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Health Benefits of *Plectranthus amboinicus*: From Traditional Use to Modern Pharmacology

Supriya Yatakona and Sathasivam Sivamalar*

Department of Research, Meenakshi Academy of Higher Education and Research (MAHER), Chennai - 600078, Tamil Nadu, India; drsivamalar@maher.ac.in

Abstract

Plectranthus amboinicus, commonly known as Indian Borage or *Karpooravalli,* is a herbal medicine that belongs to the family *Lamiaceae* and has been used traditionally for centuries in Southeast Asia and the Caribbean. Its bioactive compounds, such as rosmarinic acid, thymol, and carvacrol, show antibacterial, antifungal, antiviral, anti-inflammatory, and anticancer effects. It is highly potent against most of the pathogens, including Methicillin-Resistant *Staphylococcus aureus* (MRSA) and *Escherichia coli*, and may, therefore, also be useful for some viral protection, such as Human Immunodeficiency Virus (HIV) and Herpes Simplex Virus type 1. *P. amboinicus* has also shown bronchodilatory activity, and hence it finds useful applications in keeping the respiratory system healthy. It possesses well-defined anti-inflammatory properties too. This herb is fit for treatment due to its potent anti-inflammatory properties, besides the fact that it possesses antimicrobial and antiviral properties. It is therefore appropriate as an alternative to using the drug. Its medicinal virtues have also been found valuable in the management of diabetic conditions, lowering blood sugar content and accelerating wound healing. Through its antioxidant property, this plant helps the body overcome oxidative stress and gives immune action a healthy boost. Furthermore, recent studies have shown that it enhances maternal care, manage urolithiasis and enhance lactation.

Major Findings: The profusion of bioactive constituents within *P. amboinicus* endows the plant with significant antimicrobial, antiviral, anti-inflammatory, antioxidant, and antidiabetic attributes. The medicinal significance of this plant is underscored by its therapeutic efficacy in addressing urolithiasis, respiratory ailments, wound healing, immune system enhancement, and promotion of lactation.

Keywords: Anti-inflammatory, Health, *Plectranthus amboinicus*, Pharmacology, Traditional Use

Abbreviations: Methicillin-resistant *Staphylococcus aureus* (MRSA), *Escherichia coli* (*E. coli*), Human Immunodeficiency Virus (HIV), Herpes Simplex Virus type 1 (HSV-1), Non-Steroidal Anti-Inflammatory Drugs (NSAIDs).

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1. Introduction

The cost-effectiveness, safety, and effectiveness of plant-based drugs in treating a wide range of medical conditions make them indispensable in global public health. Herbal remedies prominently feature in Siddha, Ayurveda, Unani, and folk medicine among other alternative medical practices. The World Health Organisation projects that 80% of patients are still depending on these remedies due to increased accessibility, the relatively lower prices, and lack of side effects when compared with allopathic medicine[1].

Many modern drugs based on plants and their pharmacological activities depend on traditional knowledge, further demonstrating the role played by natural resources in contemporary medicine. Natural plant compounds are now the backbone of drug discovery since pharmaceutical industries are now acquiring their new medicines from these regions, thus fueling global demand for medicinal plants[2].

Some of the economically important genera in the *Lamiaceae* family are *Plectranthus*, *Salvia*, *Ocimum*, and *Mentha*, which also have a number of ethnobotanical benefits. There are over 300 species of *Plectranthus*

*Author for correspondence

in the tropical and subtropical regions of Africa, Australia, and Asia. The genus's essential oils are well studied and are essentially the cause of its nutritional and medicinal value. The most popular species of *Plectranthus*, with a sweet, pungent fragrance smelling like oregano, is Indian Borage, which has been widely used in traditional medicine for skin diseases, cough, and asthma. Thymol, carvacrol, and β-caryophyllene are extracted as being responsible for such properties in *Plectranthus* species[3,4]. A few perennial herbs such as *P. amboinicus* grow up to a height of one metre or so.

When its fleshy, glandular leaves are crushed, it emits the typical minty aroma. It is used for cooking purposes as well as medicinal applications. This plant thrives well in tropical and subtropical climatic areas. Its wide phytochemical composition includes essential oils, flavonoids, and phenolic compounds, which justify the wide range of therapeutic effects it possesses, including antibacterial, anti-inflammatory, and anti-diabetic qualities[5,6]. It is useful for diabetes care because recent studies have established that the plant lowers the glucose level in the blood and hastens the process of wound healing.

Moreover, *P. amboinicus* has been shown to express a high level of antibacterial activity, especially against Gram-positive and Gram-negative bacteria, and in consideration of the growing antibiotic-resistant world, it may serve as a natural alternative to these antibiotics. Its bioactive compounds are thought to potentially possess anticancer properties; studies even suggest that maybe this plant can offer safer chemotherapy when it comes to Dalton's Lymphoma (DLA), as well as other specific cancer types[7]. Although it could thrive almost anywhere, *P. amboinicus* prefers to grow in well-fertilised soil with proper drainage and even partial shade.

Due to its outstanding adaptability, it can be cultivated indoors in both tropical and colder climates, and mainly it is propagated by stem cuttings. Low maintenance requirements and resistance of the plant to heat and drought render it attractive for both small-scale and commercial farming[8]. From the farm point of view, *P. amboinicus* is a potential crop for sustainable farming. Due to integrated pest management and organic fertilisers, it minimises the effect of the farmer on the environment and improves biodiversity. These environmentally friendly farm practices not only enhance the yield of plants but also create long-term environmental stewardship. This plant is one of the strong contenders for commercial production in various agro-ecological zones due to efficient agricultural management and sustainability.

The many therapeutic benefits of the phytochemical compositions of *P. amboinicus* range from antimicrobial and anti-inflammatory properties to antioxidants that add to its properties for a healthy system as well as digestive health. The significant antioxidant nature of rosmarinic acid contributes immensely to reducing oxidative stress in the body as well as preventing chronic diseases, such as heart disease. This plant is also of great importance for its medicinal purpose, as it maintains intestinal health and prevents infections due to its bactericidal effect, especially against pathogenic bacteria, which does not harm the body in contrast to the synthetic antibiotics usually used[9]. In this regard, *P. amboinicus* is a plant that has a wide scope of use in traditional medicine and as a new, harmless remedy for ordinary diseases.

2. Applications of *Plectranthus amboinicus*

2.1 Therapeutic Role of *Plectranthus amboinicus* in Respiratory Health

Karpooravalli is an Ayurvedic medicine used traditionally for ages to treat respiratory disorders, including asthma, coughs, sore throats, and colds. This plant has been known for centuries in herbal medicine, and both water decoctions and fresh leaf extracts have medicinal properties. Lately, it has gained much attention, mainly because of its significant medicinal properties, which are primarily attributed to the active constituents like thymol and carvacrol. Both of them are good expectorants and thereby help reduce respiratory distress, enabling easier mucus excretion and easier breathing. The general ability of the plant to alleviate symptoms and support health in the respiratory system is why this plant is the backbone of Indian traditional medicine. The other significant usage of *Karpooravalli* (also known as *Plectranthus amboinicus)* is in veterinary medicine to treat respiratory disorders in cattle. The leaf infusions of this herb have been documented to be able to treat coughs and other allied problems. Similar uses are reflected in traditional practices in

places like Zulu medicine, despite the lack of official documentation, highlighting the plant's worldwide medicinal significance. Apart from its therapeutic qualities, *Karpooravalli* is also used in cooking.

It is commonly used to add flavour and health benefits to food in Indian cuisine. Antibacterial compounds in the leaf extracts can support the immune response by inhibiting bacterial growth while also adding flavour to meals. Since they release phytochemicals and essential oils when chewed, fresh leaves are a convenient at-home remedy for respiratory discomfort. These compounds alleviate sinus pain, nasal congestion, and sore throats. Such an advantage of the plant has been found in both the culinary techniques and the health aspect concerning respiration. Further research is needed to be done on the pharmacological properties of *P. amboinicus* to confirm and strengthen its role in supporting respiratory function and treating related conditions[10].

2.2 Wound-healing Potential of *Plectranthus amboinicus*

Plectranthus amboinicus is widely used in wound healing. Traditionally, the paste prepared from the leaves of the plant is applied topically to wounds as a poultice. This has been reported to significantly improve wound healing by increasing collagen deposition, reducing the epithelialisation period, and accelerating wound contraction. Research has shown that the plant accelerates the healing process, and thus it is a useful natural remedy for wounds. For example, research on albino rats showed that after applying a 10% paste made from the leaves and roots of *Karpooravalli*, epithelialisation significantly increased. The ability of this plant to heal wounds depends upon bioactive compounds. It has been found in the sick giant murals that administering plant extracts also increased immunological responses and sped up wound closure. This reveals how the plant increases immunity, which further helps to heal wounds faster and better[11].

Its antibacterial activity prevents infection, which may delay the healing process, and anti-inflammatory activity prevents chronic inflammation, which may delay the healing process. Ethanolic extracts of *P. amboinicus* have been proven in studies with diabetic mice whose wound healing is usually hampered to reduce the wound areas by up to 76.6%. The polyherbal suspension composed of *Punica granatum* and *P. amboinicus* increased collagen deposition and wound contraction. In addition, the plant has very high zinc content, which is an essential element that plays a crucial role in all physiological activities required for the regeneration of tissues. *P. amboinicus* is a very effective wound healing agent due to its properties and immunity-boosting ability. As a result, it has gained increased attention in the clinical and traditional medicine areas as a very useful treatment for chronic and acute wounds[12].

2.3 Skin Applications: Treating Cuts, Burns, and Allergies

It has been well known for a long time that *P. amboinicus* is very good for the skin and hair. In general, this multi-purpose plant can be used to cure scalp conditions such as dandruff and dry, itchy scalps. Mix some *Karpooravalli* essential oil with carrier oil and apply it directly to the scalp to treat dandruff. The natural remedy reduces the symptoms and the cause of dandruff by nourishing the scalp and reducing irritation. This is one of the medicinal herbs that have been used to heal burns, cuts, allergic reactions, and encourage healthy hair. It is normally used as a poultice to treat the areas of affliction. Because it possesses anti-inflammatory properties, this plant heals quickly, providing a solution for various types of skin irritations.

Plectranthus amboinicus is used in dermatology for lots of well-established purposes, and it is especially used in treatments for various skin disorders. With anti-inflammatory properties, it helps reduce the redness and swelling that develops because of stings, bites of insects, and conditions like psoriasis and eczema. People suffering from these conditions may have minimal discomfort and recover fast through this rapid response to inflammation[13]. Even in the treatment of infectious diseases of the skin, the wider usage can be further confirmed by how this traditional plant, *P. amboinicus,* is applied in Brazil to manage ulcerations of the skin due to *Leishmania braziliensis*. Moreover, the fact that a sap extract is commonly used in India testifies to its high acceptance and the extent to which it has been widely applied for managing skin ailments.

This oil has an antifungal nature, and the fungus *P. amboinicus* exhibits special potential against *Malassezia furfur* responsible for dandruff. Using

agar diffusion, its effectiveness was tested on shampoo that contained ketoconazole; that is one common standard of treatment against dandruff[14]. Essential oil prevents dandruff-causing fungus, so it is natural and has been used by many as a substitute for chemicals. Pounded leaves find application in hair and skincare practices among people, baking the paste on an open flame before being applied to burns and wounds; the process works faster in addition to antiseptics.

2.4 Insect and Animal Bites Treatment

Plectranthus amboinicus has been used to treat bites from venomous insects such as scorpions and centipedes in many parts of Asia. The leaves are bruised or applied as a poultice directly to the affected area to extract the juice. This practice has been especially common in countries like Malaysia, where people are more likely to be bitten by centipedes and scorpions. The leaf juice can serve as a natural mosquito repellent for outdoor activities such as camping to avoid mosquitoes. The plant reduces the effects of venom and repels mosquitoes, which makes it of extreme importance in traditional medicines concerning the treatment of animal and insect bites. The active principles of the plant could be useful in neutralising toxins and inflammation, thus explaining its wide use in the treatment of such conditions.

Recent studies have been conducted on the extracts of *P. amboinicus* as an antidote to scorpion venom. More than 70% effectiveness in the prevention of fibroblast cell lysis was exhibited by aqueous extracts of *P. ambonicus* when tested against the venom of the scorpion species *Heterometrus laoticus*[15]. It would appear from this that the plant could be a good home remedy for scorpion stings. However, cytotoxicity associated with the extracts was reported within the same study, pointing out that even though *P. amboinicus* appears to have excellent potential as a snake venom antidote, much more work is needed before its full safety profile might be considered. As this compound may have cytotoxic activities, further research needs to be conducted on its potential use in medicine. The plant is yet to be used in most folk medicine regions despite such risks, and its presence in ethnobotanical remedies is a common phenomenon.

2.5 Eco-friendly Alternatives: Plant-based Insecticides for Mosquito Control

Plectranthus amboinicus has gained popularity because it has twin applications: As a repellent for mosquitoes and a natural healing agent for malaria. As a topically applied repellent reduces the chances of being bitten by mosquitoes, while it has proven to be very promising for malaria treatment caused by mosquitoes, which can even decrease fever sometimes. The plant is said to have between 75% and 90% potency depending on dosages. This indicates that in regions where diseases, such as malaria, are caused by mosquitoes, the plant may be used as an adjuvant therapy. *Plectranthus amboinicus* is rich in phytochemicals and has wide applications in controlling mosquitoes.

It contains various bioactive compounds, including proteins, glycosides, alkaloids, carbohydrates, flavonoids, tannins, saponins, and fixed oils. Among the countless biological activities presented by this plant, these compounds justify its insecticidal, antiviral, and antioxidant effects. This is an indication that *P. amboinicus* extracts possess significant larvicidal activity against the major mosquito species that cause dengue fever, such as *Aedes aegypti,* and malaria species, such as *Anopheles gambiae*. This is further supported by the insecticidal compounds that include carvacrol, oleic acid, and hexadecanoic acid, which act as natural agents in mosquito control. Since *P. amboinicus* is an environmentally friendly alternative to synthetic pesticides, it can be a long-term mosquito control agent. Most chemical pesticides are hazardous to the environment, contaminate non-target organisms, and eventually lead to the emergence of insect resistance. On the other hand, plant-based insecticides of *P. amboinicus* are economical and environmentally friendly, especially in developing countries where mosquito-borne diseases prevail[16].

3. Biological Characteristics of *Plectranthus amboinicus*

The leaf has a variety of biological characteristics, including antibacterial, antifungal, anti-inflammatory, anti-cancer, and antibacterial activity against a range of clinical strains (Figure 1).

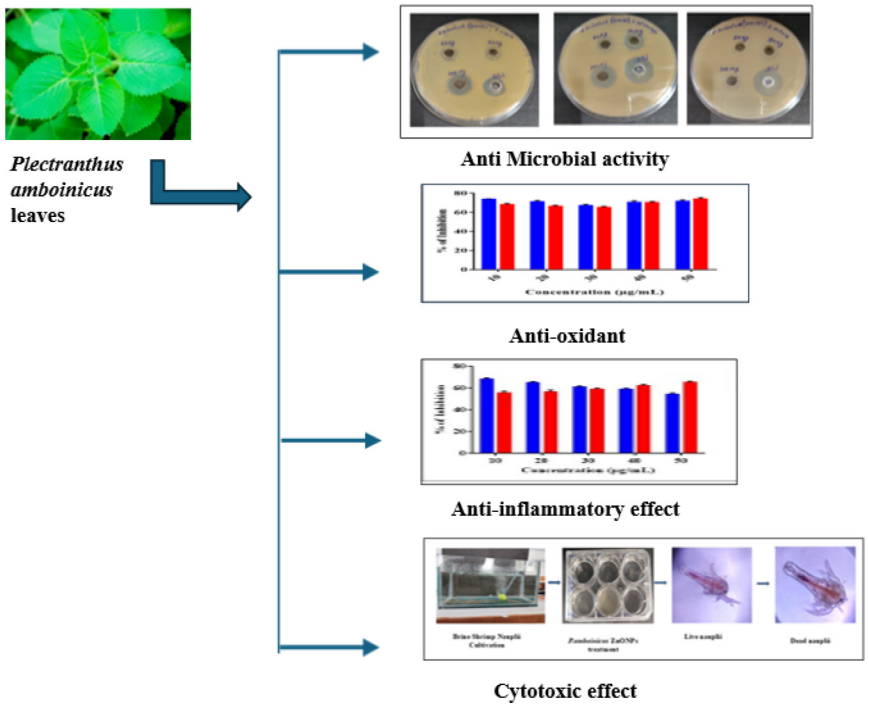


Figure 1. Biological activity of *P. amboinicus*.

3.1 Anti-Inflammatory Potential of *Plectranthus amboinicus*

Plectranthus amboinicus has always caught the fancy of everybody as a result of its analgesic and anti-inflammatory action, particularly in treating respiratory tract infections that include common conditions such as colds and influenza. Headache, sore muscles, and even general unrest greatly impede people's functioning at work and other responsibilities. The capability of inhibiting pain and inflammation for this plant makes it a medicine with great therapeutic value. One of the traditional remedies for respiratory infections is eating *Karpooravalli* rasam or soup prepared from its leaves, which not only nourishes but also enhances its therapeutic effects. Thus, *Karpooravalli's* usage as both a medicinal herb and dietary supplement means it holds a significant position in both traditional healing practices and modern wellness.

Inflammation is the typical response of the body to tissue damage or infection, which tries to return the tissue to its normal function. Acute inflammation acts as a protective mechanism in attracting immune cells for tissue repair; however, an unresolved acute response can itself result in chronic inflammation. Chronic inflammation has been associated with autoimmune diseases, cardiovascular diseases, and rheumatoid arthritis. Tissue dysfunction is frequently accompanied by the phenomenon[17]. *P. amboinicus*, besides, has also been reported to possess anti-inflammatory effects attributed to bioactive compounds involving quercetin, flavonoids, and terpenoid derivatives, which modulate acute inflammation, including paw oedema, by controlling oxidative stress and inhibiting inflammatory pathways through Activator Protein (AP)-1 binding activity[18]. Low toxicity to human fibroblast cells and additional antimicrobial and analgesic activities raise the value of this plant as a safe and effective therapeutic agent in the treatment of disorders associated with inflammation. Traditional use, combined with pharmaceutical potential, makes *P. amboinicus* an invaluable component of herbal and contemporary pharmaceutical approaches[19].

3.2 Use of *Plectranthus amboinicus* as a Herbal Remedy in Oral Care

Besides its widely known analgesic and anti-inflammatory properties, *P. amboinicus* has been observed to improve dental health. Another among its traditional uses is as an ingredient in mouthwash-a preparation made by boiling leaves in water. Simple treatment at home indeed proves to be effective and, therefore, prevents the manifestation of a variety of

oral problems through a highly statistically significant reduction in the development of oral bacterial infections. The main constituent responsible for this antimicrobial activity is carvacrol, which is a monoterpenoid phenol that possesses high antibacterial activity. Therefore, the use of *Karpooravalli* as a mouthwash would improve oral hygiene and act as a natural remedy against diseases like periodontal disease and dental caries, which are major public health issues among a large portion of the population. These pathogens, at an important scale, threaten public health unless preventive and curative measures are taken. Carvacrol enhances the ability of *P. amboinicus* to inhibit oral pathogenic bacteria. Research study points that the incorporation of carvacrol in mouthwash products presents an antagonistic action against microbial growth, thus reducing opportunities to be infected by oral bacteria[20]. This makes it a good substitute for traditional medicines for oral disorders, particularly for those people desiring alternative methods of therapy. It would prove to be an excellent complement to the emerging demand for herbal and alternative remedies, as *P. amboinicus* might present a safe, effective, and affordable way to promote dental health and guard against complications under oral care routines.

3.3 Anti-Cancer Properties of *Plectranthus amboinicus*

Plectranthus amboinicus is a tremendous potential natural remedy with strong anti-cancer effects using its essential oils and raw leaf extracts. Studies have shown that the leaf extracts of *Karpooravalli* suppress the growth of breast cancer cells, and its essential oil has an immense effect on lung cancer cells. Cancer is the cause of death in almost all parts of the world. The process involves the excessive growth of aberrant cells, commonly described as the malfunctioning of genes controlling tumour suppression because they supervise the cell cycle and apoptosis; when there are diminished molecules of adhesion receptors holding tissue together for adequate cell-cell communication, these tumours appear malignant[21]. In addition, the mechanisms for cancer development are multifold and include mutations in genes, chromosomal breaks, and epigenetic changes such as DNA methylation and aberrant gene expressions[22].

Bioactive compounds, flavonoids, with strong anticancer and antioxidant activity exist in the ethanolic extract of *P. amboinicus* leaves. Flavonoids, one of the key factors involved in cancer, reduce oxidative stress due to free radicals. The aqueous extracts of the plant show phenolic compounds which demonstrate inhibition of growth for Sarcoma-180 as well as Ehrlich ascites carcinoma cell lines by more than 70%. Other plant compounds that include terpenoids such as β-sitosterol, monoterpenoids like carvacrol, diterpenoids, and sesquiterpenoids further enhance its chemotherapeutic properties. These studies show different ways *P. amboinicus* can impact the growth of the tumour and is, hence, considered a potential candidate for cancer treatment using natural therapies[23]. Some other findings from the studies conducted about *P. amboinicus* essential oil reveal cytotoxic activities against many strains of cancer cell lines.

The oil was highly active against Hepatocellular carcinoma, G2 (HEPG2) and cell lines Michigan Cancer Foundation-7 (MCF-7), which are representatives of hepatocellular carcinoma and breast carcinoma, respectively. Its high IC_{50} values bestow significant therapeutic potential on it. In this regard, an IC_{50} value of 2.46 µg/mL was observed against MCF-7 cells for the chloroform fraction of the ethanolic extract. Based on these results, *P. amboinicus* can become a future natural drug to treat several cancers, including breast, liver, and mouth cancer. Further research and clinical trials have to be undertaken to standardise the effect and make these drugs for further medical use[24].

3.4 *Karpooravalli*: The Holistic Remedy to Diabetes and its Complications

Among various popular natural remedies for the management of diabetes, one common drug that is considered good and imparts multiple benefits in controlling blood sugar levels and regulating complications of this disease is *Karpooravalli,* because uncontrolled diabetes is mostly associated with persistent hyperglycemia. Consequently, the greatest challenge faced by diabetic patients is maintaining optimum levels of blood glucose levels.

It is also known for its excellent therapeutic actions on high blood sugar. It can thus be employed as a supportive treatment to help diabetes be managed

naturally. Besides its role in blood sugar stabilisation, *Karpooravalli* is also used to support the healing of delayed wounds, one of the complications of diabetes. People often take longer to heal wounds than others because of poor blood flow and high blood sugar, among other factors. This may lead to ulcers and infections, such as diabetic foot ulcers, mainly in the extremities. Treatment of wounds with *karpooravalli* extract accelerates healing considerably, especially for patients suffering from diabetic foot ulcers. It relieves inflammation, heals tissues, and prevents infections, which are the most common complaints in the case of diabetic wounds. Besides making the life of a diabetic patient easier, these curative properties also reduce the risk of new diseases. Since it heals wounds much better and also lowers the blood sugar level, *Karpooravalli* is a holistic treatment that is replete with many advantages in managing diabetes.

3.5 *Karpooravalli*: A Powerful Medicine for Indigestion, Diarrhoea, and Dyspepsia

Karpooravalli is a well-known remedy for several digestive problems, including indigestion, diarrhoea, and dyspepsia. This is because it naturally heals. Thus, it's a great remedy for relieving pain, promoting digestion, and healing the digestive tract. It might be quite useful in the case of diarrhoea as well, for its control of diarrhoea and decrease of inflammation in the digestive tract. It also controls bowel movements. Its application to dyspepsia disease- that's bloating and nausea accompanied by pain in the abdomen- hints at several uses in relieving digestive disorders. *Karpooravalli's* prebiotic effects are one of its more interesting and significant benefits. This is a term that describes substances that tend to promote the growth of beneficial probiotic bacteria in the gut.

These probiotic bacteria are very important to the gut microbiome. They aid in the immune system, nutrient absorption, and general digestive health. *Karpooravalli* encourages these beneficial bacteria, thus restoring the balance of the gut flora, enhancing digestion, and preventing the overgrowth of harmful bacteria. This is a prebiotic that improves gut health and further supports long-term digestive well-being. *Karpooravalli* is therefore two-pronged in that aspect: Long-term medicine for digestive health as well as short-term medicine for digestive health.

3.6 Karpooravalli as an Arthritis Drug

Plectranthus amboinicus is one of the herbal remedies with high potential as a natural treatment for arthritic patients, particularly elderly patients with persistent joint pain and inflammation. Arthritis is marked by joint oedema, stiffness, and extreme discomfort, particularly osteoarthritis and rheumatoid arthritis, which reduce mobility and quality of life. Non-Steroidal Anti-Inflammatory Drugs (NSAID) are present in conventional medications, which, though effective, come with side effects like an increase in gastrointestinal distress as well as a higher chance of cardiovascular diseases. The use of bioactive compounds from *Karpooravalli* has great potential to become a much safer alternative because it contains such potent anti-inflammatory agents like terpenoids and flavonoids. Besides reducing joint pain and inflammation, the consumption of this traditional soup made from leaves of *Karpooravalli* helps avert unwanted side effects accompanying prescription medicines. This is one more reason why *Karpooravalli* is a wonderful, non-threatening, and integrated treatment to manage arthritis. Its antioxidant characteristics also reduce oxidative stress, which further helps in the progression of degeneration of cartilage inside the joints. Inclusion of *Karpooravalli* in the diet would benefit patients by providing them with long-term pain relief and increased mobility, thus improving their general health. *P. amboinicus* has shown great promise in the treatment of rheumatoid arthritis in addition to general benefits for arthritis through mechanisms that are different from those of traditional NSAID.

Karpooravalli has more extensive anti-inflammatory effects than NSAID, which target the cyclooxygenase enzyme to reduce inflammation. It may reduce the production of cytokines similar to the effects of protective drugs like corticosteroids such as prednisolone but without the dangers of side effects. As reported in some unpublished studies, a single dose of 5000 mg/kg of *P. amboinicus* extract was not shown to have toxic effects; hence, it appears to be safe and an important drug for therapy. This research may be an opening opportunity for the application of this medicine as a disease-modifying therapy for rheumatoid arthritis, thereby reducing the utilisation of traditional drugs. This will improve outcomes in patients by using *Karpooravalli* as an alternative, safer and sustainable substitute to pharmaceutical interventions. Further studies to determine and clarify the bioactive

compounds that exactly lead to the mentioned effects will legitimise the utilisation of *Karpooravalli* as an adjuvant to other therapies and establish its position in clinics[25].

3.7 *Plectranthus amboinicus*: Antiplatelet Activity and Cardiovascular Benefits

The antiplatelet activity of the extract from the stem of *P. amboinicus* promises positive assurance of the benefits such an extract may offer to cardiovascular wellbeing. Platelets are important for haemostasis, as they can form clots and stop bleeding. But then, too much aggregation in platelets leads to very significant heart attacks, strokes and cardiovascular diseases like thrombosis and atherosclerosis. Adenosine Phosphate (ATP) was used here as the agonist in platelet-rich plasma as a medium to evaluate the antiplatelet effects of the stem extract of *P. amboinicus*. Higher concentrations from 50 to 250 µg/mL caused more significant platelet aggregation inhibition at the highest concentration; hence, the outcome was an expression of a dose-response relationship. The alteration in platelet function that has been observed might be part of the explanation of the extract, as it probably lowers the possibility of thrombotic events and thus preserves the haemostatic balance. *P. amboinicus* stem extract is possibly a safer alternative to conventional drugs with undesired side effects on antiplatelet activity. This activity, in its capacity as a therapeutic agent in cardiovascular care, would also be further developed by continuing the research on the isolation and identification of bioactive compounds causing it. This alteration in platelet function opens up the possibility that the extract may reduce the risk of thrombotic events and maintain haemostatic balance.

Plectranthus amboinicus stem extract might be a safer alternative natural antiplatelet drug rather than antiplatelet drugs that bring adverse effects. Further studies to identify and isolate bioactive compounds responsible for such activity will further stabilise the potential of this activity to be a therapeutic agent in the cardiovascular care system[26]. More importantly, the similar bioactivity of extracts from parent and tissue-cultured plants promotes sustainable production without overfishing the wild populations and conserves biodiversity as well as provides medicinal applications. *P.amboinicus* is a precious resource for interventions in cardiovascular health, ranging from improvement in heart function to the promotion of platelet regulation[27].

3.8 Antioxidant Activities

This herb, *Karpooravalli*, is a natural remedy in the fight against oxidative stress and in boosting the immune system due to the many antioxidants contained within it. Free radicals are unstable chemical elements that can cause harm to cells, leading to many health complications, including inflammation and chronic diseases. The human body uses antioxidants to combat free radicals. Consumers can enjoy the antioxidant property; furthermore, the status of health due to this product will also improve among people as they start consuming the diverse varieties of *Karpooravalli*. Due to its strong property of antioxidant, this *Karpooravalli* is essentially its oil, both *in vitro* as well as *in vivo* models indicate a potential ability through which this oil of *Karpooravalli* was reducing the stress due to cancer in lungs which was caused due to cell lines. These protective effects are postulated to originate from the phytochemical compounds found in the essential oil, such as thymol and carvacrol[28].

In addition to the antioxidant property, other potential applications of *Karpooravalli* essential oil exist. Other evidence that would indicate the capacity of this oil to fight oxidative stress is through research that has shown that its application to animal models increases the concentration of non-enzymatic antioxidants such as reduced glutathione. This increase implies that *Karpooravalli* essential oil may have the capacity to boost the natural antioxidant defence in the body in addition to combating oxidative damage. Essential oil is also a good subject for further studies and possibly for its therapeutic uses in the medicinal line since it is low-cost compared to the usual prescription formulation and without any sign of side effects observed during animal studies[28]. Other than essential oil, aqueous extract of leaf *P. amboinicus* has exhibited remarkable antioxidant properties, wherein noteworthy ferrous ion chelating, nitric oxide scavenging, and superoxide scavenging have been reported. Bhatt and Negi conducted a study in which they concluded that *Karpooravalli* leaves possess a high content of polyphenolic content. This compound is associated with notable DPPH free radical-scavenging abilities and significant overall antioxidant activity[29]. However, Khanum reported that ethanolic leaf extract possesses antioxidant activity despite containing a low total flavonoid and phenolic content[30]. All these findings highlight the potential of *Karpooravalli* as a healthful natural antioxidant source and how it can help prevent and promote health.

3.9 Analgesic Activity: A Natural Alternative to Conventional Pain Relief

Recently, renewed interest has been gathered in the analgesic activity that *P. amboinicus* holds, especially for the reduction of pain. In this regard, abdominal pain and cramping were caused by the injection of acetic acid in animal models. By doing this, intraperitoneal injection induces a release of histamine, serotonin, and prostaglandins like Prostaglandin E2 (PGE2) and Prostaglandin F2 (PGF2). This, therefore, implies that in this formulation, *P. amboinicus* dramatically reduced the pain responses and cramping of the rat but could not reduce the neurogenic (phase) pains, as their mechanisms are different, a factor that includes the activation of peripheral nerves. These results show that *P. amboinicus* can be utilised in the management of conditions caused by inflammation and pain, as it exerts greater analgesic activity on inflammatory pain compared with neuropathic pain.

In addition, the anti-inflammatory activity of *P. amboinicus* might be the reason why it has shown effectiveness in pain relief, in addition to its analgesic activity. This is due to mechanisms that include suppression of cyclooxygenase-2 (COX-2), inducible nitric oxide synthase (iNOS), and nuclear factor kappa B (NF-κB) expression, all being crucial in inflammation. *P. ambonicus* prevents pain due to its reduction of inflammation-associated pain, thereby inhibiting the inflammatory cause and deactivating the mediators. This reduces inflammation and pain simultaneously; therefore, this is the reason why *karpooravalli* is considered to be a great option for treatment regarding inflammation conditions naturally. The research of Punet Kumar S would support the idea of plant-based analgesics that could be used as part of an integrated pain management plan, particularly for patients seeking alternative options to the often side-effected traditional NSAID[31].

4. Therapeutic Potential of *Plectranthus amboinicus* in Urolithiasis Management

Specific for lipid-lowering activity, encouraging effects of hydro alcoholic extracts of the leaves of *P. amboinicus* in complications of urolithiasis treatment, which might reduce triglycerides and cholesterol levels in rats induced with urolithiasis, were established. A decline in lipid levels can be crucial to achieve improvement in the general state of renal function and to cease stone recurrence. The results of the study indicate that *P. amboinicus* can be used as a natural medicine for metabolic disorders that play a role in the pathogenesis of kidney stones. The plant extract is bidirectional, and that is the cure for present conditions and prevention of future ones. This makes it a suitable option for those who are prone to developing urolithiasis[32].

5. Larvicidal Activity of *Plectranthus amboinicus*

Mosquitoes have been said to kill millions of people yearly with diseases that could easily spread within both humans and animals. The *P. amboinicus* essential oil is a larvicide, which is useful in the economic and sustainable control of mosquito populations responsible for the spread of malaria. Studies by Senthilkumar and Venkatesalu confirmed the larvicidal activity of *P. amboinicus* essential oil against *A. aegypti* after 12 and 24 hours of exposure, with LC_{50} values of 33.5 and 28.3 ppm, respectively. In the study by Lima *et al.*, the oil was also found to be larvicidal against *A. aegypti*, the vector of dengue and yellow fever, at an LC_{50} value of 58.9 ± 0.4 µg/mL. Further tests after 48 hours established the mortality effect of the oil on Anopheles gambiae. The highest activities against *A. aegypti*, *Anopheles stephensi,* and *Culex quinquefasciatus* were obtained with the leaf extract of *P. amboinicus* in ethyl acetate. Recently, it was reported that zinc oxide nanoparticles synthesised from *P. amboinicus*, Pam-ZnO NPs, are lethal to 100% of *C. quinquefasciatus, A. Stephens,* and *Culex tritaeniorhynchus* larvae, which were in the fourth stage. Histopathological studies of the treated larvae are an alternative as well as environmentally friendly means of pest management against chemical pesticides. This tissue damage has been documented[33-36].

6. Lactogenic Activity of *Plectranthus amboinicus*

For generations, the Batak tribe of North Sumatra has used *P. amboinicus* because of its lactogenic properties that help promote breast milk in new mothers.

The reason it's a popular addition to soups and other dishes in the postpartum period is its nutritional and therapeutic properties. *P. amboinicus* has important

nutrients like potassium, zinc, magnesium, iron, and carotene in abundant quantities and promotes quality breast milk while improving growth and development of infants. Intake of *P. amboinicus* leaves aids in increasing the mineral content in breast milk, thus helping infants grow stronger and have a healthier metabolic system. This proves that the plant is vital to diets among mothers, especially where health care is inaccessible and fits the custom. It manifests the possibility of blending knowledge from the traditional system of medicine with contemporary maternal healthcare strategies, wherein *P. amboinicus* proves to be a valuable herb for the well-being of mothers and newborns[37].

7. Bioactive Compounds and Therapeutic Insights of *Plectranthus amboinicus*

Plectranthus amboinicus is endowed with a wide spectrum of pharmacological activities due to its numerous bioactive phytoconstituents. Leaf essential oils and extracts rich in carvacrol, p-cymene, α-Terpinolene, and β-caryophyllene exhibit significant antibacterial and antifungal properties. Biogenic zinc oxide nanoparticles synthesised from the leaf extract display potent inhibition of multidrug-resistant pathogens such as *Salmonella typhimurium*, *E. coli*, *Mycobacterium tuberculosis*, and Methicillin-resistant *Staphylococcus aureus* (MRSA), vindicating their traditional application against infections[38]. Its antifungal essential oils are also effective against *Aspergillus, Candida, Fusarium, Penicillium*, and *Saccharomyces*[39]. Carvacrol, which is effective in inhibiting the proliferation of HIV, Herpes Simplex Virus type 1(HSV-1), and VSV, is responsible for most of the antiviral activity of the plant[40]. This makes it a natural antiviral treatment. Moreover, as bronchodilators and anti-inflammatory compounds, carvacrol-containing extracts are useful in treating respiratory conditions such as cough, bronchitis, influenza, and asthma[41] (Table 1).

Table 1. Major bioactive constituents of *Plectranthus amboinicus* and their therapeutic applications

Pharmacological Activity	Plant Part Used	Bioactive Compound	Potential Effect	References
Antibacterial activity	Leaf extract/Essential oil/ Decoction	Biogenic zinc oxide nanoparticles	Controls MRSA biofilm growth; inhibits *Escherichia coli*, *Salmonella typhimurium*, and *Mycobacterium tuberculosis*.	38
Antifungal activity	Leaf extract/Essential oil	Carvacrol, p-Cymene, α-Terpinolene, β-caryophyllene	Fungitoxic against *Aspergillus*, *Candida*, *Fusarium*, *Penicillium*, *Saccharomyces*	39
Antiviral activity	Leaf/ Ethanolic extract	Carvacrol	Exhibits antiviral activity against VSV, HSV1 and HIV.	40
Respiratory diseases	Leaf extract/ Decoction/Essential oil	Carvacrol	Used for influenza, cough, asthma, bronchitis; acts as a bronchodilator.	41
Larvicidal potential	Leaf extract/ Essential oil	Biogenic zinc oxide nanoparticles	100% mortality in *Anopheles stephensi*, *Culex quinquefasciatus, Culex tritaeniorhynchus*	34
Oral diseases	Essential oil	Carvacrol	Antagonistic effect with mouthwash.	20
Digestive diseases	Leaf extract/Juice	Carvacrol	Stimulates *Lactobacillus*; relieves constipation; prevents gas formation.	38
Antitumor activity	Leaf extract/ Crude hydro alcoholic	Flavone (Luteolin), flavonols	Inhibits sarcoma and carcinoma tumours; induces apoptosis in A549 cells.	42
Anti-inflammatory activity	Aerial part/ Ethanol, methanol, hexane	Rosmarinic acid, Shimobashiric acid, Thymoquinone	Inhibits DNA binding; reduces paw oedema; boosts IgG, IgM, and lysozyme activity.	17
Skin disease	Leaf extract/Essential oil/ Leaf juice	Thymol, 1, 8-Cineole, β-Pinene, α-pinene, phenolics	Inhibits *Malassezia furfur*; heals cuts, skin allergies, burns.	4
Lactogenic properties	Leaf	Iron and carotene	Increases breast milk production in new mothers.	37
Antiepileptic activity	Leaf, stem, root extracts	Alkaloids, flavonoids, saponins	Effective anticonvulsant and antiepileptic.	43
Antioxidant activity	Leaf extracts/ Essential oil	Carvacrol and Thymol	Inhibits DPPH free radical and hydroxyl radical formation.	44

8. Anti-biofilm and Antimicrobial Activities of *Plectranthus amboinicus*

Methanol and ethyl acetate extracts of *P. amboinicus* have shown potent antibiofilm activity, especially against biofilm-producing pyrogens such as Streptococcus pyogenes, associated with inflammatory diseases such as pharyngitis and infection of the upper respiratory system. These pyrogens produce biofilms that deepen infections and complicate healing by providing a protective zone against antimicrobial agents. At lower concentrations, it was the methanolic extract that gave the best of the three at inhibiting the development of biofilms. The bioactives (phytochemicals) make the pathogens, such as *S. pyogenes*, more susceptible to immune responses and treatment by interfering with the bacterial signalling pathways involved in the formation of biofilms. In light of the growing antibiotic resistance trend, this research points out *P. amboinicus* as a natural drug to be used for treating biofilm-related infections[45].

Besides, the broad-spectrum antimicrobial activity of *P. amboinicus* is attributed to the action of phenolic acids, flavonoids, tannins, and essential oils. Its impact against most bacterial pathogens that cause diseases of the intestine and nasopharynx, such as *S. typhimurium*, *S. aureus*, and *E. coli*, makes it a possible alternative because its antibacterial potential has remarkably approached that of conventional drugs despite the growing concern regarding drug resistance. The plant interferes with the metabolic processes involved in bacterial growth, lyses cells, and breaks down bacterial cell walls. In addition, the capability of the plant to destroy foodborne illness-causing bacteria such as *Bacillus cereus* and *Listeria monocytogenes* contributes to its promise for food preservation. *P. amboinicus* is among the potential candidates for functional foods and nutraceuticals due to its strong antibacterial activity along with the antioxidant compounds like gallic acid, caffeic acid, and rosmarinic acid. The leaves and oil extracts from *P. amboinicus* possess wonderful antifungal activity. They inhibit the growth of fungi by up to 60% in pathogens such as *Aspergillus niger*, *Aspergillus ochraceus*, and *Penicillium* species.

These fungi cause massive danger to stored agricultural produce and result in decreased quality of food, thus bringing about great economic losses.

Fungal infection also produces mycotoxins as poisonous metabolites, with about 25% contribution to the production of worldwide grains and a highly detrimental threat to both human and animal health. Nanoparticles obtained from *P. amboinicus* have manifested strong antifungal ability that offers environmentally friendly pathways to control fungal contamination both in agriculture and food reserves. Its efficacy against problematic fungi such as *A. niger* and *Candida albicans* is validated through the similar antifungal properties of related species such as *Coleus aromaticus*. These results demonstrate how *P. amboinicus* and other related plants can be sustainable alternatives to synthetic antifungal agents, reducing chemical preservatives used in food and agriculture[46].

9. Anti-viral Activity of *Plectranthus amboinicus* (*Karpooravalli*)

Plectranthus amboinicus, *Karpooravalli*, has shown significant antiviral activity against viral infections by vesicular stomatitis virus, herpes simplex virus type 1, and human immunodeficiency virus. The inhibition study shows that this plant is capable of inhibiting these viruses, especially HIV, accounting for the largest number of AIDS (Acquired Immunodeficiency Syndrome) cases around the world. The extracts of *Karpooravalli* may be an excellent candidate for the development of prophylactic drugs against STIs because they have been shown to prevent HIV transmission when applied topically. Given the increasing difficulties presented by the drug-resistant strains and the adverse side effects of traditional antiviral drugs, the special qualities exhibited by *Karpooravalli* make it a good substitute in searching for novel, safe, and effective treatments for STIs, including HIV/AIDS. Moreover, plant-derived antiviral compounds have been of renewed interest because they may also serve as topical microbicides, agents applied topically to stop the spread of sexually transmitted diseases.

10. Plant-derived Antiviral Leads for Drug Discovery.

Plant-derived molecules have thus come into sharp focus with an emerging increase in resistance and demand for safe medications. This is exemplified by ethanolic extracts from *Karpooravalli* that show

significant inhibitory effects against both HSV-1 and Vesicular Stomatitis Virus (VSV) at a minimum inhibitory concentration as low as 0.1 mg/mL. The data emerging on the antiviral properties of various plant-based natural products lead to the belief that these alternatives may be a more reliable and safe source for antiviral drugs rather than synthetic counterparts. Further, with growing data confirming the efficacy of plant-based extracts in treating viral conditions, the prospect of natural substances as auxiliary or potential alternatives to treatments is expected to be developed. Plant-based antiviral microbicides could be more effective in Sexually Transmitted Infection (STI) prevention programs, including HIV. Using plant-derived compounds in the design of antiviral drugs aligns with the international quest for discovering new, non-toxic treatments for chronic viral infections[47].

11. Phytochemicals Fight against COVID-19

Plant-derived compounds have also been recently studied in the context of novel viral threats, such as the COVID-19 virus SARS-CoV-2 (Severe Acute Respiratory Syndrome Coronavirus 2). Five phytochemicals-carvacrol, eugenol, apigenin, luteolin, and rosmarinic acid have been identified in *P. amboinicus* and *Ocimum sanctum*, having potential activity against the virus. This has been made possible with Absorption, Distribution, Metabolism, and Excretion (ADME) analyses and molecular docking. This makes such compounds possible inhibitors of the replication of SARS-CoV-2 by virtue of a high affinity towards binding viral proteins. Eugenol and carvacrol, two compounds commonly found in the essential oils listed above, were found to inhibit viral replication through significant antiviral properties that make them excellent candidates for formulation in antiviral formulations for COVID-19. Although there is a dire need for further experimental proof, these results indicate that traditional plant-based drugs may indeed form a very important basis for some new antiviral drug designs. The two favourable drug-likeness profiles suggest good permeability and good solubility—making them better candidates for clinical drugs in production. Further *in vitro* and *in vivo* studies need to be carried out for proof of safety and efficacy, with the ability to formulate delivery systems effective enough for maximum bioavailability, though computationally promising[48].

12. Conclusion

The plant, Indian borage, *P. amboinicus*, has gained a lot of interest lately due to its multiple applications for treatment. Beyond medical applications, *P. amboinicus* has a lot to promise. It can be applied to address environmental health problems. The bioactive compounds of the plant remain available for therapeutic use, thus ensuring public health and environmental preservation. Further studies were conducted to explore its complete potential, which clearly indicated the importance of *P. amboinicus* in future pharmaceutical development. The plant has great importance because it can link together traditional herbal knowledge with the most modern scientific discoveries and could be used as a possible tool for the creation of natural alternatives to synthetic drugs.

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14. References

1. Sandhya S, Kumar PS, Vinod KR, Banji D, Kumar K. Plants as potent anti diabetic and wound-healing agents - A review. Hygeia J Drugs Med. 2011; 3(1):11-19.
2. Swamy MK, Pokharen N, Dahal S, Anuradha M. Phytochemical and antimicrobial studies of leaf extract of *Euphorbia neriifolia*. J Med Plants Res. 2011; 5(24):5785-5788.
3. Khare RS, Banerjee S, Kundu K. *Coleus aromaticus* Benth - A nutritive medicinal plant of potential therapeutic value. Int J Pharma Bio Sci. 2011; 2(3):B500-B512.
4. Bhatt P, Joseph GS, Negi PS, Varadaraj MC. Chemical composition and nutraceutical potential of Indian borage (*Plectranthus amboinicus*) stem extract. J Chem. 2013; 2013:320329. https://doi.org/10.1155/2013/320329

5. Fu L, Fu Z. *Plectranthus amboinicus* leaf extract-assisted biosynthesis of ZnO nanoparticles and their photocatalytic activity. Ceram Int. 2015; 41(2):2492-2496. https://doi.org/10.1016/j.ceramint.2014.10.069 PMCid: PMC12537310.
6. Tiwari DK, Nagar H, Dwivedi GA, Tripathi RK, Jena J. Evaluation of anti-anxiety activity of *Plectranthus amboinicus* (Lour.) on rats. Asian J Pharm Clin Res. 2012; 5(4):110-113.
7. Castillo-Téllez M, Martínez OS, Miranda-Mandujano E, Galvez GH, López DA, Castillo-Téllez B, Cetina-Quiñones AJ. Solar drying of oregano leaves (*Plectranthus amboinicus*, Lour.): Analysis of experimental performance under a tropical climate. Energy Explor Exploit. 2024; 42(5):1895-1921. https://doi.org/10.1177/01445987241234389
8. Bandeira M, Giovanela M, Roesch-Ely M, Devine DM, da Silva Crespo J. Green synthesis of zinc oxide nanoparticles: A review of the synthesis methodology and mechanism of formation. Sustain Chem Pharm. 2020; 15:100223. https://doi.org/10.1016/j.scp.2020.100223
9. Arumugam G, Swamy MK, Sinniah UR. *Plectranthus amboinicus* (Lour.) Spreng: botanical, phytochemical, pharmacological and nutritional significance. Molecules. 2016; 21(4):369. https://doi.org/10.3390/molecules21040369 PMid:27043511 PMCID: PMC6274163.
10. Muniandy K, Hassan Z, Isa MH. The action of *Coleus aromaticus* as a potential wound healing agent in experimentally induced diabetic mice. Perintis eJournal. 2014; 4(1):1-30.
11. Nikhil K, Yavagal PC. Antibacterial efficacy of *Plectranthus amboinicus* extracts against *Streptococcus mutans*: An in vitro study. Int J Ayurveda Pharma Res. 2015.
12. Vera R, Mondon JM, Pieribattesti JC. Chemical composition of the essential oil and aqueous extract of *Plectranthus amboinicus*. Planta Med. 1993; 59(2):182-183. https://doi.org/10.1055/s-2006-959641 PMid:17230354.
13. Selvakumar P. Studies on the anti-dandruff activity of the essential oil of *Coleus amboinicus* and *Eucalyptus globulus*. Asian Pac J Trop Dis. 2012; 2:S715-S719. https://doi.org/10.1016/S2222-1808(12)60250-3
14. Uawonggul N, Chaveerach A, Thammasirirak S, Arkaravichien T, Chuachan C, Daduang S. Screening of plants acting against *Heterometrus laoticus* scorpion venom activity on fibroblast cell lysis. J Ethnopharmacol. 2006; 103(2):201-207. https://doi.org/10.1016/j.jep.2005.08.003 PMid:16169172.
15. Balasubramani G, Ramkumar R, Krishnaveni N, Sowmiya R, Deepak P, Arul D, Perumal P. GC-MS analysis of bioactive components and synthesis of gold nanoparticle using *Chloroxylon swietenia* DC leaf extract and its larvicidal activity. J Photochem Photobiol B. 2015; 148:1-8. https://doi.org/10.1016/j.jphotobiol.2015.03.016 PMid:25854160.
16. Ashaari NS, Ab Rahim MH, Sabri S, Lai KS, Song AAL, Abdul Rahim R, *et al*. Functional characterization of a new terpene synthase from *Plectranthus amboinicus*. PLoS One. 2020; 15(7):e0235416. https://doi.org/10.1371/journal.pone.0235416 PMid:32614884 PMCID: PMC7332032.
17. Chen YS, Yu HM, Shie JJ, Cheng TJ, Wu CY, Fang JM, Wong CH. Chemical constituents of *Plectranthus amboinicus* and the synthetic analogs possessing anti-inflammatory activity. Bioorg Med Chem. 2014; 22(5):1766-1772. https://doi.org/10.1016/j.bmc.2014.01.009 PMid:24491635.
18. Barbosa MD, Wilairatana P, Leite GM, Delmondes GD, Silva LY, Júnior SC, Dantas LB, Bezerra DS, Beltrão IC, Dias DD, Ribeiro-Filho J. *Plectranthus* species with anti-inflammatory and analgesic potential: A systematic review on ethnobotanical and pharmacological findings. Molecules. 2023; 28(15):5653. https://doi.org/10.3390/molecules28155653 PMid:37570622 PMCID: PMC10419981.
19. Cruz MG, Lopes Júnior ML, Freitas MCC, Freitas ACGA, Santos LS, Corrêa MJC, *et al*. Levantamento etnobotânico de plantas medicinais na comunidade Guajará de Carapajó, Cametá-PA. In: Lopes Junior ML, Cruz MG, editors. Open Science Research VII. Vol. 7. São Paulo: Editora Científica Digital; 2022; 7:1408-1431. https://doi.org/10.37885/221010721
20. Santos FA, Serra CG, Bezerra RJ, Figueredo FG, Matias FF, Menezes IR, Costa JG, Coutinho HD. Antibacterial activity of *Plectranthus amboinicus* Lour. (*Lamiaceae*) essential oil against *Streptococcus mutans*. Eur J Integr Med. 2016; 8(3):293-297. https://doi.org/10.1016/j.eujim.2015.11.021
21. Li BT, Smit EF, Goto Y, Nakagawa K, Udagawa H, Mazières J, Nagasaka M, Bazhenova L, Saltos AN, Felip E, Pacheco JM. Trastuzumab deruxtecan in HER2-mutant non-small-cell lung cancer. N Engl J Med. 2022; 386(3):241-251. https://doi.org/10.1056/NEJMoa2112431 PMid:34534430 PMCID: PMC9066448.
22. Chaft JE, Rimner A, Weder W, Azzoli CG, Kris MG, Cascone T. Evolution of systemic therapy for stages I-III non-metastatic non-small-cell lung cancer. Nat Rev Clin Oncol. 2021; 18(9):547-557. https://doi.org/10.1038/s41571-021-00501-4 PMid:33911215 PMCID: PMC9447511.
23. Manurung K, Sulastri D, Zubir N, Ilyas S. *In silico* anticancer activity and *in vitro* antioxidant of flavonoids in *Plectranthus amboinicus*. Pharmacogn J. 2020; 12:1573-1577. https://doi.org/10.5530/pj.2020.12.215
24. Almalki A, Abutaha N, Al-Doaiss AA, Mohammed AZ, Wadaan MA. Cytotoxicity, *in vivo* toxicity, and chemical composition of the hexane extract of *Plectranthus amboinicus* (Lour.) Spreng. Environ Sci Pollut Res. 2021; 28(35):48141-48153. https://doi.org/10.1007/s11356-021-13796-8 PMid:33899147.
25. Roy S, Hasan I, Guo B. Recent advances in nanoparticle-mediated antibacterial applications. Coord Chem Rev. 2023; 482:215075. https://doi.org/10.1016/j.ccr.2023.215075
26. Norazsida R, Pakeer O, Taher M. The antimalarial properties of essential oils of the leaves of Malaysian

Plectranthus amboinicus (Lour.) Spreng in mice infected with *Plasmodium berghei*. IIUM Med J Malays. 2017; 16(1). https://doi.org/10.31436/imjm.v16i1.359
27. Hole RC, Juvekar AR, Roja G, Eapen S, D'Souza SF. Positive inotropic effect of the leaf extracts of parent and tissue culture plants of *Coleus amboinicus* on an isolated perfused frog heart preparation. Food Chem. 2009; 114(1):139-141. https://doi.org/10.1016/j.foodchem.2008.09.047
28. Manjamalai A, Grace DV. Volatile constituents and antioxidant property of essential oil from *Plectranthus amboinicus* (Lour.). Int J Pharm Biol Sci. 2012; 3:445-458.
29. Bhat P, Hegde G, Hegde GR. Ethnomedicinal practices in different communities of Uttara Kannada district of Karnataka for treatment of wounds. J Ethnopharmacol. 2012; 143(2):501-514. https://doi.org/10.1016/j.jep.2012.07.003 PMid:22820243.
30. Al-Elwany OA, Hemida KA, Abdel-Razek MA, El-Mageed TAA, El-Saadony MT, AbuQamar SF, *et al*. Impact of folic acid in modulating antioxidant activity, osmoprotectants, anatomical responses, and photosynthetic efficiency of *Plectranthus amboinicus* under salinity conditions. Front Plant Sci. 2022; 13:887091. https://doi.org/10.3389/fpls.2022.887091 PMid:35968108 PMCID: PMC9367479.
31. Punet Kumar S, Kumar N. *Plectranthus amboinicus*: A review on its pharmacological and pharmacognostical studies. Am J Physiol. 2020; 10(2):55-62. https://doi.org/10.5455/ajpbp.20190928091007
32. Chiu YJ, Huang TH, Chiu CS, Lu TC, Chen YW, Peng WH, Chen CY. Analgesic and anti-inflammatory activities of the aqueous extract from *Plectranthus amboinicus* (Lour.) Spreng, both *in vitro* and *in vivo*. Evid Based Complement Alternat Med. 2012; 2012:508137. https://doi.org/10.1155/2012/508137 PMid:21915187 PMCID: PMC3170901.
33. Senthilkumar A, Venkatesalu V. Chemical composition and larvicidal activity of the essential oil of *Plectranthus amboinicus* (Lour.) Spreng against *Anopheles stephensi*: A malarial vector mosquito. Parasitol Res. 2010; 107(5):1275-1278. https://doi.org/10.1007/s00436-010-1996-6 PMid:20668876.
34. Baranitharan M, Dhanasekaran S. Mosquitocidal efficacies of medicinal plant *Coleus aromaticus* Benth. (*Lamiaceae*) leaf extracts against *Aedes aegypti* (Linn.) (*Diptera: Culicidae*), the chikungunya vector. Int J Curr Res Chem Pharm Sci. 2014; 1:61-67.
35. Lima MA, Oliveira FD, Gomes GA, Lavor PL, Santiago GM, Nagao-Dias AT, Arriaga AM, Lemos TL, Carvalho MD. Evaluation of larvicidal activity of the essential oils of plant species from Brazil against *Aedes aegypti* (*Diptera: Culicidae*). Afr J Biotechnol. 2011; 10(55):11716-11720.
36. Jayaraman M, Senthilkumar A, Venkatesalu V. Evaluation of some aromatic plant extracts for mosquito larvicidal potential against *Culex quinquefasciatus*, *Aedes aegypti*, and *Anopheles stephensi*. Parasitol Res. 2015; 114(4):1511-1518. https://doi.org/10.1007/s00436-015-4335-0 PMid:25630696.
37. Silitonga M, Ilyas S, Hutahean S, Sipahutar H. Levels of apigenin and immunostimulatory activity of leaf extracts of bangunbangun (*Plectranthus amboinicus* Lour.). Int J Biol. 2015; 7(1):46-53. https://doi.org/10.5539/ijb.v7n1p46
38. Shubha JR, Bhatt P. *Plectranthus amboinicus* leaves stimulate growth of probiotic *Lactobacillus plantarum*: Evidence for ethnobotanical use in diarrhoea. J Ethnopharmacol. 2015; 166:220-227. https://doi.org/10.1016/j.jep.2015.02.055 PMid:25796406.
39. Murthy PS, Ramalakshmi K, Srinivas P. Fungitoxic activity of Indian borage (*Plectranthus amboinicus*) volatiles. Food Chem. 2009; 114(3):1014-1018. https://doi.org/10.1016/j.foodchem.2008.10.064
40. Asiimwe S, Borg-Karlsson AK, Azeem M, Mugisha KM, Namutebi A, Gakunga NJ. Chemical composition and toxicological evaluation of the aqueous leaf extracts of *Plectranthus amboinicus* Lour. Spreng. Int J Pharm Sci Invent. 2014; 3(2):19-27.
41. Cartaxo SL, de Almeida Souza MM, de Albuquerque UP. Medicinal plants with bioprospecting potential used in semi-arid northeastern Brazil. J Ethnopharmacol. 2010; 131(2):326-342. https://doi.org/10.1016/j.jep.2010.07.003 PMid:20621178.
42. Ramalakshmi P, Subramanian N, Saravanan R. Antimicrobial activity of *Coleus amboinicus* on six bacterial strains. Int J Curr Res. 2014; 6(11):9909-9914.
43. Bhattacharjee P, Majumder P. Investigation of phytochemicals and anticonvulsant activity of the plant *Coleus amboinicus* (Lour.). Int J Green Pharm. 2013; 7(3). https://doi.org/10.4103/0973-8258.120223
44. Khanum H, Ramalakshmi K, Srinivas P, Borse BB. Synergistic antioxidant action of oregano, ajowan and borage extracts. Food Nutr Sci. 2011; 2(5):387. https://doi.org/10.4236/fns.2011.25054
45. Chang JM, Cheng CM, Hung LM, Chung YS, Wu RY. Potential use of *Plectranthus amboinicus* in the treatment of rheumatoid arthritis. Evid Based Complement Alternat Med. 2010; 7(1):115-120. https://doi.org/10.1093/ecam/nem168 PMid:18955284 PMCid:PMC2816374.
46. Brandão EM, Brandão PH, Souza IA, Paiva GS, de C Carvalho M, Lacerda CM. Antineoplastic effect of aqueous extract of *Plectranthus amboinicus* in Ehrlich ascites carcinoma. J Cancer. 2013; 4(7):573. https://doi.org/10.7150/jca.6730 PMid:23983822 PMCID: PMC3753532.
47. Vijayakumar S, Vinoj G, Malaikozhundan B, Shanthi S, Vaseeharan B. *Plectranthus amboinicus* leaf extract-mediated synthesis of zinc oxide nanoparticles and its control of methicillin-resistant *Staphylococcus aureus* biofilm and blood-sucking mosquito larvae. Spectrochim Acta A Mol Biomol Spectrosc. 2015; 137:886-891. https://doi.org/10.1016/j.saa.2014.08.064 PMid:25280336.

48. Shakthi MN, Natarajan K, Padmini MR, Jawahar NK. Potential of *Plectranthus amboinicus* and *Ocimum sanctum* phytoconstituents as antiviral agents against SARS-CoV-2: an *in silico* investigation. Int J Pharm Sci Res. 2023; 14:2984-2995.

Author Contribution

YS contributed to the conceptualisation of the study, study methodology, literature review, manuscript drafting, and preparation of the initial manuscript version. SS conceptualised and supervised the research, provided intellectual guidance throughout the study, critically reviewed and edited the manuscript, and approved the final version for publication. Both authors contributed to the interpretation of the findings, critically revised the manuscript for important intellectual content, approved the final manuscript, and accepted accountability for all aspects of the work. All authors have read and agreed to the published version of the manuscript.