

REVIEW



Health-promoting properties of *Plectranthus amboinicus*: a comprehensive review

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ABSTRACT

Plectranthus amboinicus, known as Cuban oregano or Indian borage, is a botanical species with various health benefits. This comprehensive analysis aims to clarify the scientific foundations of *P. amboinicus* as a phytotherapeutic agent, focusing on its botanical traits, phytochemical composition, and applications in healthcare. *P. amboinicus* is a perennial herbaceous plant recognized for its fleshy, fragrant leaves and adaptability to diverse ecological environments. Its historical use in different cultures for medicinal and culinary purposes is well-documented and demonstrates its significance as a valuable botanical resource. *P. amboinicus* has a complex chemical composition containing multiple bioactive compounds. Phenolic compounds, such as carvacrol and thymol contribute to its antioxidant and antimicrobial properties. Essential oils, terpenes, and other phytoconstituents further enhance its therapeutic potential. The applications of *P. amboinicus* in healthcare are extensive. It is efficient in alleviating respiratory issues, gastrointestinal disorders, and skin conditions. Its antioxidant and anti-inflammatory properties support its relevance in modern healthcare. *P. amboinicus* presents a compelling subject for botanical research and holds promise for promoting health and well-being. A comprehensive understanding of its safety profile and potential adverse effects is crucial, especially in therapeutic contexts. Ongoing scientific investigations and clinical trials are necessary to validate its therapeutic scope and ensure its judicious integration into health-promoting protocols.

KEYWORDS

Health benefits; Phytochemical composition; *Plectranthus amboinicus*; Therapeutic potential

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Introduction

Herbal medicines are known to have a range of health-promoting activities [1]. *Plectranthus amboinicus*, a well-recognized member of the Lamiaceae family, shares its family with commercially significant genera like *Plectranthus*, *Salvia*, *Ocimum*, and *Mentha*, known for their diverse ethnobotanical benefits. *P. amboinicus*, commonly referred to as Indian borage, is a succulent herb distinguished by its fleshy leaves and distinctive oregano-like flavor and aroma. It holds significance in both culinary science and medicine. Its leaves contain essential oils and bioactive compounds, which render it to be a valuable resource in traditional and contemporary herbal medicine. This plant also has a well-documented history in traditional remedies and exhibits therapeutic potential in conditions such as influenza, bronchitis, and epilepsy [2-4]. It has a relieving action against various symptoms such as coughs, sore throats, and nasal congestion. Additionally, it offers relief from discomfort caused by animal and insect bites and serves as a natural stimulant for breast milk production [5-7].

P. amboinicus naturally thrives in tropical and warm regions, including those of Africa, Asia, and Australia. It exhibits distinct physical characteristics such as vibrant, succulent heart-shaped leaves with scalloped edges. It can reach heights of around 50 cm, and its horizontal stems can measure up to 180cm. The leaves of *P. amboinicus* contain an ample amount of essential oils comprising a diverse range of bioactive compounds. Notable constituents include Carvacrol, Thymol, β -Caryophyllene, α -Humulene, γ -Terpinene, p-Cymene, α -Terpineol, β -Selinene, along with various phytocompounds

like flavonoids, cinnamic derivatives, and terpenes [8]. Carvacrol and Thymol are well-known for their anti-inflammatory properties, which are valuable in mitigating inflammation-related health issues. Extensive research supports the antibacterial properties, strong antioxidant capabilities, and hydrophobic characteristics of Carvacrol [9]. Furthermore, these compounds exhibit potent antioxidant capabilities, which help in combating harmful free radicals and oxidative stress within the body [10]. Certain constituents, such as β -Caryophyllene, may also contribute to the anticancer effects of the plant. The presence of flavonoids, cinnamic derivatives, and terpenes further augments its therapeutic potential [11]. The rich phytochemical profile of *P. amboinicus* warrants further investigation for its utility in both traditional and modern healthcare practices [5]. In this regard, this article provides a comprehensive overview of *P. amboinicus* as a therapeutic plant.

Phytochemical Composition

The essential oil derived from *P. amboinicus* is composed of several volatile constituents. These constituents can be categorized into distinct chemical groups, namely oxygenated monoterpenes, monoterpene hydrocarbons, oxygenated sesquiterpenes, and sesquiterpene hydrocarbons [5]. These compounds are mostly responsible for its characteristic aroma and therapeutic attributes [12-14]. Its leaves contain over 100 bioactive substances, including phenolic acids (e.g., rosmarinic acid, chlorogenic acid, caffeic acid, hydroxycinnamic acid, and p-coumaric acid), flavonoids

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(including quercetin, luteolin, apigenin, and guanine), carotenoids, steroidal glycosides, alkaloids, saponins, tannins, and phytosterols [14-16].

The phytochemical composition can vary based on factors such as geographical location, growth conditions, and plant age. The composition of essential oils is subject to various factors, including geographical location, growing conditions, and extraction methods [17]. Variations in soil composition, climate, altitude, and environmental conditions can lead to differences in phytochemicals [18]. Growing conditions, such as soil quality and sunlight exposure, can influence oil development, and stressors like drought can prompt the plant to produce different compounds [19]. The age of the plant at harvest also plays a role in the essential oil's composition [20]. The timing of harvest can affect constituents [21]. Extraction techniques can yield varying results [22]. Genetic variations within *P. amboinicus* populations lead to distinct oil profiles [23,34]. Environmental factors, such as light intensity and temperature, influence essential oil quality and composition in the Lamiaceae family. Higher light intensity can affect the relative concentration of specific compounds, while others may decrease [25].

Gas chromatography analysis has revealed carvacrol and thymol to be the primary components, each constituting over 20% of the oil's composition in the Indian variety [26]. The essential oil derived from the dried leaves of *P. amboinicus* originating from the Comoros Archipelago, have shown the major constituents to be carvacrol, camphor, Δ -3-carene, λ -terpinene, O-cymene, and α -terpinene [27]. In Colombian *P. amboinicus*, the essential oil contains a total of fifteen different compounds, with carvacrol as the predominant constituent, constituting 75.9% of the composition. Other significant compounds include α -bergamotene, p-cymene, α -humulene, 4-terpineol, caryophyllene oxide, β -guaiane, 1-octen-3-ol, α -muurolene, caryophyllene, 3-hexen-2-ol, γ -terpinene, isothymol, 2-carene, and β -bisabolene [28]. In Uganda, phytochemical analysis of aqueous extracts has identified various chemical compounds, including tannins, saponins, flavonoids, steroid glycosides, and polyuronides. Gas chromatography-mass spectrometry analysis further revealed that linalool was the most abundant compound, followed by nerol acetate, geranyl acetate, and carvacrol [29]. Essential oil from Thai *P. amboinicus* is characterized by oxygenated monoterpenes as the primary constituents, followed by monoterpene hydrocarbons, sesquiterpene hydrocarbons, and oxygenated sesquiterpenes [30].

Anti-Inflammatory Properties

Inflammation is a complex biological process that occurs in response to tissue injuries or exposure to pathogens. Its primary goal is to restore normal tissue structure and function. This process is essential for the defense mechanisms of the organisms. Acute inflammation is a well-regulated, transient response that serves as a beneficial mechanism when dealing with infectious pathogens such as bacteria or viruses. During acute inflammation, immune cells are recruited to the site of injury or infection, and various chemical signals coordinate the immune response. This process aids in eliminating harmful agents, initiating tissue repair, and contributing to the overall healing process [31,32]. In contrast, chronic inflammation is a persistent and undesirable

phenomenon. Unlike acute inflammation, which has a clear purpose and resolution, chronic inflammation can persist in the body for extended periods. Prolonged inflammation can lead to the development of various inflammatory diseases, including rheumatoid arthritis, cardiovascular diseases, and autoimmune disorders. In chronic inflammation, the immune system may fail to resolve the issue effectively, which causes continuous tissue damage and dysfunction [33]. Under typical circumstances, when the body encounters acute inflammatory stimuli, a series of coordinated cellular and molecular responses take place to address imminent injury or infection and restore tissue equilibrium. However, when acute inflammation is not properly controlled, it can transition into a chronic state, contributing to the development and perpetuation of various chronic inflammatory disorders [34]. Inflammation can stem from various causes, categorized as infectious or non-infectious factors. When the body experiences tissue damage, a complex chemical signaling cascade is initiated to facilitate tissue repair. These signaling molecules induce the migration of white blood cells (leukocytes) from the bloodstream to the specific injury sites. At the site of injury, these activated leukocytes release cytokines, which regulate various aspects of the inflammatory response [35].

Research into the medicinal potential of *Plectranthus* has primarily focused on a subset of 62 species. Scientific investigations have provided evidence that these species possess therapeutic properties, including analgesic and anti-inflammatory effects [36]. These therapeutic applications have been recognized in addressing a range of inflammation-related conditions affecting the skin, infections, the digestive system, and respiratory disorders [4]. Quercetin, present in *P. amboinicus* extract, has demonstrated effectiveness in preventing acute liver injury induced by difenoconazole exposure. This compound acts as an anti-inflammatory, antioxidant, antiaggregant, and hepatoprotective agent. The plant is also enriched with flavonoids and caffeic acid, which further contribute to its remarkable antioxidant and anti-inflammatory properties [37,38]. The anti-inflammatory effect of the plants has been shown in many reports. A significant reduction in paw edema was observed following the administration of hexanoic extract from *P. amboinicus*, especially at higher doses [10]. In another study, an aqueous extract of *P. amboinicus* was subjected to evaluation for its impact on AP-1 binding activities, a cellular process associated with inflammation. The extract exhibited inhibition in DNA-binding activities related to AP-1, with increased inhibition at higher concentrations, and demonstrated no significant toxicity to human fibroblast cell line Detroit 551 [39]. Terpenoid derivatives, known for their diverse biological activities, further enhance the pharmacological potential of *P. amboinicus*. Cinnamic compounds, recognized for their anti-inflammatory and antioxidant properties, add to the plant's medicinal value. These phytochemicals found in *P. amboinicus* leaves support both its traditional use in ethnobotanical medicine and its potential in the development of novel anti-inflammatory and chemotherapeutic agents [40]. The leaves of *P. amboinicus* also have a long history of use in traditional folk medicine due to their easy accessibility for collection and preparation, as well as their analgesic and antimicrobial property that alleviate pain and inhibit harmful microorganisms [41,42].

Antioxidant Capabilities

An imbalance between pro-oxidant and antioxidant substances in the body characterizes oxidative stress. This imbalance can harm essential macromolecules, including lipids, proteins, and DNA, and lead to their degeneration. Oxidative stress can induce various forms of DNA damage, such as single- and double-stranded DNA breaks and modifications to DNA bases. These DNA lesions have significant consequences, such as disruption of the accurate interpretation of genetic information, which potentially leads to permanent alterations in the genetic material. These genetic changes play critical roles in carcinogenesis and mutagenesis [43,44].

A comprehensive study investigated the antioxidant activity in sixteen distinct *Plectranthus* species using three well-established *in vitro* assays: DPPH (2,2-diphenyl-1-picrylhydrazyl), ABTS (2,2-azinobis (3-ethylbenzothiazoline 6-sulfonate)), and FRAP (ferric reducing antioxidant power using 2,4,6-tripyridyl-s-triazine). The extracts of *P. amboinicus*, *P. barbatus*, and *P. argentatus*, along with the 90% methanol extracts of *P. caninus*, *P. fruticosus subsp. james*, and *P. argentatus*, exhibited the highest antioxidant activity in the DPPH assay. About 50% of the DCM (Dichloromethane) extracts showed potent antioxidant activity, exceeding even L-ascorbic acid, a well-known reference compound. These findings highlight the remarkable antioxidant potential present in various *Plectranthus* species, which could have significant implications for their utilization in diverse applications, from pharmaceuticals to functional foods. The ethanolic extract and the ethyl acetate fraction obtained from the leaves of *P. amboinicus* have demonstrated significant antioxidant properties in reducing paw edema. These findings show that the relative potency of these extracts reached 83.37% and 88.66%, respectively. This substantial antioxidant activity highlights the therapeutic potential of *P. amboinicus* and its constituents in addressing inflammatory conditions [45]. Further exploration and utilization of these plant-derived antioxidants hold the potential to contribute to the development of novel antioxidant-based therapies and dietary supplements [46].

Anticancer Potential

Cancer poses a significant challenge to human health and ranks among the leading causes of mortality, closely following cardiovascular diseases. This devastating disease is primarily characterized by uncontrolled cell growth, often attributed to the activation of tumor suppressor genes, which promote unchecked cell proliferation while inhibiting the apoptotic mechanisms of the body. Malignant tumors result from the delicate balance of cell adhesion receptors. These receptors facilitate tissue-specific cell attachments and are essential for maintaining proper cell-to-cell connections. However, the development of cancer often involves the down-regulation of these receptors, disrupting normal cellular adhesion. Conversely, there is an up-regulation of cell adhesion receptors that enhance cell motility, contributing to the progression of malignancy. The complex mechanisms underlying cancer initiation and progression encompass various factors, including genetic mutations, chromosomal aberrations, dysregulated signaling pathways, and altered gene expression or activity. Epigenetic changes, affecting DNA residues and gene expression, may also contribute to cancer development [47,48].

The ethanolic extract of *P. amboinicus* (Lour.) Spreng leaves

contain various flavonoid compounds, all of which exhibit remarkable anticancer and antioxidant activity. These compounds are known to neutralize harmful free radicals within the body and reduce oxidative stress [49]. The aqueous extract obtained from *P. amboinicus* inhibits the growth of Sarcoma-180 and Ehrlich ascite carcinoma cells by over 70% possibly due to the presence of phenolic compounds. The phytochemicals of *P. amboinicus*, such as diterpenoids, sesquiterpenoids, monoterpenoids (carvacrol), terpenoids (β -sitosterol), caffeic acid, and cinnamic derivatives, possess chemotherapeutic effects [10]. The essential oil from *P. amboinicus* leaves exhibits high IC₅₀ values of 22.5 μ g/mL on the breast carcinoma cell line (MCF-7) and 24.5 μ g/mL on the Hepatocellular carcinoma cell line (HepG2), indicating its potential anticancer activity [49]. The hexane fraction from the ethanolic extract of the leaves shows cytotoxic effects against human breast cancer MCF-7 cells, with an IC₅₀ value of 8.85 μ g/mL, while the chloroform fraction is more active, with an IC₅₀ value of 2.46 μ g/mL. Mass spectrometer analysis indicates that (7-acetoxy-6-hydroxyroyleanone) present in the essential oil of *P. amboinicus* possesses greater cytotoxic activity against MCF-7 cells [50]. A significant reduction in the percentage of viable cells was observed as the concentration of the *P. amboinicus* extract increased. Notably, the IC₅₀ value, representing the concentration at which 50% of the cells were inhibited, was determined to be 53.0 μ g/mL for *P. amboinicus*. This data indicates that the plant extract possesses notable cytotoxicity against oral cancer cells [1].

Conclusions

P. amboinicus, known for its succulent aromatic leaves and adaptability to various environments, has a rich history of use across cultures as a valuable botanical resource. Its phytochemical complexity, which includes phenolic compounds like carvacrol and thymol, along with essential oils and terpenes, imparts antioxidant, anti-inflammatory, anticancer, and therapeutic properties. The health applications of *P. amboinicus* are extensive, with documented benefits in treating respiratory, gastrointestinal, and dermatological conditions, supported by its antioxidant and anti-inflammatory capabilities. It stands as a compelling subject for ongoing botanical research and holds great promise in enhancing health and well-being. Rigorous scientific investigations and clinical trials are imperative to validate its broad therapeutic potential and facilitate its prudent incorporation into health-improving protocols.

Disclosure statement

No potential conflict of interest was reported by the authors.

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