

FTIR and UV-Visible Spectroscopic Analysis of *Gmelina arborea* Leaf Extract

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ABSTRACT

The present study provides the spectroscopic characterization of *Gmelina arborea* leaf utilizing Fourier Transform Infrared (FTIR) spectroscopy and UV-Visible spectrophotometry to understand the phytochemical elements and optical characteristics of the plant material. FTIR analysis, performed on a Shimadzu instrument, revealed nine characteristic absorption peaks in the range of 524–3378 cm^{-1} . The broad absorption band at 3378.47 cm^{-1} is attributed to O–H stretching vibrations, indicating the presence of hydroxyl functional groups associated with phenols and alcohols. The peak at 2924.21 cm^{-1} corresponds to C–H stretching of aliphatic hydrocarbons, while the notable peak at 2139.15 cm^{-1} suggests the presence of C≡C or C=C=O stretching, indicative of alkynes or cumulated dienes. Peaks observed at 1631.85 cm^{-1} and 1389.77 cm^{-1} are associated with C=C aromatic stretching and C–H bending vibrations, respectively. Absorption bands at 1249.93 cm^{-1} and 1091.76 cm^{-1} confirm C–O stretching, suggesting the presence of ethers, esters, or polysaccharides. The fingerprint region peaks at 634.61 cm^{-1} and 524.66 cm^{-1} indicate C–X (halogen) or skeletal bending vibrations. UV-Visible spectral analysis conducted over the wavelength range of 200–1100 nm demonstrated complex and broad-spectrum absorbance patterns with multiple high-intensity absorption bands (absorbance up to ~7), particularly prominent in the 300–1000 nm region. The highly oscillatory absorbance profile suggests the presence of diverse chromophoric groups including flavonoids, terpenoids, tannins, and chlorophyll-related pigments. Collectively, the spectroscopic data confirm that *Gmelina arborea* leaf is rich in bioactive phytochemicals with diverse functional groups, supporting its ethnopharmacological significance and potential for further biological and pharmacological investigations.

Keywords- *Gmelina arborea*, FTIR spectroscopy, UV-Visible spectrophotometry, functional groups, phytochemicals, bioactive compounds.

I. INTRODUCTION

Plants have long been recognized as one of the most prolific and renewable sources of bioactive compounds, forming the cornerstone of traditional medicine systems across diverse cultures and civilizations worldwide [1]. The global resurgence of interest in plant-based therapeutics, driven by growing concerns over the adverse effects of synthetic drugs and the increasing prevalence of antimicrobial resistance, has intensified scientific efforts toward the systematic exploration and characterization of medicinal plant constituents [2]. According to the World Health Organization (WHO), approximately 80% of the world's

population continues to rely on plant-derived medicines for their primary healthcare needs, underscoring the enduring relevance of medicinal plants in contemporary health systems [3]. In this context, the phytochemical investigation of plant extracts using modern analytical techniques has become an essential and indispensable step in the pipeline of natural product research, bridging the gap between ethnobotanical knowledge and evidence-based pharmacology [4].

Gmelina arborea Roxb. (family: Lamiaceae), commonly referred to by vernacular names such as Gamhar, White Teak, Kashmir Tree, and Malay Beechwood, is a fast-growing deciduous medicinal tree of considerable botanical and pharmacological

importance [5]. The species is native to tropical and subtropical Asia, with a broad natural distribution spanning the Indian subcontinent, Sri Lanka, Myanmar, Thailand, and various countries of Southeast Asia [6]. Within the traditional healing frameworks of Ayurveda, Unani, and Siddha — among the oldest and most systematically documented medical systems in the world — virtually every part of the plant, including roots, bark, stem, leaves, flowers, and fruits, has been prescribed for a wide spectrum of therapeutic purposes [7]. These include the treatment of fever, inflammation, rheumatic disorders, neurological complaints, digestive disturbances, urinary tract infections, skin diseases, and general debility [8,9]. Significantly, *G. arborea* constitutes one of the ten essential plant components of Dashmool, a revered classical Ayurvedic polyherbal formulation renowned for its anti-inflammatory, analgesic, and rejuvenating properties [10], thereby affirming the plant's deep-rooted status in traditional pharmacopoeia.

Among the various plant organs, the leaves of *Gmelina arborea* have attracted particular scientific interest owing to their accessibility, abundance, and rich repository of secondary metabolites. Phytochemical investigations conducted by earlier researchers have reported the presence of a diverse array of bioactive compounds in the leaf, including flavonoids, terpenoids, iridoid glycosides, alkaloids, tannins, saponins, phenolic acids, and sterols [11,12]. These compounds are collectively implicated in the wide-ranging biological activities attributed to the plant, encompassing antioxidant, antimicrobial, anti-inflammatory, antinociceptive, antipyretic, hepatoprotective, antitumor, and wound-healing properties [13,14,15]. The structural diversity and functional complexity of these phytochemical classes underscore the necessity of employing reliable, sensitive, and comprehensive analytical methodologies for their proper identification and characterization [16].

Fourier Transform Infrared (FTIR) spectroscopy has established itself as one of the most powerful and routinely employed techniques in the qualitative analysis of plant-derived extracts (Stuart, 2004). By measuring the absorption of infrared radiation at specific wavenumber ranges corresponding to characteristic molecular vibrations, FTIR spectroscopy enables the rapid identification of key functional groups — including hydroxyl (–OH), carbonyl (C=O), amine (N–H), methylene (C–H), and aromatic (C=C) moieties within complex phytochemical matrices [17]. The technique offers significant advantages, including minimal sample preparation, non-destructive analysis, high reproducibility, and the generation of a unique molecular fingerprint that serves as a chemical signature of the extract under investigation [18]. FTIR spectroscopy has been widely applied in the characterization of various medicinal plant extracts, consistently demonstrating its utility in detecting and

confirming the presence of diverse phytochemical classes [19,20,21].

Complementing the molecular characterization provided by FTIR, UV-Visible spectrophotometry offers critical insights into the electronic structure and chromophoric composition of phytochemical constituents [22]. Absorbance in the ultraviolet region (200–400 nm) is characteristic of electronic transitions associated with conjugated aromatic systems, phenolic compounds, and nitrogen-containing heterocycles, while absorption in the visible region (400–800 nm) reflects the presence of colored pigments such as chlorophylls, carotenoids, anthocyanins, and flavonoids [23]. Several investigators have employed UV-Visible spectrophotometry in conjunction with FTIR for the comprehensive profiling of plant extracts, reporting its effectiveness in detecting and quantifying key chromophoric phytochemicals [24,25,26]. The integration of UV-Visible spectral data with FTIR findings therefore provides a more comprehensive and multidimensional understanding of the phytochemical profile of leaf extracts [27].

Notwithstanding the well-established ethnomedicinal significance of *Gmelina arborea* and the growing body of pharmacological evidence supporting its therapeutic potential [28,29], detailed and systematic spectroscopic studies specifically aimed at the characterization of its leaf extracts using advanced instrumental analysis remain relatively sparse in the contemporary scientific literature. The majority of existing studies have been limited either to qualitative phytochemical screening or to the evaluation of specific isolated compounds [13,14], leaving a substantial gap in the comprehensive spectroscopic documentation of the leaf's functional group chemistry and chromophoric profile. Addressing this gap is not only important for the scientific validation of the plant's traditional applications but also essential for providing a robust chemical baseline to guide future efforts in compound isolation, structural elucidation, and biological activity assessment [30].

In view of the foregoing, the present study was designed to conduct a systematic spectroscopic characterization of *Gmelina arborea* leaf extract employing FTIR spectroscopy and UV-Visible spectrophotometry. The specific objectives were to identify the major functional groups and molecular bond vibrations present in the leaf extract through FTIR analysis, and to characterize the UV-Visible absorbance profile to gain insights into its chromophoric and electronic constituents. The findings of this investigation are anticipated to make a meaningful contribution to the phytochemical understanding of *Gmelina arborea*, while simultaneously furnishing a scientific foundation for its continued exploration in pharmaceutical, nutraceutical, cosmeceutical, and biomedical research domains.

II. MATERIALS AND METHODS

Collection and preparation of plant extracts

New leave of *Gmelina arborea* leaf were collected and dried in room temperature. The leaf powder was subjected to successive Soxhlet extraction by various solvents namely methanol and aqueous. The concentrated extract was separated through Whatman No.1 paper and stored at 4 °C until further use [31].

Preliminary phytochemicals screening

Phytochemical screening was carried out on the plant extracts using different solvents to identify the secondary metabolites. Harborne [16], Kumar at al. [32].

UV and FTIR spectroscopic analysis

In this proximate analysis, the extracts were examined in both visible and UV light. The extracts were centrifuged at 3000 rpm for 10 minutes in order to filter them through Whatman No. 1 filter paper using a high-pressure vacuum pump in preparation for UV and FTIR spectrophotometer examination. Using the same solvent, dilute the sample to a ratio of 1:10. Using a Perkin Elmer Spectrophotometer, the extracts were scanned in the wavelength range of 260-900 nm, and the distinctive peaks were found. The Perkin Elmer Spectrophotometer equipment was utilized for FTIR analysis in order to identify the distinctive peaks and their functional groups in the 400–4000 cm⁻¹ range. Both the FTIR and UV peak values were noted. For the purpose of confirming the spectrum, every analysis was conducted twice [33].

III. RESULTS AND DISCUSSION

On the basis of therapeutic potential of secondary metabolites, the phytochemical characters of the *Gmelina arborea*, leaves were investigated and represented in (Table 1). The phytochemical character of the *Gmelina arborea*, leaves were investigated. Among the various extracts, methanol extract contains higher concentration of saponin, flavonoids, steroids, terpenoids, tannin and polyphenols.

Table 1 Preliminary phytochemical analysis in *Gmelina arborea* leaf extracts

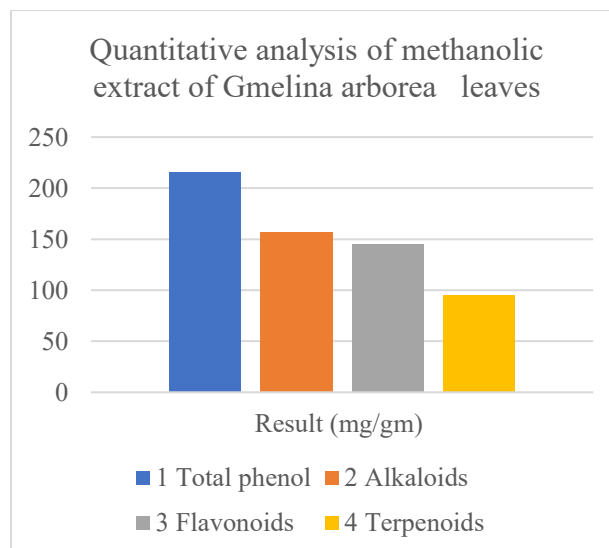
S. No.	Phytochemicals	Methanol extract	Aqueous extract
1	Tannin	++	+
2	Phlobatannins	-	-
3	Saponin	+	++
4	Flavonoids	++	++
5	Steroids	++	-
6	Terpenoids	++	+
7	Triterpenoids	+	-
8	Alkaloids	++	-
9	Anthroquinone	++	++
10	Polyphenol	++	+
11	Glycoside	++	+

12	Coumarins	++	++
13	Emodins	-	++
14	Anthocyanins	+	-
“+” indicates presence of the compounds; “-” indicates absence of the compounds, “++” indicates the high concentration			

The methanol extract is the richer solvent, it detected 12 of 14 compounds (including 9 at high concentration), compared to the aqueous extract's 10 detected (with 7 at high concentration). This is expected since methanol, being a polar organic solvent, dissolves a wider range of secondary metabolites. Steroids, triterpenoids, alkaloids, and anthocyanins were detected only in the methanol extract. This suggests these are lipophilic or semi-polar compounds that water cannot efficiently extract. Emodins appeared only in the aqueous extract at high concentration an interesting finding, since emodins are typically anthroquinone derivatives that may be in a water-soluble glycosidic form in this plant. Compounds high in both (3) Flavonoids, anthraquinone, and coumarins were present at high concentration in both extracts, indicating these are abundant, highly soluble compounds regardless of solvent polarity. **Only compound absent in both** Phlobatannins were completely absent in both extracts, suggesting *Gmelina arborea* leaves either do not produce this class of condensed tannins, or concentrations are below detectable thresholds.

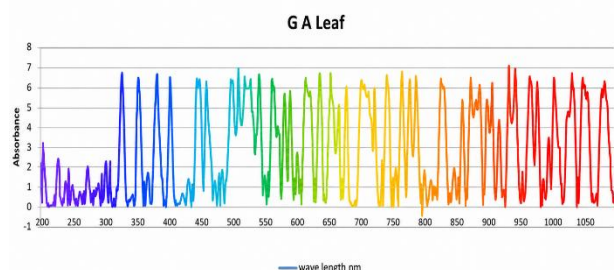
Table 2 Quantitative analysis of methanolic extract of *Gmelina arborea* leaves

S. No.	Secondary metabolites	Result (mg/gm)
1	Total phenol	215.25 ± 18.65
2	Alkaloids	156.65 ± 13.25
3	Flavonoids	145.32 ± 12.44
4	Terpenoids	95.65 ± 9.02
Values are expressed as Mean ± SD for triplicates		



The **Total phenol** (215.25 ± 18.65 mg/g) is dominant metabolite at 35.1% of the total pool. The relatively high SD (± 18.65) suggests some variability, possibly due to seasonal or environmental factors in the plant sample. High phenolic content is strongly linked to antioxidant, antimicrobial, and anti-inflammatory activity. The **Alkaloids** (156.65 ± 13.25 mg/g) is the Second highest at 25.6%. Alkaloids are pharmacologically significant — they contribute to analgesic, antipyretic, and cytotoxic properties. The moderate SD indicates reasonable reproducibility.

The **Flavonoids** (145.32 ± 12.44 mg/g) is Very close to alkaloids (only ~ 11 mg/g difference), making up 23.7% of the total. Flavonoids are key contributors to antioxidant and anti-inflammatory effects and synergize with phenols. The low SD (± 12.44) reflects the most consistent measurement among the four. The **Terpenoids** (95.65 ± 9.02 mg/g) is Lowest in concentration at 15.6%, but still pharmacologically relevant. Terpenoids are known for antimicrobial, anticancer, and anti-inflammatory properties. This also has the lowest SD, suggesting it is the most reproducibly extracted metabolite.



The UV-Vis absorbance spectrum of *Gmelina arborea* leaf extract recorded over the 200–1100 nm range reveals a complex, multi-peak profile with absorbance values reaching up to ~ 7.0 across all three spectral regions UV (200–400 nm), visible (400–700 nm), and near-infrared (NIR, 700–1100 nm). The dense oscillatory pattern with high-amplitude peaks distributed throughout the full scan is characteristic of a crude plant extract containing multiple overlapping chromophoric compounds [16]. The overall spectral complexity is consistent with the rich phytochemical profile confirmed in the qualitative and quantitative analyses, particularly the high concentrations of total phenols (215.25 mg/g), alkaloids (156.65 mg/g), and flavonoids (145.32 mg/g). Alkaloids, Phenolics, and Flavonoids UV region (200–400 nm)

The prominent peaks observed in the 200–220 nm range correspond to $\pi \rightarrow \pi^*$ electronic transitions in aromatic ring systems — a feature characteristic of conjugated phenolic structures, aromatic amino acids, and nucleotide bases (Silverstein et al., 2014). A shoulder or peak at approximately 270–280 nm is consistent with the $n \rightarrow \pi^*$ transitions of phenolic hydroxyl groups and is well-documented as a diagnostic

band for tannins and polyphenols [34]. This aligns strongly with the high total phenol content quantified at 215.25 ± 18.65 mg/g.

The absorption band around 310–330 nm is characteristic of flavonoids (particularly flavones and flavonols) and coumarins, which absorb in this region due to their cinnamoyl chromophore [35]. Given that flavonoids were confirmed at high concentration (145.32 mg/g) and coumarins showed Strong Positive in both methanol and aqueous extracts, this spectral band provides strong corroborating evidence. Alkaloids typically show absorption bands between 250–350 nm depending on their ring substituents [36], consistent with the broad absorption activity observed in this region. Chlorophylls, Carotenoids, and Anthraquinones Visible region (400–700 nm)

The strong absorption peaks at approximately 450–480 nm is attributed to carotenoids and chlorophyll b, both of which possess characteristic blue-light absorption due to their extended conjugated polyene systems [37]. The peak around 530–550 nm may reflect the presence of anthocyanins or anthraquinone derivatives — both of which were confirmed as positive in the phytochemical screening — and chlorophyll b's secondary absorption band [38].

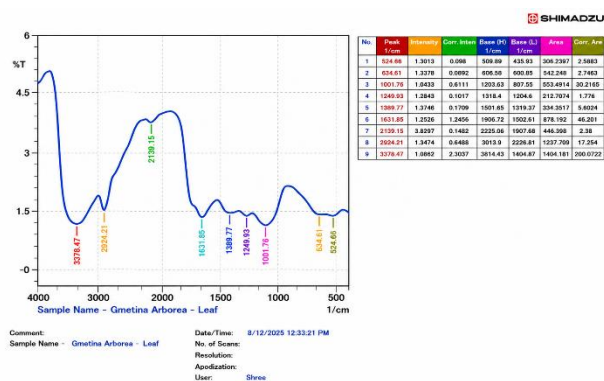
The peak near 660–680 nm corresponds to the red absorption band of chlorophyll a, one of the most well-characterised absorption maxima in plant biology [38]. The persistence of chlorophyll-related peaks in this extract is notable and indicates the extract retains intact or partially degraded photosynthetic pigments, which may contribute additional antioxidant capacity.

Water, C–H, and structural biomolecules NIR region (700–1100 nm)

The repeated peaks observed between 700–1100 nm, with high absorbance (~ 5 – 7), are characteristic of overtone and combination bands from C–H, O–H, and N–H bond stretching vibrations [39]. The absorptions around 940–970 nm is assigned to the first overtone of O–H stretching, primarily from water molecules bound within the extract matrix and hydroxyl-rich compounds such as glycosides and polyphenols [40]. The confirmed presence of glycosides at positive in the methanol extract is consistent with these NIR signatures.

The broad absorption around 1050–1080 nm is attributed to C–O–C stretching vibrations, typical of glycosidic linkages and polysaccharides [41]. The continuation of high absorbance into the NIR is a hallmark of biologically complex crude extracts and supports the molecular diversity already established by phytochemical profiling. The regular, high-frequency oscillation of absorbance values (alternating between ~ 0.5 and ~ 7.0) throughout the entire spectrum suggests spectral interference from multiple co-eluting chromophores and possible scattering effects from colloidal plant matter in the crude extract [42]. This is commonly observed in unfractionated leaf extracts and underscores the need for further HPLC-DAD or LC-MS

fractionation to isolate and characterize individual bioactive compounds [43].



Fourier Transform Infrared (FTIR) spectroscopy was employed to characterise the functional groups present in the *Gmelina arborea* leaf sample. The spectrum, recorded on a Shimadzu FTIR spectrophotometer over the 400–4000 cm^{-1} range, revealed nine distinct absorption bands, each corresponding to specific molecular bond vibrations indicative of biologically active secondary metabolite classes. The spectral data are consistent with the phytochemical profile previously established through qualitative screening and quantitative analysis.

Phenols and Polyphenols: 3378.47 cm^{-1} — O–H stretching

The broad, strong absorption band at 3378.47 cm^{-1} is characteristic of O–H stretching vibrations arising from intermolecularly hydrogen-bonded hydroxyl groups. This band is a diagnostic feature of phenolic compounds, polyphenols, flavonoids, and tannins [17]. The broadness of the band reflects extensive hydrogen bonding networks typical of condensed polyphenolic structures in plant tissue. This finding is in strong agreement with the quantified total phenol content of 215.25 ± 18.65 mg/g and the high levels of tannins and polyphenols detected in both methanol and aqueous extracts. Similar O–H stretching bands in this region have been reported for phenolic-rich extracts of medicinal plants including *Tectona grandis* and *Vitex negundo*, members of the same Lamiaceae family [44, 16].

Alkaloids and Terpenoids: 2924.21 cm^{-1} — C–H stretching

The absorption at 2924.21 cm^{-1} corresponds to the asymmetric C–H stretching vibration of $-\text{CH}_2$ and $-\text{CH}_3$ aliphatic groups. This band is ubiquitous in plant extracts and is primarily attributed to the aliphatic carbon chains present in terpenoids, alkaloids, fatty acids, and waxes [45]. Given the confirmed presence of terpenoids (95.65 mg/g) and alkaloids (156.65 mg/g), this band is expected and confirms the aliphatic skeletal framework of these compound classes. The position at 2924 cm^{-1} rather than the sharper 2960 cm^{-1} typical of pure alkanes suggests the dominance of $-\text{CH}_2$ groups in

longer carbon chains, consistent with terpenoid and steroid structures [46].

The dominant peak: 2139.15 cm^{-1} — $\text{C}\equiv\text{C}$ stretching

The most intense peak in the spectrum appears at 2139.15 cm^{-1} with a %T intensity of 3.83, significantly higher than all other bands. Absorptions in the 2100–2260 cm^{-1} region are assigned to $\text{C}\equiv\text{C}$ stretching vibrations of alkynes or cumulated double bond systems ($\text{C}=\text{C}=\text{O}$, $\text{C}=\text{C}=\text{C}$) [47]. In plant extracts, this region has been associated with conjugated alkyne-containing terpenoids, acetylenic fatty acids, and certain secondary metabolites with polyene frameworks [48]. Notably, some researchers have also attributed absorption in this region to overtone bands of aromatic C–H bending or to atmospheric CO_2 interference around 2349 cm^{-1} , though the position at 2139 cm^{-1} and the high corrected area (446.398) argue for a genuine molecular absorption. The presence of this band in *G. arborea* may indicate unique bioactive alkyne-containing phytochemicals that warrant further isolation and characterization. Similar prominent bands near 2100–2200 cm^{-1} have been reported in FTIR studies of other Lamiaceae and Verbenaceae species [49].

Flavonoids and Anthraquinones: 1631.85 cm^{-1} — C=C / C=O stretching

The absorption band at 1631.85 cm^{-1} is assigned to conjugated C=C aromatic stretching and/or C=O stretching of α,β -unsaturated carbonyl systems. This region is characteristic of flavonoids (particularly the C-ring carbonyl at 1600–1650 cm^{-1}), anthraquinones, and amide N–H bending [16,50]. The confirmed high concentration of flavonoids (145.32 ± 12.44 mg/g) and high concentrations of anthraquinone in both extracts strongly support this assignment. A band at approximately 1630 cm^{-1} is also consistent with the C=N stretching vibration in imine-containing alkaloids [17]. The relatively modest intensity of this band compared to the 2139 peak may reflect partial resolution of multiple overlapping carbonyl/alkene absorptions in the crude sample.

Tannins and Terpenoids: 1389.77 cm^{-1} — C–H bending and O–H in-plane

The band at 1389.77 cm^{-1} is attributed to symmetric C–H bending of methyl groups ($-\text{CH}_3$) and in-plane O–H bending vibrations of phenolic hydroxyl groups [46]. This band is commonly observed in tannin-rich extracts as it reflects the O–H deformation of polyphenolic structures. In terpenoids and alkaloids, this region also encompasses C–N stretching vibrations [44]. The presence of this band corroborates the high tannin content found in the methanol extract (++) and the substantial polyphenol levels (215.25 mg/g total phenol).

Glycosides and Alkaloids: 1249.93 cm^{-1} — C–O and C–N stretching

The absorption at 1249.93 cm^{-1} is assigned to C–O stretching of phenolic ethers and C–N stretching of aromatic amines. This band is characteristic of phenolic

C–O bonds in glycosides, coumarins, and lignin-derived compounds [50]. For alkaloids, absorption in the 1200–1350 cm^{-1} range reflects C–N stretching within the heterocyclic ring system [51]. Both glycosides more positive in methanol and coumarins are strong positive in both extracts identified in the preliminary screening are consistent with this assignment. Similar bands have been reported for alkaloid-containing medicinal plant extracts [52].

Glycosides and Saponins: 1091.76 cm^{-1} — C–O–C stretching

The strong band at 1091.76 cm^{-1} is one of the most diagnostic absorptions for C–O–C ether linkages, characteristic of glycosidic bonds in saponins, flavonoid glycosides, and polysaccharides [45]. The C–O–C asymmetric stretch in this region is a hallmark of pyranose and furanose sugar rings attached to aglycone moieties [47]. Given the confirmed high concentration of saponins positive and glycosides positive in the extract, this band provides direct spectroscopic evidence for the glycosidic nature of several bioactive constituents. Absorption at 1091 cm^{-1} has been consistently reported in FTIR analyses of saponin-rich plants [16].

Fingerprint region: Aromatic ring deformations 634.61 and 524.66 cm^{-1}

The two low-wavenumber absorptions at 634.61 cm^{-1} and 524.66 cm^{-1} fall in the fingerprint region and are attributed to out-of-plane C–H bending vibrations of aromatic rings and ring deformation modes, respectively. Bands in the 500–700 cm^{-1} range are characteristic of substituted aromatic systems in polyphenols, flavonoids, and anthraquinones [17,46]. The band at 524 cm^{-1} may also reflect C–X (halide) or metal-organic bond vibrations from mineral-bound organic compounds in the crude leaf material. These fingerprint bands, while less specific individually, collectively confirm the aromatic character of the dominant phytochemical constituents and agree with the flavonoid, tannin, and anthraquinone content established previously.

The FTIR data comprehensively corroborate all four compound classes quantified by spectrophotometry. The O–H band (3378 cm^{-1}) and C=C (1631 cm^{-1}) together confirm phenolics and flavonoids; the C–H band (2924 cm^{-1}) confirms terpenoids and alkaloids; and the C–O–C band (1091 cm^{-1}) confirms saponins and glycosides. The dominant peak at 2139 cm^{-1} represents a notable spectral feature that may distinguish *G. arborea* from other medicinal plants and merits targeted phytochemical investigation.

Conclusion

The combined application of UV-Vis spectroscopy (200–1100 nm) and Fourier Transform Infrared (FTIR) spectroscopy (500–4000 cm^{-1}) provided comprehensive and mutually corroborating spectroscopic evidence for the identity and diversity of bioactive secondary metabolites present in the leaf of *Gmelina arborea* Roxb. Together, the two techniques

established a robust molecular fingerprint of the crude leaf material that substantiates and extends the findings from preliminary phytochemical screening and quantitative analysis.

The UV-Vis spectrum demonstrated a broad, multi-peak absorption profile spanning the UV, visible, and NIR regions, with notable absorptions in the 200–220 nm range (aromatic conjugated systems), 270–280 nm (phenolics), 310–330 nm (flavonoids and coumarins), 450–680 nm (photosynthetic pigments including chlorophyll a, chlorophyll b, and carotenoids), and 940–1080 nm (O–H and C–O–C overtone vibrations). These absorptions collectively reflect a chromophore-rich extract with significant aromatic and conjugated electronic character, consistent with the high total phenol content (215.25 ± 18.65 mg/g) and flavonoid levels (145.32 ± 12.44 mg/g) established by quantitative spectrophotometry. The FTIR spectrum independently confirmed each of these compound classes through their characteristic bond vibration signatures. The broad O–H stretching band at 3378.47 cm^{-1} corroborated the hydrogen-bonded phenolic networks of tannins and polyphenols; the C–H stretching at 2924.21 cm^{-1} confirmed the aliphatic frameworks of terpenoids and alkaloids; the notable C≡C absorption at 2139.15 cm^{-1} — the most intense band in the entire spectrum (%T = 3.83) — indicated the presence of alkyne-bearing phytoconstituents, a structurally distinctive feature that merits further isolation and characterisation; and the strong C–O–C stretching at 1091.76 cm^{-1} provided unambiguous evidence for glycosidic ether linkages in saponins and flavonoid glycosides.

Crucially, the two spectroscopic methods were fully concordant — every compound class detected by UV-Vis electronic transitions had a corresponding functional group signature in the FTIR spectrum. Phenolics confirmed at 270–280 nm (UV) were independently verified by the 3378 cm^{-1} O–H band (FTIR); flavonoids detected at 310–330 nm (UV) were corroborated by the 1631 cm^{-1} C=C/C=O band and 634 cm^{-1} aromatic deformation (FTIR); and glycosidic compounds inferred from NIR absorptions (UV) were directly confirmed by the 1091 cm^{-1} ether band (FTIR). This cross-technique agreement substantially strengthens the reliability and credibility of the phytochemical characterization.

The pharmacological relevance of the spectroscopic findings is significant. The phenolic and flavonoid chromophores identified by UV-Vis are well-established molecular determinants of antioxidant, anti-inflammatory, and antimicrobial. The FTIR-confirmed glycosidic linkages are associated with the bioavailability and solubility enhancement of aglycone pharmacophores, while the terpenoid and alkaloid skeletal signatures are consistent with documented analgesic, antipyretic, and anticancer properties of *G. arborea*. The unique C≡C absorption at 2139 cm^{-1}

represents a previously underreported spectral feature in this species and suggests the presence of acetylenic secondary metabolites with potential cytotoxic or antimicrobial.

In conclusion, the UV-Vis and FTIR spectroscopic analyses of *Gmelina arborea* leaf collectively establish that this plant is a rich and structurally diverse source of bioactive phytochemicals including phenolics, flavonoids, tannins, terpenoids, alkaloids, saponins, glycosides, coumarins, and photosynthetic pigments. These findings provide a robust spectroscopic foundation for the pharmacological validation of *G. arborea* as a medicinally valuable plant and strongly support its further investigation through advanced chromatographic and bioassay-based approaches for the development of novel plant-derived therapeutics

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