Anisomeles Indica Loaded Hydrogel for Topical Management of Fungal Infections: A Comprehensive Review

Ankita dagadu Kshirsagar
Ratndeep College of Pharmacy Ratnapur

***Abstract*—Fungal infections are among the most common infectious diseases affecting humans worldwide and continue to pose a significant public health challenge due to their increasing prevalence, recurrent nature, and emerging antifungal resistance. Conventional antifungal therapies are often associated with limitations such as adverse effects, prolonged treatment duration, poor patient compliance, and reduced effectiveness against resistant fungal strains. Consequently, there is growing interest in the development of alternative therapeutic approaches utilizing medicinal plants and advanced drug delivery systems. Anisomeles indica (L.) Kuntze, a medicinal herb belonging to the family Lamiaceae, has been traditionally used for the treatment of skin disorders, microbial infections, inflammation, and wound healing. Phytochemical investigations have revealed the presence of several bioactive compounds including diterpenoids, flavonoids, phenolic compounds, terpenoids, sterols, and essential oils, which contribute to its diverse pharmacological activities. Scientific studies have demonstrated that A. indica possesses significant antifungal, antibacterial, antioxidant, anti-inflammatory, and wound-healing properties, highlighting its potential as a natural therapeutic agent for fungal skin infections. Hydrogel-based drug delivery systems have gained considerable attention for topical applications due to their biocompatibility, high water content, controlled drug release characteristics, and enhanced patient acceptability. Incorporation of Anisomeles indica extract into hydrogel formulations may improve phytochemical stability, enhance skin penetration, prolong drug retention at the site of infection, and provide sustained antifungal activity.**

This review summarizes the global burden of fungal infections, challenges associated with antifungal resistance, botanical and phytochemical aspects of Anisomeles indica, its pharmacological and antifungal properties, and the potential application of hydrogel-based delivery systems for topical antifungal therapy. The review also highlights recent advances in herbal antifungal formulations and future perspectives for the development of effective plant-based hydrogel systems for the management of fungal skin infections.

***Index Terms*—Anisomeles indica, Fungal Infections, Antifungal Activity, Hydrogel, Herbal Drug Delivery, Phytochemicals, Topical Therapy, Medicinal Plants.**

I. INTRODUCTION

Fungal infections are among the most prevalent infectious diseases worldwide and continue to represent a major public health concern. These infections affect millions of individuals annually and range from superficial infections involving the skin, hair, nails, and mucous membranes to severe invasive diseases affecting internal organs [1,2]. The incidence of fungal infections has increased considerably over the past few decades due to factors such as urbanization, increased prevalence of diabetes mellitus, prolonged use of broad-spectrum antibiotics, organ transplantation, cancer chemotherapy, and the growing population of immunocompromised patients [2,3].

Superficial fungal infections are particularly common in tropical and subtropical countries where high temperature and humidity favor fungal growth and transmission. Dermatophytosis, candidiasis, tinea infections, and onychomycosis are among the most frequently encountered fungal diseases and are often associated with itching, inflammation, discomfort, and recurrent episodes that negatively affect patient quality of life [4,5]. Despite being rarely life-threatening, these infections contribute significantly to healthcare costs and social burden worldwide.

The treatment of fungal infections primarily relies on synthetic antifungal agents such as azoles, polyenes, allylamines, and echinocandins. Although these drugs

have demonstrated substantial therapeutic efficacy, their use is frequently associated with several limitations including toxicity, drug interactions, prolonged treatment duration, recurrence of infection, and increasing antifungal resistance [5,6]. The emergence of resistant fungal strains has become a serious challenge in clinical practice and has reduced the effectiveness of many conventional antifungal therapies [6]. Therefore, there is an urgent need to identify safer and more effective alternatives for the management of fungal infections.

Medicinal plants have served as valuable sources of therapeutic agents for centuries and continue to play a crucial role in modern drug discovery. Plant-derived bioactive compounds possess diverse pharmacological activities and often exhibit antimicrobial effects through multiple mechanisms of action, thereby reducing the likelihood of resistance development [7,8]. Numerous medicinal plants have demonstrated promising antifungal, antibacterial, antioxidant, and anti-inflammatory properties, making them attractive candidates for the development of novel antifungal therapies.

Among these medicinal plants, Anisomeles indica (L.) Kuntze has gained considerable scientific attention because of its rich phytochemical composition and broad spectrum of biological activities. The plant belongs to the family Lamiaceae and is widely distributed throughout tropical and subtropical regions of Asia, including India, China, Sri Lanka, and Malaysia [9–11]. Traditionally, A. indica has been used for the treatment of fever, inflammation, skin disorders, microbial infections, and wound healing [10,11]. Phytochemical studies have identified the presence of diterpenoids, flavonoids, phenolic compounds, terpenoids, sterols, and essential oils, which contribute significantly to its therapeutic potential [12–15].

Several investigations have reported the antimicrobial and antifungal activities of Anisomeles indica against a variety of pathogenic microorganisms. In addition to its antifungal properties, the plant exhibits antioxidant, anti-inflammatory, antibacterial, and wound-healing activities that may enhance its therapeutic effectiveness in the management of fungal skin infections [16–20]. These pharmacological properties support the traditional use of the plant and justify its further exploration as a natural antifungal agent.

Recent advances in pharmaceutical technology have emphasized the importance of novel drug delivery systems for improving the therapeutic performance of plant-derived bioactive compounds. Among these systems, hydrogels have emerged as highly promising carriers for topical drug delivery because of their excellent biocompatibility, high water content, controlled drug release characteristics, and patient-friendly nature [21–25]. Hydrogel formulations can improve the stability of phytochemicals, enhance skin penetration, prolong retention at the site of application, and provide sustained therapeutic activity.

The incorporation of Anisomeles indica extract into hydrogel systems represents a novel approach for the development of effective topical antifungal formulations. Such systems may combine the pharmacological advantages of the plant with the pharmaceutical benefits of hydrogel technology, resulting in improved therapeutic outcomes and enhanced patient compliance. Therefore, the present review aims to comprehensively discuss the global burden of fungal infections, antifungal resistance, botanical and phytochemical characteristics of Anisomeles indica, its pharmacological activities, and the potential application of hydrogel-based delivery systems for the management of fungal skin infections.

II. GLOBAL BURDEN OF FUNGAL INFECTIONS

Fungal infections constitute a major global healthcare concern and affect millions of individuals annually. These infections range from superficial diseases of the skin, hair, nails, and mucosal surfaces to severe invasive infections involving internal organs [1,2]. Although fungal diseases are often considered less significant than bacterial and viral infections, their prevalence has increased substantially over the past few decades due to changing environmental conditions, expanding immunocompromised populations, and the emergence of antifungal-resistant pathogens [2,3].

It is estimated that more than one billion people worldwide suffer from fungal infections each year, making them among the most common infectious diseases globally [1]. Superficial fungal infections account for the majority of cases and are particularly prevalent in tropical and subtropical regions where high temperature and humidity promote fungal growth and transmission [4]. Common fungal infections

include dermatophytosis, candidiasis, tinea infections, and onychomycosis, all of which contribute significantly to patient discomfort and healthcare expenditure [4,5]. Several factors have contributed to the increasing incidence of fungal infections. The growing prevalence of diabetes mellitus, HIV/AIDS, cancer, organ transplantation, and long-term immunosuppressive therapy has increased susceptibility to opportunistic fungal pathogens [2,3]. In addition, prolonged use of broad-spectrum antibiotics disrupts normal microbial flora and facilitates fungal colonization and infection [3].

Among pathogenic fungi, dermatophytes are responsible for the majority of superficial fungal infections. Species belonging to the genera Trichophyton, Microsporum, and Epidermophyton commonly infect keratinized tissues such as skin, hair, and nails [4]. Opportunistic fungi including Candida albicans and Aspergillus fumigatus are also major causes of both superficial and systemic infections, particularly in immunocompromised individuals [3,6]. The socioeconomic burden associated with fungal infections is substantial. Chronic and recurrent infections frequently result in itching, inflammation, discomfort, cosmetic disfigurement, social stigma, and reduced quality of life [5]. Furthermore, invasive fungal infections are associated with prolonged hospitalization, increased healthcare costs, and elevated mortality rates among vulnerable patient populations [3].

In recent years, the emergence of antifungal-resistant fungal strains has further complicated disease management and increased concerns regarding treatment effectiveness [6]. Consequently, there is growing interest in the exploration of alternative therapeutic agents, particularly medicinal plants and plant-derived bioactive compounds, which may offer safer and more effective approaches for fungal infection management [7,8].

Table 1. Common Fungal Pathogens and Associated Diseases

Fungal Pathogen	Associated Disease
Trichophyton rubrum	Dermatophytosis
Microsporum canis	Tinea capitis
Candida albicans	Candidiasis
Candida auris	Drug-resistant candidiasis
Aspergillus fumigatus	Aspergillosis
Cryptococcus neoformans	Cryptococcosis

III. ANTIFUNGAL RESISTANCE: CURRENT CHALLENGES

Antifungal resistance has emerged as a serious global healthcare challenge and is increasingly recognized as a major obstacle in the effective management of fungal infections [6]. The extensive use of antifungal drugs in clinical practice, agriculture, and veterinary medicine has contributed to the development of resistant fungal strains, resulting in reduced therapeutic efficacy and increased treatment failures [2,6].

Currently, the treatment of fungal infections primarily relies on four major classes of antifungal agents: polyenes, azoles, allylamines, and echinocandins [5]. Although these drugs have significantly improved patient outcomes, prolonged and inappropriate use has accelerated the emergence of resistant fungal pathogens [6]. Resistance mechanisms include genetic mutations, overexpression of drug efflux pumps, biofilm formation, and alterations in drug target sites, enabling fungal cells to survive despite antifungal therapy [6].

Among fungal pathogens, Candida species have shown alarming levels of antifungal resistance. The emergence of multidrug-resistant Candida auris has become a major public health concern because of its ability to survive in healthcare environments and resist multiple antifungal agents [2]. Similarly, resistant strains of Candida albicans and Aspergillus species have been increasingly reported worldwide, limiting available treatment options [6].

Dermatophytes responsible for superficial fungal infections have also developed resistance to commonly prescribed antifungal drugs. Terbinafine-resistant Trichophyton species have been reported in several countries, leading to recurrent and difficult-to-treat dermatophytic infections [4,6]. Such resistance often necessitates prolonged treatment and increases healthcare costs.

Another important factor contributing to antifungal resistance is fungal biofilm formation. Biofilms are structured microbial communities surrounded by an extracellular matrix that protects fungal cells from antifungal agents and host immune responses [6]. Fungal cells within biofilms exhibit significantly higher resistance compared to free-living cells, making infections persistent and difficult to eradicate.

The growing problem of antifungal resistance highlights the urgent need for alternative therapeutic

approaches. Medicinal plants have gained considerable attention because they contain multiple bioactive compounds capable of targeting fungal pathogens through diverse mechanisms [7,8]. Plant-derived phytochemicals may disrupt fungal membranes, inhibit biofilm formation, interfere with enzyme systems, and suppress fungal virulence factors, thereby reducing the likelihood of resistance development [19–23].

Consequently, medicinal plants such as Anisomeles indica have emerged as promising candidates for the development of novel antifungal therapies. Their rich phytochemical composition and multi-target mechanisms of action may provide effective alternatives to conventional antifungal drugs and help address the growing challenge of antifungal resistance [19–23].

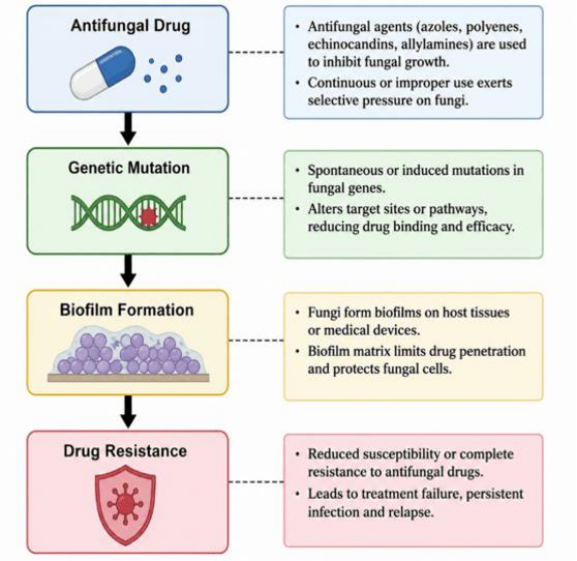

Figure 1. Major Mechanisms of Antifungal Resistance

Table 2. Factors Contributing to Antifungal Resistance

Factor	Consequence
Prolonged Antifungal Use	Selection of resistant strains
Genetic Mutations	Reduced drug sensitivity
Biofilm Formation	Protection from antifungal agents
Efflux Pumps	Decreased intracellular drug levels
Incomplete Treatment	Recurrence of infection
Agricultural Fungicide Use	Cross-resistance development

IV. BOTANICAL PROFILE OF ANISOMELES INDICA

Anisomeles indica (L.) Kuntze is an aromatic medicinal herb belonging to the family Lamiaceae. The plant is widely distributed throughout tropical and subtropical regions of Asia and has been extensively used in traditional systems of medicine for the treatment of fever, inflammation, skin disorders, microbial infections, and wound healing [9–12]. Owing to its rich phytochemical composition and diverse pharmacological activities, A. indica has attracted considerable scientific attention in recent years.

4.1 Taxonomical Classification

The taxonomical classification of Anisomeles indica is presented in Table 3.

Table 3. Taxonomical Classification of Anisomeles indica

Taxonomic Rank	Classification
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Lamiales
Family	Lamiaceae
Genus	Anisomeles
Species	Anisomeles indica (L.) Kuntze

4.2 Geographical Distribution

Anisomeles indica is commonly found in India, China, Sri Lanka, Thailand, Malaysia, and other Southeast Asian countries [10,11]. The plant grows abundantly in grasslands, roadsides, wastelands, forest margins, and cultivated fields. It thrives under warm climatic conditions and adapts well to different soil types.

4.3 Morphological Characteristics

Anisomeles indica is an erect aromatic herb that generally reaches a height of 1–2 m. The stem is quadrangular, branched, and slightly pubescent. Leaves are arranged oppositely, ovate-lanceolate in shape, and possess serrated margins. The plant produces characteristic purple to lavender-colored bilabiate flowers arranged in terminal spikes [10–12].

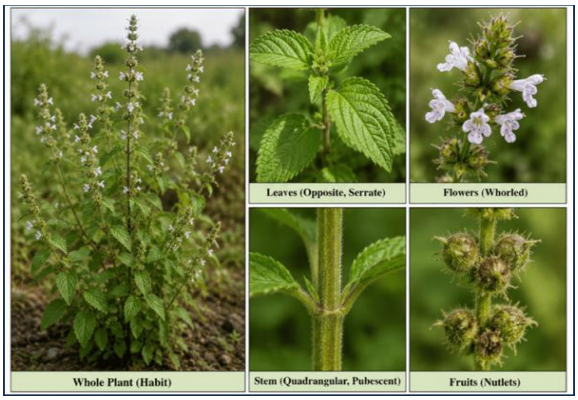

Figure 2. Habit and Morphological Features of Anisomeles indica

4.4 Traditional Uses

The plant has been traditionally employed in Ayurveda, Siddha, and folk medicine for the treatment of various ailments [9,10]. Different parts of the plant, particularly the leaves and aerial portions, are used for medicinal purposes.

Traditional applications include:

- Fungal infections
- Skin diseases
- Fever
- Inflammation
- Rheumatism
- Respiratory disorders
- Wound healing

4.5 Medicinal Importance

The medicinal significance of Anisomeles indica is mainly attributed to the presence of bioactive phytochemicals such as diterpenoids, flavonoids, phenolic compounds, terpenoids, sterols, and essential oils [13–15]. These constituents are responsible for its antifungal, antibacterial, antioxidant, anti-inflammatory, and wound-healing activities, making the plant a promising candidate for the development of herbal antifungal formulations.

The rich ethnomedicinal history and scientifically validated pharmacological properties of Anisomeles indica provide a strong foundation for its application in modern pharmaceutical research, particularly in hydrogel-based topical drug delivery systems for fungal skin infections.

V. PHYTOCHEMICAL CONSTITUENTS OF ANISOMELES INDICA

The therapeutic potential of Anisomeles indica is primarily attributed to its rich phytochemical composition. Phytochemical investigations have revealed the presence of several biologically active secondary metabolites including diterpenoids, flavonoids, phenolic compounds, terpenoids, sterols, and essential oils [13–18]. These compounds contribute significantly to the antimicrobial, antifungal, antioxidant, anti-inflammatory, and wound-healing properties of the plant.

Among the reported phytochemicals, diterpenoids are considered the major bioactive constituents of A. indica. Ovatodiolide and anisomelic acid are the most extensively studied compounds and have demonstrated significant antimicrobial and anti-inflammatory activities [13,14]. Flavonoids such as apigenin and luteolin possess potent antioxidant properties and may contribute to the antifungal activity of the plant by interfering with fungal cell functions [15,18]. Phenolic compounds including acteoside and isoacteoside have also been identified in Anisomeles indica. These compounds exhibit strong free radical scavenging activity and help protect biological tissues against oxidative damage [16]. In addition, plant sterols such as β-sitosterol and stigmasterol contribute to anti-inflammatory and wound-healing effects [14].

Essential oils present in the aerial parts of the plant contain volatile constituents with reported antimicrobial activity. These compounds may enhance the overall therapeutic efficacy of Anisomeles indica through synergistic interactions with other phytochemicals [21,22]. The presence of multiple bioactive constituents allows Anisomeles indica to exert diverse pharmacological effects through different mechanisms of action. This phytochemical diversity is particularly important in antifungal therapy, as it may reduce the likelihood of resistance development and improve treatment outcomes [19–23].

Table 4. Major Phytochemical Constituents of Anisomeles indica

Phytochemical	Chemical Class	Reported Activity
Ovatodiolide	Diterpenoid	Antifungal, Anti-inflammatory

Anisomelic Acid	Diterpenoid	Antimicrobial
Apigenin	Flavonoid	Antioxidant
Luteolin	Flavonoid	Anti-inflammatory
Acteoside	Phenolic Compound	Antioxidant
Isoacteoside	Phenolic Compound	Antimicrobial
β-Sitosterol	Sterol	Wound Healing
Stigmasterol	Sterol	Anti-inflammatory

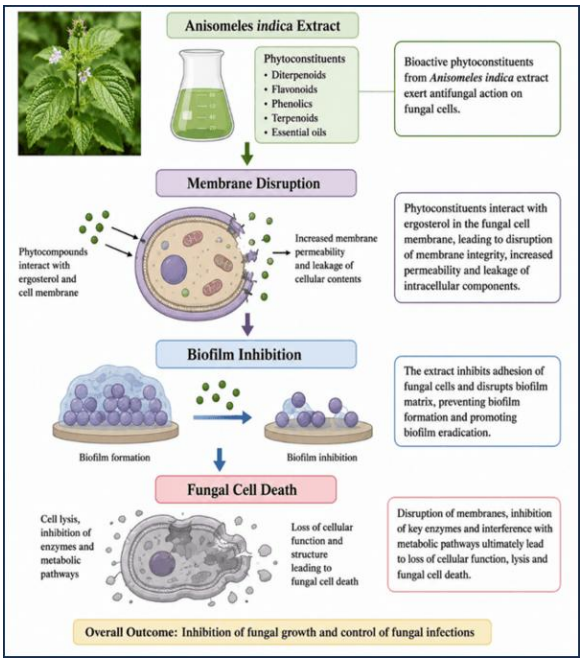

Figure 3. Major Phytochemical Classes Present in Anisomeles indica

The diverse phytochemical profile of Anisomeles indica provides a scientific basis for its traditional medicinal applications and supports its potential use in the development of hydrogel-based topical antifungal formulations.

VI. PHARMACOLOGICAL ACTIVITIES OF ANISOMELES INDICA

Anisomeles indica possesses a wide range of pharmacological activities that support its traditional medicinal use. Scientific studies have demonstrated that the plant exhibits antifungal, antibacterial, antioxidant, anti-inflammatory, and wound-healing properties, primarily due to the presence of diterpenoids, flavonoids, phenolic compounds, and essential oils [16–23]. These biological activities make A. indica a promising candidate for the development of herbal formulations for the management of fungal skin infections.

6.1 Antifungal Activity

The antifungal activity of Anisomeles indica has attracted considerable attention because of the increasing prevalence of fungal infections and antifungal resistance. Plant extracts and isolated phytochemicals have shown inhibitory effects against several pathogenic fungi, including Candida albicans, Aspergillus species, and dermatophytes [19–23]. The antifungal effect is mainly attributed to disruption of fungal cell membranes, inhibition of fungal growth, and suppression of biofilm formation.

6.2 Antibacterial Activity

Studies have reported significant antibacterial activity of Anisomeles indica against both Gram-positive and Gram-negative bacteria [19,20]. The antimicrobial activity is associated with the presence of flavonoids, terpenoids, and phenolic compounds that interfere with bacterial cell membrane integrity and metabolic processes.

6.3 Anti-inflammatory Activity

Inflammation is commonly associated with microbial infections and tissue damage. Several phytochemicals present in Anisomeles indica, particularly diterpenoids and flavonoids, exhibit anti-inflammatory properties by reducing inflammatory mediator production and suppressing oxidative stress [14,18]. This activity may help reduce irritation, redness, and swelling associated with fungal skin infections.

6.4 Antioxidant Activity

The plant contains numerous antioxidant compounds capable of scavenging free radicals and protecting cells from oxidative damage [15,16]. Flavonoids and phenolic compounds are primarily responsible for the antioxidant activity of A. indica. These effects may contribute to tissue protection and accelerate the healing process during fungal infection treatment.

6.5 Wound-Healing Activity

Traditional medicinal systems have long used Anisomeles indica for wound management and skin disorders [9,10]. Scientific evidence suggests that the plant promotes tissue regeneration, reduces microbial contamination, and supports wound healing through

its antimicrobial, antioxidant, and anti-inflammatory effects [18].

Table 5. Pharmacological Activities of Anisomeles indica

Activity	Major Constituents	Therapeutic Importance
Antifungal	Ovatodiolide, Flavonoids	Inhibition of fungal growth
Antibacterial	Phenolics, Terpenoids	Control of bacterial infections
Anti-inflammatory	Diterpenoids, Flavonoids	Reduction of inflammation
Antioxidant	Flavonoids, Acteoside	Protection from oxidative stress
Wound Healing	Sterols, Phenolics	Tissue regeneration

The broad spectrum of pharmacological activities exhibited by Anisomeles indica highlights its potential as a valuable medicinal plant for the development of topical antifungal formulations. These properties provide a strong scientific basis for incorporating the plant extract into hydrogel-based drug delivery systems for improved management of fungal skin infections [24–30].

VII. ANTIFUNGAL MECHANISM OF ANISOMELES INDICA

The antifungal activity of Anisomeles indica is attributed to the presence of bioactive phytochemicals such as diterpenoids, flavonoids, phenolic compounds, and essential oils [19–23]. These compounds inhibit fungal growth through multiple mechanisms, including disruption of fungal cell membranes, inhibition of ergosterol biosynthesis, suppression of biofilm formation, and interference with fungal virulence factors.

Unlike conventional antifungal drugs that often target a single pathway, the phytochemicals present in A. indica act on multiple fungal targets simultaneously, thereby reducing the risk of resistance development and improving therapeutic effectiveness [19,23].

The multi-target antifungal action of Anisomeles indica highlights its potential as a natural antifungal agent for topical applications.

VIII. HYDROGEL DRUG DELIVERY SYSTEMS

Hydrogels are three-dimensional polymeric networks capable of retaining large amounts of water while maintaining structural integrity. Due to their biocompatibility, high water content, controlled drug release properties, and patient-friendly nature, hydrogels are widely used for topical drug delivery applications [25–30].

Incorporation of Anisomeles indica extract into hydrogel formulations may improve phytochemical stability, enhance skin penetration, prolong retention at the site of infection, and provide sustained antifungal activity [24–30]. These advantages make hydrogels promising carriers for herbal antifungal formulations.

Table 6. Advantages of Hydrogel-Based Drug Delivery

Property	Benefit
Controlled Release	Sustained action
High Water Content	Cooling effect
Biocompatibility	Reduced irritation
Skin Retention	Improved efficacy

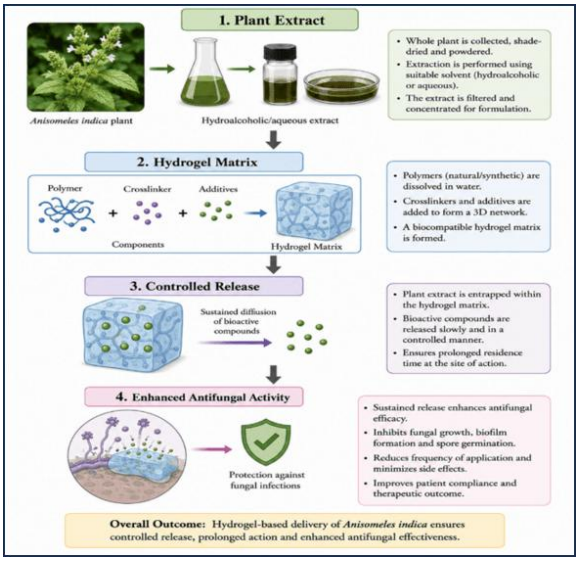

Figure 4. Hydrogel-Based Delivery of Anisomeles indica

IX. RECENT ADVANCES IN HERBAL ANTIFUNGAL HYDROGELS

Recent studies have demonstrated the potential of herbal hydrogels as effective alternatives to conventional topical antifungal formulations [24–30]. Plant-derived extracts incorporated into hydrogel

systems have shown improved skin retention, controlled drug release, enhanced antifungal activity, and better patient compliance.

Hydrogel formulations containing medicinal plant extracts and essential oils have exhibited promising activity against Candida albicans, Aspergillus species, and dermatophytes. These findings suggest that herbal hydrogels may represent a safe and effective strategy for the management of fungal skin infections.

The combination of Anisomeles indica extract with hydrogel technology may further improve therapeutic outcomes by providing sustained delivery of bioactive compounds directly to the site of infection.

X. POTENTIAL OF ANISOMELES INDICA LOADED HYDROGEL

The incorporation of Anisomeles indica extract into hydrogel systems represents a promising strategy for the topical treatment of fungal infections. The plant possesses antifungal, antioxidant, anti-inflammatory, and wound-healing properties, while hydrogels provide controlled drug release, improved skin retention, and enhanced patient compliance [19–30].

An A. indica loaded hydrogel may enhance the stability of phytochemicals, increase local drug concentration at the site of infection, and provide sustained antifungal activity. In addition, the hydrogel matrix can maintain a moist environment that supports skin repair and improves therapeutic outcomes.

The combined advantages of medicinal plant extracts and hydrogel technology make Anisomeles indica loaded hydrogels a potential alternative to conventional topical antifungal formulations.

XI. FUTURE PERSPECTIVES

Despite the promising pharmacological activities of Anisomeles indica, further research is required to establish its clinical usefulness in antifungal therapy. Future studies should focus on detailed phytochemical characterization, standardization of plant extracts, formulation optimization, and stability evaluation [13–18].

Advanced hydrogel technologies such as nano-hydrogels, bioadhesive hydrogels, and stimuli-responsive hydrogels may further improve drug delivery efficiency and therapeutic effectiveness. Additionally, in-vivo studies and clinical trials are necessary to confirm the safety, efficacy, and long-term benefits of Anisomeles indica loaded hydrogel formulations.

Continued research in this area may contribute to the development of effective, safe, and affordable herbal antifungal therapies.

XII. CONCLUSION

Fungal infections remain a major global health concern due to their increasing prevalence and growing antifungal resistance. Medicinal plants have emerged as valuable sources of bioactive compounds with potential applications in antifungal therapy. Anisomeles indica is a promising medicinal herb rich in diterpenoids, flavonoids, phenolic compounds, and other phytochemicals that contribute to its antifungal, antioxidant, anti-inflammatory, and wound-healing activities [13–23].

Hydrogel-based drug delivery systems offer several advantages for topical administration, including controlled drug release, enhanced skin retention, improved patient compliance, and better therapeutic efficacy [25–30]. The incorporation of Anisomeles indica extract into hydrogel formulations may provide an effective approach for the management of fungal skin infections.

Overall, Anisomeles indica loaded hydrogel represents a promising herbal formulation with significant potential for future pharmaceutical development and topical antifungal therapy.

REFERENCES

[1] World Health Organization, Fungal Diseases and Public Health Importance. Geneva, Switzerland: WHO, 2024.

[2] M. C. Fisher, A. Alastruey-Izquierdo, J. Berman, T. Bicanic, E. M. Bignell, P. Bowyer, et al., “Tackling the emerging threat of antifungal resistance,” Nature Microbiology, vol. 7, no. 1, pp. 13–24, 2022.

[3] J. R. Perfect, “The impact of fungal infections on global health,” Clinical Infectious Diseases, vol. 65, Suppl. 2, pp. S385–S390, 2017.

[4] B. Havlickova, V. A. Czaika, and M. Friedrich, “Epidemiological trends in skin mycoses worldwide,” Mycoses, vol. 51, Suppl. 4, pp. 2–15, 2008.

[5] A. K. Gupta and S. G. Versteeg, "Topical treatment of fungal infections," Drugs, vol. 77, no. 8, pp. 851–867, 2017.
[6] D. Sanglard, "Emerging threats in antifungal-resistant fungal pathogens," Frontiers in Medicine, vol. 9, Art. no. 857462, 2022.
[7] M. M. Cowan, "Plant products as antimicrobial agents," Clinical Microbiology Reviews, vol. 12, no. 4, pp. 564–582, 1999.
[8] D. J. Newman and G. M. Cragg, "Natural products as sources of new drugs," Journal of Natural Products, vol. 83, no. 3, pp. 770–803, 2020.
[9] K. R. Kirtikar and B. D. Basu, Indian Medicinal Plants, vol. 3. Dehradun, India: International Book Distributors, 2019.
[10] R. N. Chopra, S. L. Nayar, and I. C. Chopra, Glossary of Indian Medicinal Plants. New Delhi, India: CSIR, 2019.
[11] D. J. Mabberley, Mabberley's Plant-Book, 4th ed. Cambridge, U.K.: Cambridge University Press, 2018.
[12] M. Heinrich, J. Barnes, S. Gibbons, and E. M. Williamson, Fundamentals of Pharmacognosy and Phytotherapy, 3rd ed. Amsterdam, The Netherlands: Elsevier, 2018.
[13] J. B. Harborne, Phytochemical Methods, 3rd ed. London, U.K.: Chapman and Hall, 2018.
[14] W. C. Evans, Trease and Evans Pharmacognosy, 17th ed. Amsterdam, The Netherlands: Elsevier, 2021.
[15] A. N. Panche, A. D. Diwan, and S. R. Chandra, "Flavonoids: An overview," Journal of Nutritional Science, vol. 5, Art. no. e47, 2016.
[16] J. Dai and R. J. Mumper, "Plant phenolics: Extraction, analysis and biological properties," Molecules, vol. 15, no. 10, pp. 7313–7352, 2010.
[17] M. Wink, Functions and Biotechnology of Plant Secondary Metabolites. Hoboken, NJ, USA: Wiley-Blackwell, 2019.
[18] B. Salehi, J. Sharifi-Rad, E. Capanoglu, et al., "Beneficial effects of plant flavonoids," Biomolecules, vol. 10, no. 7, Art. no. 1074, 2020.
[19] T. P. T. Cushnie and A. J. Lamb, "Antimicrobial activity of flavonoids," International Journal of Antimicrobial Agents, vol. 38, no. 2, pp. 99–107, 2011.
[20] V. K. Gupta, A. Fatima, U. Faridi, et al., "Antimicrobial potential of medicinal plants," Journal of Ethnopharmacology, vol. 114, no. 2, pp. 114–120, 2008.
[21] F. Nazzaro, F. Fratianni, L. De Martino, et al., "Effect of essential oils on pathogenic microorganisms," Pharmaceuticals, vol. 6, no. 12, pp. 1451–1474, 2013.
[22] I. H. N. Bassolé and H. R. Juliani, "Essential oils in combination and antimicrobial therapy," Molecules, vol. 17, no. 4, pp. 3989–4006, 2012.
[23] A. Sharma, R. D. C. Flores-Vallejo, A. Cardoso-Taketa, and M. L. Villarreal, "Antifungal activity of medicinal plants," Journal of Fungi, vol. 7, no. 5, Art. no. 364, 2021.
[24] S. A. Tamboli, A. V. Bhalerao, and P. R. Patil, "Herbal antifungal nanoemulgel formulation and evaluation," International Journal of Pharmaceutical Sciences and Research, vol. 12, no. 7, pp. 3765–3775, 2021.
[25] R. C. Rowe, P. J. Sheskey, and M. E. Quinn, Handbook of Pharmaceutical Excipients, 8th ed. London, U.K.: Pharmaceutical Press, 2017.
[26] M. E. Aulton and K. M. G. Taylor, Aulton's Pharmaceutics: The Design and Manufacture of Medicines, 6th ed. Amsterdam, The Netherlands: Elsevier, 2022.
[27] P. J. Sinko, Martin's Physical Pharmacy and Pharmaceutical Sciences, 7th ed. Philadelphia, PA, USA: Lippincott Williams & Wilkins, 2017.
[28] N. A. Peppas, P. Bures, W. Leobandung, and H. Ichikawa, "Hydrogels in pharmaceutical formulations," European Journal of Pharmaceutics and Biopharmaceutics, vol. 50, no. 1, pp. 27–46, 2000.
[29] E. M. Ahmed, "Hydrogel: Preparation, characterization and applications," Journal of Advanced Research, vol. 6, no. 2, pp. 105–121, 2015.
[30] E. Caló and V. V. Khutoryanskiy, "Biomedical applications of hydrogels," European Polymer Journal, vol. 65, pp. 252–267, 2015.
[31] J. S. Boateng, K. H. Matthews, H. N. E. Stevens, and G. M. Eccleston, "Wound healing dressings and drug delivery systems," Journal of Pharmaceutical Sciences, vol. 97, no. 8, pp. 2892–2923, 2008.
[32] P. Kaur, P. Sharma, and S. Arora, "Antifungal efficiency of plant extract-loaded hydrogels," International Journal of Biological Macromolecules, vol. 183, pp. 1702–1716, 2021.

[33] M. M. Elgohary, R. M. Hassan, and M. El-Sayed, “Development and evaluation of herbal hydrogel formulations,” Pharmaceutical Development and Technology, vol. 27, no. 8, pp. 915–926, 2022.
[34] A. M. Ghonim, M. M. Ibrahim, and A. A. Abdelrahman, “Synergistic antifungal hydrogel systems for topical delivery,” AAPS PharmSciTech, vol. 25, no. 3, Art. no. 96, 2024.
[35] P. Upadhyay, N. Sharma, and A. Singh, “Herbal gels synthesized from medicinal plants as antimicrobial agents,” Journal of Applied Pharmaceutical Science, vol. 13, no. 4, pp. 120–128, 2023.