FT-IR & Gas Chromatography - Mass Spectroscopy Analysis of *Canna Indica* L. Flowers: A Green Route to Silver Nanoparticle Synthesis

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ABSTRACT

This study examines the phytochemical profile of Canna indica flower extract using Fourier Transform Infrared spectroscopy and Gas Chromatography-Mass Spectrometry to determine its role as a green reducing and stabilizing agent in the biosynthesis of silver nanoparticles. FTIR analysis revealed distinct absorption bands, including a strong peak at 2927 cm^{-1} for aliphatic C-H stretching vibrations, a prominent band at 1031 cm^{-1} for C-O stretching vibrations in alcohols and phenolic compounds, and multiple bands between 920 and 776 cm^{-1} for aromatic C-H bending vibrations. A faint band at 353 cm^{-1} suggests potential metal-oxygen interactions, which are crucial for nanoparticle stability. GC-MS profiling revealed a wide range of bioactive compounds, including saturated and unsaturated fatty acids (such as palmitic and linoleic acids), fatty acid esters, phytosterols, terpenoids, and phenolic derivatives. The presence of these functional groups and phytochemicals enhances the extract's ability to effectively reduce silver ions and stabilize the resulting nanoparticles. Overall, the study demonstrates that Canna indica flower extract is a rich, eco-friendly source of bio-compounds suited for the sustained green synthesis of silver nanoparticles, with interesting applications in nanotechnology and biomedicine.

Key Words *- Canna indica L., FT-IR, GC-MS, Green route, sliver nanoparticles.*

1. INTRODUCTION

"Herbal medicine is a genuine gift from nature, offering safe and efficient remedies for human health. Plants have long been used to alleviate sickness and improve overall well-being. Even today, herbal medicines are critical for maintaining overall health and disease prevention.

Richard Feynman, a physicist, proposed the theoretical concept of nanotechnology in 1959[1]. Nanotechnology is concerned with understanding and manipulating matter at the atomic and molecular levels [2]. Metal nanoparticles with a variety of physicochemical properties have attracted a lot of attention in recent decades [3]. Because of their ultra-small size and high surface area to volume ratio, nanoparticles have sparked a lot of interest in their application, as they differ in both physical and chemical properties from the majority of identical chemical compositions [4-6]. Nanoparticles' unique optoelectronic and physicochemical features make them useful in a variety of applications, including medical diagnostic imaging, treatment regimens, and pharmaceutical products [7]. There are two primary methods for manufacturing nanoparticles: top-down and bottom-up approaches, both of which provide control over particle morphology, size, and function [8]. The top-down approach involves turning bulk materials into nanoscale particles via physical processes such as ball milling, lithography, etching, and sputtering [9]. The bottom-up method, on the other hand, assembles nanoparticles from atomic or molecular units, which typically requires the use of strong chemical reducing agents like hydrazine or sodium borohydride, as well as stabilizers and organic solvents like toluene and chloroform. While these methods are effective for manufacturing homogeneous and high-purity nanoparticles, they are typically expensive and pose environmental and health risks [10]. As a result, attention has shifted to green synthesis techniques, which emphasize the use of non-toxic, sustainable materials such as biological reducing agents, safe solvents, and natural capping agents, resulting in a more environmentally friendly and cost-effective method of nanoparticle synthesis [11].

1.1 Green Synthesis of Nanoparticles

Green-synthesized nanoparticles have received a lot of interest in recent years as an alternative to traditional chemical and physical processes because they are simple, inexpensive, and environmentally friendly [12]. This biosynthetic technique uses natural resources to decrease and stabilize metal ions, eliminating the need for harsh chemicals or energy-intensive procedures and thereby fulfilling the criteria of sustainable nanotechnology. Metallic nanoparticles can be produced from entire cells, cell-free extracts, or biomolecules originating from plants, algae, fungus, and bacteria, as seen in Figure 1.1. Compliance with green chemistry principles, which emphasize the use of non-toxic solvents, renewable reducing agents, and safe stabilizers to ensure low environmental impact and improved biocompatibility, is one of the most important aspects of green synthesis [13]. Green synthesis has several advantages over conventional approaches, including decreased toxicity, lower cost, and the ability to produce vast quantities under benign experimental settings.

Plant-mediated synthesis is particularly favourable among the various biological routes due to the diverse variety of phytochemicals found in plant extracts, including flavonoids, terpenoids, phenolics, and proteins. These chemicals rapidly reduce metal ions while stabilising nanoparticles, resulting in particles that are more uniform and stable than those generated using microbial techniques. Plant-based synthesis is speedier, more environmentally friendly, and scalable, making it a viable approach for biomedical and pharmaceutical applications.

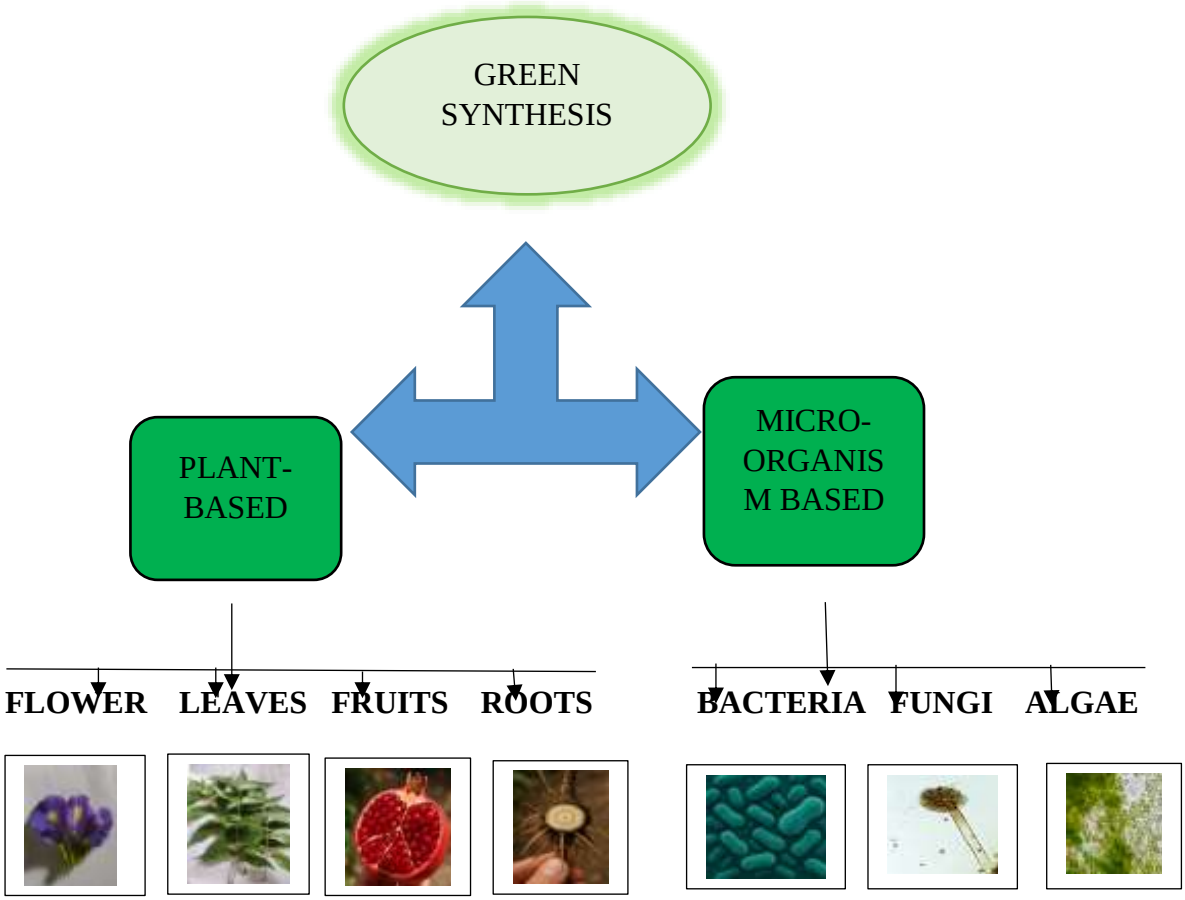


Figure 1.1 Different Types of Green Synthesis

1.1.1 Nanoparticle Synthesis Using Flower Extracts

Flowers are considered one of the most attractive biological resources for green nanotechnology because they contain a wide range of bioactive phytochemicals, including flavonoids, terpenoids, alkaloids, tannins, phenolic acids, and proteins. These metabolites can act as both reducing and stabilising agents in nanoparticle production, making flowers extremely useful for this purpose. The phytoconstituents found in flower extracts serve a dual purpose: they not only speed up the reduction of metal ions to nanoparticles, but they also work as natural capping agents, coating the surface and preventing aggregation, so boosting long-term stability. Such multifunctional activity improves the quality, homogeneity, and dispersion of nanoparticles synthesised from flowers.

Furthermore, the structural diversity of chemicals found in flowers allows for the effect of nanoparticle size, shape, and morphology, which is extremely desirable for biological and pharmacological applications. Flower-mediated synthesis is more environmentally friendly, requires less labour, and is more convenient than microbiological techniques. Microorganisms necessitate carefully maintained sterile conditions, controlled nutrient media, and regular cultivation, which can be technically difficult, time-consuming, and expensive. Furthermore, recovering and purifying nanoparticles from microbial cultures sometimes includes multiple downstream stages, which adds to the method's complexity. In contrast, flower-based synthesis can be completed quickly under mild reaction conditions, needs less energy, and uses less harmful chemicals.It also offers a greener option with a lower environmental effect while retaining scalability and reproducibility. Flowers are an appealing raw material for large-scale nanoparticle synthesis due to their natural abundance, ease of availability, and renewable nature. Importantly, this strategy adheres to the principles of green chemistry by reducing harmful by-products and fostering safe, sustainable synthesis. Thus, flower-mediated nanoparticle creation is developing as a low-cost, ecologically friendly, and highly efficient technique, as shown in Figure 2, which displays the overall biosynthetic pathway involved in this process [14].

METAL SALT SOLUTION + FLOWER EXTRACT

Reduction M^+ → FNP^0

Flower mediates nanoparticles (heterogeneous and poor yield).

Optimization of reaction conditions such as pH, incubation temperature.,
Concentration of metal salt, and conc. of flower extract
(Homogeneous & high yield)

Stability of flower mediated nanoparticles
(Flower proteins, other phytochemical)

Characterization of flower mediated nanoparticles
(UV, FTIR, SEM/TEM, XRD, and ZETA SIZER)

Figure 1.2 Depicts the General Mechanism of Nanoparticles Formation From Flower Extract. M+ (Metal), FNP^0 (Floral Nanoparticles).

1.1.2 Silver Nanoparticles

Silver nanoparticles have a huge surface area, which improves biological interactions, catalytic potential, and atomic-level responses when compared to bulk equivalents of the same chemical composition. Silver nanoparticles are typically formed in two stages: first, silver ions (Ag^+) are reduced to elemental silver (Ag^0), followed by nucleation, aggregation, and stabilization, resulting in colloidal clusters. This entire process is frequently helped by biological agents that act as natural reducing and capping agents. Notably, silver nanoparticles derived from flower extracts have demonstrated a wide range of practical uses, as described in table 1.1 and related studies [15, 16].

Table 1.1 Sliver Nanoparticles Synthesized By Various Flower.

FAMILY	FLOWER VARIETY	APPLICATION
Fabaceae	*Cassia angustifolia*	Antioxidant & cytotoxicity activity.[17]
Apocyanaceae	*Plumeria rubra*	Antibacterial activity against *E.coli* and *B.subtilus*.[18]
Malvaceae	*Hibiscus rosa-sinensis*	Antibacterial activity against *Aeromonas hydrophilla*.[19]
Convolvulaceae	*Ipomoea digitata* Linn	Antibacterial activity against *Staphylococcus epidermidia* & catalytic activity against methylene blue.[20]
Asteraceae	*Tagetes erecta*	Antifungal activity against *Candida albicans*.[21]
Sapotaceae	*Madhuca logifolia*	Antibacterial activity against *B.cereus* & *Staphyloccocus saprophyticus*.[22]

1.2 Plant Profile

Canna indica, sometimes known as Indian shot, is a plant species from the *Cannaceae* family. It is native to the Americas and has naturalized elsewhere.

Table 1.2 Taxonomical classification

KINGDOM	PLANTAE
Subkingdom	Tracheobiont

Super division	Spermatophyta
Division	Magnoliophyta
Class	Liliopsida
Subclass	Zingiberidae
Order	Zingiberidae
Family	Cannaceae
Genus	*Canna*
Species	*Indica L.*

Figure 1.3 *Canna indica L.*

The flowers are hermaphrodites. The normally huge flowers are zygomorphic and trifold. Pedicels are typically 0.2-1 cm (1⁄8-3⁄8 in) long, red or yellow-orange, with some varieties measuring 4.5-7.5 cm (2-3 in) long. The sepals are roughly triangular, 1-1.7 cm (1⁄2-3⁄4 in) long, while the petals are upright, measuring 4-6.5 cm. The tube is 1.5–2 cm length. The bracts are shaped differently. The three free sepals are usually green. The three petals are green, or, depending on the type, yellow, orange, red, and pink. A stamen column is formed when the base of the petals and the staminodien unite. There are two circles, each of which originally had three stamens. The petals and staminodes are often yellow or scarlet. The three carpels are attached to a constant underneath (syncarp) ovary with a soft-spiky surface and several central-angle-constant ovules. Pollen accumulates on the stylus' abaxial (off-axis) surface.

1.2.1 Traditional uses

Canna indica flowers have traditionally been used to treat eye illnesses, wounds, and inflammation because to its soothing properties. Decoctions are useful for treating fevers and mild diseases. They are also used to alleviate diarrhoea and stomach pain. The flowers act as a diuretic for urinary difficulties. Poultices made from flowers alleviate swelling and joint pain. In folk medicine, they're used to regulate menstruation and relieve cramps [23-26].

1.3 Fourier Transform Infrared Spectroscopy

Fourier transform infrared (FT-IR) spectroscopy is an important non-destructive analytical technique for identifying the functional groups of chemical constituents. It is widely used for quality control in the food, beverage, and pharmaceutical industries [27]. FT-IR spectroscopy

has lately gained popularity due to its low noise, fast speed, excellent repeatability, ease of use, low cost, and other benefits. FT-IR is becoming more useful in analysing herbal compounds [28].

1.4 Gas Chromatography- Mass Spectrometry

Gas chromatography-mass spectroscopy (GC-MS) is a combination analytical method for detecting and identifying compounds in plant samples [29]. GC-MS is essential for phytochemical research and chemotaxonomic studies of medicinal plants that contain biologically active components [30].

2. MATERIALS & METHODS

2.1 Plant Collection

Canna indica flower was collected in May 2025 at Thalavaipettai and nearby villages in Erode district, Tamil Nadu. Dr. K. N. Sunil Kumar, Research Officer and Head of Pharmacognosy at the Centre Council for Research in Siddha, Chennai, Ministry of AYUSH, Government of India, recognised and authenticated the obtained plant material (C07042501I). *Canna indica* was cleaned, shade-dried to a consistent weight at room temperature, then ground into a coarse powder. It is maintained in airtight containers and can be used for future phytochemical studies.

2.2 Extraction

For one week, around 100 gm of dried flower powder are macerated in 1000 milliliters of ethanol. The flower extract was stored at room temperature and utilized for additional experiments.

2.3 FT-IR

The Fourier Transform Infrared Spectrophotometer (FTIR) is widely recognized as a powerful analytical tool for identifying functional groups and analyzing chemical bonds in a substance. The approach works on the principle that specific chemical bonds absorb infrared radiation at specific wavelengths, allowing molecular structures to be identified by interpreting the resulting spectra. In this investigation, FTIR analysis was done on dried powder samples derived from various plant solvent extracts. A translucent pellet was created by finely grinding about 10 mg of dried *canna indica* extract and 100 mg of potassium bromide (KBr). The KBr discs underwent FTIR analysis using a Shimadzu IR Spirit, ATR with a scan range of 400 to 4000 cm^{-1} and a resolution of 4 cm^{-1}.

2.4 GC-MS

To begin the GC-MS analysis, concentrated *Canna indica* flower extract was produced and dissolved in an appropriate solvent. Before injection, the solution was filtered with a 0.22 µm PTFE syringe filter to remove any particulate materials. The GC-MS analysis was performed on a Shimadzu GC-QP2010 Ultra with an auto-sampler and an RTX-5MS capillary column (30 m × 0.25 mm × 0.25 µm film thickness). Helium was used as the carrier gas at a constant flow rate of 1.0 mL/min. The injection volume was 1 µL in split mode (10:1).The injector

temperature remained at 250 °C. The oven temperature program was set as follows: beginning temperature 50 °C (hold 2 min), ramp at 10 °C/min to 280 °C, and hold for 10 minutes. The interface and ion source temperatures were maintained at 280 and 200 °C, respectively. Mass spectra were collected in electron impact mode at 70 eV, with a scan range of 50-600 m/z and a scan speed of 0.30 s/scan. To avoid solvent interference, the cut-off time was changed. The NIST library was used to acquire data and match spectral patterns for compound identification.

3. RESULT

3.1 FT-IR

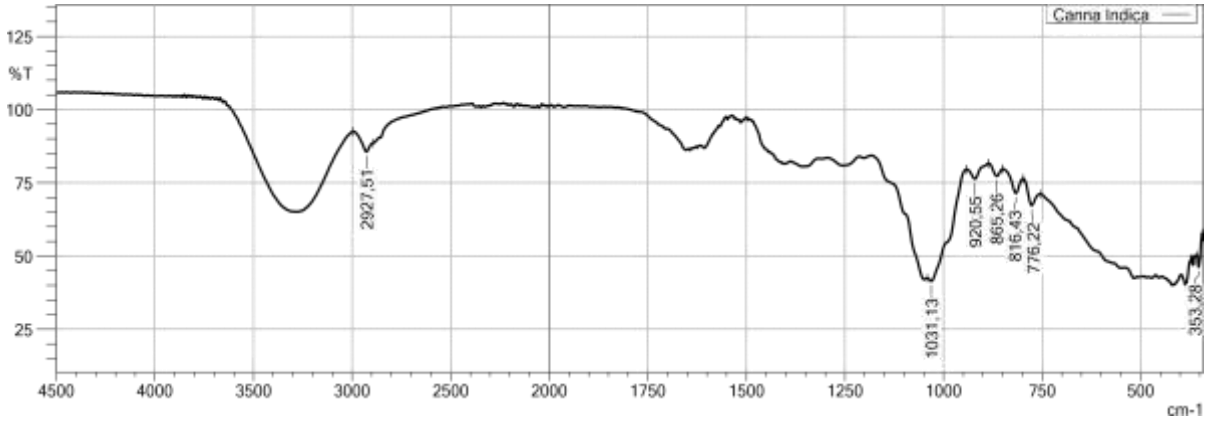


Figure 1.4 FT-IR Report of *Canna Indica L.*

Table 1.3 Interpretation of FT-IR Report of *Canna Indica L.*

S.NO	FREQUENCY (Cm^{-1})	TYPE OF COMPOUNDS	BOND RESPONSIPLE	INTENSITY
1	2927	Fatty acids, alkanes, steroids	C-H stretching(-$CH_{2-,}$ -CH_3)	Strong
2	1031	Alcohol, Phenols, ether, glycosides	C-O stretching	Strong
3	920	Aromatic , Carbohydrate	C-H bending	Medium
4	865	Flavonoids,Phenolic compounds	Aromatic C-H out-of-plane	Medium
5	816	Aromatics with ortho-substitutions	C-H out-of-plane blending	Medium
6	776	Aromatic substitutions	C-H out-of-plane	Weak to Medium
7	353	Phyto-compounds-metal interactions	Metal-O skeletal stretching	Weak

3.2 GC-MC

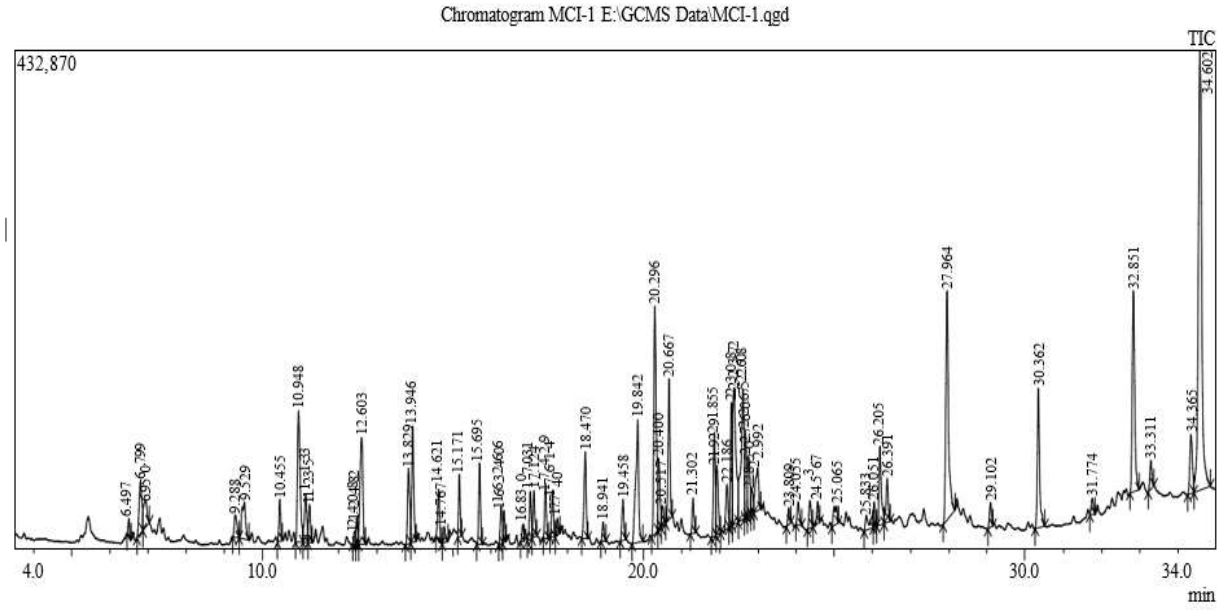
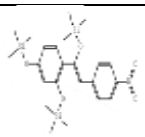
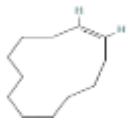
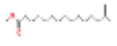
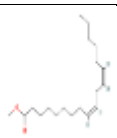
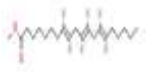
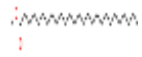
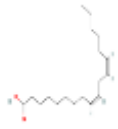
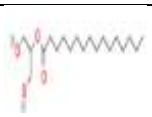
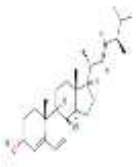
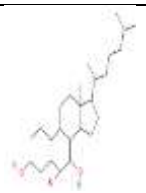
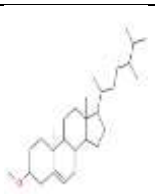


Figure 1.5 GC-MS Report of *Canna Indica L.*

Table 1.4 Interpretation of GC-MS Report of *Canna Indica L.*

S.NO	RETENTION TIME	AREA (%)	NAME	MOLECULAR FORMULA& WEIGHT	CHEMICAL STRUCTURE	COMPOUND
1	12.408	0.25	4-[(Z)-1-Hydroxy-2-(4-nitrophenyl)ethenyl]benzene-1,3-diol, 3 TMS derivative	C23H35NO5Si3 & 489		Phenolic
2	16.83	0.28	Cyclododecene, (Z)-	C12H22 & 166		Terpenoid
3	19.842	3.39	Pentadecanoic acid, 14-methyl-, methyl ester	C17H34O2 & 270		Fatty acid ester
4	20.296	5.6	n-Hexadecanoic acid	C16H32O2 & 256		Fatty acid
5	20.667	2.64	Hexadecanoic acid, ethyl ester	C18H36O2 &284		Fatty acid ester

6	21.855	2.05	9,12-Octadecadienoic acid, methyl ester	C19H34O2 & 294		Fatty acid ester
7	21.929	1.33	8,11,14-Eicosatrienoic acid, methyl ester	C21H36O2 &320		Fatty acid ester
8	22.186	0.96	Heptacosanoic acid, methyl ester	C28H56O2 &424		Fatty acid ester
9	22.308	2.36	9,12-Octadecadienoic acid (Z,Z)-	C18H32O2 &280		Fatty acid
10	26.205	1.75	Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester	C19H38O4 & 330		Fatty acid ester
11	32.851	4.8	Ergosta-4,6,22-trien-3.alpha.-ol	C28H44O & 396		Pytosterol
12	33.311	0.59	alpha.-Tocopheryl acetate	C31H52O3 & 472		Terpenoid
13	34.365	1.5	3.alpha.,7.beta.-Dihydroxy-5.beta.,6.beta.-epoxycholestane	C27H46O3 &418		Pytosterol derivatives
14	34.602	13.69	Campesterol	C29H50O &414		Pytosterol

4. DISCUSSION

The FT-IR analysis of *Canna indica* flower extract identified the functional groups necessary for nanoparticle production. The absorption peaks at 2927 cm^{-1} (C-H stretching of alkanes and fatty acids), 1031 cm^{-1} (C-O stretching of alcohols and phenolics), and 920-776 cm^{-1} (aromatic C-H bending) indicated the presence of fatty acids, phenolic compounds, and aromatics. Metal-oxygen interactions are important for nanoparticle stability, as demonstrated by a small peak at 353 cm^{-1}. GC-MS profiling identified 62 compounds, 14 of which were biologically active.

These comprised fatty acids, esters, phenolic compounds, terpenoids, and phytosterols. These compounds enable the extract to function as a reducing and capping agent in the green synthesis of silver nanoparticles.

5. CONCLUSION

The FT-IR and GC-MS analyses revealed that *Canna indica* flower extract contains several bioactive compounds and functional groups capable of reducing and stabilising silver nanoparticles. Out of the 62 compounds discovered, 14 displayed significant bioactivity, showing the extract's potential as a green and environmentally friendly nanoparticle producer.

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