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Original Research Article

Evaluation of Composition and Antioxidant Potential of *Cordia macleodii*

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Abstract:

Cordia macleodii is one of the widely used traditional medicinal herbs. The current work was undertaken to systematically extract bioactive components from the fresh plant parts and evaluate their antioxidant potential. Using ethanol as the solvent, volatile chemical components were extracted from the plant material by Soxhlet extraction. Subsequently, GC-HR-MS and FTIR analysis were used to further evaluate the extract. The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay and 2,2'- Azinobis [3-ethylbenzothiazoline-6-sulfonic acid (ABTS)] were used to evaluate the antioxidant potentialof the extract *in vitro*. Quantification of total flavonoid content (TFC) and total phenolic content (TPC) was done against standard solutions of quercetin and gallic acid, which were used in the study as positive controls. The GC-HR-MS analysis reveals two bioactive compounds [(1H)- pyrrol-3-propanoic acid,2 ethoxy carbonyl-4-ethoxy carbonyl methyl]-5,5'-methylene, bis-diethyl ester and Spino [9,9'] difluorene,2,2'-[2,5,8,11-tetraoxado decane-1,12-diye). The FTIR spectrum showed that there were several different functional groups present. Findings of *in vitro* antioxidant tests revealed that the leaves had the highest total phenolic content (402.19 ± 0.025 mg GAE/g), the highest total phenolic content (93.59 ± 0.01), and the highest ABTS (102.59 ± 0.001) of any plant. To fully evaluate this plant's therapeutic potential, more pharmacognostic research is required.

Keywords: GC-HR-MS, FTIR, TPC, TFC, Antioxidant

Introduction

Reactive oxygen species (ROS) or free radicals are produced over what the body can neutralize and remove, which leads to oxidative stress (Pizzino *et al.*, 2017). These very reactive molecules, known as free radicals, can harm lipids, proteins, DNA, and other cellular constituents, which in turn can cause a host of health problems and accelerate the aging process. Molecules known as antioxidants are essential for shielding biological structures and

cells from oxidative stress-related harm (Phaniendra, Jestadi and Periyasamy, 2015).

Free radicals are neutralized by antioxidants, stopping them from damaging cells. They do this by donating electrons to the free radicals, effectively stabilizing them and reducing their harmful effects. Antioxidants can be enzymes produced within the body, as well as compounds derived from dietary sources (Lobo *et al.*, 2010). Traditional medicines are the therapeutic methods of treatments that have been passed down through the ages in a variety of cultures and societies. While many conventional treatments have demonstrated encouraging results in treating a range of illnesses, it is crucial to examine the subject from a scientific standpoint to fully comprehend both the advantages and disadvantages of these bioactive chemicals (Yuan *et al.*, 2016). The common elements of traditional treatment regimens can interact with the body's biological systems and could alter particular biochemical pathways suggesting their role in therapeutics. For instance, salicin, which is found in willow bark and other herbal medicines is used to relieve pain, it gets converted by the body into salicylic acid, which has analgesic and anti-inflammatory properties (Cordia and Dc, 2021).

Alkaloids, flavonoids, and terpenoids are examples of secondary metabolites that plants make that have the ability to suppress microbial infestations. For example, antimicrobial action against bacteria, fungi, and viruses has been demonstrated by extracts from plants such as garlic, turmeric, and neem (Nawaz *et al.*, 2023). The therapeutic efficacy of these herbal traditional remedies can vary based on dosage, formulation and individual variability, despite the fact that modern research has demonstrated promising outcomes (Prasathkumar *et al.*, 2021). Furthermore, certain herbs have the potential to cause side effects or interact negatively with pharmaceuticals, which emphasises the significance of speaking with medical specialists before using herbal remedies in conjunction with conventional treatments (Valli and Giardina, 2002). In conclusion, traditional medicines cover a broad range of treatments and methods that have been utilized for many years to treat different illnesses. To better comprehend their potential contributions to contemporary healthcare, scientific study is continuously examining their safety, efficacy, and underlying mechanisms (Nariya, Shukla, and Acharya, 2012).

Cordia macleodii and related species

Cordia macleodii (griff) hook. F. & Thomas, a prominent member of the Boraginaceae family, stands as a noteworthy medicinal arboreal species (Hook and Family-, 2011). Its habitat predominantly encompasses moist and deciduous woodlands within central India, as well as the Deccan, southern, and western regions. It is commonly referred to by vernacular appellations as 'Dadhiman,' 'Dahipalas,' or 'Dahiman.' this plant has been traditionally used in various traditional medicine systems for its potential medicinal properties (Al-musayeib *et al.*, 2011).

Due to its wide range of medicinal applications, Cordia macleodii has been used extensively in traditional medicine. The leaves, bark, and roots of the plant are used to treat a variety of illnesses (Kumar *et al.*, 2011). This covers the management of skin conditions, gastrointestinal issues, and the reduction of fever, cough, and cold symptoms. The Cordia genus, which includes species like *Cordia dichotoma, Cordia myxa, Cordia oblique, Cordia africana, Cordia alliodora, Cordia colloccoca, Cordia lutea, Cordia oblongifolia, Cordia sinensis, and Cordia subcordata*, has been recognised for its noteworthy anti-inflammatory properties even though Cordia macleodii has received little scientific scrutiny. Although it is conceivable to extrapolate to Cordia macleodii, validation requires empirical research.

Additionally, studies on Cordia species' antioxidant capability show that they have the ability to protect cells from the damaging effects of free radicals. Initial research on a number of Cordia species, including the ones mentioned above, points to a potential antioxidant effect,

which implies that Cordia macleodii might exhibit similar traits (Bhide, Pillai, *et al.*, 2011). Relatedly, studies on the Cordia species hint at the possibility of anti-diabetic properties linked to particular chemicals, suggesting that blood sugar management might be possible. This is an exciting prospect that may extend to Cordia macleodii; further research is required to definitively confirm its anti-diabetic potential.

Tests conducted in laboratories on a few Cordia species have revealed their antibacterial potential. This antibacterial activity, which has been shown in vitro, suggests that Cordia macleodii may possess similar properties (Cordia and Hook, 2019). These qualities are promising for the treatment of infections. Moreover, Cordia macleodii has long been used in traditional medicine for wound healing purposes due to its purported antibacterial and anti-inflammatory qualities. Furthermore, the traditional use of Cordia macleodii to treat digestive disorders like dyspepsia and heartburn suggests possible benefits for supporting digestive health. Finally, a potential pathway for respiratory health benefits is suggested by the historic use of Cordia macleodii in the treatment of respiratory ailments, such as colds and coughs. In conclusion, intensive research is needed to fully explore the medicinal potential of Cordia macleodii due to its diverse therapeutic profile, which is based on both conventional wisdom and early scientific indications.

It's vital to remember that, in contrast to other extensively researched medicinal plants, scientific study on *Cordia macleodii* is very limited, despite possible anecdotal evidence and historic practises supporting these putative medicinal characteristics little is known about the phytochemical makeup of *Cordia macleodii*.

In order to bridge this knowledge gap, the current work was conducted to develop standardised procedures for assessing *Cordia macleodii's* antioxidant qualities in both its bark and leaves. These researches opens the door for further research opportunities in understanding this plant and developing new therapeutic agents.

Materials and methods

Collection of plant sample

The bark of *Cordia macleodii* was collected from Amarkantak region (Madhya Pradesh) and further identified and authenticated by the Department of Botany, Guru Ghasidas Vishwavidyalaya, Koni, Bilaspur. In this investigation, the plant's bark constituted the subject of interest and was selected as the primary material for the study. The procedure commenced with the careful collection of the bark, followed by meticulous processing.

The collected bark was methodically sectioned into smaller pieces, subsequently undergoing a controlled desiccation process in the shade to facilitate preservation. Once fully dried, the bark material was subjected to mechanical reduction, wherein it was pulverized into a finely textured powder using mortar and pestle, ensuring that the resulting powder exhibited a consistent and homogeneous composition. For the purpose of sustained integrity and to prevent any potential alteration or contamination, the finely powdered bark material was securely stored within an airtight container.

This step was a prerequisite for the subsequent analytical phases of the study, maintaining the material’s integrity and ensuring its suitability for further analysis and experimentation.

Figure 1: *Cordia macleodii* (a) Whole plant, (b) Leaves, (c) Bark

Preparation of extract

Soxhlet extraction

Approximately 20 grams of finely powdered plant material was meticulously selected for this study and subsequently subjected to a rigorous extraction process, following the established principles of the Soxhlet extraction method. The chosen solvent for this extraction was ethanol, a suitable choice for its efficacy in solubilizing a wide range of phytochemicals. The extraction process was executed, extending over duration of 24 to 30 hours. During this period, the solvent ethanol underwent repeated cycles of heating and condensation within the Soxhlet apparatus, ensuring comprehensive extraction of the plant material's bioactive constituents. Upon completion of the extraction procedure, the resultant extracts were separated from any residual plant material using Whatman filter paper No. 2. Subsequently, to enhance the concentration of the extracts, a concentration step, as described by Kim *et al.* 2013, was used. The concentrated extracts, now refined and enriched with the bioactive compounds of interest, was systematically preserved under controlled storage conditions, specifically at a temperature of 4°C, to safeguard their stability and integrity until the forthcoming analytical assessments. Furthermore, the percentage yield of the extracted material was accurately quantified utilizing the following formula, as a key metric to gauge the efficiency of the extraction process:

$$\text{Yield (\%)} = \frac{Weight\ of\ crude\ extract\ (g)}{Dried\ extract\ weight\ (g)} \times 100$$

Qualitative Phytochemical screening

According to the usual process employed by the Ayurvedic Pharmacopoeia of India, the dried sample was used for physicochemical and preliminary phytochemical analysis. Phytoconstituents were determined qualitatively using different chemical methods. The *Cordia macleodii* bark's phytochemical screening revealed a variety of phytochemical compounds, including phenols, flavonoids, alkaloids, tannins , steroids, carbohydrates, terpenoids, triterpenoids, and glycosides (Bhide, Shukla, *et al.*, 2011).

GC-HR-MS analysis

A gas-chromatograph coupled with mass spectrometry (GC-HRMS) has a superior ability in analyzing organic compounds qualitatively and quantitatively. We have used GC-HR-MS instrument at IIT Bombay Saif. It has head space facility with FID detector that can withstand upto 280˚c temperature. GC-MS analysis of the whole plant extract of *Cordia macleodii* was performed using Jeol, Model Accu TOF GCV, specification EI/ CI Source Time of Flight Analyser Mass range is 35-800 amu, and Mass resolution is 5000. The GC used in this study

was Agilent 7890 FID detector, Head Space injector and Combipal autosampler.

FTIR

The FTIR spectrometer (Bruker Alpha II FTIR) equipped with a Diamond Crystal ATR (Attenuated Total internal Reflectance) was used in the study. Samples were grounded with spectroscopy grade KBr and a pellet of a homogeneous mixture was prepared using a hydraulic press. 5µl of sample was applied as a drop of sample on top of the diamond head. The spectrum of the unknown component was juxtaposed with the spectra of the known components archived within the library. Furthermore, this compound underwent characterization through infrared (IR) and ultraviolet (UV) analyses. The extracted compound from the bark of *Cordia macleodii* was subsequently subjected to spectral detection. The spectrometer run Opus 7.8 software.

Determination of phytochemical constituents

Total phenolic content

Using Folin Ciocalteu's reagent, the total phenolic content was estimated using the methodology established by Miliauskas et al. In short 10µl of the bark extract, 100µl of Folin-Ciocalteu's reagent, and 80µl of 5% sodium carbonate were carefully mixed in a reaction mixture. This mixture was allowed to sit at room temperature for two hours under dark conditions. When the incubation period was over and a bright, strong blue tint appeared, absorbance was measured at a wavelength of 730 nm. To determine the total phenolic content, gallic acid was employed as a standard reference compound. The results were expressed in terms of gallic acid equivalents (GAE) and quantified as milligrams of GAE per gram of dry sample.

$$C = (c \times V) / m$$

Where, C = Total content of phenolic compounds (GAE mg gm-1 of plant extract), c = concentration of gallic acid established from the calibration curve (mg ml-1), V = The volume of extract in ml and m = The weight of crude plant extract in gm (Cordia and Hook, 2019).

Total flavonoid content

Using an aluminium chloride colorimetric assay, as described by Chang et al. total flavonoid concentration was determined. A reaction mixture including 20µl of bark extract, 6µl of 5% sodium nitrite solution, 6µl of 10% aluminium chloride solution, 40µl of 1M sodium hydroxide solution, and 80µl of DH_2O was created in order to start the assay. After an incubation time of six minutes, distilled water was used to adjust the mixture's volume to 152µl, and rapidly agitated. The mixture appeared orange-yellow in colour which is suggestive of the development of flavonoid complexes. The resulting solution's absorbance was measured at 510 nm, and a calibration curve was created using Quercetin compound as reference. Total flavonoid concentration was expressed in terms of milligrams of Quercetin equivalents per milligram of dry mass (mg gm^-1).

$$C = (c \times V) / m$$

Where, C = Total content of flavonoids (QUE mg gm-1 of plant extract), c = concentration of Quercetin established from the calibration curve (mg ml-1), V = The volume of extract in ml and m = The weight of crude plant extract in gm (Qureshi and Haleem, 2009).

Antioxidant assay

Antioxidants are essential for preventing oxidative damage to the cells, boosting health, and neutralising free radicals and ROS. Of these antioxidants, flavonoids—phenolic chemicals present in a wide variety of plants—have drawn the most notice due to their strong antioxidant capabilities. Flavonoids considerably increase the total antioxidant capacity of plant phenolic compounds by efficiently scavenging free radicals and harmful ROS (Chandrakar and Dixit, 2017).

DPPH (2,2-diphenyl-1-picrylhydrazyl)

The capacity of extracts to scavenge the free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH)

can be used to measure their antioxidant activity. The DPPH assay is a commonly employed method for assessing the ability of natural substances to scavenge radicals. In this investigation, the antioxidant potential of several extracts was evaluated using the DPPH assay technique, as reported by (Athmouni *et al.*, 2016). 0.1 mM DPPH solution was prepared in methanol. Throughout the experiment, the solution was kept dark to prevent light from compromising its integrity. To measure the antioxidant activity, standards and extracts at various concentrations were prepared.22µl samples with different concentrations were incubated with 200µl of 0.1 mM DPPH solution. After 30 minutes of incubation, the reaction mixture was measured at 517 nm. The amount of DPPH radical scavenging was assessed by observing change in the colour of the DPPH solution, which suggests that the antioxidant components in the extracts were reducing the free radical (Yu *et al.*, 2021).

ABTS (2,2'-Azinobis(3-ethylbenzothiazoline-6-sulfonic acid) test

The ABTS test was used to look at *Cordia macleodii's* capacity for radical scavenging. To summarize, the ABTS radical cation was mixed with potassium persulfate and left to incubate in the dark for a full day prior to use. Subsequently, ethanol was added to the ABTS solution to dilute it and measure the absorbance at 734 nm. After 6 minutes, the absorbance at 734 nm was measured in a composite that contained the diluted ABTS solution and the extract of *Cordia macleodii*. We used ascorbic acid as a positive control. The following formula was used to determine the sample's scavenging capacity: The ABTS radical scavenging activity (%) was calculated as $[(A0 – A) / A0] \times 100$, where A denotes the absorbance when the samples are present and A0 is the absorbance of the control reaction (Athmouni *et al.*, 2016).

Results and Discussion

A preliminary phytochemical examination of *Cordia macleodii* leaves and bark has identified a number of significant phytochemical substances, including tannins, phenols, flavonoids, saponins, alkaloids, and glycosides. As of now, a thorough analysis of these plant components provides a wide variety of bioactive compounds with a promise for the creation of new pharmaceuticals.

Percentage yield of crude extracts

20 g of plant powder was used for extraction with the solvent using a Soxhlet extraction. The percentage of yield of extract is 8.86%

Antioxidant capacities of hydromethanolic extract of *Cordia macleodii* was assessed by 2 types of antioxidant tests, including DPPH and ABTS assays.

Significant *in vitro* DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity was demonstrated by the ethanolic extracts obtained from *Cordia macleodii*, in a dose-dependent manner. L-ascorbic acid, a common antioxidant, on the other hand, showed strong DPPH radical scavenging ability. Notably, at a concentration of 1 milligram per millilitre (mg/ml), the % DPPH radical scavenging activity of *Cordia macleodii's* ethanolic extract stayed rather constant. The IC_{50} values, or the amounts of the examined plant extracts needed to scavenge 50% of the DPPH radicals, was determined as 93.59±0.01 mg/ml. These findings underscore the robust DPPH radical scavenging potential of the *Cordia macleodii* extract while highlighting the superior efficacy of L-ascorbic acid as a reference antioxidant in this context.

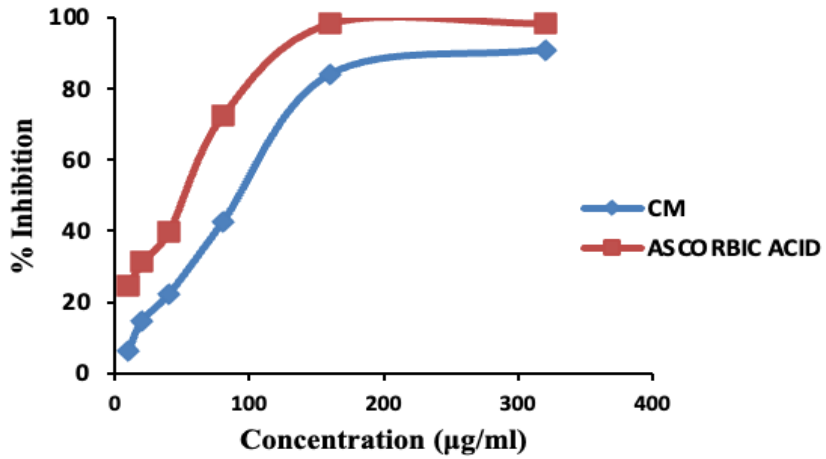


Figure 2: DPPH radical scavenging activity of the ethanolic extract of *Cordia macleodii* bark and standard Ascorbic acid.

The chemical reaction between potassium persulfate and ABTS results in the creation of the ABTS radical cation (ABTS+), which is a blue-green chromogenic molecule. When an antioxidant reductant is present, the radical's colourful appearance changes to that of its colourless counterpart, ABTS. A detectable shift in absorbance, measured at a wavelength of 734 nm, coincides with this transformation. The intrinsic antioxidant capacity of *Cordia macleodii* extract was assessed in the context of this study. The findings demonstrated the existence of antioxidant activity in these extracts, with the ethanolic extract having the greatest inhibitory concentration (IC_{50}), determined to be 102.59±0.001 micrograms per millilitre (µg/ml). This observation suggests a noteworthy capacity of *Cordia macleodii* extracts to effectively scavenge free radicals, thereby underscoring their potential utility as agents for mitigating oxidative stress.

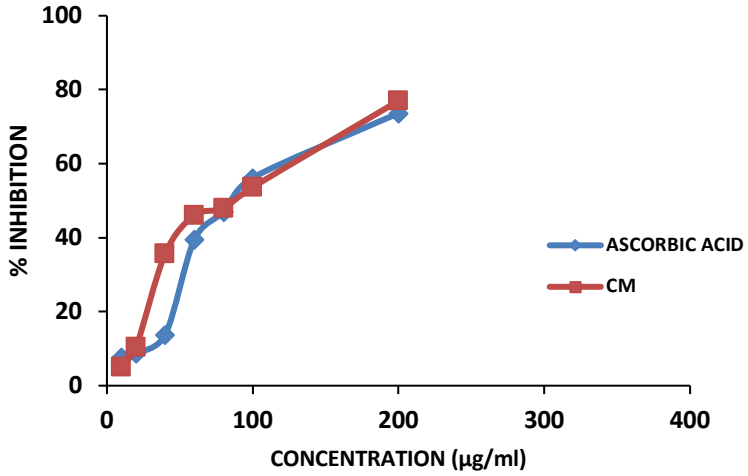


Figure 3: ABTS radical scavenging activity of the ethanolic extract of *Cordia macleodii* bark and standard Ascorbic acid.

Total Phenolic Contents

Using gallic acid as the reference standard, the Folin–Ciocalteu (F–C) method we quantified the total phenolic content in the bark of *Cordia macleodii*. By using this analytical method, the absorbance values at different gallic acid concentrations were measured, and the results were used as the basis for creating a calibration curve. Y = 0.0047x, where 'Y' stands for absorbance values and 'x' for gallic acid concentration, the regression equation generated from the calibration curve was used to calculate the total phenolic content of the extracted samples. The regression equation's coefficient of determination (R^2) was found to be 0.994, suggesting that the calibration curve has a high degree of linearity and dependability. The final measure of the total phenolic content was expressed as milligrams (mg/g) of gallic acid equivalents (GAE) per gram of the sample's dry weight. In the bark extract total phenolic content (TPC) value was determined to be 402.19 ± 0.025 mg GAE/g. This quantitative measure indicates the possible bioactive components in the bark samples under examination by providing useful information about the concentration of phenolic compounds in the samples.

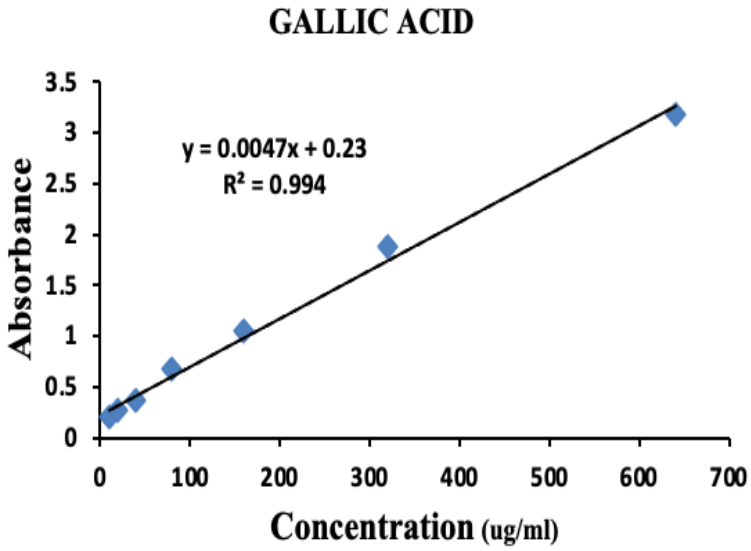


Figure 4: Calibration curve of Gallic acid.

Total Flavonoid Contents

The total flavonoid content was measured using the regression equation derived from the calibration curve, which is written as Y = 0.0037x, where 'x' stands for quercetin concentration and 'Y' stands for absorbance values. This regression equation's coefficient of determination (R^2) was found to be 0.9956, indicating a strong linear relationship. The total flavonoid concentration was reported as milligrams (mg/g) of quercetin equivalents (QE) per gram of the sample's dry weight. The grown bark extract's total flavonoid content (TFC) value was measured and found to be 8.83 ± 0.001 mg QE/g. This quantitative analysis reveals good amount of flavonoid contents in the bark samples under investigation, indicating their potential as bioactive constituents. It is also notable that the trends in the total phenolic content values and the total flavonoid content values were similar. The link between these two types of phytochemicals in the bark extracts is highlighted by this observation. It's crucial to recognise the polarity of the solvents used in the extraction process that can affect the concentration of both phenolic and flavonoid chemicals, adding another level of complexity to the compositional profile of the extracts.

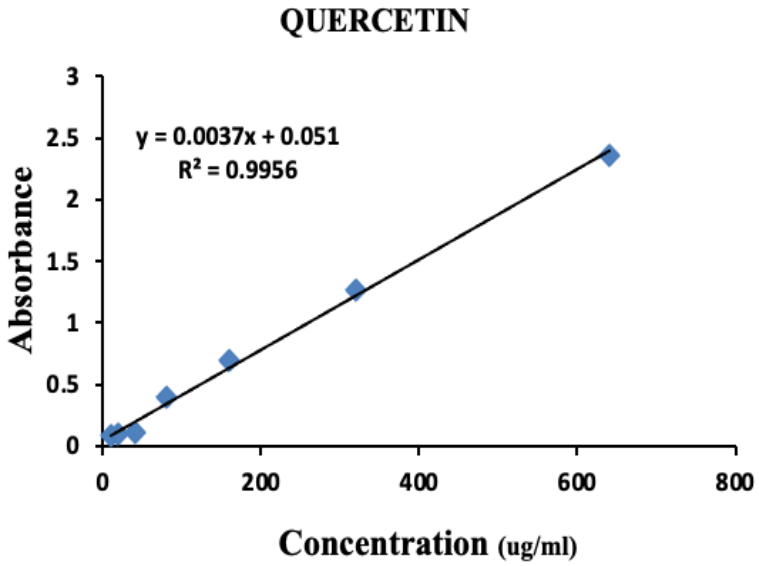


Figure 5: Calibration curve of Quercetin.

FTIR

Fourier Transform Infrared Spectrophotometer (FTIR) analysis was used in this study to determine which functional groups and chemical bonds were present in the various plant components. For the analysis, dried powder made from solvent extracts of every plant specimen was used. The samples were scanned over a wavelength range of 610.03 to 4000 cm^-1 for the analysis. The distinctive chemical bonds in the sample molecules were identified by interpreting the ensuing infrared absorption spectra, which gave important information about the samples' composition and structure.

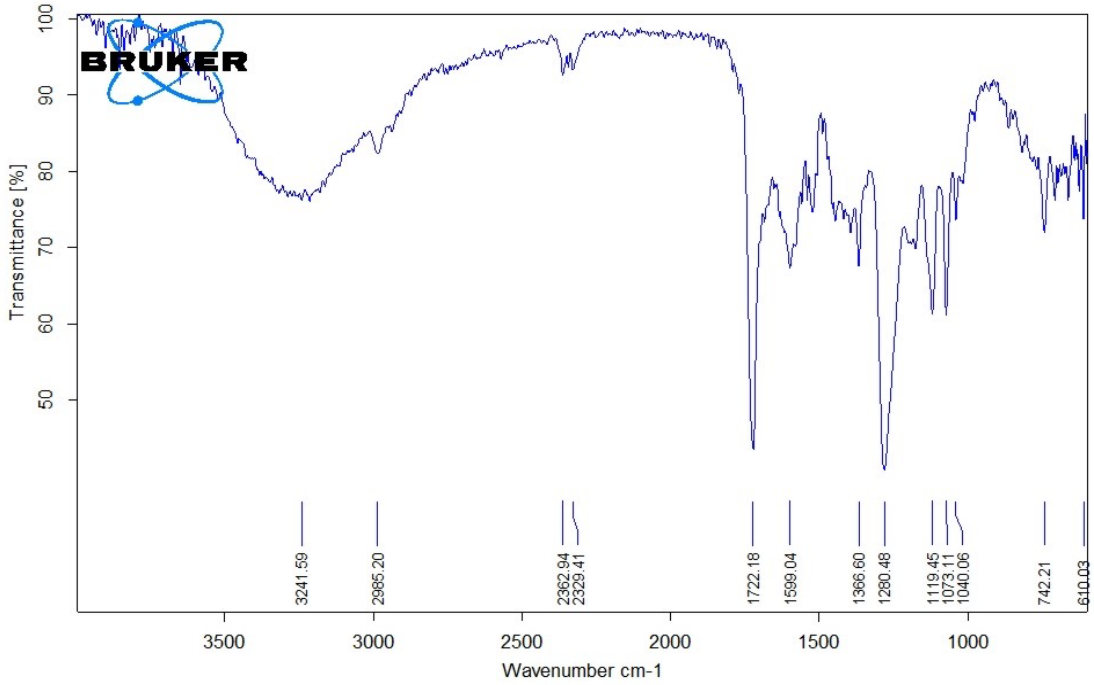


Figure 6: FTIR spectra of ethanolic extract of *Cordia macleodii*.

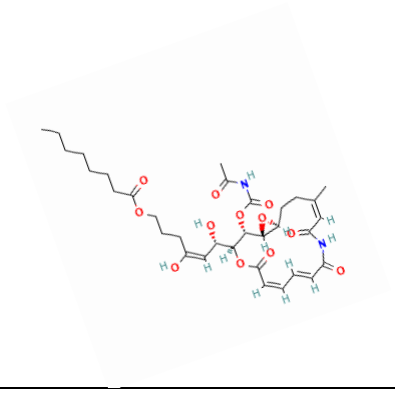
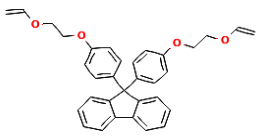
Table 1: Fourier Transform Infrared Spectrophotometer (FTIR) analysis of Phytochemicals in *Cordia macleodii.*

S. no.	WAVENUMBER (cm^{-1})		ASSIGNMENTS
	EXP.	LIT.	
1.	610.03	680-610 700-600	Alkyne C-H bond Aliphatic bromo compounds C-Br strech
2.	742.26	750-720 770-730 770-735 800-700	Methylene $(CH_2)n$ C-H mono substitution (phenyl) C-H 1,2 Disubstitution (Ortho) Aliphatic chloro compound, C-Cl stretch
3.	1040.06	1225-950 1150-1000	Aromatic C-H in plate bend Aromatic fluoro compound, C-F strech
4.	1073.11	1225-950 1150-1000	Aromatic C-H in plate bend Aliphatic fluoro compound, C-F strech
5.	1119.45	1225-950 1150-1000 1130-1080	Aromatic C-H in plane bend Aliphatic fluoro compound, C-F strech Sulphate ion
6.	1260.48	1270-1230	Aromatic ethers, aryl-o strech
7.	1366.60	1380-1350 1370-1365	Nitrate ion Iso (doublet)
8.	1599.04	1615-1580 1650-1590 1650-1550	C=C-C aromatic ringstrech Primary amine, NH bend Secondary amine, >N-H bend
9.	1722.18	1725-1705 1725-1700	Ketone Carboxylic acid
10.	2329.41	2000-2500	Triple bond
11.	2362.94	2000-2500	Triple bond
12.	2965.20	2970-2950	Methyl C-H asymmetrical strech
13.	3241.59	3570-3200 3400-3200	Hydroxyl group, H-bonded OH stretch Normal polymeric OH strech

GC-HR-MS

Two bioactive compounds that were identified from the GCHRMS analysis of Ethanolic crude extract of *Cordia macleodii* bark are [(1H)-pyrrol-3-propanoic acid,2 ethoxy carbonyl-4-ethoxy carbonyl methyl]-5,5'-methylene,bis-diethyl ester and Spino [9,9'] difluorene,2,2'-[2,5,8,11-tetraoxado decane-1,12-diye).

Table 2: Gas chromatography- high resolution mass spectroscopy (GC-HRMS) analysis of phytochemicals in *Cordia macleodii.*

S. No.	RT (Min)	Name of the Compound	Molecular formula	MW g/mol	Peak area %	Structure of Compound
1.	4.12	[(1H)- pyrrol-3-propanoic acid,2 ethoxy carbonyl-4-ethoxy carbonyl methyl]-5,5'-methylene,bis-diethyl ester	$C_{33}H_{46}N_2O_{12}$	662	21.14	
2.	4.68	Spino [9,9'] difluorene,2,2'-[2,5,8,11-tetraoxado decane-1,12-diye).	$C_{33}H_{30}O_4$	490	19,243.51	

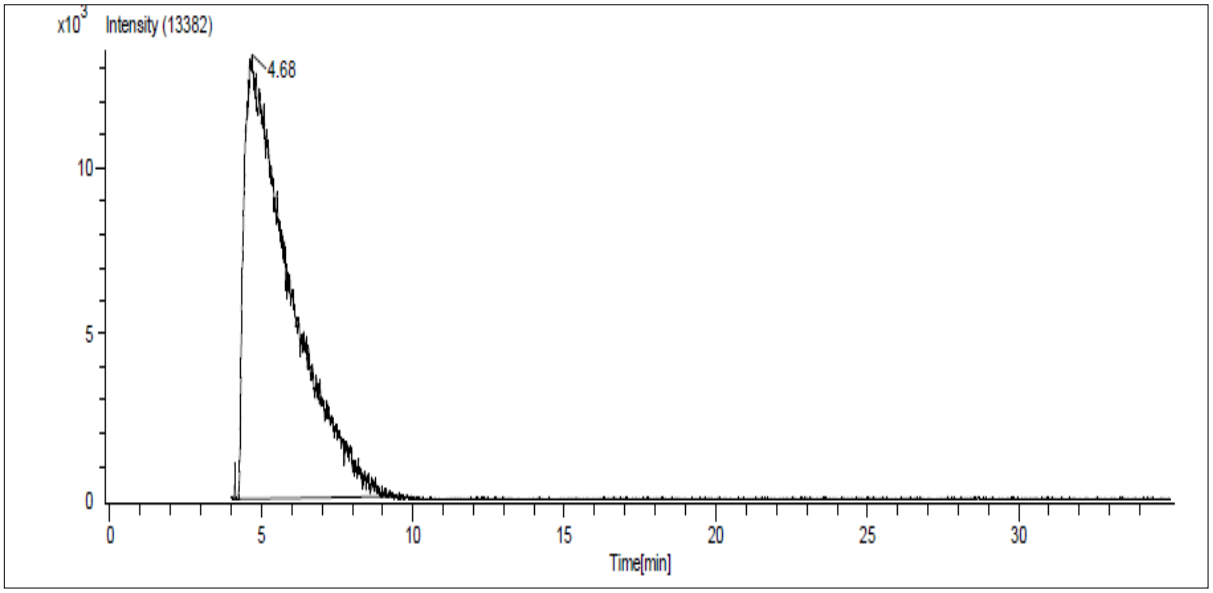


Figure 7: Gas chromatography high resolution mass spectroscopy (GC-HRMS) chromatogram of *Cordia macleodii.*

Conclusion:

Cordia macleodii bark extract has shown impressive antioxidant capabilities. For any compound to work as a drug of choice depends on various factors, including its interaction with the target and largely dependent on the functional groups that are present on the compound. In the present study *Cordia macleodii* was subjected to Fourier-transform infrared spectroscopy (FTIR) analysis and the results indicated the presence of several functional groups, including hydroxyl, carbonyl, and amine groups. These groups are frequently linked to the characteristics that make a compound useful as a herbal drug (Table 1 and Figure 6). The antioxidant and antibacterial properties of the plant are probably attributed to these functional groups. The plant was analysed using gas chromatography-mass spectrometry (GCMS), which revealed a wide variety of chemicals, such as flavonoids, alkaloids, terpenes, and phenolic compounds (Table 2 and Figure 7). Numerous reports have indicated that these chemicals have a range of therapeutic benefits, such as antibacterial, antioxidant, anti-inflammatory, anticancer, and antidiabetic effects. The results of this study offer a solid basis for investigation into different parts of *Cordia macleodii* plant in order to fully explore the potential of this plant and discover its therapeutic benefits. Present work suggests that *Cordia macleodii* is an important plant and holds a lot of promise for its usage in formulation of herbal medicine addressing bacterial infections, free radical, inflammation, cancer, and diabetes.

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