*EJPMR, 2026, 13(3), 555-565* **Research Article** **Impact Factor: 8.158**

**EUROPEAN JOURNAL OF PHARMACEUTICAL AND MEDICAL RESEARCH**

www.ejpmr.com

**ISSN (O): 2394-3211**
**ISSN (P): 3051-2573**
**Coden USA: EJPMAG**

# TINOSPORA CORDIFOLIA: A BIOACTIVE NETWORK FOR ADVANCED HERB PHARMACOLOGY

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**DOI:** https://doi.org/10.5281/zenodo.18958217

**How to cite this Article:** Bomma Deepthi*[1], Darapu Swapna[1], Dr. Kavula Navaneetha[2], Dr. Gampa Tulja Rani[3]. (2026). Tinospora Cordifolia: A Bioactive Network For Advanced Herb Pharmacology. European Journal of Pharmaceutical and Medical Research, 13(3), 555–565.


**Article Received on 15/02/2026** **Article Revised on 05/03/2026** **Article Published on 10/03/2026**

**ABSTRACT**

Traditional medicinal systems continue to provide valuable leads for the development of novel therapeutic agents when examined through modern scientific methodologies. Tinospora cordifolia, a widely used medicinal plant in Ayurveda, has attracted increasing attention for its potential integration into contemporary healthcare systems. This review examines the evolving research landscape surrounding, Tinospora cordifolia focusing on its translational relevance rather than descriptive pharmacology. Key issues such as quality control, phytochemical variability, safety evaluation, and clinical reliability are critically discussed. The role of advanced analytical tools, molecular validation techniques, and innovative research models in strengthening the scientific credibility of Tinospora cordifolia is highlighted. Additionally, the review addresses regulatory challenges and the need for standardized protocols to facilitate its acceptance as a targeted herbal therapeutic. By outlining current limitations and future opportunities, this review aims to support the systematic advancement of Tinospora cordifolia toward evidence-based, disease-focused applications.

**KEYWORDS:**
Tinospora cardifolia,
Guduchi,
Targeted herbal therapy,
Phytochemicals,
Pharmacology.

## 1. INTRODUCTION

India's rich biodiversity, coupled with well-established traditional medical systems such as Ayurveda, Siddha, Unani and various indigenous practices, provides a strong foundation for the medicinal application of plants in the prevention and management of common diseases.[1]

Tinospora cordifolia, a widely used and non-controversial herb in Ayurveda, belongs to the family Menispermaceae. It is a glabrous, woody climbing shrub native to India and distributed across tropical regions of Burma and Sri Lanka.[2]

The plant is characterized by a grayish-white, deeply fissured stem with prominent lenticels, soft porous wood, and cordate, long-petiolate leaves with reticulate venation. It bears small unisexual flowers and red, fleshy aggregate fruits composed of multiple drupelets, reflecting its distinct botanical identity.[3]

**Figure 1: Tinospora cordifolia leaf showing characteristics heart shaped lamina.**

**Figure 2: Tinospora cordifolia plant material and traditional herbal preparation.**

## 2. Botanical Description and Distribution

**Scientific name**: Tinospora cordifolia (Willd.) Hook. f- & Thomson

**Family:** Menispermaceae

**Morphology:** Large deciduous climbing shrub with succulent stems, cordate leaves, aerial roots, and small yellow-green flower.[4]

**Distribution:** Widely distributed in India, Sri Lanka, Myanmar, and tropical regi ons of Asia.[5]

## 3. Phytochemical Profile of Tinospora cordifolia

Tinospora cordifolia contains diverse bioactive compounds responsible for its multitarget pharmacological effect.[6],[7],[8],[9].[10]

**Table 1: Major Phytoconstituents of Tinospora cordifolia.**

| Plant part | Active components | Representative compounds | Therapeutic property | Extraction method |
|---|---|---|---|---|
| **Leaves** | Flavonoids, Phenolics | Quercetin, Luteolin, Apigenin | Antioxidant, Anti-inflammatory, Anti-allergic | Cold maceration, Ultrasound-assisted extraction |
| **Stem** | Diterpenoid lactones | Tinosporide, Cordifolide, Columbin | Anti-inflammatory, Hepatoprotective, Antipyretic | Soxhlet extraction, Reflux extraction |
| **Roots** | Alkaloids | Berberine, Palmatine | Antidiabetic, Immunomodulatory | Acid–base extraction, Soxhlet extraction |
| **Flowers** | Flavonoids, Phenolics | Quercetin, Luteolin | Anti-inflammatory, Antioxidant, Anti-allergic | Cold maceration, Soxhlet extraction |
| **Seeds** | Fattyacids, Alkaloids | Linoleic acid, Oleic acid | Anti-inflammatory, Nutritive, Antimicrobial | Soxhlet extraction |
| **Bark** | Alkaloids, Diterpenoid lactones, Polysaccharides | Berberine, Tinosporide, Polysaccharides | Immunostimulatory, Anti-infective | Hotwater extraction followed by ethanol precipitation |

## 4. Giloy (tinospora cordifolia): A Rasayana Herb at the Interface of Ayurvedha and Modern Therapeutics

- **Ayurvedhic Identity and Conceptual Framework**

In Ayurvedha Giloy to by several synonymous names including *Guduchi, Amritavalli, Chakaralakshana and Jwaraghna*, reflecting its medicinal stature. It is classified as *Rasayanadravya*, a group of rejuvenative herbs believed to promote longevity, vitality, and resistance against disease. According to Ayurvedic doctrine, *Rasayana* therapy is not merely symptomatic treatment but a systemic intervention aimed at strenthening bodily tissues (*Dhatus)*, enhancing metabolic efficency *(Agni)*, and improving immune competance *(Vyadhikshamatva)*. Giloy is therefore traditionally recommended for convalescence, chronic illness, imuune deficency, and prematuring aging.[11]

- **Ayurvedic Pharmacodyanamics (Dravyaguna)**

Giloy exhibits a characteristic pharmacological profile described in Ayurveda as follows:

| Attribute | Description |
|---|---|
| *Rasa* ( Taste) | *Tikta*(bitter),*Kashaya*(astringent) |
| *Guna* (Quality) | *Laghu* (light), *Snigdha* (unctuous) |
| *Virya* (potency) | *Ushna* (hot) |
| *Vipaka* ( Post-digestive effect) | *Madhura* (sweet) |
| *Prabhava* (Specific action) | *Rasayana*, *Jwaraghna* |

This pharmacodynamic profile confers Giloy its *Tridoshaghna* property balancing *vata, Pitta ,and Kapha* making it therapeutically versatile across a wide spectrum of disorders.[12],[13]

- **Therapeutic Indications in Classical Ayurveda**

Classical Ayuvedic treatises describe Giloy as a drug of choice for numerous systemic disorders:

- **Charaka samhita:** *jwara* (fever), *Prameha* (diabetes) , *Kustha* (skin disorders), *Pandu* (anemia), *Kamala* (jaundice)
- **Sushruta Samhita:** *Rakta pitta* (bleeding disorders), *Vrana* (wounds), *Daha* (burning sensation)
- **Ashtanga Hridaya:** Trishna (excessive), Yakrit vikara (liver disorders), Shotha (inflammation)

The consistent mention of Giloy across major Ayurvedic compendia highlights its long standing therapeutic relevance.[14]

- **Classical Ayurvedic Formulations of Giloy**

Giloy is a key ingredient in numerous classical formulations, many of which remain widely used in contemporary Ayurvedhic practice:

| Formulation | Therapeutic Application |
|---|---|
| *Guduchi Satva* | Fever, diabetes, general debility |
| *Sanshamani Vati* | Chronic and malarial fever |
| *Amritarishta* | Liver disorders, anemia, chronic fever |
| *Guduchi Ghrita* | Cognitive impairment, memory loss |
| *Amrita Guggulu* | Arthritis and inflammatory disorders |
| *Guduchi Churna* | Immunity enhancement |

These dosage forms represent early examples of rational phytopharmaceutical design based on disease targeting.

- **Giloy as a Rasayana and Adaptogen**

Giloy is traditionally prescribed as a systemic rejuvenator and is now increasingly recognized as a planta daptogen. Rasayana therapy aims to:

- Enhance longevity (*Ayushya*)
- Promote strength (*Balya*)
- Improve cognition (*Medhya*)
- Delay aging (*Vayasthapana*)
- Strengthen immune resilience (*Vyadhikshamatva*)

Modern pharmacology correlates these actions with Giloy's immunomodulatory, antioxidant,neuroprotective, and anti-stress properties, validating its classification as a biological response modifier.

- **Integration with Panchakarma and Preventive Medicine**

Giloy is widely incorporated into Ayurvedic detoxification and rejuvenation protocols including:

- ***Virechana*** (therapeutic purgation)
- ***Basti*** (medicated enema)
- ***Nasya*** (nasal therapy)
- ***Rasayana Chikitsa*** (rejuvenation therapy)

Seasonal administration of Giloy-based decoctions is recommended as part of *Ritucharya* (seasonalregimen) to prevent infections and enhance adaptive immunity, especially during monsoon and winter seasons.

- **Mythological and Cultural Significance**

In Indian mythology, Giloy is believed to have originated from the divine nectar (*Amrita*) that fell upon Earth during the cosmic event of *Samudra Manthan*. This symbolic origin reinforces its cultural identity as a life-sustaining, rejuvenating herb.[15]

- **Correlation with Modern Biomedical Science**

| Ayurvedic Concept | Modern Interpretation |
|---|---|
| *Rasayana* | Immunomodulator and adaptogen |
| *Jwaraghna* | Antipyretic and antiviral |
| *Medhya* | Neuroprotective |
| *Balya* | Anabolic and rejuvenative |
| *Agnideepana* | Digestive enzyme modulation |
| *Tridoshaghna* | Homeostatic regulation |

This convergence highlights Giloy as a bridge between traditional medicine and modern systems biology.

- **Future Directions in Integrative Herbal Medicine**

The growing scientific interest in Giloy opens new translational opportunities:

- Standardization of classical formulations
- Prakriti-based personalized Rasayana therapy
- Genomic Ayurveda and phytochemical fingerprinting
- Integration with modern drug delivery systems
- Evidence-based clinical validation

## 5. PHARMACOLOGICAL ACTIVITIES

### 5.1 Immunomodulatory Activity

Tinospora cordifolia is best known for its potent immunomodulatory effects, which justify its classification as a Rasayana drug in Ayurveda. Polysaccharides such as arabinogalactan and alkaloids like magnoflorine stimulate macrpphage activation, enhance phagocytosis, and modulate both humoral and cell-mediated immunity.[16],[17] Experimental studies have demonstrated increased production of cytokines sueh as interleukin-2 (IL-2), interferon-I, and tumor necrosis factor-cc, indicating activation Of Tlymphocytes and natural killer cells. Guduchi also helps normalize immune responses, preventing excessive inflammation while maintaining host defense.[18] This dual immunostimulatory—immunoregulatory action makes it valuable in autoimmune disorders, recurrent infections, and as an adjuvant in vaccination strategies. The multitarget immune action supports its role in targeted herbal immunotherapy.[19],[20]

### 5.2 Anti-inflammatory Activity

The anti-inflammatory potential of T- cordifolia is attributed mainly to diterpenoid lactones such as tinosporide and cordifolide.[21],[22] These compounds inhibit key inflammatory mediators including cyclooxygenase (COX), lipoxygenase (LOX), and pro-inflammatory cytokines.[23] Guduchi suppresses NF-KB signaling, a central pathway involved in chronic inflammatory diseases. In vivo studies have shown significant reduction in edema, granuloma formation, and arthritic symptoms- Unlike conventional NSAIDs, Tinospora exhibits anti-inflammatory activity with minimal gastric toxicity- This makes it suitable for long-term targeted management of chronic inflammatory conditions such as rheumatoid arthritis and inflammatory bowel disease.[24]

### 5.3 Antidiabetic Activity

Tinospora cordifolia exhibits significant antihyperglycemic and insulin-sensitizing effects, making it a promising agent for targeted diabetes management.[25] Alkaloids and glycosides present in the stem enhance perypheral glucose utilization and improve insulin secretion.[26] The plant has been shown to inhibit glueoneogenesis while promoting glycogen synthesis in the liver. Antioxidant protection of pancreatic Il-cells further contributes to sustained glycemic control.[27] Clinical and preclinical studies report reductions in fasting blood glucose and improved lipid profiles. These multifaceted mechanisms support Guduchi as a complementary targeted therapy for type 2 diabetes mellitus.[28]

### 5.4 Antioxidant Activity

Oxidative stress plays a central role in the pathogenesis of many chronic diseases, and T. cordifolia demonstrates strong antioxidant potential.[29] The presence of phenolic compounds, flavonoids, and diterpenes enables effective scavenging of free radicals.[30] Tinospora cordifolia contains diverse bioactive compounds responsible for its multitarget pharmacological effect. The hepatoprotective activity of Tinospora cordifolia has been validated against drug ‗induced and toxin-induced liver damage. Diterpenoid lactones stabilize hepatocyte membranes and prevent leakage of liver enzymes. Guduchi reduces oxidative stress and inflammatory infiltration in hepatic tissue.[31],[32]

### 5.5 Antimicrobial Activity

Tinospora cordifolia exhibits broad-spectrum antimicrobial activity against bacteria, fungi, and certain viruses.[33] Extracts have shown effectiveness against Gram-positive organisms such as Staphylococcus aureus and Gram-negative organisms like Escherichia coli. The antimicrobial action is attributed to alkaloids, diterpenes, and phenolic compounds that disrupt microbial cell walls and inhibit enzymatic systems. Guduchi also enhances host immune defense, indirectly contributing to antimicrobial efficacy.[34] This dual direct and indirect action supports its use in targeted treatment of infectious diseases. It is especially valuable in managing infections in immunocompromised patients.[35]

### 5.6 Neuroprotective and Cognitive-Enhancing Activity

Neuroprotective effects ofTinospora cordifolia are linked to its antioxidant and anti ‗inflammatory propenies.[36] Guduchi reduces neuronal oxidative damage and inhibits neuroinflammation, which are key contributors to neurodegenerative diseases.[37]

Experimental studies suggest improvement in memmy, learning, and cognitive function. Modulation of neurotransmitter levels and protection against stress-induced neuronal damage have also been reported. These actions support its traditional use as a Medhya Rasayana. Therefore, Tinospora holds promise as a targeted herbal therapeutic in neurological and cognitive disorders.[38]

### 5.7 Anticancer Activity

Tinospora cordifolia has demonstrated anticancer potential through multipl e mechanisms.[39] Bioactive compounds induce apoptosis, inhi bit tumor cell proliferation, and arrest the cell cycle. Guduchi also modulates immune surveillance, enhancing the body's ability to recognize and destroy malignant cells.[40] Anti-angiogenic and antioxidant actions further contribute to its anticancer effects. Studies indicate reduced chemotherapy-induced toxicity when used as an

adjuvant. These findings support its emerging role in targeted compl ementary cancer therapy.[41]

**Table 2: Pharmacological Activities and Target Pathways.**

| Activity | Target Pathway/Mechanism | Potential Indication |
|---|---|---|
| **Immunomodulatory** | Cytokine regulation, macrophage activation | Auto immune disorders |
| **Anti-inflammatory** | NF KB. COX, LOX inhibition | Arthritis, IBD |
| **Antidiabetic** | Insulin signaling, P-cell protection | Type 2 diabetes |
| **Hepatoprotective** | Antioxidant enzymes, membrane stabilization | Liver disorders |
| **Anticancer** | Apoptosis, immune modulation | Adjunct cancer therapy |

## 6. Materials and Methods followed for Extraction Procedures

Extraction is the process of isolating and concentrating bioactive constituents from crude plant material using suitable solvents and methods. It is a crucial initial step in herbal drug development, as it converts raw plant parts into concentrated extracts that can be easily analyzed, standardized, and formulated. The choice of extraction technique and solvent significantly influences the yield, quality, and biological activity of the extract. Methods such as cold maceration, Soxhlet extraction, and ultrasonic-assisted extraction are commonly used for Tinospora cordifolia. Proper extraction ensures consistent therapeutic efficacy and supports further pharmacological and formulation studies.[42]

### 6.1 Plant Material Collection and Identification

The harvested Tinospora cordifolia from an uncontaminated environment and authenticated by a taxonomist. A reference specimen is deposited in a recognized herbarium for documentation.

### 6.2 Pre-processing of Plant Material

The collected stems are thoroughly rinsed with distilled water to eliminate adhering impurities. The material is shade-dried at ambient temperature until complete removal of moisture, ensuring the preservation of heat-sensitive constituents.

### 6.3 Pulverization

In Tinospora Cordifolia the plant part most commonly used Mature stem.

Dried plant material is mechanically pulverized to obtain a coarse powder. The powder is sieved to ensure uniform particle size and stored in moisture-resistant containers prior to extraction.

### 6.4 Solvent Selection

Appropriate solvents are chosen based on polarity to extract desired phytoconstituents. Commonly employed solvents include petroleum ether, chloroform, ethanol, methanol, and distilled water, with hydroalcoholic mixtures frequently used for comprehensive extraction.

### 6.5 Extraction Techniques

- **Continuous Hot Extraction (Soxhlet Method)**

A measured quantity of powdered drug is packed into a Soxhlet extractor and extracted with the selected solvent (ethanol 95% or 75%) over several cycles until exhaustive extraction is achieved. The obtained extract is concentrated under reduced pressure using a rotary vacuum evaporator and dried to constant weight.

- **Cold Maceration**

The powdered material is immersed in the solvent(ethanol : water, 70:30) and kept in a closed container for a specified duration with occasional agitation. After extraction, the mixture is filtered and the filtrate is concentrated to obtain the extract.

### 6.6 Concentration and Storage

The final extracts are dried, weighed to determine extractive yield, and preserved in airtight containers under refrigerated conditions to maintain stability and prevent degradation.[43]

### Extraction Procedure for Antioxidant Activity of Tinospora cordifolia

#### A. Leaf Extraction Procedure (Antioxidant Activity)

- **Collection and Processing**

Fresh leaves of Tinospora cordifolia were collected, thoroughly washed with distilled water to remove extraneous matter, and shade-dried at ambient temperature. Shade drying was preferred to minimize degradation of thermolabile antioxidant compounds such as flavonoids and phenolic acids. The dried leaves were pulverized into coarse powder and passed through sieve no. 40 for uniform particle size.

- **Solvent Selection**

A 70% ethanol–water mixture was selected as the extraction solvent due to its proven efficiency in extracting polyphenols and flavonoids responsible for antioxidant activity.

- **Extraction Method (Cold Maceration)**

Approximately 100 g of leaf powder was transferred into a clean, stoppered conical flask containing 1000 mL of 70% ethanol. The mixture was allowed to stand for 72 hours at room temperature with intermittent shaking to enhance solvent penetration and mass transfer. After maceration, the extract was filtered through muslin cloth

followed by Whatman No.1 filter paper. The remaining marc was re-macerated for an additional 24 hours to ensure exhaustive extraction.

- **Concentration and Storage**

The combined filtrates were concentrated using a rotary evaporator under reduced pressure at a temperature not exceeding 40 °C. The dried extract was weighed to determine percentage yield and stored in amber-colored airtight containers at 4 °C until antioxidant evaluation.

- **Scientific basis:** Leaves are known to contain higher levels of flavonoids and phenolic antioxidants, which are better preserved using non-thermal extraction methods.

**B. Stem Extraction Procedure (Antioxidant Activity)**

- **Collection and Processing**

Mature stems of Tinospora cordifolia were collected, cleaned, and shade-dried for 10–15 days due to their higher moisture content and fibrous nature. The dried stems were cut into small fragments and ground into coarse powder, followed by sieving through sieve no. 40.

- **Solvent Selection**

A 70% hydro-alcoholic solvent was selected to ensure efficient extraction of phenolic compounds, diterpenoid lactones, and polysaccharides associated with antioxidant activity.

- **Extraction Method (Soxhlet Extraction)**

About 50 g of stem powder was packed into a Soxhlet apparatus and extracted using 70% ethanol for 6–8 hours until the siphon tube showed colorless solvent. Continuous hot percolation ensured complete extraction of rigid stem constituents.

- **Concentration and Storage**

The extract was filtered and concentrated under reduced pressure using a rotary evaporator below 45 °C. The dried stem extract was stored in airtight amber-colored containers at 4 °C for further antioxidant studies.

- **Scientific basis:** Soxhlet extraction is more suitable for woody stem material to achieve exhaustive recovery of bound phenolic antioxidants.

**C. Antioxidant Evaluation (Common for Both Extracts)**

The antioxidant potential of leaf and stem extracts was evaluated using standard in-vitro assays such as:

- PPH radical scavenging assay
- Reducing power assay
- Hydrogen peroxide scavenging assay
- These methods assess the ability of extracts to neutralize free radicals and prevent oxidative damage.

**Extraction Procedures of Tinospora cordifolia stem for Anti-inflammatory Activity**

**A. Cold Maceration Method**

- **Plant Material Preparation**

Fresh and healthy leaves of Tinospora cordifolia were collected and washed thoroughly with distilled water to remove dust and impurities. The leaves were shade-dried at room temperature and then ground into a coarse powder using a mechanical grinder.

- **Selection of Solvent**

A hydro-alcoholic solvent system (70% ethanol : 30% water) or methanol–water mixture was selected, as it effectively extracts anti-inflammatory phytoconstituents such as alkaloids, flavonoids, and glycosides.

- **Maceration Process**

A known quantity of the powdered leaf material was weighed and transferred into a closed container. The solvent was added in a 1:10 (w/v) ratio, and the mixture was allowed to stand at room temperature for 48–72 hours. The contents were shaken intermittently (2–3 times daily) to enhance extraction efficiency.

- **Filtration**

After maceration, the mixture was filtered first through muslin cloth and subsequently through Whatman filter paper to remove particulate matter.

- **Concentration**

The filtrate was concentrated either under reduced pressure using a rotary evaporator or by allowing the solvent to evaporate at room temperature to obtain the crude extract.

**Storage**

The dried extract was stored in an airtight container at 4 °C until further anti-inflammatory evaluation.

**B. Soxhlet Extraction Method**

- **Plant Material Preparation**

Leaves of Tinospora cordifolia were collected, washed thoroughly, shade-dried, and coarsely powdered.

- **Loading of Sample**

An accurately weighed quantity of the powdered leaf material (approximately 20–50 g) was placed into a filter paper thimble and inserted into the Soxhlet apparatus.

- **Selection of Solvent**

Ethanol, methanol, or a hydro-alcoholic solvent was used, as these solvents are known to efficiently extract anti-inflammatory bioactive compounds.

- **Soxhlet Extraction**

The Soxhlet apparatus was assembled with a round-bottom flask containing the selected solvent and heated gently. Continuous hot percolation was carried out for 6–8 hours until the solvent in the siphon tube became colorless, indicating exhaustive extraction.

- **Concentration of Extract**

The obtained extract was concentrated usinga rotary evaporator or water bath to remove excess solvent.

- **Drying and Storage**

The concentrated extract was dried completely, the percentage yield was recorded, and the extract was stored in an airtight container at 4 °C for further analysis.

**C. Ultrasonic-Assisted Extraction Method**

- **Sample Preparation**

Shade-dried leaves of Tinospora cordifolia were pulverized into coarse powder. About 10 g of the powdered material was accurately weighed.

- **Solvent Addition**

To the powder, 100 mL of hydro-alcoholic solvent was added, maintaining a 1:10 (w/v) ratio.

- **Ultrasonication**

The mixture was subjected to ultrasonication at a frequency of 35–40 kHz for 20–30 minutes at a controlled temperature of 30–40 °C. Higher temperatures were avoided to prevent degradation of thermolabile anti-inflammatory compounds.

- **Filtration**

The extract was filtered using Whatman No.1 filter paper to remove undissolved particles.

- **Concentration**

The filtrate was concentrated under reduced pressure using a rotary evaporator or water bath at temperatures below 40°C.

- **Storage**

The dried extract was stored in airtight containers at 4 °C until used for anti-inflammatory studies.[44]

**Extraction Procedures of Tinospora cordifolialeaf for Anti-inflammatory Activity**

**A. Cold Maceration Method**

- **Preparation of Plant Material**

Healthy, mature stems of Tinospora cordifolia were collected and thoroughly washed with distilled water to remove dirt and extraneous matter. The stems were shade-dried at room temperature, cut into small pieces, and coarsely powdered using a mechanical grinder.

- **Selection of Solvent**

A hydro-alcoholic solvent system (70% ethanol : 30% water) or methanol–water mixture was selected, as it is effective in extracting anti-inflammatory phytoconstituents such as alkaloids, diterpenoid lactones, flavonoids, and glycosides.

- **Maceration Process**

A measured quantity of the powdered stem material was transferred into a closed container, and solvent was added in a 1:10 (w/v) ratio. The mixture was kept at room temperature for 48–72 hours with occasional shaking (2–3 times daily) to facilitate efficient extraction.

- **Filtration**

After completion of maceration, the mixture was filtered through muslin cloth followed by filtration using Whatman filter paper to remove insoluble material.

- **Concentration**

The filtrate was concentrated under reduced pressure using a rotary evaporator or allowed to evaporate slowly at room temperature to obtain the crude stem extract.

- **Storage**

The dried extract was stored in airtight containers at 4 °C until further anti-inflammatory evaluation.

**B. Soxhlet Extraction Method**

- **Preparation of Plant Material**

Stems of Tinospora cordifolia were collected, washed, shade-dried, and ground into coarse powder.

- **Loading of Sample**

An accurately weighed quantity of powdered stem material (20–50 g) was placed into a filter paper thimble and positioned in the Soxhlet extractor.

- **Selection of Solvent**

Ethanol, methanol, or a hydro-alcoholic solvent was selected due to their ability to dissolve anti-inflammatory constituents present in the stem.

- **Soxhlet Extraction**

The Soxhlet apparatus was assembled with a round-bottom flask containing the selected solvent and heated gently. Continuous hot extraction was carried out for 6–8 hours until the solvent in the siphon tube appeared nearly colorless, indicating completion of extraction.

- **Concentration of Extract**

The extract was concentrated using a rotary evaporator or water bath to remove excess solvent.

- **Drying and Storage**

The concentrated extract was dried completely, the extraction yield was recorded, and the extract was stored in airtight containers at 4 °C for subsequent analysis.

**C. Ultrasonic-Assisted Extraction Method**

- **Sample Preparation**

Shade-dried stems of Tinospora cordifolia were coarsely powdered, and 10 g of the powder was accurately weighed.

- **Solvent Addition**

To the powdered stem material, 100 mL of hydro-alcoholic solvent was added, maintaining a 1:10 (w/v) ratio.

- **Ultrasonication**

The mixture was subjected to ultrasonication at a frequency of 35–40 kHz for 20–30 minutes at a controlled temperature range of 30–40 °C. Excessive heating was avoided to prevent degradation of bioactive compounds.

- **Filtration**

Following ultrasonication, the extract was filtered using Whatman No.1 filter paper.

- **Concentration**

The filtrate was concentrated under reduced pressure using a rotary evaporator or water bath at temperatures below 40°C.

- **Storage**

The dried stem extract was stored in airtight containers at 4°C until used for anti-inflammatory studies.

**Extraction Procedure of Tinospora cordifolia Flowers for Antioxidant Activity**

- **Preparation of Plant Material**

Fresh flowers of Tinospora cordifolia were collected during the flowering season and cleaned thoroughly with distilled water to remove dust and foreign matter. The flowers were shade-dried at room temperature to preserve heat-sensitive antioxidant compounds. After complete drying, the material was coarsely powdered using a mechanical grinder and passed through sieve no. 40.

- **Selection of Solvent**

A hydro-alcoholic solvent (70% ethanol: 30% water) or methanol–water mixture was selected, as it is effective for extracting phenolic compounds, flavonoids, and glycosides, which contribute significantly to antioxidant activity.

- **Extraction Method – Cold Maceration**

An accurately weighed quantity of flower powder (about 50–100 g) was placed in a closed container. The selected solvent was added in a 1:10 (w/v) ratio, and the mixture was kept at room temperature for 48–72 hours. Intermittent shaking was performed 2–3 times daily to enhance solvent penetration and extraction efficiency.

- **Filtration**

After maceration, the mixture was filtered first through muslin cloth and then through Whatman No.1 filter paper to obtain a clear extract.

- **Concentration of Extract**

The filtrate was concentrated under reduced pressure using a rotary evaporator or by evaporation on a water bath at a temperature below 40 °C, yielding a crude dried extract.

- **Storage**

The dried flower extract was transferred into airtight amber-colored containers and stored at 4 °C until further antioxidant evaluation.

- **Evaluation of Antioxidant Activity**

The antioxidant potential of the flower extract was assessed using standard in-vitro assays such as:

- DPPH radical scavenging assay
- Hydrogen peroxide scavenging assay
- Reducing power assay

**Evaluation of Antimicrobial Activity of Tinospora cordifolia Seeds**

- **Preparation of Seed Material**

Mature seeds of Tinospora cordifolia were collected and washed thoroughly with distilled water to remove dust and impurities. The seeds were shade-dried at room temperature until a constant weight was achieved. The dried seeds were then coarsely powdered using a mechanical grinder and passed through sieve no. 40. The powdered material was stored in airtight containers until extraction.

- **Extraction of Seed Material**

The powdered seed material was subjected to extraction using a hydro-alcoholic solvent system (70% ethanol : 30% water) by the cold maceration method. A known quantity of seed powder was soaked in solvent in a 1:10 (w/v) ratio and kept at room temperature for 48–72 hours with intermittent shaking. After maceration, the mixture was filtered and the filtrate was concentrated under reduced pressure using a rotary evaporator. The dried extract was stored at 4 °C until antimicrobial evaluation.

- **Microorganisms Used**

The antimicrobial activity of the seed extract was assessed against selected Gram-positive and Gram-negative bacterial strains, including:

- Staphylococcus aureus
- Bacillus subtilis
- Escherichia coli
- Pseudomonas aeruginosa

- **Preparation of Test Solutions**

The dried seed extract was dissolved in a suitable solvent such as dimethyl sulfoxide (DMSO) or sterile distilled water to obtain different concentrations for antimicrobial testing.

- **Antimicrobial Assay – Agar Well Diffusion Method**

Sterile nutrient agar medium was poured into Petri dishes and allowed to solidify. The test microorganisms were evenly spread over the agar surface using sterile cotton swabs. Wells of uniform diameter were made in the agar using a sterile cork borer. Measured volumes of the seed extract solutions were added into the wells.

- A standard antibiotic (such as ciprofloxacin) was used as a positive control, while the solvent served

as a negative control. The plates were incubated at 37 °C for 24 hours.

- **Observation and Interpretation**

After incubation, the plates were examined for zones of inhibition around the wells. The diameter of the inhibition zones was measured in millimeters, and the antimicrobial activity of the seed extract was assessed by comparing it with the standard drug.[45],[46]

**7. Novel Dosage Forms and Targeting Stratrgies of Tinospora cordifolia**

- **Nanoparticle-based formulations** improve the stability, bioavailability, and site-specific delivery of *Tinospora cordifolia* bioactive compounds.
- **Phytosomal systems** enhance absorption by increasing the lipid compatibility of plant constituents.
- **Controlled and sustained-release dosage forms** provide prolonged therapeutic action and reduce the frequency of administration.
- **Organ-targeted delivery systems** direct active constituents toward specific tissues such as the liver, pancreas, or immune cells.
- **Transdermal delivery systems** allow continuous drug release while avoiding hepatic first-pass metabolism.
- **Mucoadhesive formulations** increase contact time at absorption sites, improving therapeutic effectiveness.
- **Polyherbal or combination formulations** enable synergistic action and disease-specific targeting.
- **Standardized herbal extracts** ensure uniformity in phytochemical content and reproducible therapeutic outcomes.
- **Stimuli-responsive delivery systems** (pH- or enzyme-sensitive) enable controlled release at specific disease sites.[47]

**8. Safety, Toxicity, and Regulatory Aspects**

Guduchi is generally safe at therapeutic doses; however, standardization, quality control, and pharmacovigilance are essential for targeted applications. Future Perspectives.[48],[49]

Integration of omics technologies, Al-driven phytochemical screening, and advanced delivery systems can accelerate the development of Guduchi-based targeted herbal therapeutics.[50]

**9. Applications of Tinospora cordifolia**

Acts as a potent immunomodulator, enhancing innate and adaptive immune responses.

- Used as an antipyretic, especially in chronic and recurrent fevers.
- Exhibits strong anti-inflammatory and anti-arthritic activity, useful in arthritis and inflammatory disorders.
- Shows antidiabetic potential by improving glucose utilization and insulin sensitivity.
- Provides hepatoprotective effects, supporting liver function and detoxification.
- Possesses antioxidant properties, reducing oxidative stress and cellular damage.
- Demonstrates antimicrobial activity against bacteria, fungi, and parasites.
- Widely used in pharmaceutical, nutraceutical, cosmetic, and targeted herbal therapeutic formulation

**ACKNOWLEDGEMENT**

The authors would like to convey their heartfelt appreciation to the teaching faculty and laboratory personnel of the Department of Pharmaceutical Sciences for their constant support, guidance, and encouragement during the development of this review. We gratefully recognize the insights gained from classical Ayurvedic texts as well as modern scientific literature, which together provided the conceptual and scientific basis for this work. We also acknowledge the contributions of various researchers and academicians whose published findings on *Tinospora cordifolia* significantly enhanced the understanding of its phytochemical composition, pharmacological relevance, and translational applications.

**RESULTS AND DISCUSSION**

The reviewed evidence shows that *Tinospora cordifolia* contains diverse bioactive compounds distributed across its leaves, stems, roots, seeds, flowers, and bark, contributing to multiple therapeutic effects. Extraction methods such as hydro-alcoholic maceration, Soxhlet, and ultrasonic techniques effectively isolate phenolics, flavonoids, alkaloids, diterpenoid lactones, and polysaccharides. In-vitro assays confirm strong antioxidant potential, while anti-inflammatory studies demonstrate inhibition of key pathways like COX, LOX, and NF-κB. Antimicrobial testing reveals activity against both Gram-positive and Gram-negative organisms. These activities depend significantly on the plant part selected, solvent polarity, and extraction procedure. Modern formulation strategies including phytosomes and nanoparticles improve bioavailability and targeted delivery of active constituents. The discussion highlights the alignment between Ayurvedic Rasayana concepts and modern immunomodulatory and adaptogenic findings. However, phytochemical variability and lack of standardization remain major challenges. Advanced analytical tools and standardized protocols are essential for consistent therapeutic outcomes. Overall, *Tinospora cordifolia* shows strong potential as a scientifically validated, multi-target herbal therapeutic.

**10. CONCLUSION**

Tinospora cordifolia is a medicinal plant of significant therapeutic importance, combining traditional Ayurvedic wisdom with growing scientific evidence. Its wide range of pharmacological activities, including immune

enhancement, anti-inflammatory, antipyretic, antidiabetic, hepatoprotective, antioxidant, and antimicrobial effects, makes it a versatile candidate for managing diverse health conditions. These benefits are attributed to its rich profile of bioactive compounds such as alkaloids, diterpenoid lactones, glycosides, and polysaccharides. The increasing incorporation of Tinospora cordifolia into pharmaceutical, nutraceutical, cosmetic, and targeted herbal formulations highlights its clinical relevance. Nevertheless, rigorous standardization, quality assurance, and comprehensive clinical investigations are required to validate its efficacy and ensure safe, evidence-based therapeutic use.

Tinospora cordifolia represents a promising herbal resource with multifaceted therapeutic potential and growing relevance in modern healthcare. Beyond its established immunomodulatory and anti-inflammatory roles, emerging studies suggest its usefulness in metabolic regulation, stress adaptation, and tissue protection, indicating its broader role as a systemic rejuvenator. The synergistic interaction of its phytoconstituents contributes to multi-target actions rather than single-pathway effects, making it especially suitable for chronic and lifestyle-related disorders. Its traditional classification as a Rasayana aligns well with current concepts of preventive medicine and holistic health management.

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