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OVERVIEW OF BIOACTIVE COMPOUNDS, BIOLOGICAL PROPERTIES AND THERAPEUTIC EFFECTS OF *PLECTRANTHUS AMBOINICUS*

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Abstract

Plectranthus amboinicus (Lour.) Spreng is a perennial plant belonging to the Lamiaceae family which is found naturally in the tropics and warm regions of Australia, Asia and Africa. This plant has therapeutic properties (antioxidant, anti-inflammatory, antimicrobial, antitumor, antiepileptic and analgesic activities) attributed to its phytochemical compounds (76 volatiles and 30 non-volatile compounds belonging to different classes of phytochemicals such as monoterpenoids, diterpenoids, triterpenoids, sesquiterpenoids, phenolics, flavonoids, esters, alcohols and aldehydes), which are highly valued in the pharmaceutical industry. P. amboinicus is widely used in traditional medicine to treat respiratory, cardiovascular, digestive, urinary and skin conditions such as cold, cough, fever, asthma, constipation, headache and skin diseases. In recent years, due to the increased interest in herbal treatments, numerous research studies have been conducted to document the traditional uses of P. amboinicus and to find new biological effects of this plant. This review provides comprehensive information on the biological properties and bioactive compounds responsible for the therapeutic effects of P. amboinicus.

Key words*: Indian borage, medicinal plant, phytochemicals, biological activities, pharmacological properties.*

INTRODUCTION

According to the World Health Organization, about 80% of people worldwide use traditional herbal medicines to treat various diseases and help maintain health due to their low cost and negligible side effects compared to allopathic medicines (Sandhya et al., 2011; Swamy et al., 2011; Swamy & Sinniah, 2015; Swamy et al., 2015). The widespread use of natural products has led to increased global demand for medicinal plants. Current research aims to explore and exploit new plant species for their medicinal properties (Kumara et al., 2012; Mohanty et al., 2014; Swamy et al., 2015). Several genera of the *Lamiaceae* family, such as *Plectranthus*, contain plant species that have important pharmacological properties. Over 300 species of *Plectranthus* are found naturally in tropical and warm regions of Australia, Asia and Africa (Retief, 2000). More than 85% of the literature on *Plectranthus* refers to the therapeutic value of the species of this genus, followed by its nutritional and horticultural properties attributed to its aromatic nature and ability to produce essential oil (Alasbahi & Melzig, 2010; Grayer et al., 2010). *Plectranthus amboinicus* (Lour.) Spreng is one of the most documented species of the *Plectranthus* genus. *P. amboinicus*, commonly known as Indian borage, is a plant renowned for its medicinal properties and distinct oregano-like aroma and smell (Lukhoba et al., 2006). This plant is widely used both in folk medicine and for culinary purposes. This is mainly due to the high amounts of bioactive compounds in the essential oil of its leaves, such as Carvacrol (Castillo & Gonzalez, 1999), Thymol (Singh et al., 2002), β-Caryophyllene, α-Humulene, γ-Terpinene, p-Cymene, α-Terpineol and β-Selinene (Murthy et al., 2009; Senthilkumar & Venkatesalu, 2010). These

biochemical constituents exhibit several biological activities (antioxidant, anti-inflammatory, antimicrobial, antitumor, antiepileptic and analgesic activities) due to which this plant is widely used in traditional medicine to treat conditions such as cold, cough, fever, asthma, constipation, headache and skin diseases (Bhatt & Negi, 2012; Gonçalves et al., 2012; Arumugam et al., 2016). This review provides comprehensive information on the bioactive compounds, biological properties and therapeutic effects of *P. amboinicus*.

BIOACTIVE COMPOUNDS OF *P. AMBOINICUS*

The specialized literature highlighted the presence in the phytochemical composition of *P. amboinicus* of several volatiles and non-volatile compounds belonging to different classes of phytochemicals.

The essential oil of *P. amboinicus* contains 76 volatile compounds belonging to the classes of monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons and oxygenated sesquiterpenes. The two major compounds of essential oil are Carvacrol and Thymol (Lukhoba et al., 2006; Can Baser, 2008; Roshan et al., 2010; Khare et al., 2011).
P. amboinicus also contains 30 non-volatile compounds belonging to the classes of phenolic acids, flavonoids, monoterpene hydrocarbons, sesquiterpene hydrocarbons, oxygenated monoterpenes and esters (Khare et al., 2011; El-hawary et al., 2012a).
However, the chemical profile varies depending on various factors such as geographical area, climate, harvesting stage of plant material and extraction method (Swamy & Sinniah, 2015).
Tables 1 and 2 show the main volatile and non-volatile compounds of *P. amboinicus*.

Table 1. The main volatile compounds of *P. amboinicus*

Phytochemical class	Compound name	Plant origin	Plant part	References
Monoterpene hydrocarbons	δ-3-Carene	India, Malaysia, Mauritius, Morocco	Leaf	Gurib-Fakim et al. (1995) Mallavarapu et al. (1999) Hassani et al. (2012) Erny Sabrina et al. (2014)
	p-Cymene	Brazil, Cambodia, India, Malaysia, Venezuela	Aerial part, leaf	Mallavarapu et al. (1999) Singh et al. (2002) Koba et al. (2007) Murthy et al. (2009) Velasco et al. (2009) Da Costa et al. (2010) Senthilkumar & Venkatesalu (2010) Joshi et al. (2011) Kweka et al. (2012) Manjamalai & Grace (2012) Erny Sabrina et al. (2014)
	Limonene	India, Mauritius	Leaf	Gurib-Fakim et al. (1995) Mallavarapu et al. (1999)
	β-Myrcene	Cambodia, India, Venezuela	Leaf	Mallavarapu et al. (1999) Koba et al. (2007) Murthy et al. (2009) Velasco et al. (2009) Manjamalai & Grace (2012)
	Ocimene	Morocco	Leaf	Mallavarapu et al. (1999) Hassani et al. (2012)
	α-Phellandrene	India, Comoros, Mauritius, Venezuela	Leaf	Gurib-Fakim et al. (1995) Mallavarapu et al. (1999) Velasco et al. (2009) Hassani et al. (2012)
	β-Phellandrene	India	Leaf	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	α-Pinene	Cambodia, India	Leaf	Mallavarapu et al. (1999) Koba et al. (2007)
	β-Pinene	India	Leaf	Mallavarapu et al. (1999)
	Sabinene	Cambodia, India, Morocco	Leaf	Mallavarapu et al. (1999) Koba et al. (2007) Hassani et al. (2012)
	α-Terpinene	India, Mauritius	Leaf	Gurib-Fakim et al. (1995) Mallavarapu et al. (1999) Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)

Phytochemical class	Compound name	Plant origin	Plant part	References
				Manjamalai & Grace (2012) Tewari et al. (2012)
	γ-Terpinene	Brazil, Cambodia, India, Malaysia, Mauritius	Leaf	Gurib-Fakim et al. (1995) Mallavarapu et al. (1999) Koba et al. (2007) Murthy et al. (2009) Da Costa et al. (2010) Senthilkumar & Venkatesalu (2010) Kweka et al. (2012) Manjamalai & Grace (2012) Erny Sabrina et al. (2014)
	α-Terpinolene	Brazil, Morocco	Leaf	Da Costa et al. (2010) Hassani et al. (2012)
	α-Thujene	Comoros, India, Venezuela	Leaf	Mallavarapu et al. (1999) Velasco et al. (2009) Senthilkumar & Venkatesalu (2010) Hassani et al. (2012) Kweka et al. (2012)
Oxygenated monoterpenes	Camphor	Comoros, Malaysia, Mauritius	Leaf	Gurib-Fakim et al. (1995) Hassani et al. (2012) Erny Sabrina et al. (2014)
	Carvacrol	Cambodia, India, Malaysia, Mauritius, Venezuela	Aerial part, leaf, flower	Gurib-Fakim et al. (1995) Mallavarapu et al. (1999) Singh et al. (2002) Mangathayaru et al. (2005) Murthy et al. (2009) Velasco et al. (2009) Senthilkumar & Venkatesalu (2010) Joshi et al. (2011) Kweka et al. (2012) Manjamalai & Grace (2012) Tewari et al. (2012) Asiimwe et al. (2014) Erny Sabrina et al. (2014)
	Carvone	India	Leaf	Mallavarapu et al. (1999)
	1,8-Cineole	India	Leaf	Mallavarapu et al. (1999) Singh et al. (2002) Knab et al. (2008) Rout et al. (2012)
	Eugenol	Cambodia, India	Leaf	Mallavarapu et al. (1999) Koba et al. (2007) Uma et al. (2011) Tewari et al. (2012)
	Geraniol	Mauritius	Leaf	Gurib-Fakim et al. (1995)
	Linalool	Comoros, Mauritius	Leaf	Gurib-Fakim et al. (1995) Hassani et al. (2012)
	Methyl carvacrol	India	Leaf	Mallavarapu et al. (1999)
	Methyl eugenol	Cambodia	Leaf	Mallavarapu et al. (1999) Koba et al. (2007)
	α-Terpineol	Comoros, India, Venezuela	Leaf	Mallavarapu et al. (1999) Velasco et al. (2009) Hassani et al. (2012)
	Terpinen-4-ol	Brazil, India, Mauritius	Leaf	Gurib-Fakim et al. (1995) Mallavarapu et al. (1999) Singh et al. (2002) Murthy et al. (2009) Da Costa et al. (2010) Hassani et al. (2012) Tewari et al. (2012)
	Thymol	Brazil, Cambodia, India, Venezuela	Aerial part, leaf	Mallavarapu et al. (1999) Singh et al. (2002) Roja et al. (2006) Murthy et al. (2009) Velasco et al. (2009) Da Costa et al. (2010) Senthilkumar & Venkatesalu (2010) Joshi et al. (2011) Uma et al. (2011) Kweka et al. (2012) Manjamalai & Grace (2012) Tewari et al. (2012)
	Thymol methyl ether	Brazil	Leaf	Da Costa et al. (2010)
Sesquiterpene hydrocarbons	α-Amorphene	Cambodia	Leaf	Koba et al. (2007)
	Aromadendrene	Brazil, India	Leaf	Da Costa et al. (2010) Manjamalai & Grace (2012)

Phytochemical class	Compound name	Plant origin	Plant part	References
	trans-α-Bergamotene	Brazil, Comoros, India, Venezuela	Aerial part, leaf, flower	Murthy et al. (2009) Velasco et al. (2009) Da Costa et al. (2010) Joshi et al. (2011) Hassani et al. (2012)
	trans-β-Bergamotene	Cambodia	Leaf	Koba et al. (2007)
	γ-Cadinene	Cambodia	Leaf	Koba et al. (2007)
	δ-Cadinene	Cambodia, India	Leaf	Mallavarapu et al. (1999) Murthy et al. (2009)
	α-Calacorene	India	Aerial part	Joshi et al. (2011)
	cis-Calamenene	Cambodia	Leaf	Koba et al. (2007)
	β-Caryophyllene	Brazil, India, Venezuela	Leaf, flower	Mallavarapu et al. (1999) Murthy et al. (2009) Velasco et al. (2009) Da Costa et al. (2010) Joshi et al. (2011) Hassani et al. (2012) Manjamalai & Grace (2012)
	γ-Caryophyllene	India	Leaf	Mangathayaru et al. (2005)
	α-Copaene	Comoros, India	Leaf	Mallavarapu et al. (1999) Hassani et al. (2012)
	α-Cubebene	India	Aerial part, leaf	Murthy et al. (2009) Joshi et al. (2011)
	(E,Z)-α-Farnesene	France	Leaf	Prudent et al. (1995) Mallavarapu et al. (1999)
	Germacrene D	Cambodia	Leaf	Koba et al. (2007)
	γ-Gurjunene	India	Aerial part	Joshi et al. (2011)
	Humulene	Brazil, Cambodia, India, Morocco, Venezuela	Aerial part, leaf	Roja et al. (2006) Koba et al. (2007) Velasco et al. (2009) Da Costa et al. (2010) Senthilkumar & Venkatesalu (2010) Joshi et al. (2011) Hassani et al. (2012) Kweka et al. (2012)
	α-Muurolene	Cambodia, France, Mauritius	Leaf	Gurib-Fakim et al. (1995) Prudent et al. (1995) Koba et al. (2007)
	Patchoulene	India, Mauritius	Leaf	Gurib-Fakim et al. (1995) Mangathayaru et al. (2005)
	β-Selinene	Comoros, India	Leaf	Senthilkumar & Venkatesalu (2010) Uma et al. (2011) Hassani et al. (2012) Kweka et al. (2012)
	β-Sesquiphellandrene	Cambodia	Leaf	Prudent et al. (1995)
Oxygenated sesquiterpenes	Caryophyllene oxide	Cambodia, India, Venezuela	Aerial part, leaf	Mallavarapu et al. (1999) Koba et al. (2007) Murthy et al. (2009) Velasco et al. (2009) Senthilkumar & Venkatesalu (2010) Joshi et al. (2011) Uma et al. (2011) Kweka et al. (2012) Tewari et al. (2012)
	β-Cedrene epoxide	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	β-Copaen-4-α-ol	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	1-Epi-cubenol	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	β-Eudesmol	India	Leaf	Mallavarapu et al. (1999)
	β-Himachalene oxide	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	Humulene oxide	India	Leaf	Mallavarapu et al. (1999)
	Spathulenol	India	Leaf	Singh et al. (2002) Tewari et al. (2012)
Others (alcohols, aldehydes, esters, fatty acids, phenylpropanoids, terpenes)	1,2-Benzenediol 4-(1,1 dimethylethyl)	India	Leaf	Uma et al. (2011)
	Chavicol	India	Leaf	Rout et al. (2012)
	Methyl chavicol	India	Aerial part	Senthilkumar & Venkatesalu (2010) Joshi et al. (2011) Kweka et al. (2012)
	α-Corocalene	India	Aerial part	Joshi et al. (2011)
	Dihydro carveol	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	Durohydroquinone	India	Leaf	Uma et al. (2011)

Phytochemical class	Compound name	Plant origin	Plant part	References
	1,4 Eicosadiene	India	Leaf	Uma et al. (2011)
	Ethyl Salicylate	India	Leaf	Rout et al. (2012)
	(Z)-1,3-Hexadiene	France	Leaf	Prudent et al. (1995)
	(Z)-3-Hexen-1-ol	France	Leaf	Prudent et al. (1995) Mallavarapu et al. (1999)
	Methyl octanoate	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	1-Octen-3-ol	India, Mauritius, Venezuela	Leaf	Gurib-Fakim et al. (1995) Mallavarapu et al. (1999) Velasco et al. (2009) Tewari et al. (2012)
	Oleic acid	India	Leaf	Uma et al. (2011)
	2-Phenyl ethyl tiglate	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	Phytol	India	Leaf	Uma et al. (2011)
	Squalene	India	Leaf	Uma et al. (2011)
	Tetradecanal	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	India	Leaf	Uma et al. (2011)
	Thymol acetate	India	Leaf	Mallavarapu et al. (1999) Tewari et al. (2012)
	Trans-sabinene hydrate	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)
	Undecanal	India	Aerial part	Senthilkumar & Venkatesalu (2010) Kweka et al. (2012)

Table 2. The main non-volatile compounds of *P. amboinicus*

Phytochemical class	Compound name	Plant origin	Plant part	Extract type	References
Phenolic acids	Caffeic acid	Egypt, India	Leaf, stem, root	Methanol extract	El-hawary et al. (2012a) Bhatt et al. (2013)
	Gallic acid	India	Stem	Methanol extract	Bhatt et al. (2013)
	p-Coumaric acid	Egypt, India	Leaf, stem, root	Methanol extract, ethyl acetate fraction	El-hawary et al. (2012a) Bhatt et al. (2013)
	Rosmarinic acid	Egypt, India, Thailand	Leaf, stem, root	Methanol extract, ethyl acetate fraction	El-hawary et al. (2012a) Bhatt et al. (2013) Chen et al. (2014)
	Salvianolic acid A	Thailand	Aerial part	Water extract	Chen et al. (2014)
	Shimobashiric acid	Thailand	Aerial part	Water extract	Chen et al. (2014)
Flavonoids	Chrysoeriol	Egypt, Philippines	Leaf, stem, root	Chloroform extract, ethyl acetate fraction	Ragasa et al. (1999) El-hawary et al. (2012a)
	Cirsimaritin	Philippines	Leaf	Chloroform extract	Ragasa et al. (1999)
	Eriodictyol	Egypt	Leaf, stem, root	Ethyl acetate fraction	El-hawary et al. (2012a)
	Luteolin	Egypt	Leaf, stem, root	Ethyl acetate fraction	El-hawary et al. (2012a)
	Rutin	India	Stem	Methanol extract	Bhatt et al. (2013)
	Salvigenin	Philippines	Leaf	Chloroform extract	Ragasa et al. (1999)
	Thymoquinone	Thailand	Aerial part	Water extract	Chen et al. (2014)
	Quercetin	Egypt	Leaf, stem, root	Ethyl acetate fraction	El-hawary et al. (2012a) Bhatt et al. (2013)
	5,4'-Dihydroxy-6,7-dimethoxy flavone	Egypt	Leaf, stem, root	Ethyl acetate fraction	El-hawary et al. (2012a)
	5,4'-Dihydroxy-3,7-dimethoxy flavone	Egypt	Leaf, stem, root	Ethyl acetate fraction	El-hawary et al. (2012a)
	5-O-Methyl-luteolin	Egypt	Leaf, stem, root	Ethyl acetate fraction	El-hawary et al. (2012a)
	3,5,7,3',4'-Pentahydroxy flavanone	Egypt	Leaf, stem, root	Ethyl acetate fraction	El-hawary et al. (2012a)
	4',5,7-Trihydroxyflavone (apigenin)	Egypt	Leaf, stem, root	Ethyl acetate fraction	El-hawary et al. (2012a)

BIOLOGICAL PROPERTIES AND THERAPEUTIC EFFECTS OF *P. AMBOINICUS*

In folk medicine, formulations from *P. amboinicus* are used in the treatment of various ailments, such as cough, fever, nasal congestion, headaches, oral diseases, colic, indigestion, hepatopathy, convulsions, epilepsy, gallstones, nephrolithiasis or rheumatism. The fresh leaves are also used to soothe burns or animal and insect bites and to treat skin wounds and inflammation. In addition, due to the high content of minerals (calcium, iron, magnesium, potassium, zinc), this plant can be consumed as food to maintain health or in combination with probiotic

products to restore normal intestinal microflora (Arumugam et al., 2016).

The long-term use of *P. amboinicus* in naturopathic medicine in many countries of the world is demonstrated by numerous scientific studies reporting strong antimicrobial, antioxidant, anti-inflammatory, antitumor, analgesic, larvicidal, antileishmanial, anthelmintic, wound healing, lactogenic, antiepileptic and anticonvulsant properties of this plant species. It has also been found that the essential oil from this plant can be used as a natural repellent or agent to control mosquito populations (Arumugam et al., 2016).

However, due to the high variability of its chemical composition, further research on the biological activities and potential pharmacological applications of this species is needed (Arumugam et al., 2016).

Table 3 shows in detail the biological properties and therapeutic effects of *P. amboinicus*.

Table 3. Biological properties and therapeutic effects of *P. amboinicus*

Biological properties	Plant part / Extract type	Therapeutic effects	References
Antibacterial properties	Leaf extract / Decoction / Essential oil	Antibacterial properties against *Bacillus cereus, B. subtilis, Enterococcus faecalis, E. faecium, Escherichia coli, Klebsiella pneumoniae, Lactobacillus, Mycobacterium tuberculosis*, *Proteus mirabilis, Pseudomonas aeruginosa, Salmonella typhimurium, Shigella bayedir, Staphylococcus aureus, Streptococcus mutans, Vibrio cholerae* and *Yersinia enterocolitica*	Frame et al. (1998) Akagawa et al. (2003) Oliveira et al. (2007) Vermelho et al. (2007) Bhatt & Negi (2012) Bhatt et al. (2013) Majee et al. (2013) Oliveira et al. (2013) Muniandy et al. (2014) Aguiar et al. (2015) Shubha & Bhatt (2015) Vijayakumar et al. (2015) Manojkanna et al. (2017) Sireesha et al. (2017) Ismayil & Nimila (2019) Manojkanna et al. (2019) Sreelakshmy & Thangapandiyan (2019) Jena et al. (2023)
Antifungal properties	Leaf extract / Essential oil	Fungitoxic properties against *Aspergillus flavus*, *A. niger*, *A. ochraceus*, *A. oryzae*, *Candida albicans*, *C. krusei, C. parapsilosis, C. stellatoidea, C. tropicalis*, *C. versatilis*, *Fusarium* sp., *Penicillium* sp. and *Saccharomyces cerevisiae*	Oliveira et al. (2007) Murthy et al. (2009) El-hawary et al. (2012b) Manjamalai et al. (2012) Majee et al. (2013) EL-Zefzafy et al. (2016) Manojkanna et al. (2017) Sivaranjani et al. (2019)
Antiviral properties	Ethanolic leaf extract	Antiviral properties against human immunodeficiency virus (HIV), herpes simplex virus type 1 (HSV-1) and vesicular stomatitis virus (VSV)	Hattori et al. (1995) Kusumoto et al. (1995) Ali et al. (1996) Asiimwe et al. (2014)
Antioxidant properties	Aqueous, ethanolic, methanolic, acetone and ethyl acetate leaf extract / Essential oil	Significant inhibition of DPPH free radical and hydroxyl radical formation; high nitric oxide scavenging, superoxide scavenging and ferrous ion chelating capacity	Kumaran & Karunakaran (2006) Khanum et al. (2011) Bhatt & Negi (2012) Manjamalai & Grace (2012) Gurning (2020) Terto et al. (2020) Puspitarini et al. (2023)
Anti-inflammatory properties	Aqueous, ethanolic, methanolic and hexanoic extract from the aerial part	Inhibitory effect on DNA binding activities; inhibitory activities on activator protein 1 (AP-1) and tumor necrosis factor alpha (TNF-α); positive effect on carrageenan-induced paw edema; increased IgG and IgM levels and lysozyme activity in rats	Gurgel et al. (2009) Chiu et al. (2012) Manjamalai & Grace (2012) Chen et al. (2014) Silitonga et al. (2015) Puspitarini et al. (2023)
Antitumor properties	Ethanolic, hexanoic and ethyl acetate leaf extract / Crude hydroalcoholic extract / Essential oil	Cytotoxic activity against Sarcoma 180 cell line (S-180), cervical adenocarcinoma cells (HeLa), breast cancer cell lines (MCF-7, MDA-MB-231, T-47D), colorectal cancer cell lines (HT-29, HCT-116), human lung cancer cell line (A549), oral cancer cell line (KB), Vero cells lines and Ehrlich ascites carcinoma tumors in mice	Gurgel et al. (2009) Hasibuan et al. (2013) Ramalakshmi et al. (2014) Rosidah & Hasibuan (2014) Hasibuan & Rosidah (2015) Hasibuan et al. (2015) Thirugnanasampandan et al. (2015) Hasibuan & Sumaiyah (2019) Caroline et al. (2023) Gupta et al. (2024) Mujamammi et al. (2024)
Analgesic properties	Aqueous,	Soothing effect on headaches, backaches and	Chiu et al. (2012)

Biological properties	Plant part / Extract type	Therapeutic effects	References
	alcoholic and ethyl acetate leaf extract	musculoskeletal conditions such as neck and back pain	El-hawary et al. (2012b) Majee et al. (2013) Chen et al. (2014)
Larvicidal, antileishmanial and anthelmintic properties	Ethyl acetate leaf extract / Alcoholic extracts of leaves, stems and roots / Essential oil	Larvicidal properties against *Aedes aegypti* (the main vector of dengue, yellow fever and dengue haemorrhagic fever), *Anopheles stephensi* (malaria vector mosquitoes), *Anopheles gambiae, Culex quinquefasciatus* and *Culex tritaeniorhynchus*; antileishmanial activity against *Leishmania braziliensis*; anthelmintic activity against the intestinal parasite *Pheritima posthuman*	Senthilkumar & Venkatesalu (2010) Lima et al. (2011) Prasenjit et al. (2011) Verma et al. (2012) Baranitharan & Dhanasekaran (2014) Lima et al. (2014) Jayaraman et al. (2015) Vijayakumar et al. (2015) Gonçalves (2017)
Wound healing properties	Aqueous and ethanolic extract of leaves and roots / Leaf and root paste	Preventing or reducing the risk of wound infection and stimulating wound healing in diabetic mice by increasing collagen deposition and reducing wound epithelialization time; good wound healing properties of *P. amboinicus* and *Punica granatum* suspension	Warriner & Burrell (2005) Sunitha et al. (2010) Soni et al. (2011) Jain et al. (2012) Muniandy et al. (2014)
Lactogenic properties	Leaves	Increase in breast milk production in new mothers due to the high content of nutrients in the leaves, especially carotene and iron; increasing the mineral content of milk (iron, magnesium, potassium and zinc)	Silitonga et al. (2015)
Antiepileptic and anticonvulsant properties	Aqueous and alcoholic extract of leaves, stems and roots	Antiepileptic and anticonvulsant effects in the treatment of nervous disorders, including epilepsy and convulsions	Jain & Lata (1996) Castillo & Gonzalez (1999) Bhattacharjee & Majumder (2013)
Biological properties against respiratory diseases	Leaf extract / Decoction / Juice / Essential oil	Expectorant and bronchodilator properties in the treatment of flu, cough, bronchitis, asthma and sore throat, properties attributed mainly to the compounds carvacrol and thymol in the essential oil of the plant	Jain & Lata (1996) Castillo & Gonzalez (1999) Singh et al. (2002) Cano & Volpato (2004) Cartaxo et al. (2010)
Biological properties against digestive diseases	Leaf extract / Juice	Stimulating effect on the growth of *Lactobacillus plantarum*; inhibitory effect on the growth of *Escherichia coli*, *Salmonella typhimurium, Shigella* sp. and *Vibrio* sp.; prevents the formation of gases in the gastrointestinal tract and facilitates the elimination of gases; positive effect in treating diarrhea, constipation, dyspepsia and indigestion	Gurib-Fakim et al. (1995) Jain & Lata (1996) Ong & Nordiana (1999) Hassani et al. (2012) Shubha & Bhatt (2015) Sivaranjani et al. (2019) Leesombun et al. (2023)
Biological properties against cardiovascular diseases	Aqueous leaf extract	Positive inotropic activity in isolated frog heart; positive effect in the treatment of congestive heart failure	Hole et al. (2009)
Biological properties against genitourinary diseases	Aqueous, ethanolic and ethyl acetate leaf extract / Leaf decoction / Juice	Effective in treating urinary and kidney disorders and vaginal discharges; increased urine volume and the electrolyte concentration (Na, K and Cl ions) in male albino rats; dissolving crystals in the urinary tract; uric acid reducing activity; good results in cisplatin-induced nephropathies, increasing the expression of TGF-1β (transforming growth factor-1β) and thus inhibiting renal necrosis and cellular infiltration	Yoganarasimhan (2000) Jose & Janardhanan (2005) Palani et al. (2010) Patel et al. (2010) El-hawary et al. (2012b) Amarasiri et al. (2018) Sahrial & Solfaine (2019) Wang et al. (2023)
Biological properties against oral diseases	Essential oil	Antibacterial effect alone or combined with mouthwash, modulating the activity of the mouthwash against *Streptococcus mutans*, the main bacteria responsible for dental caries	Santos et al. (2016)
Biological properties against skin diseases	Leaf extract / Leaf juice / Paste / Ethanolic root extract ointment / Essential oil	Anti-dandruff effect due to the inhibitory activity on the development of dandruff-producing fungus *Malassezia furfur*; antiseptic properties on cuts; antipsoriasis effect; positive effect in the treatment of skin ulcerations caused by *Leishmania braziliensis*, skin allergies and skin burns acting as an antiseptic and promoting healing	França et al. (1996) Jain & Lata (1996) Harsha et al. (2003) Bhat et al. (2012) Selvakumar et al. (2012) Vijayalakshmi et al. (2019)
Biological properties against animal and insect bites	Leaves / Aqueous leaf extract	Effective as a poultice for scorpion and centipede bites and as an antidote for scorpion venom (*Heterometrus laoticus*)	Jain & Lata (1996) Uawonggul et al. (2006)
Biological properties against other diseases	Aqueous, ethanolic and acetonic leaf extract	Effective in treating infectious diseases such as fever, cholera and meningitis, and sensory disorders associated with eye and ear problems such as conjunctivitis and acute edematous otitis; hepatoprotective effect; photoprotective activity; antidiabetic activity by inhibiting alpha-amylase	Neuwinger (2000) Harsha et al. (2002) Patel (2011) Bole & Kumudini (2014) Terto et al. (2020) Silitonga et al. (2023)

CONCLUSIONS

P. amboinicus is a valuable aromatic medicinal plant rich in bioactive constituents with a wide range of biological properties. This plant is effective in treating cardiovascular, respiratory, skin, oral, urinary and digestive diseases. The important therapeutic effects of *P. amboinicus* confirm the possibility of its use in more cost-effective and safer natural drug formulations than allopathic drugs. However, future investigations should aim to isolate and identify new bioactive compounds from *P. amboinicus* and test their effectiveness in treating other human diseases. Further research is also needed on the toxicity of these isolated compounds and human safety aspects regarding the use of this plant. Therapeutic applications of *P. amboinicus* may also extend its use as a functional nutraceutical food.

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