019). Hexadecanoic acid, ethyl ester (0.13%), an ester of palmitic acid, shows antibacterial and anti-inflammatory activity (Starlin et al. 2019). Finally, hexa-1,3,5-triyne (0.09%) is a polyacetylene compound, a rare class of natural products with reported antifungal and cytotoxic effects (Rabha et al. 2023).

The diverse array of bioactive compounds identified in the *F. jangomas* fruit extract highlights its significant potential for various medicinal applications. Their synergistic effects may contribute to the extract's overall therapeutic efficacy, supporting its traditional use in treating metabolic and oxidative stress-related disorders. Consequently, *F. jangomas* fruit represents a valuable natural resource for the development of novel plant-based pharmaceuticals and nutraceuticals. The identification of these bioactive molecules via GC-MS/MS thus provides a biochemical basis for the traditional use of this fruit in ethnomedicine.

In conclusion, the present study highlights the rich phytochemical diversity and therapeutic potential of the hydroalcoholic fruit extract of *F. jangomas*. Preliminary phytochemical screening confirmed the presence of several bioactive constituents, including alkaloids, flavonoids, phenolic compounds, glycosides, saponins, sterols, and carbohydrates—all of which are known to contribute significantly to antioxidant and disease-modulating activities. Advanced analysis using GC-MS/MS enabled the identification of 23 compounds, many of which are reported to possess notable pharmacological effects. Among these, glycidyl palmitate, 5-hydroxymethylfurfural (HMF), thiophene and piperidine derivatives, decanedioic acid esters, and phenolic compounds such as coumarin and eugenol, were recognized for their antioxidant, antimicrobial, anti-inflammatory, neuroprotective, and antidiabetic properties. The findings of this study provide preliminary

support for traditional medicinal claims. Future research should focus on the isolation and structural characterization of key constituents, followed by comprehensive biological evaluations using in vitro, in silico, and in vivo approaches to elucidate their mechanisms of action. Overall, this study establishes *F. jangomas* fruit extract as a valuable natural reservoir of pharmacologically active compounds with potential applications in the treatment of oxidative stress-related and metabolic disorders, paving the way for the development of novel plant-derived therapeutic agents.

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