

# Champaca Derived Anti Infection A Review of Isolation Method and Antimicrobial Activities

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**Abstract**—Magnolia champaca, also known as Michelia champaca, is a flowering species in the Magnoliaceae family. It is known worldwide for its strong therapeutic value and important role in traditional medicine. This review examines the plant as a source of bioactive secondary compounds, including oxoaporphine alkaloids, flavonoids, and sesquiterpene lactones, which contribute to its potent anti-infection properties. Researchers isolate these active compounds using various methods like maceration, Soxhlet extraction, and microwave-assisted techniques with different solvents such as methanol, n-hexane, and chloroform. Advanced chromatography techniques, including Column Chromatography, High-Performance Liquid Chromatography, and Gas Chromatography-Mass Spectroscopy, help identify and purify key compounds such as Liriodenine, Parthenolide, and Tributyl acetylcitrate. Pharmacological studies show that these extracts have broad-spectrum antibacterial effects against human pathogens like Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa, often by disrupting cell membranes or causing oxidative stress. Additionally, bark extracts display strong antifungal activity against pathogens like Curvularia verruculosa, while sesquiterpene lactones from the flowers show significant antimalarial activity. The plant also has potential for the green synthesis of silver nanoparticles to improve antimicrobial effectiveness. Combining traditional knowledge with scientific isolation methods highlights M. champaca as a sustainable and effective source for creating new plant-based anti-infection agents.

**Index Terms**—Magnolia champaca; Antimicrobial activity; Phytochemical profile; Extraction methods; Liriodenine; Natural products

## I. INTRODUCTION

Magnolia champaca (L.) Baill. ex Pierre, formerly known as Michelia champaca, is a valued evergreen flowering tree in the ancient Magnoliaceae family, one of the earliest angiosperm families. This species grows widely in tropical and subtropical regions of South and Southeast Asia and is known for its continuous flowering, aesthetic appeal, and medicinal uses. It has several local names, including Champa in Hindi, Champaka in Bengali, Sambagam in Tamil, and Atigandhaka in Sanskrit, which reflect its deep cultural and traditional significance 1.

Magnolia champaca plays an important role in the cultural, religious, and medicinal practices of India and its neighboring countries 2. The tree is especially famous for its fragrant flowers, which can be pale yellow to deep orange. Because of their captivating scent, these flowers are commonly used in religious ceremonies, garlands, and perfumes. The species earned the nickname “Joy Perfume Tree” after its essential oil became a key ingredient in the famous fragrance Joy, which was historically the world’s second best-selling perfume 3. This recognition significantly boosted global demand for M. champaca flower oil.

In addition to being beautiful and aromatic, *M. champaca* holds great pharmacological value. Traditional medicine systems like Ayurveda, Siddha, and Unani have documented its use over centuries for various ailments 4. Different parts of the plant—flowers, bark, leaves, roots, and seeds—have been used as treatments for ulcers, fever, cough, colic, inflammation, skin diseases, leprosy, digestive issues, and also as stimulants and tonics 5.

Recent scientific studies have increasingly confirmed these traditional uses. Phytochemical analysis of *M. champaca* has identified various bioactive compounds, including alkaloids, flavonoids, phenolic compounds, tannins, saponins, and essential oils. These compounds show a range of pharmacological effects, such as antimicrobial, antioxidant, anti-inflammatory, antidiabetic, gastroprotective, and cytotoxic properties 6,7. The growing interest in plant-based medicines has highlighted *M. champaca* as a promising option for drug discovery and herbal research.

Botanically, *M. champaca* is a large, long-lived evergreen tree that can grow between 30 to 50 meters tall in its natural environment. It is often planted in temples, gardens, and along roads because of its lush leaves, fragrant flowers, and sacred value 8. Besides its medicinal and beauty attributes, the species also supports local economies. Its timber is sought after for its fine texture and durability, making it ideal for furniture, carvings, plywood, and construction. Additionally, its essential oil is in high demand in the global cosmetic and fragrance markets 9.

Despite its wide distribution and being classified as “Least Concern” on the IUCN Red List 10, *M. champaca* faces growing threats from overharvesting, habitat destruction, and low natural seed production. The species has low seed viability, and its oily seeds can spoil quickly and fall prey to animals. To ensure its long-term survival in tropical forests, conservation efforts, including micropropagation, nursery cultivation, and sustainable harvesting, are being pursued 11.

### 1.1 Botanical and Geographical Profile

*Magnolia champaca* has a straight, cylindrical trunk with a dense, spreading crown. The tree typically reaches about 30 meters in height for the *champaca*

variety, while the *pubinervia* variety can grow up to 50 meters. The bark ranges from smooth to slightly rough and is ashy-grey to brown in color, with a fibrous inner layer that has medicinal properties. The leaves are simple, alternate, leathery, and can be lanceolate or ovate in shape, with a shiny upper side and a pointed tip.

The flowers are large, solitary, and found in the axil of the leaves. They consist of about 15 narrow, long tepals arranged in a spiral. These tepals curve upward and release a strong, pleasant scent, especially in the early morning and evening. The flowers bloom nearly year-round under suitable conditions.

Geographically, *M. champaca* is native to the Indian subcontinent and Southeast Asia. It thrives in humid tropical evergreen and semi-evergreen forests across the sub-Himalayan region, Northeast India, Sri Lanka, Malaysia, Indonesia, and southern China 12. The species grows well at altitudes between 250 and 1,500 meters, but it has been found at elevations up to 2,100 meters above sea level 13. Warm temperatures, high humidity, and well-drained loamy soil favor its growth.

### 1.2 Economic and Cultural Significance

The economic importance of *Magnolia champaca* is diverse. The essential oil, primarily extracted from the flowers, is highly prized in the luxury perfume and cosmetics markets for its rich floral scent and fixative qualities 14. In India and Southeast Asia, fresh flowers are traditionally worn in hair, made into garlands, and used in religious offerings, symbolizing purity, prosperity, and devotion 15.

The timber from *M. champaca* is lightweight, durable, and easy to work with, making it suitable for crafting furniture, carvings, plywood, paneling, and musical instruments. The leaves serve as fodder for silkworms, supporting silk production, while the heartwood and fallen branches are often used as firewood in rural areas 16. Therefore, the species is essential for both traditional economies and modern industries.

### 1.3 Therapeutic Importance

In Ayurvedic and Unani traditions, *Magnolia champaca* is viewed as a powerful “traditional healer” with a wide range of medicinal uses 17. Modern

pharmacological research has confirmed many of these traditional claims:

- Antimicrobial activity: Extracts from the bark, leaves, flowers, and seeds show strong antibacterial and antifungal effects against various pathogens 18.
- Metabolic regulation: Flower buds and leaf extracts appear to have antidiabetic and antihyperglycemic properties, indicating potential benefits for metabolic issues 19.
- Anti-inflammatory and pain-relieving effects: The plant has been used traditionally for conditions like rheumatism, gout, and inflammatory joint disorders. Experimental studies support this usage 20.
- Gastroprotective activity: Both alcoholic and water-based extracts reveal protective effects against gastric ulcers and damage caused by acid 21.
- Other medicinal uses: The plant is also utilized as a fever reducer, mild laxative, expectorant, and antidote for snake and scorpion bites in traditional medicine 22.

#### 1.4 Conservation Status

Although *Magnolia champaca* is currently listed as Least Concern by the IUCN 10, local populations face serious threats from overharvesting, habitat fragmentation, and unsustainable flower collection. The species has poor natural regeneration because its seeds are short-lived, oily, and vulnerable to insect, bird, and rodent predation.

In the past, strict laws against cutting down the tree were enforced in countries like Nepal, but these restrictions were eased in 2007. In response, conservation programs such as Nepal's Hariyo Ban Program have been launched to promote sustainable practices through seedling production, the establishment of breeding orchards, and community-led conservation efforts 23. New propagation techniques, including tissue culture and micropropagation, are being explored to ensure the long-term survival of this ecologically and medicinally significant species.



## II. PHYTOCHEMICAL PROFILE OF MAGNOLIA CHAMPACA

*Magnolia champaca* (syn. *Michelia champaca*), a member of the family Magnoliaceae, is recognized for its exceptionally rich and chemically diverse phytochemical composition. Extensive phytochemical investigations have revealed the presence of both primary metabolites, which support basic physiological processes, and a wide range of secondary metabolites responsible for the plant's therapeutic, ecological, and aromatic properties. These bioactive constituents underpin the long-standing traditional uses of *M. champaca* in antimicrobial, anti-inflammatory, antioxidant, and neuroprotective applications <sup>25,26</sup>.

### 2.1 Primary Metabolites

Primary metabolites such as carbohydrates, starch, proteins, amino acids, and lipids are ubiquitously distributed across plant tissues, particularly in the bark and leaves. These compounds primarily function in energy storage, structural integrity, and cellular metabolism.

While primary metabolites do not directly exhibit strong pharmacological activities, they play an essential role in supporting the biosynthesis and accumulation of secondary metabolites. Seasonal fluctuations and environmental factors such as soil composition and moisture availability may significantly influence the concentration of these metabolites.

## 2.2 Secondary Metabolites

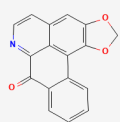
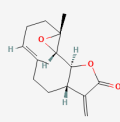
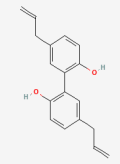
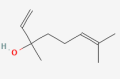
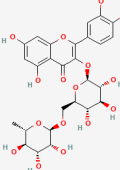
The pharmacological significance of *M. champaca* is largely attributed to its abundance of secondary metabolites, including alkaloids, flavonoids, phenolic lignans, terpenoids, sterols, tannins, saponins, and volatile essential oils. Several studies have reported the isolation of bioactive alkaloids and sesquiterpene lactones from different plant parts, particularly the bark and branches, contributing to antimicrobial, cytotoxic, and antimalarial activities <sup>26,28</sup>.

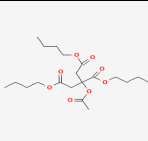
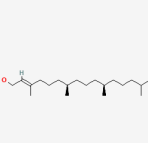
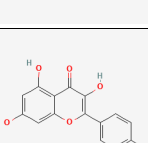
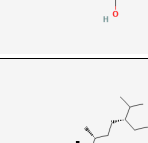
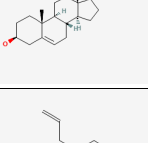
Volatile constituents present in the flowers are responsible for the characteristic aroma of *M.*

*champaca* and exhibit notable seasonal variation, which has been well documented through essential oil analysis <sup>25</sup>. Additionally, volatile esters and related compounds derived from plant sources have been shown to possess antifungal properties, supporting the antimicrobial relevance of aromatic constituents present in *M. champaca* <sup>29</sup>.

The qualitative and quantitative distribution of these secondary metabolites varies markedly among flowers, bark, leaves, roots, and seeds, and is further influenced by phenological stage, environmental conditions, and geographical location.

Table 1: Phytochemical Distribution by Plant Part

Bioactive Compound	Chemical Classification	Primary Plant Part(s)	Reported Biological Activity	Molecular Formula	Molecular Weight (g/mol)	Chemical Structure	references
Liriodenine	Oxoaporphine alkaloid	Root bark, stem bark, branches.	Potent antimicrobial, cytotoxic, and anticancer activity against lung and breast adenocarcinoma.	C <sub>17</sub> H <sub>9</sub> NO <sub>3</sub>	275.26		18,26
Parthenolide	Germacranolide sesquiterpene lactone	Leaves, flowers, root bark.	Potent schizonticidal antimalarial and anti-inflammatory properties.	C <sub>15</sub> H <sub>20</sub> O <sub>3</sub>	248.32		27,28
Magnolol	Phenolic lignan	Bark, flowers.	Powerful antioxidant, neuroprotective, and anti-inflammatory agent.	C <sub>18</sub> H <sub>18</sub> O <sub>2</sub>	266.33		2
Linalool	Oxygenated monoterpene	Flowers (up to 25.1%), leaves.	Primary aromatic constituent for perfumery; exhibits antibacterial activity.	C <sub>10</sub> H <sub>18</sub> O	154.25		25
Rutin	Glycosidic flavonoid	Bark (up to 51.1 mg/g), flowers.	Significant antioxidant and radical scavenging capacity.	C <sub>27</sub> H <sub>30</sub> O <sub>16</sub>	610.52		2

Tributyl acetylacrylate	Volatile ester	Bark.	Acts as a botanical fungicide against rice leaf spot fungi ( <i>C. verruculosa</i> ).	$C_{20}H_{34}O_8$	402.48		29
Phytol	Acyclic diterpene alcohol	Leaves.	Demonstrates strong antibacterial efficacy by inducing oxidative stress in pathogens.	$C_{20}H_{40}O$	296.53		2
Quercetin	Aglycone flavonoid	Flowers, seeds, leaves.	Notable antioxidant, anti-inflammatory, and antimicrobial properties.	$C_{15}H_{10}O_7$	302.24		2
$\beta$ -Sitosterol	Stigmastane-type phytosterol	Root bark, stem bark, flowers.	Contributes to the plant's anti-inflammatory and metabolic support properties.	$C_{29}H_{50}O$	414.71		26
Honokiol	Phenolic lignan	Bark, flowers.	Synergistic antioxidant and antimicrobial activity; neuroprotective effects.	$C_{18}H_{18}O_2$	266.33		2

### III. EXTRACTION AND ISOLATION METHODS

Extracting and isolating bioactive compounds from *Magnolia champaca* (also known as *Michelia champaca*) is a key step in studying its antimicrobial and medicinal potential. Various parts of the plant—bark, flowers, leaves, seeds, and roots—contain different secondary metabolites like alkaloids, flavonoids, phenolic acids, terpenoids, sesquiterpene lactones, and essential oils. Therefore, the choice of extraction and isolation methods largely depends on the type of plant material, the polarity of the target compounds, and the goals of the biological evaluation<sup>30</sup>. Both traditional and modern extraction techniques have been used to obtain crude extracts with the best yield and bioactivity.

#### 3.1 Primary Extraction Techniques

Primary extraction is the process of separating bioactive compounds from the plant structure using suitable solvents and conditions. Several methods have been reported for extracting from *M. champaca*.

- **Maceration:**

Maceration is a straightforward and commonly used extraction method, especially for bark and leaves. In a standard process, about 1 kg of dried and powdered bark is soaked in methanol for 24 hours at room temperature, with occasional stirring to help the solvent penetrate. This process is typically repeated three times to ensure maximum extraction of soluble compounds. The combined extracts are then filtered and concentrated under reduced pressure using a rotary evaporator. Some studies have used a hydroalcoholic solvent system (70% ethanol in water) for longer maceration periods of up to four days at controlled temperatures (around 18°C), which helps preserve sensitive constituents and improves extraction efficiency<sup>31</sup>.

- **Soxhlet Extraction:**

Soxhlet extraction is frequently used for thorough extraction of leaves, stems, and bark. This method allows for continuous extraction with solvents of increasing polarity, which helps separate a wide range

of compounds. Common solvent sequences include n-hexane for non-polar lipids and terpenes, chloroform for moderately non-polar compounds, methanol or ethanol for polar flavonoids and phenolics, and finally water. For floral material, petroleum ether is often used for 24 hours to isolate fat-soluble compounds, while acetone extraction for up to 40–50 cycles has effectively extracted bioactive sesquiterpene lactones and phenolic compounds<sup>32</sup>.

- **Hydrodistillation:**

Hydrodistillation is the preferred method for extracting essential oils from fresh *M. champaca* flowers, known for their strong fragrance and therapeutic qualities. This process typically uses a Clevenger-type apparatus, where about 500 g of freshly collected flowers are immersed in 1000 mL of distilled water and boiled for around four hours. The volatile oil is then separated, dried over anhydrous sodium sulfate, and stored in the refrigerator until analysis. This method works particularly well for isolating monoterpenes and sesquiterpenes, which are responsible for antimicrobial and aromatic properties<sup>33</sup>.

- **Microwave-Assisted Extraction (MAE):**

Microwave-assisted extraction is a modern and efficient technique that is increasingly used to extract heat-stable secondary metabolites like sesquiterpene lactones from *M. champaca* flowers. MAE has several advantages over traditional methods, such as shorter extraction times, less solvent use, and improved extraction yield. Research shows that microwave irradiation disrupts cell walls, allowing faster solvent penetration and better recovery of active compounds compared to classic Soxhlet or maceration methods<sup>28</sup>.

### 3.2 Fractionation and Partitioning

After primary extraction, crude extracts go through fractionation to simplify their chemical makeup and concentrate active compounds. Liquid–liquid partitioning is the most commonly used method for this.

Usually, methanolic or ethanolic crude extracts are mixed with water and then partitioned with solvents of increasing polarity like n-hexane, chloroform, ethyl acetate, and n-butanol. Each fraction selectively enriches certain classes of compounds. For example,

non-polar fractions (n-hexane and chloroform) often contain terpenoids and alkaloids, while ethyl acetate and n-butanol fractions are rich in flavonoids, phenolic acids, and glycosides. Specifically, partitioning extracts from the bark with n-hexane and chloroform has been shown to concentrate highly active antifungal compounds, which exhibit greater activity than the crude extract<sup>34</sup>.

### 3.3 Isolation and Purification Techniques

To isolate and purify individual compounds from bioactive fractions, several chromatographic methods are used.

- **Column Chromatography (CC):**

Column chromatography is the main technique for isolating pure compounds from *M. champaca* extracts. Silica gel is often used as the stationary phase, while mobile phases consist of solvent systems with gradually increasing polarity. Typical elution systems include n-hexane–acetone or n-hexane–ethyl acetate mixtures, usually starting from a 9:1 ratio and progressing to more polar combinations. Fractions with similar TLC profiles are combined and further purified to yield individual bioactive compounds.

- **Thin-Layer Chromatography (TLC):**

TLC is widely used for preliminary analysis, tracking fractionation progress, and assessing purity. It helps identify phytochemicals by comparing R<sub>f</sub> values and visualizing results under UV light or after applying detection reagents like vanillin–sulfuric acid.

- **High-Performance Liquid Chromatography (HPLC) and HPTLC:**

Advanced techniques like HPLC and HPTLC are used for both qualitative and quantitative analysis of marker compounds. These methods have estimated bioactive constituents such as quercetin, gallic acid, and parthenolide in various extracts and fractions of *M. champaca*, ensuring consistency and standardization of plant-based preparations<sup>35</sup>.

### 3.4 Identification and Characterization

The identification and characterization of isolated compounds require advanced analytical techniques.

- **Gas Chromatography–Mass Spectrometry (GC–MS):**

GC–MS is the main tool for analyzing volatile compounds and the components of essential oils from *M. champaca* flowers and bark. It has identified key constituents like linalool,  $\beta$ -caryophyllene, and tributyl acetyl citrate, which play an important role in antimicrobial activity.

- **Fourier-Transform Infrared Spectroscopy (FTIR):** FTIR spectroscopy is used to identify functional groups in crude extracts and purified fractions. Characteristic absorption bands show the presence of phenolic hydroxyl groups, alkanes, alkenes, carbonyl groups, and carboxylic acids.

- **Spectral Analysis (NMR and MS):** Pure compounds isolated from *M. champaca*, especially sesquiterpene lactones and alkaloids, are further characterized using advanced spectroscopic techniques like  $^1\text{H-NMR}$ ,  $^{13}\text{C-NMR}$ , and mass spectrometry. These analyses provide clear structural confirmation and molecular weight information, allowing for accurate identification of the isolated compounds<sup>36</sup>.

#### IV. ANTIMICROBIAL ACTIVITIES OF MAGNOLIA CHAMPACA

*Magnolia champaca* (also known as *Michelia champaca*) shows a wide range of antimicrobial activity in its various parts, including leaves, seeds, flowers, stem bark, and root bark. These properties suggest that the plant could help develop new botanical fungicides and clinical antibiotics to fight resistant pathogens<sup>18</sup>.

##### 4.1 Antibacterial Activity

The plant has strong inhibitory effects on both Gram-positive and Gram-negative bacteria, targeting pathogens linked to skin infections, food poisoning, and dental decay.

- **Gram-positive Efficacy:** Extracts and essential oils work well against strains like *Staphylococcus aureus*, *Bacillus subtilis*, *Enterococcus faecalis*, and *Micrococcus luteus*. The methanolic flower essential oil is particularly effective against *Streptococcus mutans*, which causes dental caries, showing a 30 mm zone of inhibition<sup>37</sup>. Hexane leaf extracts have proven even more potent against *S. aureus*, with an inhibition zone of 31 mm.

- **Gram-negative Efficacy:** Significant activity has been noted against *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Klebsiella pneumoniae*, and *Vibrio cholerae*.

- **Nano-biotechnology Applications:** Green synthesis of silver nitrate nanoparticles (AgNPs) using fruit extracts produced particles with strong antibacterial properties at concentrations between 200 and 1000  $\mu\text{g/ml}$ <sup>38</sup>.

##### 4.2 Antifungal Activity

The sources emphasize the plant's effectiveness against various molds, yeasts, and agricultural pathogens.

- **Agricultural Applications:** Bark extracts, particularly in methanol and n-hexane fractions, show very strong inhibitory effects against *Curvularia verruculosa*, which causes leaf spot disease in rice. The n-hexane fraction achieved an inhibition zone of 32.45 mm. Leaf extracts are also harmful to the rice fungus *Pyricularia oryzae*.

- **Clinical and Food Pathogens:** The plant is effective against *Candida albicans*, *Aspergillus niger*, and *Glomerella cingulata*. Essential oils from the flowers have moderate effectiveness as fungistatic and fungicidal agents against post-harvest pathogens like *Fusarium oxysporum*<sup>29</sup>.

##### 4.3 Antimalarial and Antitubercular Activity

- **Antimalarial:** Isolated sesquiterpene lactones from the flowers, specifically parthenolide and costunolide diepoxide, have shown strong schizonticidal activity. In rodent studies, these compounds reduced parasitemia by 85.18% and 83.65% respectively at a dose of 20 mg/kg<sup>28</sup>.

- **Antitubercular:** Both chloroform and methanol extracts of *M. champaca* show high inhibition (above 90%) against multi-drug resistant (MDR) *Mycobacterium tuberculosis* at concentrations of 10 to 100 mg/ml<sup>39</sup>.

##### 4.4 Key Bioactive Constituents

The plant's antimicrobial effectiveness mainly stems from its unique secondary metabolites.

- **Liriodenine:** Identified as a key active ingredient, especially in the root bark, it provides a broader and more potent effect than some standard antimicrobial agents.

- **Bark Compounds:** Analyses via GC-MS showed that tributyl acetylcitrate and terephthalic acid, dodecyl-2-ethylhexyl ester work together to inhibit fungal growth.
- **Other Components:** Phytochemical screenings also attribute alkaloids, tannins, saponins, flavonoids, and phenols to the plant's overall capacity to fight infections<sup>18,40</sup>.

## V. MECHANISMS OF ANTIMICROBIAL ACTION

The antimicrobial effectiveness of *Magnolia champaca* comes from its wide range of bioactive secondary metabolites, which use several methods to combat pathogens. Research, including molecular docking and biochemical tests, has revealed key ways these compounds work.

### 5.1 Membrane and Cell Wall Disruption

Essential oils from the flowers and leaves of *M. champaca* primarily kill bacteria by targeting their outer membranes and cell walls. These volatile oils interact with cytoplasmic proteins, causing structural instability. Studies show that the oils have a stronger effect on Gram-positive species, such as *Staphylococcus aureus*, because the lack of an outer lipopolysaccharide membrane allows easier penetration than in Gram-negative bacteria.

### 5.2 Targeted Protein Inhibition (Antimalarial Action)

The plant's sesquiterpene lactones, particularly parthenolide and costunolide diepoxide, demonstrate strong activity against malarial parasites. Molecular docking studies indicate that costunolide diepoxide binds tightly to important parasitic proteins like SERCA (Sarco/endoplasmic reticulum  $Ca^{2+}$ -ATPase) and DHFR (Dihydrofolate reductase). By binding to these targets, the compounds disrupt the parasite's calcium management and DNA synthesis, effectively halting its lifecycle.

### 5.3 Induction of Oxidative Stress and Cell Lysis

Certain components like phytol, found in leaf extracts, show antibacterial effects by causing oxidative stress in pathogens such as *Pseudomonas aeruginosa*. Additionally, phenolic compounds and alcohols contribute to cell lysis and the removal of free radicals,

which weaken the metabolic function of invading microbes.

### 5.4 Synergistic Antifungal Action

When targeting agricultural pathogens like *Curvularia verruculosa*, which causes rice leaf spot, the bark extract uses a chemical synergy. The compounds tributyl acetylcitrate and terephthalic acid, dodecyl-2-ethylhexyl ester work together to more effectively inhibit fungal growth than either would alone. This multi-component strategy helps prevent the fungi from quickly developing resistance.

### 5.5 Signaling Pathway Mediation

The lignans magnolol and honokiol, found in the bark, use a complex biological method to manage infections and inflammation. They influence the NF- $\kappa$ B/MAPK, Nrf2/HO-1, and PI3K/Akt pathways to adjust the host's immune response while also directly attacking pathogens such as *Streptococcus mutans* and *Candida* species<sup>28,40</sup>.

## VI. PHARMACEUTICAL AND MEDICINAL CHEMISTRY PERSPECTIVE

*Magnolia champaca* is full of bioactive secondary metabolites, providing a diverse range of chemicals for finding and developing new therapeutic agents. From a medicinal chemistry viewpoint, the plant offers various valuable structures, like oxoaporphine alkaloids, sesquiterpene lactones, and lignans, which are important for designing targeted drugs.

### 6.1 Key Bioactive Scaffolds and Therapeutic Targets

- **Oxoaporphine Alkaloids (Liriodenine):** Mainly sourced from the bark and roots, Liriodenine is a key compound responsible for broad-spectrum antibacterial and cytotoxic effects. It shows strong inhibitory action against human breast (MCF-7/MDA-MB-231) and lung (A549) cancer cell lines.
- **Sesquiterpene Lactones (Parthenolide & Costunolide):** These compounds, mainly in the flowers and leaves, are being studied for their ability to kill malaria parasites. Molecular docking studies show that costunolide diepoxide has a strong binding affinity for SERCA and DHFR proteins, which are essential targets in parasites.
- **Lignans (Magnolol & Honokiol):** Concentrated in the bark, these phenolic lignans are valued for their

protective, anti-inflammatory, and antioxidant effects. They function through several signaling pathways, including NF- $\kappa$ B/MAPK and Nrf2/HO-1, to carry out their biological roles<sup>26,28</sup>.

### 6.2 Innovative Drug Delivery and Nanotechnology

The plant is leading in the area of green nanotechnology. Researchers have successfully used *M. champaca* fruit extracts to create Silver Nitrate Nanoparticles (AgNPs)<sup>38</sup>. These nanoparticles show improved antibacterial effectiveness at concentrations ranging from 200 to 1000  $\mu$ g/ml, providing a sustainable way to fight drug-resistant pathogens.

### 6.3 Computational Modeling and ADMET Profiling

Modern medicinal chemistry uses computer-aided techniques to assess the drug-likeness of *M. champaca* components. Studies on its sesquiterpene lactones have predicted favorable ADMET (Absorption, Distribution, Metabolism, Excretion, and Toxicity) profiles, suggesting a high chance for oral bioavailability and safety in humans<sup>41</sup>.

### 6.4 Pharmaceutical Standardization and Synergism

A crucial aspect of developing pharmaceuticals from *M. champaca* is standardizing extracts to ensure consistent therapeutic strength. Furthermore, research has identified chemical cooperation between certain volatile esters, such as tributyl acetyl citrate and terephthalic acid derivatives, which work together to boost antifungal activity beyond what individual components can achieve.

### 6.5 Marketed Preparations

The pharmaceutical potential of the plant is already being recognized in various commercial applications:

- **Ayurvedic Formulations:** Well-known formulations like Candanabalalaksadi Taila and Baladhatryadi Taila use the plant for joint health and metabolic support.
- **Allopathic and Cosmetic Applications:** The plant is included in premium perfumery (like Tom Ford's *Champaca Absolute*) and skincare products (Som Rasa Silk Skin Tint) due to its antioxidant and aromatic qualities<sup>42</sup>.

## VII. LIMITATIONS AND FUTURE PROSPECTS

### 7.1 Limitations in Current Research and Application

Despite the clear antimicrobial potential of various extracts, several factors limit their immediate use in clinical settings:

- **Lack of Human Clinical Evidence:** While laboratory and animal studies show promise, there is a notable shortage of large human clinical trials to confirm effectiveness for conditions like digestion and sleep quality.
- **Methodological Debates on Extraction:** Researchers still debate the best methods for extraction. Some argue that solvent extracts better preserve compounds like magnolol, while others favor steam distillation for maximising linalool yields.
- **Chemical Variability:** The chemical makeup of the plant varies significantly. It depends on where it is grown, when it is harvested, and how it is distilled.
- **Variable Antimicrobial Efficacy:** Not all parts of the plant effectively combat every pathogen. For example, stem extracts display poor antifungal activity against some strains, while aqueous extracts may have little to no effect compared to alcoholic or organic extracts.
- **Stability and Identification Issues:** During processes like TLC bioautography, some active components may be lost due to evaporation, photo-oxidation, or insufficient concentration. This complicates the identification of the most effective agents.
- **Safety and Interaction Risks:** Highly concentrated essential oils can irritate the skin. Additionally, bioactive polyphenols like magnolol may enhance the effects of sedatives such as benzodiazepines, requiring caution for patients taking prescription medications for sleep or anxiety.

### 7.2 Future Prospects and Research Directions

The sources highlight several promising areas for future development:

- **Combating Drug Resistance:** Extracts from the leaves and stem are seen as strong candidates for creating new antimicrobials to address multi-drug resistant (MDR) bacterial and fungal infections.
- **Sustainable Sourcing via Endophytic Fungi:** A new approach involves using endophytic fungi, such as *Rhizoctonia* sp. or *Curvularia lunata*, found in the plant's tissues. These fungi produce secondary metabolites similar to the host plant and could offer an

eco-friendly, sustainable source of natural antibiotics, reducing the need for extensive harvesting of the trees.

- **Specialized Dental Applications:** The discovery of significant activity against *S. mutans*, the main cause of dental cavities, suggests a specialized future for *Champaca* essential oil in dental pharmaceutical research, creating new options for oral health<sup>43</sup>.

- **Advanced Extraction Technology:** Techniques like microwave-assisted extraction and HPTLC fingerprinting are expected to improve the isolation of effective schizonticidal (anti-malarial) compounds like parthenolide and costunolide.

- **Interdisciplinary Integration:** Future progress will likely depend on teamwork that connects traditional Ayurvedic practices with modern pharmacology to create personalized, evidence-based medicines.

### VIII. CONCLUSION

*Magnolia champaca* is an important multipurpose species that connects ancient ethnomedicine with modern pharmacology. Its wide range of chemicals, including liriodenine, parthenolide, and phenolic lignans, supports proven antimicrobial, antidiabetic, and anti-inflammatory effects. In addition to its medical benefits, it is known as the "Joy Perfume Tree" and provides quality timber, which adds to its economic value. However, the species is threatened by over-exploitation and poor seed germination, making conservation and micropropagation efforts crucial. Future research should focus on standardizing herbal formulations to effectively turn this "living factory" of phytochemicals into reliable and safe healthcare solutions worldwide. Combining traditional knowledge with solid scientific evidence will help ensure these botanical resources are sustainably developed for future generations.

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