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A Review on Antimicrobial Herbal Gels Developed Using Tinospora cordifolia

Authors: Jalkote Rutuja[1*], Bhalerao Sarika[2], Mane Ankita[3], Dake Akshay[4], Pathan Ajhar[5]

Department of Pharmaceutics, Final Year B. Pharmacy,

Latur College of Pharmacy, Hasegaon, Latur, India

Guide: Mr. Shikh K. U.* Assistant Professor, Department of Pharmaceutics,

Latur College of Pharmacy, Hasegaon, Latur, India

Abstract: -

Tinospora cordifolia, commonly referred to as Guduchi, is a widely recognized medicinal plant in the Ayurvedic system of medicine due to its extensive therapeutic applications. The plant is rich in diverse bioactive constituents such as alkaloids, diterpenoid lactones, glycosides, phenolic compounds, and polysaccharides, which are responsible for its antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory properties. Several experimental investigations have confirmed that extracts of Tinospora cordifolia exhibit effective antibacterial and antifungal activity against common pathogenic microorganisms including Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Bacillus subtilis, Candida albicans, and Aspergillus Niger.

In recent pharmaceutical research, topical herbal gels containing Tinospora cordifolia extract have gained considerable attention due to their favorable physicochemical characteristics, good skin compatibility, and enhanced antimicrobial performance. Gel bases such as Carbopol and novel vesicular carriers like transethosomes have been reported to improve skin penetration and sustain the release of active constituents. The present review aims to compile and critically analyze available scientific literature on the pharmacognostic features, phytochemical composition, antimicrobial potential, and formulation approaches of Tinospora cordifolia, highlighting its suitability for the development of an effective herbal antimicrobial gel for topical application.

Keywords

Tinospora cordifolia; Guduchi; Herbal antimicrobial gel; Phytochemicals; Antibacterial activity; Antifungal activity; Carbopol gel; Topical formulation; Wound healing; Natural antimicrobials.

1. Introduction: -

Tinospora cordifolia (Guduchi) is an important climbing shrub belonging to the family Menispermaceae and has been extensively utilized in traditional Indian medicine for centuries. It is widely prescribed for the management of various health conditions such as fever, skin infections, wounds, diabetes, liver disorders, and inflammatory diseases. Among different plant parts, the stem is considered the most therapeutically valuable due to its rich content of biologically active compounds.

Phytochemical investigations of Tinospora cordifolia have revealed the presence of alkaloids, diterpenoid lactones, glycosides, steroids, phenolics, and polysaccharides, which collectively contribute to its broad

pharmacological profile. Modern scientific studies have validated many of its traditional claims, confirming antimicrobial, antioxidant, anti-inflammatory, immunomodulatory, hepatoprotective, and wound-healing activities.

The increasing prevalence of microbial resistance and the undesirable side effects associated with synthetic antimicrobial agents have created a demand for safer and more effective alternatives. Herbal medicines have emerged as promising candidates due to their better tolerability, reduced toxicity, and improved patient acceptance. Among various dosage forms, topical gels are preferred for the treatment of skin infections because they are non-greasy, easy to apply, rapidly absorbable, and capable of providing localized drug delivery.

Incorporation of Tinospora cordifolia extract into topical gel formulations, particularly Carbopol-based gels, and advanced vesicular systems, has shown improved antimicrobial efficacy and enhanced wound-healing potential. Therefore, this review focuses on summarizing the pharmacognostic characteristics, phytochemical profile, antimicrobial evidence, and formulation strategies of Tinospora cordifolia to support its application in the development of a scientifically validated herbal antimicrobial gel. (Source: JDDT review by Farheen Khan; Plant Archives 2020; Tinospora Cordifolia – One Plant Many Roles Review)

2. Pharmacognosy of Tinospora cordifolia: -

Biological Source: Tinospora cordifolia (Willd.) Miers

Family: Menispermaceae

Tinospora cordifolia is a large, deciduous, climbing shrub commonly found in tropical regions of India. The plant is characterized by its long, twining branches and distinctive aerial roots that often hang from mature stems. The stem is cylindrical, fleshy, and light grey to brown in color, with a rough surface marked by lenticels. When dried and powdered, the stem appears pale brown with a characteristic bitter taste and mild odor. Traditionally, the stem is widely used for the preparation of Guduchi satva, a starchy extract known for its nutritive and therapeutic value.

The leaves are simple, alternate, and long-petioled with a heart-shaped (cordate) appearance. The lamina is thin, membranous, and typically measures 10–20 cm in length, with prominent venation radiating from the base. Tinospora cordifolia bears small, greenish-yellow flowers that are unisexual in nature. Male flowers are arranged in clusters, whereas female flowers usually occur singly. The flowering season generally occurs during summer, followed by fruiting in the winter season.

The fruits are drupes, typically single-seeded, with a curved seed structure. Aerial roots arise from the stem nodes and may extend downward to reach the soil. Microscopically, the stem shows well-developed vascular bundles with characteristic penta-arch or tetra-arch xylem arrangement, which is helpful for botanical identification and authentication. These distinct morphological and anatomical features serve as important pharmacognostic parameters for ensuring the purity and quality of Tinospora cordifolia used in herbal formulations.

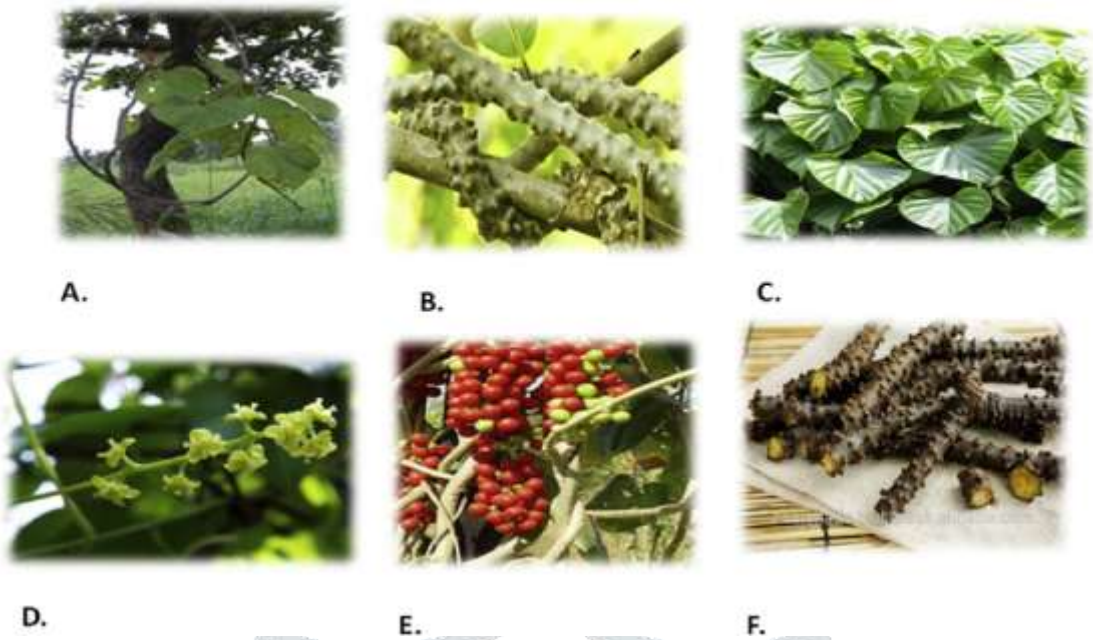

fig 1:- parts of tinospora cordifolia

3. Photochemistry of Tinospora cordifolia: —

table 1:- chemical constituents of tinospora cordifilia

Phytochemical Class	Major Constituents	Biological Activity
Alkaloids	Berberine, Palmatine, Magnoflorine, Jatrorrhizine	Strong antimicrobial, anti-inflammatory, antioxidant
Diterpenoid Lactones	Tinosporaside, Cordifolioside, Columbin	Immunomodulatory, hepatoprotective, antimicrobial
Flavonoids	Quercetin-type compounds	Antioxidant, wound healing, anti-infective
Glycosides	Tinosporin, Cordifoliosides	Anti-diabetic, antioxidant
Polysaccharides	(1→4)-α-D-Glucan	Immune boosting, macrophage activation
Steroids	B-Sitosterol, Ecdysteroids	Anti-inflammatory, tissue repair
Phenolics & Tannins	Phenolic acids,tannins	Antimicrobial, antifungal, antioxidant
Volatile Compounds	Essential oils (minor)	Mild antimicrobial effect
Overall Activity	Synergistic action of all constituents	Strong antimicrobial + wound healing potential

4. Pharmacological Activities of Tinospora Cordifolia: -

Fig 2:- pharmacological activity of tinospora cordifolia

1) Antimicrobial Activity

Tinospora cordifolia exhibits strong and broad-spectrum antimicrobial activity against a wide range of pathogenic microorganisms. This activity is mainly attributed to the presence of alkaloids such as berberine, palmatine, magnoflorine, along with phenolic compounds, flavonoids, and diterpenoid lactones. These phytoconstituents act synergistically to inhibit microbial growth and survival.

The antimicrobial mechanism involves disruption of microbial cell membrane integrity, leading to leakage of intracellular contents. Alkaloids such as berberine are known to interfere with DNA replication and transcription, thereby preventing microbial multiplication. Phenolic compounds further contribute by denaturing microbial proteins and inhibiting essential enzymatic pathways.

Several experimental studies have demonstrated effective antibacterial activity of Tinospora cordifolia extracts against Gram-positive bacteria such as Staphylococcus aureus and Bacillus subtilis, as well as Gram-negative bacteria including Escherichia coli and Pseudomonas aeruginosa. In addition to antibacterial effects, Guduchi also shows notable antifungal activity against Candida albicans and Aspergillus niger. These findings support the potential use of Tinospora cordifolia as a natural antimicrobial agent in topical gel formulations intended for the management of skin and wound infections.

2) Antioxidant Activity

Tinospora cordifolia possesses significant antioxidant activity, which plays a vital role in protecting cells and tissues from oxidative stress. The antioxidant potential of Guduchi is primarily due to the presence of flavonoids, phenolic acids, alkaloids, and diterpenoid lactones that efficiently scavenge free radicals and reactive oxygen species (ROS).

Oxidative stress is a major factor responsible for delayed wound healing and tissue damage during infections. By neutralizing ROS, Tinospora cordifolia prevents lipid peroxidation, stabilizes cell membranes, and preserves cellular integrity. Various in vitro antioxidant assays, including DPPH radical scavenging studies, have confirmed the strong antioxidant capacity of Guduchi extracts.

When incorporated into topical gel formulations, the antioxidant properties of Tinospora cordifolia help reduce oxidative damage at the site of infection or injury, thereby promoting faster tissue regeneration and improved wound healing outcomes.

3) Anti-inflammatory Activity

The anti-inflammatory activity of Tinospora cordifolia is well-documented and is closely associated with its diterpenoid lactones, alkaloids, and flavonoids. These bioactive compounds regulate inflammatory responses by modulating the release of key inflammatory mediators such as prostaglandins, tumor necrosis factor-alpha (TNF-α), and interleukins.

Guduchi extracts have been shown to inhibit cyclooxygenase (COX) and lipoxygenase (LOX) pathways, which are responsible for the synthesis of inflammatory mediators. Additionally, Tinospora cordifolia stabilizes lysosomal membranes, thereby preventing the release of tissue-damaging enzymes at the site of inflammation.

Reduction of inflammation is particularly beneficial in infected wounds, as it minimizes pain, swelling, and redness while creating a favorable environment for tissue repair. The incorporation of Guduchi extract into hydrogel formulations enhances patient comfort and supports rapid recovery.

4)Immunomodulatory Activity

Tinospora cordifolia is traditionally regarded as a potent immunomodulatory herb and is classified as a "Rasayana" in Ayurveda. Its immunomodulatory effect is mainly attributed to polysaccharides such as (1→4)-α-D-glucan, which stimulate macrophage activity and enhance phagocytosis.

Guduchi has been reported to modulate cytokine production, leading to improved immune responsiveness. It enhances both innate and adaptive immune responses by increasing antibody production and improving cellular immunity. Activation of immune cells aids in faster clearance of pathogens and provides protection against recurrent infections.

In the context of wound healing and skin infections, improved immune function plays a crucial role in preventing secondary infections and promoting effective tissue repair. Therefore, the immunomodulatory property of Tinospora cordifolia significantly enhances its therapeutic value in topical antimicrobial formulations.

5) Wound-Healing Activity

Tinospora cordifolia promotes wound healing through multiple complementary mechanisms. Its antimicrobial action prevents microbial contamination at the wound site, while antioxidant activity reduces oxidative stress that delays tissue regeneration. In addition, Guduchi stimulates fibroblast proliferation, collagen synthesis, and angiogenesis, all of which are essential processes in wound repair.

Studies have reported improved wound contraction, faster epithelialization, and enhanced granulation tissue formation following topical application of Tinospora cordifolia extract. Polysaccharides present in the plant support immune-mediated wound cleansing, while terpenoids and alkaloids strengthen connective tissue formation.

Hydrogel formulations containing Guduchi maintain a moist wound environment, enhance bioavailability of active constituents, and ensure sustained release, resulting in more efficient and faster wound healing.

6) Antidiabetic Activity

Tinospora cordifolia exhibits promising antidiabetic activity by regulating blood glucose levels through multiple mechanisms. Diterpenoid lactones and glycosides present in the plant enhance insulin secretion and improve glucose uptake by peripheral tissues. Guduchi also inhibits carbohydrate-digesting enzymes, thereby reducing postprandial glucose spikes.

Its antioxidant activity protects pancreatic β-cells from oxidative stress, while immunomodulatory effects prevent inflammatory damage associated with diabetes. Effective glycemic control contributes to improved wound healing, particularly in diabetic patients who are prone to chronic ulcers and infections.

Thus, Tinospora cordifolia plays a supportive role in managing diabetic complications and enhances the therapeutic efficacy of topical gels developed for diabetic wound care.

7) Hepatoprotective Activity

Tinospora cordifolia shows strong hepatoprotective effects by safeguarding liver cells against toxin-induced and oxidative damage. Diterpenoid lactones such as tinosporaside and cordifolioside enhance antioxidant enzyme levels, including superoxide dismutase and catalase, thereby reducing hepatic oxidative stress.

Studies have demonstrated that Guduchi administration helps normalize elevated liver enzyme levels, indicating recovery of liver function. Its anti-inflammatory and immunomodulatory properties further support hepatic tissue regeneration.

Since liver health plays an important role in metabolism and immune regulation, the hepatoprotective activity of Tinospora cordifolia indirectly contributes to enhanced resistance against infections and improved wound-healing capacity.

5. Antimicrobial Studies

Extensive experimental investigations have confirmed the antimicrobial potential of Tinospora cordifolia against a wide range of pathogenic microorganisms. Various extracts prepared using solvents such as methanol, ethanol, aqueous media, and chloroform have been evaluated for antibacterial and antifungal activity using standard in-vitro techniques including agar well diffusion, disc diffusion, and broth dilution methods.

Among different extraction solvents, methanolic and chloroform extracts generally demonstrate superior antimicrobial activity. This enhanced effect is attributed to their ability to extract higher concentrations of bioactive compounds such as alkaloids, phenolics, flavonoids, and diterpenoid lactones. These compounds act synergistically to inhibit microbial growth.

Several studies have reported significant antibacterial activity of Tinospora cordifolia extracts against common wound-associated bacteria such as Staphylococcus aureus and Bacillus subtilis (Gram-positive), as well as Escherichia coli and Pseudomonas aeruginosa (Gram-negative). Zones of inhibition reported in different studies typically range from moderate to high, indicating strong antimicrobial effectiveness. The variation in activity observed across studies is mainly influenced by factors such as extraction method, solvent type, concentration of extract, and microbial strain tested.

In addition to antibacterial activity, Tinospora cordifolia has also demonstrated noteworthy antifungal potential. Extracts have shown effective inhibition against fungal pathogens such as Candida albicans and Aspergillus niger, which are frequently responsible for superficial and opportunistic skin infections. The antifungal activity is largely attributed to the presence of tannins and phenolic compounds that disrupt fungal cell walls and interfere with their metabolic processes.

Recent research has further explored the use of Tinospora cordifolia in the green synthesis of silver nanoparticles. Plant-mediated silver nanoparticles synthesized using Guduchi extract exhibit significantly enhanced antimicrobial activity compared to crude extracts alone. This improved efficacy is due to the combined antimicrobial action of silver ions and Guduchi phytoconstituents, resulting in rapid microbial cell damage and reduced resistance development.

Overall, antimicrobial studies clearly establish Tinospora cordifolia as a potent natural antimicrobial agent. These findings strongly support its incorporation into topical herbal gel formulations for the management of infected wounds and skin infections.

6. Extraction Of Tinospora Cordifolia

The extraction process involves drying, pulverizing, and subjecting the stem powder to solvent-based and advanced extraction techniques. The figure below summarises the typical extraction workflow, including solvent extraction, enzymatic or ultrasound-assisted extraction, rotary evaporation, and purification steps like dialysis and freeze drying. These methods help obtain concentrated phytochemical-rich extracts suitable for antimicrobial gel formulation.

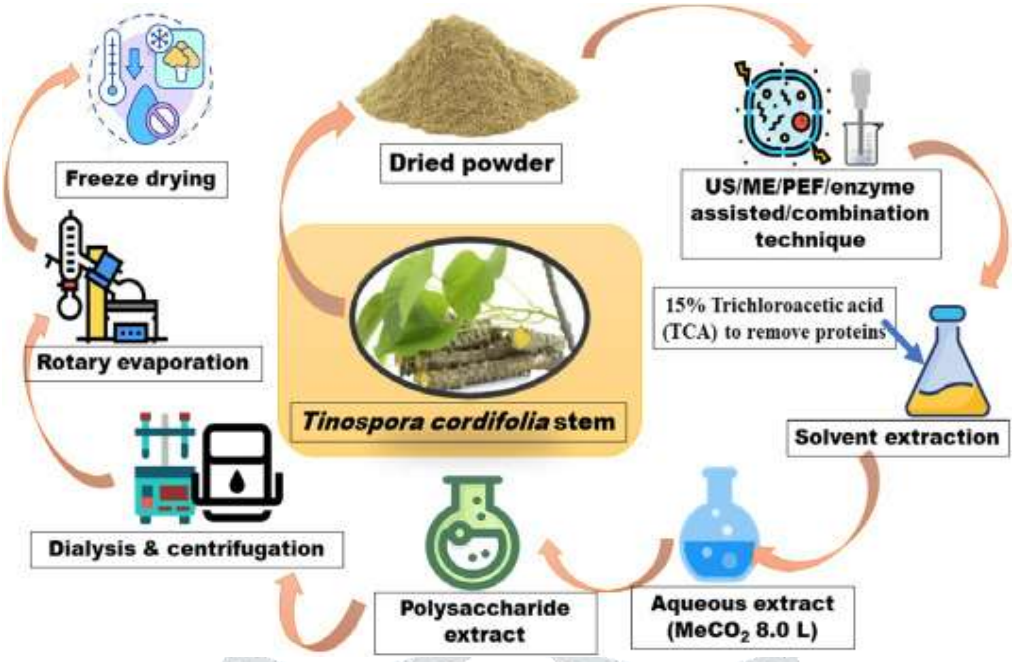

Fig 3:-General schematic representation of extraction and purification steps of Tinospora cordifolia stem.

7. Mechanism of Antimicrobial Action of Tinospora cordifolia

The antimicrobial activity of Tinospora cordifolia is mediated through multiple complementary mechanisms involving its diverse phytochemical constituents. Unlike synthetic antimicrobials that often act through a single target, Guduchi exerts a multi-targeted action, reducing the risk of microbial resistance.

A. Disruption of Microbial Cell Membrane

Alkaloids, terpenoids, and phenolic compounds present in Tinospora cordifolia interact with the lipid bilayer of microbial cell membranes. This interaction increases membrane permeability, leading to leakage of essential intracellular components such as ions, proteins, and nucleic acids. Loss of membrane integrity ultimately results in microbial cell death.

B. Denaturation of Microbial Proteins and Enzymes

Phenolic compounds and tannins present in Guduchi bind to microbial proteins and enzymes, causing structural alterations and loss of function. This denaturation process interferes with vital metabolic activities such as respiration, nutrient uptake, and energy production, thereby inhibiting microbial growth.

C. Inhibition of DNA and RNA Synthesis

Certain alkaloids, particularly berberine and palmatine, are capable of binding to microbial DNA. This interaction interferes with DNA replication and RNA transcription processes, preventing cell division and proliferation. As a result, microbial multiplication is effectively suppressed.

D. Induction of Oxidative Stress in Microbial Cells

Flavonoids and phenolic constituents present in Tinospora cordifolia promote the generation of reactive oxygen species (ROS) within microbial cells. Excess ROS cause oxidative damage to microbial membranes, proteins, and genetic material, leading to irreversible cellular injury and death.

E. Inhibition of Essential Metabolic Pathways

Guduchi phytochemicals inhibit key microbial enzymes involved in:

ATP (energy) synthesis

Cell wall formation

Protein synthesis

Blocking these pathways weakens microbial defense mechanisms and slows their growth, ultimately leading to cell death.

F. Prevention and Disruption of Biofilm Formation

Biofilm formation is a major factor contributing to chronic and recurrent infections. The antioxidant and anti-inflammatory constituents of Tinospora cordifolia interfere with microbial adhesion and biofilm development. By disrupting established biofilms and preventing new biofilm formation, Guduchi enhances overall antimicrobial efficacy.

8. Discussion

Critical evaluation of the reviewed literature clearly indicates that Tinospora cordifolia possesses significant antimicrobial potential supported by both traditional knowledge and modern scientific evidence. The antimicrobial activity is mainly attributed to the synergistic action of alkaloids, phenolic compounds, flavonoids, and diterpenoid lactones present in the plant. These phytoconstituents effectively inhibit a wide range of Gram-positive and Gram-negative bacteria as well as pathogenic fungi commonly associated with skin and wound infections.

Formulation studies involving Carbopol-based gels containing Tinospora cordifolia extract have demonstrated acceptable physicochemical characteristics such as suitable pH, good homogeneity, satisfactory spreadability, and stability. An increase in extract concentration generally resulted in enhanced antimicrobial activity, indicating a clear dose-dependent effect. This observation supports the suitability of Guduchi extract for topical antimicrobial formulations.

In addition to antimicrobial action, the antioxidant, and anti-inflammatory properties of Tinospora cordifolia play a crucial role in accelerating wound healing. Reduction of oxidative stress and inflammation creates a favorable environment for tissue regeneration and repair. Advanced drug delivery systems such as transethosomal and nano-based gels have shown improved skin permeation and sustained release of active constituents, suggesting promising future applications. Overall, the compiled findings strongly justify the use of Tinospora cordifolia as an effective herbal ingredient in antimicrobial gel formulations.

Advantages

1. Exhibits broad-spectrum antimicrobial activity against bacteria and fungi.
2. Rich source of bioactive phytochemicals such as alkaloids, phenolics, and terpenoids.
3. Herbal, non-toxic, and skin-friendly for topical application.
4. Shows good compatibility with Carbopol and other gel bases.
5. Possesses additional antioxidant, anti-inflammatory, and wound-healing benefits.
6. Reduces the risk of antimicrobial resistance due to multi-targeted action.

Limitations

1. Majority of studies are limited to in-vitro investigations.
2. Lack of clinical trials confirming efficacy in humans.
3. Variability in extract composition due to differences in plant source, solvent, and extraction method.
4. Limited long-term stability data for Guduchi-based gel formulations.
5. Conventional gel systems may provide only moderate skin penetration.

How To Overcome

1. Use of advanced extraction techniques such as ultrasound-assisted or microwave-assisted extraction to improve consistency.
2. Standardization of extracts using marker compounds like berberine or palmatine.
3. Development of advanced formulations such as transethosomal gels, nano-gels, or phytosomal systems to enhance skin permeation.

4. Incorporation of stabilizers and antioxidants to improve formulation stability and shelf-life.
5. Conducting in-vivo studies and clinical trials to establish safety and therapeutic efficacy.

9. Methodology

A systematic literature review was conducted using scientific databases such as Google Scholar, PubMed, and ResearchGate. Research articles related to Tinospora cordifolia, its phytochemical composition, pharmacological activities, antimicrobial potential, and topical gel formulations were collected using keywords including “Guduchi,” “Tinospora cordifolia,” “herbal antimicrobial gel,” “Carbopol gel,” and “wound healing.”

Only peer-reviewed articles published in English were considered for this review. Information regarding extraction methods, bioactive constituents, antimicrobial studies, formulation approaches, and evaluation parameters was carefully analyzed and organized. The collected data were critically reviewed and compiled to present a comprehensive overview supporting the development of an herbal antimicrobial gel using Tinospora cordifolia.

10. Conclusion

Tinospora cordifolia (Guduchi) is a valuable medicinal plant with well-documented antimicrobial, antioxidant, and anti-inflammatory properties. Its diverse phytochemical composition enables effective action against a wide range of bacterial and fungal pathogens commonly involved in skin and wound infections. Studies consistently demonstrate that Guduchi extracts and Carbopol-based gel formulations exhibit satisfactory physicochemical characteristics along with enhanced antimicrobial performance.

Advanced formulation strategies further improve skin penetration and sustained release of active constituents, highlighting the potential of Guduchi-based gels as effective topical therapeutic systems. However, further research focusing on extract standardization, formulation optimization, and clinical validation is necessary. Overall, Tinospora cordifolia represents a promising natural alternative for the development of safe and effective herbal antimicrobial gel formulations.

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