REVIEW ARTICLE

Phytochemistry, Pharmacology and Ethnobotany of *Alpinia malaccensis* (Burm F.) Roscoe and *Alpinia galanga* (L.). Wild. (Zingiberaceae): A Review

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Abstract

From ancient times onwards, medicinal plants have always been used to treat various health issues. Zingiberaceae consists of a number of medicinally important plants and these are used in various pharmaceutical formulations. *Alpinia galanga* (L.) Willd. and *A. malaccensis* (Burm f.) Roscoe belongs to the family Zingiberaceae. Extensive studies are going on to explore the pharmacological and economic importance of these species. The studies revealed many pharmaceutical properties of the species *A. galanga* and *A. malaccensis*. Both species have been used as a traditional medicine from earlier times onwards. *A. malaccensis* is used to cure nausea, vomiting and certain wounds. *A. galanga* is used for the treatment of rheumatism and respiratory diseases. Both species were reported to exhibit antibacterial, anti-cancerous, anti-inflammatory, antioxidant and antidiabetic activities. The taxa have potentially active compounds that mainly belong to the group terpenoids. Today's world is in search of plant-derived medicines and both species can be prudently utilized for the purpose. This review focuses on the studies carried on the phytochemical and pharmacological activities of *A. galanga* and *A. malaccensis*.

Keywords: *Alpinia galanga*, *Alpinia malaccensis*, Phytochemistry, Ethnobotany, Pharmacology, Zingiberaceae.

Highlights

- Ethnobotanical significance of *Alpinia galanga* and *A. malaccensis*
- Summary on the phytochemical analysis of various extracts of *A. galanga* and *A. malaccensis*
- Review on the various biological activities of both species

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Introduction

The scientific community is always in search of plants that can be used as a source of medicine. The evidence of plants used in medicine was reported from a 5000-year-old clay slab from Nagpur (Petrovska, 2012). Plants contain various secondary metabolites and this contributes to their significant therapeutic value (Rao *et al.,* 2010). Synthetic compounds used in various products such as pesticides, antioxidants, food preservatives possess health issues (Sethi *et al.,*2016), short-term effects like headache, nausea and long-term effects like cancer, infertility, etc. So, people are keen on using plant-derived compounds in pharmaceuticals, cosmetics, food preservatives and textiles.

Alpinia Roxb.is the largest, most widespread, and taxonomically complex genus of the family Zingiberaceae. It consists of 230 species that are occurring throughout tropical and subtropical regions of Asia, Australia, the Pacific region, Indonesian island groups, Andamans and the Caroline Islands (Smith, 1990; Kress *et al.,* 2005). According to the Plants of the World database (POWO, 2024), there are 246 accepted species names under the genus *Alpinia* worldwide. The plant comprises of rhizome, simple wide leaves, attractive bracts and terminal inflorescence. Plants belonging to the genus *Alpinia* are aromatic in nature as they produce essential oil and have substantial medicinal uses (Samarasinghe *et al.,* 2020). *A. officinarum*. Hence, mainly found in China and used to relieve headaches and reduce swelling and cold (Dixit *et al.,* 2012). The seeds of *A. zerumbet* (Pers.) Burtt. *et al.* Smith is used by the Miao ethnic group in Guizhou Province, China, as folk medicine and as a dietary supplement in Japan (Xiao *et al.,*2020). *A. calcarata* Roscoe is *widely cultivated in Sri Lanka, India and Bangladesh and used for cough, respiratory ailments, colds, swellings, and stomachache* (Rahman and Islam, 2015).

Alpinia galanga (L.) Willd. is commonly known as Greater Galanga. It is now widely cultivated in countries such as the Philippines, Indonesia, Thailand, India, Malaysia, Egypt and China (Lo *et al.,* 2013; Gupta *et al.,* 2014). They are perennial herbs with aromatic rhizomes. Leaves are oblong, lanceolate, acute and glabrous. The flowers are greenish-white in color. Calyx is tubular, irregularly 3-toothed. Corolla lobes are oblong, greenish claws and the blade is white and striated with red. Fruits are red and orange in color (Baldo and Serrano, 2016). *A galanga* is aromatic and contains essential oil which has active phytocompounds (Mallavarapu *et al.,* 2002).

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Alpinia malaccensis (Burm f.) Roscoe is distributed over India, Myanmar, Thailand, Peninsular Malaysia, China and Bangladesh. Commonly called Malacca Ginger, Malacca Galangal and Rieng Malacca (Lim, 2016). *A. malaccensis* often grows to a height of 4 m (Muchtaridi *et al.,* 2014; Huong *et al.,* 2015). It has long, lush green aromatic leaves and is bifarious and long petioled. During November and December, the flowers emerge above the leaves enclosed in a conical sheath, which splits to reveal a sumptuous cluster of fat pink and white buds (Mangaly and Sabu, 1992; Bhuiyan *et al.,* 2010).

The phytocompounds of both *Alpinia* species and their pharmacological aspects are well-studied and known. It is observed that the species exhibit antimicrobial and, anti-inflammatory, antioxidant activities and these activities are mainly due to the presence of phytocompounds in them. The updated review on two economically and medicinally important species will be helpful to the scientific community for further research.

Methodology

The literature for this review paper was collected from different electronic sources such as Google and, PubMed and INFLIBNET. Highly reliable updated literature was collected. The search terms used were: *Alpinia galanga*, *A. malaccensis*, phytochemistry, pharmacology, ethnobotany, traditional and medicinal uses**.**

Traditional Uses of *Alpinia galanga* and *A. malaccensis*

Different organs of plants were used in traditional medicine, cosmetics and cooking. *A. malaccensis* is an underutilized perennial plant growing widely in tropical regions of Asia, including Indo-China, Bangladesh, and Sri Lanka (Raj *et al.,* 2013). The rhizome of *A. malaccensis* is used as a traditional medicine to cure nausea, vomiting and certain wounds and also as a seasoning ingredient in processed meat (Bhuiyan *et al.,* 2010). For abdominal pain, the extract of fresh rhizome of *A. malaccensis* in boiled water is used. In Ambon, a city in Indonesia, the *A. malaccensis* rhizome is used to treat colic, ulcers and sores. Namo Rambe, Deli Serdang and North Sumatera Province community use *A. malaccensis* for treating abdominal pain (Sitorus and Satria, 2016). In Java, an Island in Indonesia, the rhizome of the *A. malaccensis* is used in traditional medicine as an antiemetic or seasoning for meat processing. Rhizome oil is used for nourishing hair and as massage oil. Fragrant essential oil of rhizome is used as a cosmetic (Muchtaridi*et al.,*2014). For a clear and strong voice, the rhizome is chewed along with the betel and also for bathing feverish people (Sahoo *et al.,*2014).

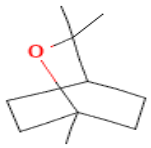
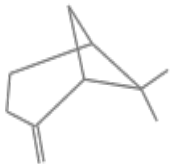
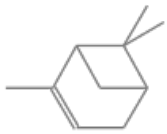
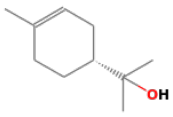
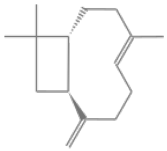
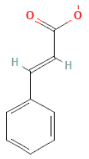
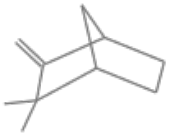
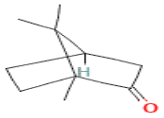
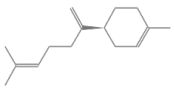
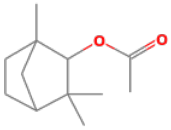
Alpinia galanga has been used in traditional medicine, especially in Thai, Ayurveda, Unani and Chinese folk medicine (Gupta *et al.,* 2014). It is used as an essential spice and food flavouring product as well as medicine among Asian folks. Used against rheumatism, treatment of respiratory diseases, bronchial catarrh, bad breath and ulcers, whooping colds in children, throat infections and fever (Jirovetz *et al.,* 2002; Rao *et al.,*2010). *A. galanga* is used in cooking and commonly used in stir-fries, curries and soups (Kress *et al.,*2005; Juntachote and Berghofer, 2005). Rhizomes are used as a spice in meat dishes and decoction of leaves to treat diarrhea and are consumed by women during illness and confinement (Oonmetta-aree *et al.,* 2006; Chan *et al.,* 2007). *A. galanga* has been used as medicine for curing stomach aches in China, and for carminative, anti-flatulent, antifungal, and anti-itching in Thailand. Due to the aromaticity and slightly sour and peppery notes, the rhizome is used as an essential component in Thai curry paste and other Asian foods (Matsuda *et al.,* 2003; Juntachote and Berghofer 2005; Oonmetta-aree *et al.,*2006; Prakatthagomol *et al.,* 2012). *A. galanga* fruits are known as antiemetic drugs and oral refreshment agents (Muchtaridi *et al.,* 2014). The fragrant and short-lived green and white, red-tipped galangal flowers are often eaten raw or used in pickles (Tang *et al.,* 2018).

Phytochemical Profile of *A. galanga* and *A. malaccensis*

Phytochemicals are non-nutrient chemical constituents isolated from plants. These chemicals play an important role in defense, pollination, reproduction, growth and signaling in plants. Phytocompounds in plant species are responsible for all the pharmacological activities (Harborne, 1998; Unnisa and Parveen, 2011). The phytochemistry of both species was extensively studied. The presence of alkaloids, flavonoids, glycosides, saponins, steroids, carbohydrates, tannin and glycosides are reported in the preliminary analysis of rhizome and leaves extract of *A. malaccensis* (Sahoo *et al.,* 2012; Sitorus and Satria, 2016; Reza *et al.,* 2021). Preliminary phytochemical analysis of *A. galanga* extracts reported the presence of carbohydrates, amino acids, alkaloids, terpenoids, flavonoids and phenols (Unnisa and Parveen, 2011; Verma *et al.,* 2015; Rani *et al.,* 2016).

Phytoconstituents of *A. malaccensis* and *A. galanga* from different countries have been reported. The essential oil and the extracts of plants are studied and confirmed the presence of various compounds by GC-MS analysis. The structure, molecular weight and molecular formula of the major compounds identified in the various extracts of *A. galanga* and *A. malaccensis* have been given in Table 1. The major compounds of *A. galanga* leaves essential oil are 1,8- cineole, β-pinene, α-pinene, camphor, camphene (Jirovetz *et al*., 2002; Raina *et al*., 2002; Mallavarapu *et al*., 2002; Menon, 2006). Rhizome essential oil contains 1,8- cineole, α-fenchyl acetate, E-methyl cinnamate, camphor, camphene, α-terpineol as the prominent compounds in GC-MS analysis (Raina *et al.,*2002; Mallavarapu *et al*., 2002; Jantan *et al.,* 2004; Menon, 2006; Arambewela *et al.,* 2007; Wu *et al.,* 2014). In a study by Jantan*et al*., (2004), the seed oil of *A. galanga* was analyzed and reported the presence of β-bisabolene, (E)-β-farnesene, (E,E)-farnesyl acetate, (Z,E)-farnesol, β-caryophyllene (Jantan *et al.,*2004). Methanolic extract of *A. galanga* rhizome and leaf mainly consists of 1,8-cineole, β-caryophyllene, β-bisabolene, Carotol, 5-hydroxymethylfurfuraland Benzenepropanal, 3-phenyl-2-butanone respectively (Mayachiew and Devahastin, 2008; Singh *et al.,* 2020). Studies are being conducted on *A. galanga* to isolate phytocompounds. For instance, Sharma *et al.,*(2021) isolated two phytometabolites, 3-methyl-6α,8βdihydroxy-7-carboxylic acid tetralin-1,9β-olide and benzyl myristate, from the methanolic extract of *A. galanga* rhizome (Sharma *et al.,* 2021). Alpigalanol a new monoterpene, had been separated from the ethyl acetate

Table 1: Structure, molecular weight and molecular formula of major compounds

S. No.	Compound	Molecular weight	Molecular formula	Structure
1	1,8-cineole	154.25	$C_{10}H_{18}O$	
2	β-pinene	136.23	$C_{10}H_{16}$	
3	α-pinene	136.23	$C_{10}H_{16}$	
4	α-terpineol	154.24	$C_{10}H_{18}O$	
5	β-caryophyllene	204.35	$C_{15}H_{24}$	
6	(E)-methyl cinnamate	162.18	$C_{10}H_{10}O_2$	
7	Camphene	136.23	$C_{10}H_{16}$	
8	Camphor	152.23	$C_{10}H_{16}O$	
9	Fenchol	154.24	$C_{10}H_{18}O$	
10	β-bisabolene	204.35	$C_{15}H_{24}$	
11	Fenchyl acetate	196.28	$C_{12}H_{20}O_2$	

fraction of *A. galanga,* which exhibited Vpr inhibitory activity (Nam Hoang *et al.,* 2021).

The essential oil of *A. malaccensis* rhizome was studied and the major compounds found to be E-methyl cinnamate, eucalyptol, phellandrene, camphor, camphene, α-fenchyl acetate (Raj *et al.,* 2013; Sethi *et al.,*2017; Vejayan *et al.,*2017). The leaves oil contains β-pinene, 1,8-cineole, camphor, α-pinene, methyl- E -cinnamate, and α-terpineol as the major compounds (Sahoo *et al.,* 2012; Huong *et al.,* 2015; Sethi *et al,.* 2016; Jusoh *et al.,* 2020). Huong *et al.,* (2015) reported methyl cinnamate (27.8%), β-pinene (18.5%) and β-phellandrene (12.9%) as the major compounds in the fruit oil of *A. malaccensis*. The ethanolic extract of *A. malaccensis* rhizome is mainly comprised of trans-beta-farnesene, farnesol, acetate and hexadecanoic acid (Somarathna *et al.,*2018). The phytoconstituents identified from *A. galanga* and *A. malaccensis* are mentioned in the Table 2.

When analyzing the compounds present in the essential oil and the extracts, the composition of the compounds varies considerably in different places. Differences in the compounds and their composition may be most likely due to its geographical location and population variations in the samples studied (Vejayan *et al.,* 2017; Zhou *et al.,* 2021). The compositional variations between the same plant parts may be attributed to differences in the ecological and climatic conditions as well as the age and nature of the plant, chemotype and handling procedure (Huong *et al.,* 2015).

Pharmacology

Anticancer

Cancer is a deadly disease and every year, millions of people lose their lives to cancer. In 2020, 19.3 million new cases of cancer were reported worldwide, with 10.0 million deaths (Sung *et al.,* 2021). Medical fields are in continuous search for a better treatment for cancer. But development of resistance to the chemotherapeutic agent and side effects are serious obstacles to this mission. Natural compounds with fewer side effects are of concern for the treatment of cancer (Samarghandian *et al.,* 2014; Suhendi *et al.,* 2017; El-Hadidy *et al.,* 2020). The cytotoxic effect of the Galanga ethanolic extract on metastatic cancer cells (4T1) is studied along with their effect on normal fibroblast cells (NIH-3T3). The study explained that ethanolic extract exhibited potential cytotoxicity towards 4T1 cells but less to the normal NIH-3T3 cells. Along with a chemotherapeutic agent, the extract behaves differently in normal and cancer cells. Ethanol extract of *A. galanga* enhances the chemotherapeutic agent (Doxorubicin) to increase the ROS level in cancer cells, but this effect was not observed in the normal cells. So, the extract can be used as a co-chemotherapeutic agent and also as an anti-ageing agent (Faradiba Nur *et al.,* 2020).

1,7-bis (4-hydroxyphenyl)-1,4,6-heptatrien-3-one (BHPHTO) and bisdemethoxycurcumin (BDMC), two compounds from ethanolic extract of *A. galanga* rhizome, exhibited antiproliferation of human melanoma A2058 cells (Lo *et al.,* 2013). *A. galanga* rhizome ethanolic extract showed significant growth inhibitory activity against HEPG2-H (hepatic cancer), MCF7 and T47D (breast cancer), HCT (blood cancer), WiDr (colon cancer), HeLa (cervical cancer) cancer cell lines (Samarghandian *et al.,*2014; Suhendi *et al.,*2017; Da'i *et al.,* 2019; El-Hadidy *et al.,* 2020). The antiproliferative activity of the *A. galanga* aqueous

Table 2: Phytoconstituents identified in *A. galanga* and *A. malaccensis*

Sl. No.	*Species*	*Plant organs*	*Extraction method*	*Phytocompounds*	*Collection area*	*Reference*
1	*A. galanga*	Rhizome	Hydrodistillation (Essential oil)	1,8-cineole, fenchyl acetate, camphor, camphene, (E)-methyl cinnamate, β-pinene, α-pinene, α-terpineol, zerumbone, eugenol	Srilanka Malayasia India India India Thailand India China	(Jirovetz *et al.,* 2002; Raina *et al.,* 2002; Mallavarapu *et al*., 2002; Jantan *et al.,* 2004; Menon, 2006; Arambewela*et al.,* 2007; Pripdeevech *et al.,* 2009; Wu *et al.,* 2014)
2	*A. galanga*	Leaf	Hydrodistillation (Essential oil)	1,8-cineole, β-pinene α-terpineol α-pinene, camphene, camphor, fenchyl acetate	India India India India	(Jirovetz *et al.,* 2002; Raina *et al.,* 2002; Mallavarapu *et al.,* 2002; Menon, 2006)
3	*A. galanga*	Stem	Hydrodistillation (Essential oil)	1,8-cineole, camphor, (E)-methyl cinnamate, guaiol, bornyl acetate, β-pinene α-terpineol, cubenol, humulene, germacrene-D	India	(Jirovetz et al., 2002)
4	*A. galanga*	Root	Hydrodistillation (Essential oil)	Fenchol, cubenol, nerolidyl acetate, α-Fenchyl acetate, 1,8-cineole, borneol, bornyl acetate and elemol	India	(Menon, 2006)
5	*A. galanga*	Rhizome	Soaking Soxhlet extraction (Methanolic extract)	1,8-cineole, β-caryophyllene, β-bisabolene β-selinene, Carotol, 5 hydroxymethylfurfural, fenchyl acetate, α-terpineol	Thailand India	(Mayachiew and Devahastin, 2008; Singh *et al.,* 2020)
6	*A. galanga*	Leaves	Soxhlet extraction (Methanolic extract)	Benzenepropanal, 3-phenyl-2-butanone	India	(Singh *et al.,* 2020)
6	*A. galanga*	Seed oil	Hydrodistillation (Essential oil)	β-bisabolene, (E)-β-farnesene, (E,E)-farnesyl acetate, (Z,E)-farnesol, β-caryophyllene	Malaysia	(Jantan *et al*., 2004)
7	*A. malaccensis*	Pseudo-stem	Hydrodistillation (Essential oil)	1,8-cineole, β-pinene, α-pinene, trans-caryophyllene, phellandrene	Vietnam Malaysia	(Huong *et al*., 2015; Jusoh *et al*., 2020)
8	*A. malaccensis*	Root	Hydrodistillation (Essential oil)	β-pinene, β- phellandrene, α-pinene, α-selina-6-en-4-ol	Vietnam	(Huong *et al*., 2015)
9	*A. malaccensis*	Fruit	Hydrodistillation (Essential oil)	Methyl cinnamate, β-pinene and β-phellandrene	Vietnam	(Huong *et al.,* 2015)
10	*A. malaccensis*	Rhizome	Hydrodistillation (Essential oil)	Phellandrene, methyl -(E) -cinnamate, β-pinene camphene, cymene, camphor, terpineol, 1,8-cineole, linalool	Bangladesh Thailand India India Malaysia	(Pripdeevech *et al.,* 2009; Bhuiyan *et al.,* 2010; Sirat *et al.,* 2011; Raj *et al.,* 2013; Sethi *et al*., 2017; Vejayan *et al.,* 2017)
13	*A. malaccensis*	Leaves	Hydrodistillation (Essential oil)	β-pinene, α-pinene, camphor, eucalyptol, methyl (E)-cinnamate, 1,8-cineole, α-phellandrene,	Vietnam Malaysia India India	(Sahoo *et al.,* 2014; Huong *et al*., 2015; Sethi *et al.,* 2016; Jusoh *et al.,* 2020)
14	*A. malaccensis*	Rhizome	Rotary shaking (Ethanolicextract)	Trans-beta-farnesene, Farnesol, acetate, Hexadecanoic acid, 1,4,7,10,13-Pentaoxacyclopentadecane	Srilanka	(Somarathna *et al.,* 2018)
15	*A. malaccensis*	Flower	Hydrodistillation (Essential oil)	Terpinen-4-ol, α-terpineol, E-methyl-cinnamate, α-caryophyllene oxide, octadecane, docosane	India	(Sethi *et al.,* 2022)

extract against human gastric adenocarcinoma epithelial cell line (AGS) cells from human gastric carcinoma has been studied. The extract showed potential antiproliferative activity with increasing concentration. The aqueous extract significantly inhibited the proliferation of AGS cells with a concentration higher than 500 µg/mL (Hadjzadeh *et al.,*2014). A compound chrysin isolated from petroleum ether and ethyl acetate mixture of *A. galanga* showed time and dose-dependent cytotoxicity towards murine Daltons lymphoma ascite (DLA) and human lung cancer (A549) cells (Lakshmi *et al.,* 2019).

Antimicrobial

Conventional chemical and synthetic antimicrobial agents possess several side effects and allergies that are harmful to humans. Also, the microbes became resistant to the long-used antimicrobial agents. So, all are seeking potential alternatives to these agents from natural sources. Several authors have analyzed the antimicrobial activity of both *A. malaccensis* and *A. galanga*.

Antifungal activity

A. malaccensis leaves essential oil, hexane, dichloromethane and methanol extracts are active against the growth of pathogenic fungi such as *Sclerotium rolfsii*, *Sclerotinia sclerotium*, *Rhizoctonia solani* and *Colletotricum falcatum* in a dose-dependent manner. The essential oil and the extracts exhibited maximum antifungal activity at the concentrations of 750 and 1000 µg/mL (Sethi *et al.,* 2016). The antifungal activity of extracts might be due to the presence of a diverse group of phytoconstituents, such as flavonoids and phenols (Winkelhausen *et al.,* 2005; Orhan *et al.,* 2010). In addition, the crude ethanolic extract of *A. galanga* showed significant antifungal activity against *Trichophyton longifusus*, *Aspergillus flavus*, *Microsporumcanis* and *Fusarium solani* (Khattak *et al.,* 2005).

Antibacterial activity

A. malaccensis leaf essential oil showed activity against *S. aureus* ATCC 29737 and *E.coli* ATCC 10536 at MIC values of 7.81 and 15.6 µg/mL, respectively and the pseudo-stem oil showed activity against *S. aureus* ATCC 29737 and *B. subtilis* ATCC 6633 both at MIC value of 31.25 µg/mL (Jusoh *et al.,*2020). *A. malaccensis* rhizome hexane and ethanol extracts showed significant antibacterial activity against food-borne bacterial strains of *S. aureus* 113 and *Listeria monocytogenes* Scott A serotype 4b (Somarathna *et al.,*2020). Hexane extract of *A. malaccensis* showed significant inhibition zone against *S. aureus* 113 and *S. aureus* MSSA SS 25D, *S. aureus* ATCC 29213, *S. aureus* ATCC 49476. 1′-Acetoxychavicol acetate purified from the rhizome hexane extract and this compound found to have antibacterial activity (Somarathna *et al.,* 2018).

Ethanol extract and essential oil of *A. malaccensis* rhizome showed antibacterial activity against *S. aureus* and *E. coli*(Sitorus and Satria, 2016). Two pyrones kavalactone and its derivative malakavalactone with antibacterial activity have been isolated from fruit acetone extract of *A. malaccensis*. These pyrones showed antibacterial activities against gram-positive *B. subtilis* and *S. aureus* and gram-negative *Enterobacter aerogenes*, *E. coli*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Shigella dysenteriae*, *Vibrio cholerae* (Juwitaningsih *et al.,* 2016). The leaf essential oil and methanol extract of *A. malaccensis* exhibited potent antibacterial activity against *S. aureus* MTCC- 3160 and *P. aeruginosa* MTCC-424(Sahoo *et al.,*2014).

Zhang *et al*., 2021 isolated antibacterial compounds from the hexane and chloroform extracts of *A. galanga* and found to be hydroxy cinnamaldehyde, cinnamaldehyde, coumaryl alcohol, and 1′-Acetoxy chavicol acetate (ACA). These compounds had bactericidal activity against *S. aureus* SJTUF strains. Among these compounds, cinnamaldehyde and Acetyl Chavicol Acetate have excellent bacteriostatic and bactericidal effects on *S. aureus* SJTUF 20758 strains with the lowest MBC value of 0.625 mg/mL. The mechanism of bacterial inhibition by 1′-Acetoxy chavicol acetate on the *S. aureus* SJTUF 20758 strain was also studied. Confocal laser scanning microscopy (CLSM) and Propidium iodide (PI) assay confirmed the membrane damage of the bacteria by 1′-Acetyl chavicol acetate. The cell membrane proteins of the bacteria could be the potential target molecule of 1′-Acetyl chavicol acetate, thereby preventing the expression of the cell membrane proteins, resulting in membrane disintegration (Zhang *et al.,*2021).

The ethanolic and methanolic extracts of *A. galanga* rhizome showed zone of inhibition against *Bacillus megaterium* MTCC 8510, *B. subtilis* MTCC 441, *B. flexus* MTCC 7024, *S. aureus* MTCC 96, *Pseudomonas oleovorans* MTCC 617, *Klebsiella pneumoniae* MTCC 7028, *Salmonella enteric* MTCC 1164 and *E. coli* MTCC 723 (Malik *et al.,* 2016). In another study by Rani *et al*., (2016), acetone, chloroform, diethyl ether and ethanol extracts of *A. galanga* leaves exhibited inhibitory activities against *E. coli*, *Bacillus cereus, S. aureus* and *K. pneumoniae*(Rani *et al.,* 2016).

Tuberculosis is an infectious disease caused by *Mycobacterium tuberculosis* bacteria. Gupta *et al.,* (2014) studied the effect of *A. galanga* rhizome ethanolic and acetone extracts on the *M. tuberculosis* H37Rv. Higher concentrations (25, 50 and 100 µg/mL) of the ethanolic and acetone extracts found to be most efficient against the *M. tuberculosis* strains (Gupta *et al.,*2014). Food-borne bacteria is a major concern at the time as the number of cases of food-associated infections are increasing. *A. galanga* essential oil and ethanol extracts have shown significant zone of inhibition against food-borne bacteria such as *E. coli* ATCC 25922, *S. aureus* ATCC 25923, *S. typhimurium* ATCC 14028 (Prakatthagomol *et al.,* 2012). Chan *et al*., (2011)reported that the methanolic extract of *A. galanga* rhizome showed antibacterial activity against *S. aureus*, and *B. cereus* at minimum inhibitory doses of 0.5 and 1.00 mg/disc (Chan *et al.,* 2011).

The antibacterial mechanism of *A. galanga* rhizome ethanolic extract was studied by Oonmetta-aree *et al.,* 2006. The mode of mechanism was analyzed on *S. aureus* 209P strain and it is explained that the extract might have increased the bacterial membrane permeability which results in the leakage of intracellular components and also the extract might interfere with the DNA synthesis. The disruption of the cell wall resulted in the release of cell materials in the cytoplasm, resulting in bacterial death (Oonmetta-aree *et al.,* 2006; Sahoo *et al.,*2014).

Antidiabetic

Diabetic mellitus is one of the non-communicable diseases but results in a higher death rate in both developed and developing countries. Putra *et al.,*(2023)studied and reported the alpha-glucosidase inhibitory activity of galangin and 1′S-1′-acetoxychavicol acetate from the *A. galanga*. Galangin and 1′S-1′-acetoxychavicol acetate exhibited antidiabetic properties having a binding affinity of -6.9 and -6.0 kcal/mol, respectively, with target protein alpha-glucosidase (Putra *et al.,* 2023). The ethyl acetate fraction of the *A. galanga* rhizome has significantly inhibited the carbohydrate-digesting enzymes such as α- amylase and α-glucosidase with IC_{50} values of 83.9 ± 0.7 and 75.2 ± 0.6 µg/mL, respectively. In addition, the fraction

also showed antiglycation activity (Nampoothiri *et al.,* 2017). The methanolic extracts of the *A. galanga* rhizome showed 71.27% α-amylase inhibition activity (Malik *et al.,*2016).

The methanolic extract of aerial parts of *A. galanga* showed significant dose-dependent hypoglycaemic effects in Streptozotocin-induced diabetic rats. The efficient reduction in blood glucose was observed after the 4th day at a dose of 400 mg/Kg body weight and after the 15th day at a dose 200 mg/Kg body weight. Hypoglycaemic effects may be due to the stimulatory effects of methanolic extract, which may have a positive response on the regenerating β-cells and on the surviving β-cells in diabetic rats (Verma *et al.,* 2015). Akhtar *et al.*, (2002) studied the hypoglycemic efficiency of powdered and methanolic extract of *A. galanga*. The result showed that the administration of powdered rhizome and methanolic aqueous extract of *A. galanga* rhizome to the normal rabbits, at a dose of 3 to 4 and 4 g/Kg, respectively, produced a significant decrease in blood glucose levels. The methanolic extract of the rhizome and leaves of the *A. malaccensis* exhibit α-amylase inhibition activity with IC_{50} values of 160.146 and 90.93 µg/mL, respectively (Samarasinghe *et al.,* 2020).

Antioxidant

Antioxidants prevent cell damage caused by free radicals. Synthetic antioxidants in some way cause skin allergies, gastrointestinal tract problems, DNA damage and have high risk of cancer (Lourenço *et al.,* 2019). So, the natural antioxidants are more preferred to protect from oxidative damage. The antioxidant property of the plant extract is mainly due to the presence of flavonoids in them. IC_{50} value of DPPH scavenging activity of the *A. malaccensis* leaves methanolic extract is 22.5 µg/mL when compared to the IC_{50} value of standard ascorbic acid 6.58 µg/mL. Based on DPPH scavenging activity, the extract exhibits antioxidant activity (Sahoo *et al.,* 2012).

The ethyl acetate fraction of *A. galanga* with IC_{50} value 97.67 ± 0.80 µm/mL inhibited the low-density lipoprotein (LDL) cholesterol oxidation. LDL oxidation is one of the major factors for atherosclerosis. Further study on the oxidative activity of *A. galanga* can open the way to new drug formulations for atherosclerosis (Nampoothiri *et al.,*2017). The flavonoid fraction of the *A. galanga* extract has significantly increased the superoxide dismutase (SOD) activity in the mice under study. SOD catalyzes the breakdown of O_2- to O_2 and H_2O_2 and thereby prevents the formation of OH- radical and thereby acting as an antioxidant (Jain *et al.,* 2012). The antioxidant activity of *A. galanga* rhizome ethanolic extract increases with the concentration (0.10–1.0 mg/mL) of the extracts and the activity is stable irrespective of heat (Juntachote and Berghofer, 2005).

Anti-inflammatory

Even though inflammation is a crucial biological process that helps to fight pathogens and repair damaged tissue, this processes also result in many severe disorders, such as rheumatoid arthritis, asthma, chronic inflammatory bowel diseases, type 2 diabetes, neurodegenerative diseases, cancer, etc. (Fürst and Zündorf, 2014). The essential oil and extracts are tested for their anti-inflammatory property and it possess potential anti-inflammatory activity due to the presence of phytocompounds such as eucalyptol, eugenol and, menthol, etc. *A. malaccensis* rhizome methanolic extract and essential oil possess inhibition of prostaglandin release mediated anti-inflammatory properties. *A. malaccensis* rhizome methanolic and essential oil exhibited antiinflammation at doses of 50 and 100 mg/Kg b.wt (Sethi *et al.,*2017).

Ethyl acetate fraction of galanga showed anti-inflammatory activity by scavenging free radicals, inhibiting Xanthine oxidase and protein denaturation (Nampoothiri *et al.*, 2017). Baldo and Serrano (2016) have analyzed the anti-inflammatory activity of Galangal rhizome extract. From the study, they found that the acetic acid-induced rats have decreased their size. On the contrary, fresh rhizome extract of *A. galanga* (75% rhizome extract + 25% distilled water) reversed the decreasing body weight of acetic acid-induced colitis mice and found that the extract has intestinal anti-inflammatory activity (Baldo and Serrano, 2016). The methanolic extract of *A. galanga* rhizome extract has significant anti-inflammatory activity, which results in the inhibition of edema induced by carrageenan (Unnisa and Parveen, 2011).

Anti-plasmid

In order to overcome the multi-drug resistance of the various bacteria, the anti-plasmid activity of the Galanga extract has been studied, and this anti-plasmid compound may eliminate the plasmid-containing drug resistance. The crude extract of the galanga eliminated the antibiotic-resistant plasmid of *S. typhi*, *E. coli* and vancomycin-resistant *Enterococcus* (VRE) with an efficiency of 92%, 82 and 8%, respectively. The compound responsible for the activity was isolated and found to be 1′-Acetoxychavicol acetate. The compound showed efficiency in curing the drug-resistant plasmid from *S. typhi* (75%), *P. aeruginosa* (70%), *E. coli* (32%) and vancomycin-resistant *Enterococcus* (66%). And also noted that the pre-exposure of the bacteria strains to 1′-Acetoxychavicol acetate significantly increased the effectiveness of antibiotics used against the bacteria. The anti-plasmid activity of the 1′-Acetoxychavicol acetate resulted in the loss of antibiotic resistance of *E. coli* strain. Thus, the strain became sensitive to ampicillin, gentamycin, kanamycin, neomycin, ciprofloxacin, cefoperazone and ceftazidime. Vancomycin-resistant *Enterococcus* became sensitive to tetracyclin, amp/cloxacillin, and amp/sulbactam and *S. typhi* became sensitive to gentamycin, kanamycin, tetracycline, and roxthromycin as a result of the 1′-Acetoxychavicol acetate induced plasmid curing (Latha *et al.,* 2009).

Insecticidal

The cigarette beetle, *Lasioderma serricorne* is a destructive primary insect pest of stored cereals, tobacco, oil seeds, dried fruits, and traditional Chinese medicinal materials. Wu *et al.* (2014) studied the repellency of *A. galanga* essential oil against cigarette beetle. In this study, he purified five compounds from the essential oil and tested contact toxicity and fumigant activity against cigarette beetle. Among the tested compounds, α- terpineol and eucalyptol exhibited good contact and fumigant toxicity.

Conclusion

Various studies on *Alpinia* species all over the globe have revealed their pharmacological effects. Ethnobotanical studies

of the two species, viz. *A. galanga* and *A. malaccensis* revealed their use among humans from earlier times onwards. Studies identified the presence of many potential phytocompounds from these species and these compounds are responsible for their pharmacological activity. Plant-based drugs have fewer side effects as compared to synthetic ones. However, confirmation of activities and side effects of the extracts and essential oil has to be done during *in-vivo* conditions and in animal models. This review paper will serve as a source to learn about studies on the phytochemistry and pharmaceutical activity of *A. galanga* and *A. malaccensis*.

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Author Contribution

Saira Sara Babu contributed to the collection of data and to the writing of the manuscript. Dr. V.P. Thomas and Dr. Binoy T. Thomas contributed to the concept and editing of the manuscript.

Conflict of interest

None

Reference

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