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Review Article

Phytochemical Profile and Pharmacological Insights of *Anisomeles malabarica* Leaf Extracts: A Comprehensive Review

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ABSTRACT

Anisomeles malabarica, a medicinal plant native to India and Southeast Asia, has been traditionally used to treat various health issues, including fever, wounds, respiratory, and digestive disorders. This review provides an overview of the bioactive compounds found in the leaves of *Anisomeles malabarica* and their therapeutic applications. Leaves are rich in diverse classes of phytochemicals, including flavonoids, phenolic acids, terpenoids, sterols, and essential oils. The extraction methods used in the study include maceration and Soxhlet extraction, and their chemical compositions form the basis of their pharmacological activities. It shows excellent antimicrobial activity against many fungi and bacteria. These anti-inflammatory effects may explain the observed antiepileptic effects. The strong antioxidant properties of *A. malabarica* stemming from its flavonoids and phenolic compounds allows for the possibility of treating diseases concerning oxidative stress. Traditionally, *Anisomeles malabarica* has shown promise in the management of diabetes and malaria. Certainly, in view of its therapeutic value, the operational challenges in this study include variations in bioactive compound quantities, the absence of standardized extraction methods, and clinical inadequacy. Future recommendations should include extensive metabolomic studies, standardization of extraction and purification methods, clinical trials, and assessment of mechanisms related to behavioral effects to substantiate its health claims in modern science for safety and efficacy for human consumption.

Keywords: *Anisomeles malabarica*, Antimicrobial, Anticancer, Bioactive compounds, Therapeutic applications.

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INTRODUCTION

Anisomeles malabarica, commonly known as Malabar catmint, is a perennial herb in the Lamiaceae family, noted for its distinct aroma and medicinal properties.[1] It is widely distributed in tropical and subtropical regions of Asia, especially throughout India and Southeast Asia, growing in a variety of habitats such as grasslands, roadside areas, and hilly terrains.[2] Traditionally, this plant has been extensively used in the treatment of various ailments, including inflammatory states, fever, respiratory ailments, digestive problems, wounds.[3] Its leaves are used in decoctions, poultices, and herbal preparations, symbolizing its long-standing relevance in Ayurvedic, Siddha, and traditional Chinese medicine.[4] The ethnomedicinal history of *Anisomeles malabarica* represents a scientific interest, prompting in-depth reports on its phytochemistry and biological activities that validate the traditional uses and pave the way for modern applications.[5] The leaves of *Anisomeles malabarica* are a reservoir of diverse bioactive compounds such as essential oils, flavonoids, terpenoids, phenolic acids, alkaloids, saponins, and tannins.[6] A variety of phytochemicals are responsible for the various pharmacological properties of this plant, including antioxidant, antimicrobial, anti-inflammatory, antipyretic, analgesic, and anticancer effects.[7] The oils extracted from its leaves contain high levels of monoterpenes and sesquiterpenes, which display important antioxidant and antimicrobial activities against several pathogenic bacteria and fungi.[8] Flavonoids and phenolic acids in the leaves have potent antioxidant properties that contribute to protecting cells from oxidative damage and hence the risk of chronic diseases such as cancer and cardiovascular system diseases.[9] Terpenoids and alkaloids showed remarkable anti-inflammatory and anticancer activities through modulation of inflammatory pathways with induction of apoptosis in cancer cells.[10] A careful study of these phytochemicals assures an impetus for investigating their chemical composition, mechanisms of action, and effects on biological systems. Recent advancements in analytical techniques, such as gas

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chromatography-mass spectrometry and high-performance liquid chromatography, have facilitated the identification and quantification of these bioactive constituents.[1] Comprehensive studies focusing on the phytochemistry of *Anisomeles malabarica* leaves not only enhance our understanding of its medicinal value but also contribute to the development of novel pharmaceutical and nutraceutical products.[2] The aim of this review is to provide insights into the bioactive compounds, chemical profiles, biological activities, pharmacological mechanisms, and potential therapeutic applications of *Anisomeles malabarica* leaves. This review attempts to encompass their traditional use and present scientific investigation, thereby establishing a bridge between ethnomedicine and evidence-based research.[3] The review will also emphasize the potential of these compounds in the pharmaceutical, nutraceutical, and cosmeceutical industries in developing natural therapeutics and health-promoting products.[5] This study synthesizes the present research as an inspiration for further investigation/deliberation for future studies on medicinally important plants. Additionally, this review studies ethnobotany, phytochemistry, pharmacology, and biotechnology for further natural product research and phytopharmacology, which will arouse great appeal as a remedy for *Anisomeles malabarica* for potent therapeutics.

METHODOLOGY

To acquire comprehensive information, Literature searches were conducted using scientific search engines and databases such as Google Scholar, PubMed, Scopus, Web of Science, Science Direct, and Wiley Online Library. A comprehensive investigation was conducted by examining various publications, theses, dissertations, and published floras.

BOTANICAL DESCRIPTION AND DISTRIBUTION

Taxonomic hierarchy

- Phylum-Tracheophyta,
- Kingdom-Plantae,
- Species-*Anisomeles malabarica*,
- Genus-Anisomeles,
- Phylum-Magnoliophyta,
- Family-Lamiaceae,
- Class-Magnoliopsida,
- Class-Magnoliatae,
- Order-Lamiales,
- Synonyms-*Ajuga fruticosa* Roxb. nom. superfl., Anisomeles cuneata J. Jacq,
- Anisomeles intermedia Wight ex Benth.[4]

Vernacular names

- Hindi: Gopoli, Codhara,
- Tamil: Peimirara, Allatu perumthumbai, Peyimarutti,
- Marathi: Gojibha,
- Malayalam: Perumtumpa, Karintumpa,
- Telugu: Moga-biran, Mogabheri,
- Kannada: Gandu kari tumbe Gandubirana gida, Mogav eerachettu,Mogabeerachettu,
- Oriya: Vaikuntha,
- Konkani: Kaktumbo,
- Sanskrit: Mahadronah, Vaikunthah.

Morphological characteristics of plant

Anisomeles malabarica, (Figure 1) an herbaceous perennial belonging to the family Lamiaceae, has its own unique morphology, from the densely pubescent leaves to the height of 1.2-2.0 m. The anatomical characteristics, which are very distinctive, include unicellular trichomes, collenchymatous and parenchymatous ground tissues, and concentrically arranged vascular bundles.[11,12] Among the considerable nutraceutical compounds present in the leaves are citral, β-sitosterol, and anisomelic acid, which contribute to the therapeutic uses of the present species.[13,14] Ethnobotanically, leaves possess several medicinal uses against different diseases in traditional medicine.[15] In summary, the morphological and anatomical characteristics of *A. malabarica* offer a good potential for therapeutic and pharmaceutical applications.[11,14]

Geographical distribution and habitat

Anisomeles malabarica, a perennial herb of the family Lamiaceae, occurs generally in the Western Ghats of India, spread from Maharashtra to Tamil Nadu with Andhra Pradesh and Kerala in between.[15] The species is distributed across different habitats, mainly in the Deccan Plateau and northeastern parts of India.[16] It usually grows in moist, well-drained soils, and is often associated with monsoonal climates that determine endophytic fungal diversity.[17] Large seasonal variability has been observed in the colonization of the endophytes on this plant with conspicuous predominance during winter.[17] *Anisomeles malabarica* has also been reported to be of medicinal value for the treatment of many ailments and is therefore used in ethno-medicine.[15] Its distribution and association indicate its versatility and relevance to local biodiversity.[18] The major threat to all species, such as industry, urbanization, and agricultural lands, is the upsurge in the need for land (Figure 2).[19]

PHYTOCHEMICAL COMPOSITION

Anisomeles malabarica has lots of bioactive compound in its leaves, stems, flowers, roots, and essential oils which are responsible for making the plant useful as a medicine. Among flavonoids, such as luteolin, apigenin, and quercetin, phenolic acids like caffeic acid, gallic acid and ferulic acid, sterols such as β-sitosterol, stigmasterol, and lupeol, tannins, and saponins, *A. malabarica* leaves are excellent sources of antioxidant, antimicrobial, and anti-inflammatory compounds.[20] The stems contain essential oils, alkaloids, tannins, and phenolic compounds that are responsible for their antimicrobial and astringent properties. The flowers contain volatile oils, flavonoids, and terpenoids such as monoterpenes (limonene, α-pinene, and β-pinene) and diterpenes (phytol and labdane diterpenes), which support the bronchodilator, antimicrobial, and hepatoprotective activities of this flower. The roots contain alkaloids, phenolic acids, steroids, and triterpenes, which contribute to their anti-inflammatory and neuroprotective effects. The essential oils extracted from the entire plant contain a large amount of monoterpenes, sesquiterpenes, and diterpenes such as β-caryophyllene, α-humulene, germacrene D, limonene, myrcene, phytol, and caryophyllene oxide, which make the plant a rich source of strong aroma as well as an important medicinal value. Each part has distinct phytochemicals that make *A. malabarica* valuable in traditional and modern herbal medicine as an antioxidant, antimicrobial, anti-inflammatory, and hepatoprotective.[21]

EXTRACTION AND ISOLATION TECHNIQUES

Solvent extraction is one of the most used methods for extracting bioactive compounds from *Anisomeles malabarica* because of its efficiency in extracting a wide range of compounds. Two primary techniques were used in this study:

- **Maceration:** This involves soaking plant material (leaves, stems, roots, or flowers) in a solvent (ethanol, methanol, chloroform, acetone, or hexane) at room temperature for an extended period, typically 24-72 hr. The plant material is stirred occasionally, and after the soaking period, the solvent is filtered off to remove the plant material. The solvent is then evaporated, leaving behind a concentrated extract. This method is simple and cost-effective.[15]
- **Soxhlet Extraction:** In this technique, where the plant material is placed in a Soxhlet apparatus. A solvent (e.g., ethanol, hexane, or chloroform) is heated, and its vapor passes through the plant material in a thimble. The solvent dissolves the desired compounds, and the solution condenses back into the collection flask, where the solvent is continuously recycled. This process is repeated until the extraction is complete, leading to a more efficient and thorough extraction compared to maceration. However, Soxhlet extraction requires more time and heat, which can degrade sensitive compounds.[22]

BIOACTIVE COMPOUNDS AND THEIR STRUCTURE

Key bioactive compounds

The leaves of *Anisomeles malabarica* contain a diverse array of bioactive compounds including flavonoids, terpenoids, phenolic acids, sterols, and alkaloids. Some of the major compounds identified were as follow: (Table 1).

- **Flavonoids:** Luteolin, Kaempferol, Quercetin,[23]
- **Phenolic Acids:** Caffeic acid, Chlorogenic acid,
- **Terpenoids:** Anisomelic acid, Betulinic acid, Ovatodiolide,
- **Sterols:** β-Sitosterol, Stigmasterol,
- **Essential Oil Components:** Eugenol, Thymol.

Chemical structures and properties

Each of these bioactive compounds have unique chemical structures that contribute to their specific pharmacological activities in *Anisomeles malabarica* (Table 2).

Biosynthesis pathways

The biosynthesis of these compounds in *Anisomeles malabarica* follows specific metabolic pathways:

- Flavonoids are synthesized via the phenylpropanoid pathway, which involves key enzymes such as chalcone synthase and flavanol synthase.[9]
- Terpenoids are derived from the mevalonate and methylerythritol phosphate pathways and are responsible for the production of diterpenes and monoterpenes.[2]
- Phenolic acids orginates from the shikimate pathway, which is essential for plant secondary metabolism.[5]

BIOLOGICAL ACTIVITIES AND THERAPEUTIC POTENTIAL

Antimicrobial effects

Anisomeles malabarica has shown tremendous antimicrobial properties on a variety of bacteria and fungi where it exhibits potency against Gram-positive and Gram-negative bacteria including Escherichia coli and Staphylococcus aureus at concentrations as low as 50 mg/mL. It also exhibited a good yield of active extracts against the larvae of various parasites and insect vectors.[23,24] The extracts from the plant contain active antiparasitic compounds against the larvae of different parasites and insect vectors, and the most potent among them

is chloroform. This broad-spectrum activity could be attributed to different phytochemicals such as flavonoids and terpenoids which are well studied for the treatment of multidrug-resistant pathogens, a growing public health issue.[24,25] *A. malabarica* could become an alternative in treatment protocols against antibiotic resistance in the increasingly crucial issue of growing antibiotic resistance, as a result of encompassing antimicrobials derived from plants.[26,27]

Anti-inflammatory effects

Anisomeles malabarica belongs to first-class activities, which exhibit potency for its anti-inflammatory and anti-epileptic properties in association. The ethyl acetate extract of the studied *A. malabarica* here showed evidence of experimentally induced seizures using the models of MES and PTZ, thereby ensuring that it does play a role in the anti-epilepsy property of *A. malabarica* thus far.[28] Because inflammation plays an integral role in the pathophysiology of ICS, this process may be linked to antiepileptic activity.[29] The antioxidant free radical scavenging activity of *A. malabarica* further established its anti-inflammatory role, based on DPPH, FRAP, and H2O2 scavenging activities.[30] Chronic low-dose *A. malabarica* treatment affords several anti-epileptic effects through protective activities against slow or constant treatment in a treatment duration-dependent manner.[31] There is sufficient evidence that herbal extracts, particularly *A. malabarica*, exert effects on the GABAergic and glutamatergic systems through multiple mechanisms and show profound anti-inflammatory properties in their management employed for anti-epileptic management.[32] *A. malabarica* is a glimmer of hope as the first option for treating epilepsy when traditional methods are ineffective or insufficient.[32]

Antioxidant activities

Anisomeles malabarica has been identified as a significant antioxidant source, and significant anti-free radical activity against DPPH, FRAP, and H2O2 has been observed, especially at a concentration of 90 mg/mL phytochemical analysis showed varied composition of flavonoids, tannins, terpenoids, and phenols which are very important for its antioxidant activities.[33] *A. malabarica* possessed more potent antioxidant activity and could have potential therapeutic effects against oxidative stress-related disorders. The importance of antioxidants in *A. malabarica* natural deserves mention because they reduce oxidative stress associated with many chronic diseases. [34,35] *Anisomeles malabarica* would lead to the innovation of a method in which it can be used in the preparation of bioactive natural antioxidants as drug candidates.[36]

Anticancer potential of *Anisomeles malabarica*

Anisomeles malabarica shows strong cancer-fighting effects because of various plant chemicals such as anisomelic acid, ovatodiolide, and betulinic acid. Anisomelic acid kills breast and cervical cancer cells by causing cell death through DNA damage and inhibiting the cell cycle.[37] Ovatodiolide, which comes from a related plant, inhibits the growth of pancreatic cancer cells by interfering with cell signaling pathway such as STAT3 and NF-κB.[38] Even extracts from this plant serve to lower inflammation and fight microorganisms, thereby enhancing its utility as for the treatment.[3,13]

Other pharmacological activities

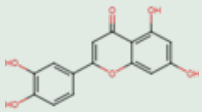
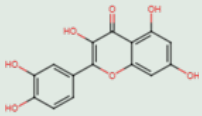
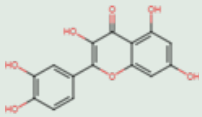
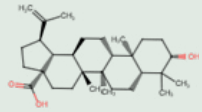
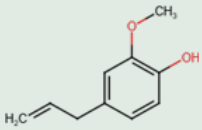
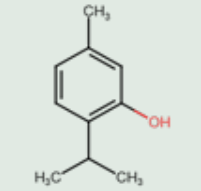
Anisomeles malabarica might work as a treatment for diabetes. Its leaf extract made with ethyl acetate had the best effect on high blood sugar at 66%, beating the other extracts tested. Long-term use of the active ingredient improved insulin sensitivity, plasma insulin, and fasting blood sugar glycosylated hemoglobin levels in diabetic rats. Flavonoids and fatty acids are the main components in the fight against diabetes.[39] Thus the fight against malaria may benefit from the use of *A. malabarica*. The ethyl acetate extract of the leaves showed notable effectiveness against Plasmodium falciparum in laboratory tests (IC_{50}≤20 μg/mL). This extract demonstrated superior efficacy against chloroquine-resistant

Table 1: Preliminary test of *Anisomeles malabarica* in different solvent.

Phytochemical	Water[49]	Methanol[21]	Ethanol[21]	Acetone[21]	Ethyl Acetate[50]	Chloroform[49]
Alkaloids	+	++	++	++	++	++
Flavonoids	++	++	++	++	++	++
Phenols and Tannins	++	++	++	++	++	+
Saponins	++	+	+	±	-	+
Terpenoids	+	++	++	-	++	+
Steroids	+	-	-	-	-	±
Glycosides	-	++	++	++	++	+
Carbohydrates	++	++	++	-	-	-
Proteins and Amino Acids	-	++	-	-	-	-

++=Strong presence; +=Moderate presence; =Absence.

Table 2: Chemical structure and their properties of *Anisomeles malabarica*.

Sl. No.	Chemical name	Structure	Properties	References
1.	Luteolin		Anti-inflammatory, Anti-cancer, and Antioxidant properties.	[51]
2.	Quercetin		Anti-oxidant, Anti-inflammatory.	[20]
3.	Anisomelic acid		Anti-inflammatory and cytotoxic properties.	[14]
4.	Betulinic acid		Anticancer activity.	[39]
5.	Eugenol		Antioxidant, anti-inflammatory, and antimicrobial.	[52]
6.	Thymol		Antiseptic, anti-inflammatory, and antibacterial agent.	[53]

strains and performed well in assays involving human cells.[40] These findings indicate that *A. malabarica* may serve as a potential source of novel treatments for conditions such as epilepsy, diabetes, and malaria, in addition to its established antibacterial and antioxidant properties.[20]

TRADITIONAL AND MODERN MEDICINAL APPLICATIONS

Use in traditional medicine systems

It is used in folk medicine, especially as an antiepileptic.[13] *Anisomeles malabarica* is used in Ayurvedic medicine, where it is employed in the treatment of fever, urinary complaints and other disorders. Its application to urinary problems is in line with Ayurvedic traditions as well as current pharmacological experiments.[41] Although *A. malabarica* is not listed, a similar plant *Anisomeles indica* is used in Taiwanese folk medicine and has been found to be active against Helicobacter pylori.[42] This indicates that plants of *Anisomeles genus* may have the similar therapeutic properties and be used in various traditional systems. *Anisomeles malabarica* has long been used in medicine to treat a variety of ailments, such as rheumatism and fevers. It has been used for mental illnesses such as dementia and to treat swellings. Furthermore, the plant has been used to increase appetite in anorexia. It is also important in traditional medicine owing to its antibacterial activities. *Anisomeles malabarica* (L.) has medicinal potential.[43] *Anisomeles malabarica* is widely used in Ayurveda and folk medicine in India. It is indicated for the treatment of epilepsy, fever, urinary tract complaints. The link between traditional medicine and the pharmacological action of the plant suggests that *Anisomeles malabarica* is potential as a source of new natural drugs.

Current pharmaceutical applications

- **Antidiabetic Activity:** *A. malabarica* may be used to treat diabetes in rat models through blood glucose and insulin sensitivity reduction. The magnitude of ethyl acetate leaf extract had a significant impact on glycemic regulation, offering a different route to the natural diabetic's management.[39]
- **Antioxidant Effects:** The flavonoids, phenolic compounds, and other phytochemical materials found

in the plant have potent anti oxidative properties. Antioxidants help reduce oxidative stress and the corresponding damage by mopping up free radicals.[3]

- **Antibacterial Properties:** This plant possesses a broad spectrum of antibacterial activity against various infections. Crude extracts of *Anisomeles malabarica* have been reported to possess antibacterial and antifungal properties, indicating their potential to promise as an alternative antimicrobial agent.[3]
- **Analgesic and anti-inflammatory properties:** Experimental evidence confirms its effectiveness as an analgesic and anti-inflammatory treatment, which is further supported by traditional applications for these conditions.

Potential for drug development of *Anisomeles malabarica*

The wide range of bioactive substances found in *Anisomeles malabarica* have great potential for drug development; flavonoids, phenols, and terpenoids are among the phytoconstituents linked to the plant's antimicrobial and antioxidant properties.[23,14] The *in vitro* evaluations showed that *A. malabarica* could scavenge free radicals by DPPH and ABTS, and both were shown to effectively inhibit the growth of E. coli and Bacillus subtilis.[44] In addition, the antidiabetic efficacy of *A. malabarica* seems very encouraging, given that it plays some role in glucose homeostasis, which become increasingly important with the rising prevalence of diabetes. In particular, some constituents with well-established medicinal properties are present, making them useful for drug development. The Medicinal utility of *A. malabarica* is vast inside the sign of establishing its scope for Medicinal and pharmaceutical products, and their use would urge further investigation into their potential therapeutic agents.

TOXICOLOGY AND SAFETY CONSIDERATIONS

Known toxicity profiles

The toxicity score of *Anisomeles malabarica* combines its therapeutic potential with its adverse effects. Higher doses (25 and 50 mg/kg) of the ethyl acetate extract demonstrated good coordination in experimental models; however, neurotoxic side effects, including reduced locomotor and motor activity, were significant.[13] The two lowest doses is 6.25 and 12.5 mg/kg were shown free from neurotoxic effects and yet retained apparent anticonvulsant activity, thus pointing to this as a dose-dependent effect. The aqueous extract showed good antioxidant activity, which could suggest some health benefits with no associated toxicity at 90 mg/mL.[2] The extracts have also been reported to show diabetic property while remaining safe.[14] Although *A. malabarica* has promising therapeutic potential, its complete toxicity profile is still poorly understood and requires further research to determine safe dosage ranges for various applications.[45]

Safety studies and evaluations

Anisomeles malabarica's antiepileptic, antidiabetic, antibacterial, and antioxidant properties have attracted much attention from research who found that there is a high degree of therapeutic validity. The ethyl acetate extract of *A. malabarica* leaves was shown to exhibit antiepileptic activity among animals, with high-dose acute treatments (25-50 mg/kg) inducing neurotoxicity while chronic low-dose treatments (6.25-12.5 mg/kg) exerted efficacy without any side effects. In a study of antidiabetics, the extract modified glucose in diabetic rats over 30 consecutive days, thereby suggesting that extract of a good safety profile for long-term use.[46] In addition, aqueous extracts have demonstrated antibacterial and antioxidant properties with no toxicity at concentrations of 50-90 mg/mL.[13] However, comprehensive long-term safety in terms of human applications is desired, as most studies used unclassifiable concentrations for direct human use.[46]

Recommended dosages and precautions of *Anisomeles malabarica*

According to the nature of the extract and its intended use, *A. malabarica* may have pharmacological effects of 100-500 mg/kg at body weight. In rat models, extracts of chloroform and ethyl-acetate have demonstrated significant anticonvulsant effects of approximately 400 mg/kg, while lower doses of 100-200 mg/kg have been found to be effective in treating diabetes and hyperlipidemia in earlier research.[47] Toxicology must be considered before any medical utility; hence, evaluation of acute and subacute toxicity studies must be undertaken prior to any

Figure 1: *Anisomeles Malabarica*.

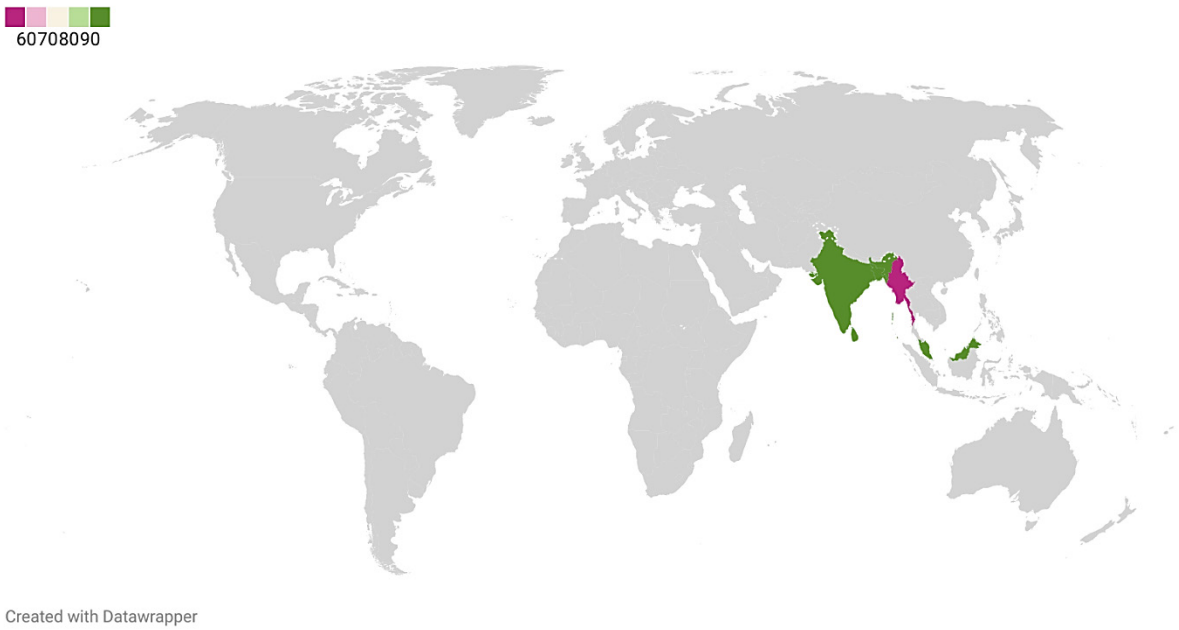


Figure 2: Worldwide and Indian geographical distributions of *A. malabarica*.

clinical application.[47] Plant extract exhibit anti-inflammatory, antimicrobial, and anticancer activities, denoting a wide range of therapeutic prospects but further investigation are needed to isolating the active compounds and clarifying their mechanisms of action.[3]

CHALLENGES AND FUTURE PERSPECTIVES

Limitations in current research

Research on *Anisomeles malabarica* is currently lacking in several areas that would be helpful to understand the range of possible medicinal effects of the species. Although Phytochemicals such as lipoxygenase inhibitors and other antibacterial and antioxidant compounds are known to exist, there is a severe lack of clinical trials to substantiate these claims[48,23] Moreover, the profile of given phytochemicals is not consistent due to differences in methods of extraction and parts used from the plants.[13,14] Furthermore, some studies reporting anatomy or pharmacognosy tend to miss traditional medicinal aspects that need to be studied in conjunction with modern techniques.[11] Finally, the lack of effective protocols to follow for extraction and analysis means that the results are non-replicable, and along with those results are the potential therapeutic uses of *A. malabarica*.[14]

Potential areas for further investigation

Examination of the leaves of *Anisomeles malabarica* could delve deep into some critical domains, especially their pharmacological activities and active biocompounds. The plant possesses some notable antibacterial activity against different pathogens such as Escherichia coli and Staphylococcus aureus, the extracts of which show effective inhibition at specific concentrations.[4,23] Moreover, the antioxidant potential which was shown through some DPPH and ABTS tests, is also *A. malabarica*; therefore it can be used to manage conditions that stem from oxidative stress.[44] The antidiabetic properties shown in animal models need to be supplemented with clinical studies to establish efficacy and safety in humans. In addition, the phytochemical profile shows the presence of flavonoids and terpenoids. There is a gap that must be filled regarding their therapeutic usage and mechanisms of actions.[23,11] *Anisomeles malabarica* which presents a unique opportunity to conduct multifaceted research towards medicinal applications.

Emerging technologies in phytochemical analysis

A new technological approach to the phytochemical investigation of *Anisomeles malabarica* leaves has seen the application of methodologies, such as GC-MS, FTIR, molecular docking, and more. These processes have enabled the determination and characterization of numerous bioactive substances, more so the flavonoids, phenolic compounds, and terpenoids, which have remarkable antioxidant and antimicrobial activities.[14,5,23] The DPPH and ABTS assays were employed in quantifying the antioxidant activity and inhibition percentages at different concentrations gave encouraging results.[5,44] Also, molecular docking studies have revealed the ability of some phytoconstituents like, 2,5-ditert-butylphenol, to act as efficient tyrosinase inhibitors which is beneficial for skin disorders.[44] This combination of new techniques not only improves the comprehension of *A. malabarica*'s phytochemical genetic makeup, but also aids in its pharmacognostic standardization towards its medicinal value.[11,14]

DISCUSSION

Numerous health-promoting bioactive chemicals can be found in the leaves of *Anisomeles malabarica*, a medicinal plant belonging to the Lamiaceae family. These consist of triterpenoids, alkaloids, terpenoids, triterpenoids, flavonoids, phenolic acids, and essential oils. Collectively, they impact hepatoprotective, antidiabetic, neuroprotective, anti-inflammatory, antibacterial, anticancer, and antioxidant properties. Strong antioxidants include phenolic acids like gallic acid and flavonoids like quercetin. They reduce the risk of chronic diseases like cancer and heart disease and aid in the battle against oxidative stress. The plant fights inflammation, infections, and even cancer with the use of terpenoids, which include substances like limonene and β-caryophyllene, and special diterpenoids like malabaricones. Steroids like β-sitosterol and triterpenoids like oleanolic acid strengthen their anti-inflammatory and liver-protective qualities, while alkaloids like anisomeline contribute pain-relieving and neuroprotective qualities. The leaves' essential oils, which include thymol and eugenol, also offer the plant potent antifungal and antibacterial qualities. The leaves have long been utilized in Ayurvedic and traditional medicine to treat fever, wounds, respiratory, digestive, and skin illnesses. Researchers are currently investigating their potential for creating herbal remedies, nutraceuticals, and natural food and cosmetic preservatives. There are obstacles to overcome, though, such establishing the long-term safety of these substances, assuring constant quality despite fluctuations in growing circumstances, and refining extraction techniques to optimize their advantages. Future research should focus on discovering new bioactive compounds, conducting clinical trials to confirm traditional uses, and developing sustainable farming practices to ensure a steady supply. By addressing these challenges,*A. malabarica* leaves could become a valuable resource for natural remedies and health-promoting products, offering a holistic approach to wellness.

CONCLUSION

The leaves of *Anisomeles malabarica* contain flavonoids, phenolic acids, terpenoids, sterols, and essential oil constituents, which contribute to the plant's remarkable pharmacological properties such as antioxidants, antimicrobial, anti-inflammatory, analgesic, and antidiabetic activities, reinforcing the traditional therapeutic uses of the plant. Despite potential benefits, the scientific work done on *A. malabarica* has some drawbacks: variation in the concentration of certain compounds, unstabilized extraction methods, and clinical validation is lacking. Future research will include detailed profiling of compounds, explanation of the biosynthetic pathway, and pharmacological tests, thus gauging their efficacy as therapeutics as well as safety. Other upcoming studies with closer investigates metabolomics and nanotechnology can further enhance its pharmaceutical applications. With an increasing exploration in science, *A. malabarica* holds a promise itself as a natural reservoir in serving curative purposes, mapping the common grounds in bridging traditional medicine to modern medicine.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

ABBREVIATIONS

A. malabarica: *Anisomeles malabarica*; **ABTS:** 2,2'-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid); **DPPH:** 2,2-Diphenyl-1-picrylhydrazyl; **FRAP:** Ferric Reducing Antioxidant Power; **GC-MS:** Gas Chromatography-Mass Spectrometry; **FTIR:** Fourier-Transform Infrared Spectroscopy; **H_2O_2:** Hydrogen Peroxide; **E. coli:** *Escherichia coli*; **IC_{50}:** Half Maximal Inhibitory Concentration; **STAT3 :** Signal Transducer and Activator of Transcription 3; **NF-κB:** Nuclear Factor Kappa-light-chain-enhancer of Activated B Cells; **DNA:** Deoxyribonucleic Acid; **MES:** Maximal Electroshock Seizure; **PTZ:** Pentylenetetrazole; **ICS:** Inhaled Corticosteroids.

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