Essential oils composition and bioactivities of most prevalent species of genus *Piper* in Malaysia: a scope review

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The genus *Piper* is among the most important genera in the Piperaceae family, consisting of over 2000 species and widely distributed globally, mainly in the Southeast Asian region. It is known for several medicinally and economically important species that have been used throughout their native range. *Piper* species have great diversity in the world's tropical regions and are represented mainly by aromatic shrubs and trees with significant production of essential oils. Essential oils are largely consumed as they are beneficial to humans as natural remedies and have been known for years to find usefulness in foods, drugs, and cosmetics. In recent years, studies on the essential oils of the Malaysian *Piper* species have been progressing, and many of them have reported interesting pharmacological activities. This review attempts to summarize information on the essential oils from Malaysian *Piper* species concerning their medicinal uses, chemical composition, and bioactivities. Information on the *Piper* species was collected via electronic search (Pubmed, SciFinder, Scopus, Google Scholar, and Web of Science) and a library search for articles published in peer-reviewed journals. Throughout our literature review, seventeen *Piper* species have been studied for their essential oil compositions in Malaysia. They were found to contain mainly of β-phellandrene, safrole, β-caryophyllene, and aromadendrene. As for bioactivities, antimicrobial, antioxidant, and cytotoxicity activities were the most reported. This review is mainly meant to provide relevant information on the chemical components and features of Malaysian *Piper* species, with an emphasis on essential oils, providing guidance for the selection of accessions or species with the best chemical profiles.

Keywords: Piperaceae, *Piper*, essential oil, composition, caryophyllene, antimicrobial

1. INTRODUCTION

Plants are a versatile source of bioactive metabolites, including polysaccharides, phenolics, alkaloids, steroids, lignins, resins, tannins, as well as essential oils [1]. Among them, essential oils obtained from plants have various applications, especially in the health, agriculture, food, and cosmetic industries. Thus far, over 3000 essential oils have been isolated from about 2000 plant species, of which 300 have been commercially used for various purposes [2]. Previous scientific studies clearly revealed that essential oils possess various pharmacological properties such as antioxidant, antimicrobial, antiviral, antimutagenic, anticancer, anti-inflammatory, and immunomodulatory activities [3].

The genus *Piper* is one of the largest and most important aromatic and medicinal plants of the Piperaceae family, which comprises four genera and approximately 2000 species distributed in the tropical and subtropical regions [4]. *Piper* and *Peperomia* are the most representative of the Piperaceae family [5]. A common description for Piperaceae taxon includes spiral-leaves,

simple stipulate or not. The inflorescence is a spike or spadix with minute flowers uni- or bisexual, bracteate, perianth absent (flowers naked without sepals or petals). The flowers only have a single pistil and stamens [6-7].

Piper species are used all over the world in traditional remedies in the Indian Ayurvedic system of medicine and in folklore medicine of Latin America and the West Indies [8]. Economically, *Piper* known as a worldwide spice market as their leaves, stems, roots, and fruit have their own uses. In Malaysia, the leaves of *P. betle* (sireh) were used for mastication and also for relieving constipation in children and poulticing ulcerated noses. The leaves were often heated and applied to the chest to relieve coughs and asthma [9]. The decoction of *P. sarmentosum* (kadok) leaves was used as an embrocation to cure pains in bones and applied to the foreheads of children suffering from headaches [10]. The leaves of *P. nigrum* were used for stomachaches, treatment of coughs, and seasoning [11].

The chemistry of *Piper* species has been widely investigated, and the phytochemical investigations from all parts have led to the isolation of a number of pharmacologically active compounds such as alkaloids, amides, propenylphenols, lignans, neolignans, terpenes, steroids, kawapyrones, piperolides, and flavonoids. They have been extensively investigated as a source of new natural products with potential antioxidant, antimicrobial, antifungal, anticholinesterase, anti-inflammatory, anti-tyrosinase, and insecticidal activities [12-17].

Recently, essential oils and other aromatic compounds sourced from plants and used as alternative medicine are gaining interest. Hence, the review regarding *Piper* essential oils has to be done to simplify and compile the information. The information was collected via electronic searches in databases such as Scopus, PubMed, Science Direct, SciFinder, and Google Scholar. This review aims to give an overview of all published reports on the chemical composition, biological activities, and medicinal uses of Malaysian *Piper* essential oils.

2. SEARCH STRATEGY

The protocol for performing this study was developed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) [18] (a) the first step was to exclude duplicate articles, (b) titles and abstracts were then read and the inclusion and exclusion criteria were applied and (c) all articles resulting from this stage were read in full, and the inclusion and exclusion criteria were applied again. Figure 1 shows the flow diagram of the identification and selection of articles. Following this step, we reached the articles chosen for the present study. This systematic review was conducted through searches using Scopus, PubMed, Science Direct, SciFinder, and Google Scholar. The keywords used were '*Piper*', 'essential oil', and 'biological activity' articles over the period from the beginning of the database until October 2022.

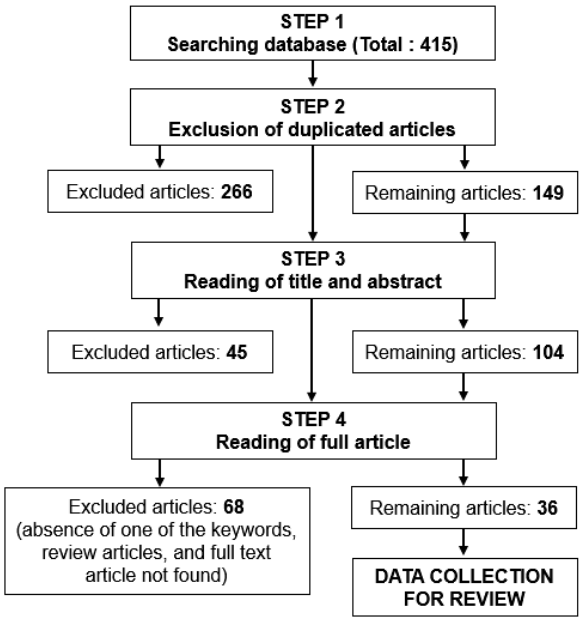

Figure 1 - PRISMA flow diagram of included studies

In addition, as a second search strategy, we included studies obtained by a manual search of the reference lists of the included studies. Articles on the genus of *Piper* that reported from Malaysia (traditional uses, essential oils, and bioactivities) were included. The inclusion of articles considered the following criteria: (1) type of publication - original research articles, (2) only articles in English, (3) articles must present the chemical composition of Malaysian *Piper* essential oils, (4) articles must discuss the bioactivity of the essential oils. As exclusion criteria, the following were used: (1) articles that did not present the search terms in the title and abstract; (2) review articles, (3) full-text articles not found, (4) articles without one of the keywords and (5) articles that did not present the composition of the essential oils.

3. MEDICINAL USES

Piper species have been known for their medicinal benefits for ages. People have been using the parts of the plant to extract essential oils for various reasons. The fruits, roots, leaves, and barks of these plant species are adopted for the therapy of diseases in different approaches, including (i) pharmaceutics (e.g. decoction, pill, powder, etc.) of signal medicine, or compound preparations with other traditional Chinese medicines; (ii) drunk as tea; (iii) eaten. The essential oils obtained are traditionally consumed as daily remedies to treat discomfort and maintain health both physically and mentally [19]. Table I shows the medicinal uses of Malaysian *Piper* species [20-32].

Table I - Medicinal uses of several Malaysian *Piper* species

Species	Part	Medicinal uses
P. abbreviatum	Leaf	Splenomegaly, stimulant, carminative, coughs & colds, flatulence [20]
P. aduncum	Leaf	Treating wounds, skin boils, infections, and diarrhea [21]
	Root	Bleeding control as antihemorrhagic [22]
P. arborescens	Leaf	Rheumatism, antiplatelet aggregation, cytotoxic [23]
P. betle	Leaf	Aromatic flavor and mouth freshness [24]
P. caninum	Leaf	Chewing, hoarseness, flavor, throat ache antiseptic [25]
P. cubeba	Leaf	Uses as diuretic and stimulant in cases of fever, gout andangina [26]
P. miniatum	Leaf	Spice, food flavour, food natural preservative [27]
P. nigrum	Leaf	To relief pain, atrophic arthritis, apathy,influenza, and febricity,and antibacterial agent,stimulant,digestive,and antitoxin [28]
P. officinarum	Fruit	As digestive, tonic, carminative in asthma, bronchitis, gastrointestinal ulsers, diarrhea or postpartum hemorrhage [29]
P. porphyrophyllum	Leaf	Leprosy, abdominal pain, skin disease, postpartum treatment, bone pain [30]
P. stylosum	Leaf	Vegetables, seasoning, poultice/ decoction, confinement [31]
P. ribesioides	Leaf	Asthma, diarrhoea, abdominal pain, flavour, alleviate chest congestion, treat urticarial [32]

4. CHEMICAL COMPOSITIONS OF THE ESSENTIAL OILS

In earlier reports, eighteen *Piper* species were described on the essential oil composition. These were *P. abbreviatum*, *P. erecticaule*, *P. lanatum*, *P. aduncum*, *P. arborescens*, *P. betle*, *P. caninum*, *P. pedicellosum*, *P. penangense*, *P. magnibaccum*, *P. maingayi*, *P. miniatum*, *P. nigrum*, *P. officinarum*, *P. porphyrophyllum*, *P. stylosum*, *P. ribesioides* and *P. muricatum.* Most of the species are reported from Sarawak, as well as from Kelantan, Perak, Johor, Selangor, and Terengganu. The extraction of the essential oils was done mostly from the leaf part, along with fruit and stem. The essential oil of *P. miniatum* has the highest total components, which was found to have sixty-four components, while the essential oil of *P. arborescens* has the highest percentage that contributed for about 97.5% of the total oils. Analysis of chemical components identified in the *Piper* essential oils shows that the oil consists of several groups of components, which are phenylpropanoids, monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, and oxygenated sesquiterpenes. Table II shows the major components identified in *Piper* essential oils from various states of Malaysia [33-47].

The major component of *Piper* essential oils consists mainly of sesquiterpene hydrocarbons. β-Caryophyllene was identified as a major component in the leaf oil of *P. erecticaule* [33], leaf and stem oils of *P. maingayi* [40]*, P. officinarum* [44], and *P. ribesioides* [46]. Meanwhile, δ-cadinene was found dominantly in the fruit oil of *P. maingayi* [41]. In other studies, germacrene D was identified as a principal component from *P. magnibaccum* (leaf oil) [39], bicyclogermacrene from *P. porphyrophyllum* (leaf oil) [45], whereas aromadendrene from *P. stylosum* (leaf and stem oils) [46] and *P. muricatum* (whole plant) [47]. In the case of oxygenated sesquiterpenes, spathulenol, (E)-nerolidol, and caryophyllene oxide were identified by their richness in the leaf oil of *P. abbreviatum* [33], *P. penangense* [38], and *P. miniatum* [27], respectively.

Besides, monoterpene hydrocarbons were found in several *Piper* essential oils. β-Phellandrene was characterised as the main component in leaf and stem oils of *P. arborescens* [35] as well as the leaf oil of *P. pedicellosum* [38]. Meanwhile, sabinene and β-pinene was identified in the stem oil of *P. porphyrophyllum* [45] and the leaf oil of *P. nigrum* [42], respectively. On the other hand, boneol was the only oxygenated monoterpene present in *Piper* oil, which was detected from the leaf oil of *P. lanatum* [33]. Furthermore, phenylpropanoids were also found in Malaysian *Piper* oils. Safrole was detected mainly in the leaf and stem oils of *P. caninum* [37]. In addition, eugenol and apiole were characterised mainly in the leaf oil of *P. betle* [36] and *P. aduncum* [34], respectively.

Based on the above results, the chemical differences between species of *Piper* could be due to the stages of development, and distinct habitat in which the plant was collected. Besides, the chemical and biological diversity of aromatic, and medicinal plants depends on factors such as climatic conditions, phase of vegetation, and genetic modifications. Such variables affect the biosynthetic pathways of the plant and therefore, the relative proportion of the main characteristic compounds [33].

Furthermore, knowledge of the factors that determine the chemical variability and yield for each species are very important in particular for commercially important species, to optimise the conditions that may affect yields and quality of essential oils. In addition to the commercial importance of the variability in yield and composition, the possible changes are also important when the essential oils and volatile are used as chemo taxonomic tools [49, 50].

5. BIOACTIVITIES

The literature study reveals the need for a thorough investigation of the pharmacological characteristics of

Table II - Major components identified from the essential oils of Malaysian *Piper* species

Species	Locality	Part	Total (No. %)	Method (Yield)	Major components
P. miniatum	Selangor	Leaf	64; 89.2%	Hydrodistillation (0.45%)	Caryophyllene oxide (20.3%) and α-cubebene (10.4%) [27]
P. abbreviatum	Sarawak	Leaf	33; 70.5%	Hydrodistillation (0.22%)	Spathulenol (11.2%), (*E*)-nerolidol (8.5%), β-caryophyllene (7.8%) and ar-curcumene (5.8%) [33]
P. erecticaule	Sarawak	Leaf	35; 63.4%	Hydrodistillation (0.18%)	β-Caryophyllene (5.7%), spathulenol (5.1%), β-cadinene (3.8%) and α-amorphene (3.8%) [33]
P. lanatum	Sarawak	Leaf	39; 78.2%	Hydrodistillation (0.25%)	Borneol (7.5%), caryophyllene oxide (6.6%) and α-amorphene (5.6%) [33]
	Selangor	Leaf	38; 90.6%	Hydrodistillation (1.34%)	Chavibetol (42.7%), β-caryophyllene (6.8%), α-cadinene (6.6%), α-muurolene (6.2%), eugenol acetate (5.9%) and γ-elemene (5.4%) [38]
P. aduncum	Selangor	Leaf	35; 38.0%	Hydrodistillation (NS)	Apiole (38.0%), methyl isobutyl ketone (8.2%), piperitone (3.3%) and caryophyllene (2.4%) [34]
	Selangor	Leaf	32; 90.8	Hydrodistillation (1.30%)	Dillapiole (64.5%), β-selinene (5.2%) and β-caryophyllene (5.1%) [38]
P. arborescens	Sarawak	Leaf	36; 97.5%	Hydrodistillation (0.24%)	β-Phellandrene (24.3%), sabinene (16.3%) and α-pinene (10.4%) [35]
		Stem	46; 90.5%	Hydrodistillation (0.16%)	β-Phellandrene (20.4%), methyl eugenol (11.0%) and β-caryophyllene (9.0%) [35]
P. betle	Kelantan	Leaf	11; 98.9%	Hydrodistillation (NS)	Eugenol (15.6%) [36]
	Selangor	Leaf	15; 96.6%	Hydrodistillation (5.10%)	Chavibetol (69.0%), eugenol acetate (8.3%), chavicol (6.0%) and γ-muurolene (5.2%) [38]
P. caninum	Perak	Leaf	36; 77.9%	Hydrodistillation (0.46%)	Safrole (17.1%), β-pinene (8.9%), linalool (7.0%) and β-caryophyllene (6.7%) [37]
		Stem	37; 87.0%	Hydrodistillation (0.31%)	Safrole (25.5%), β-caryophyllene (9.8%), germacrene D (7.8%), β-pinene (4.9%) and δ-elemene (4.1%) [37]
P. pedicellosum	Selangor	Leaf	NS	Hydrodistillation (1.11%)	β-Phellandrene (21.9%) [38]
P. penangense	Selangor	Leaf	NS	Hydrodistillation (0.23%)	(*E*)-Nerolidol (17.5%) [38]
P. magnibaccum	Perak	Leaf	25; 93.5%	Hydrodistillation (0.02%)	Germacrene D (40.8%), α-caryophyllene (8.5%) and α-cadinol (6.1%) [39]
		Stem	33; 87.6%	Hydrodistillation (0.09%)	β-Caryophyllene (19.7%), germacrene D (10.7%) and α-cadinol (8.2 %) [39]
P. maingayi	Johor	Leaf	43; 91.2%	Hydrodistillation (0.21%)	β-Caryophyllene (39.6%) [40]
		Stem	34; 83.6%,	Hydrodistillation (0.09%)	β-Caryophyllene (26.2%), α-cedrene (8.4%), caryophyllene oxide (6.7%) and *cis*-calamenene (6.2%) [41]
		Fruit	18; 78.7%	Hydrodistillation (0.17%)	δ-Cadinene (22.6%), β-caryophyllene (18.8%), α-copaene (11.2%) and α-cadinol (7.1%) [41]
P. nigrum	Sarawak	Leaf	39; 64.0%	Hydrodistillation (0.80%)	β-Pinene (12.9%) and linalool (9.5%) [42]
		Seed	40; 99.8%	Hydrodistillation (3.34%)	β-Caryophyllene (24.3%), limonene (15.8%), sabinene (15.0%) [43]
P. officinarum	Sarawak	Leaf	41; 85.0%	Hydrodistillation (0.26%)	β-Caryophyllene (11.2%), α-pinene (9.3%), sabinene (7.6%), β-selinene (5.3%) and limonene (4.6%) [44]
		Stem	41; 93.0%	Hydrodistillation (0.22%)	β-Caryophyllene (10.9%), α-phellandrene (9.3%), linalool (6.9%), limonene (6.7%) and α-pinene (5.0%) [44]
P. porphyrophyllum	Sarawak	Leaf	34; 97.3%	Hydrodistillation (0.20%)	Bicyclogermacrene (14.7%), α-copaene (13.2%), β-phellandrene (9.5%), α-cubebene (7.4%) and β-caryophyllene (6.4%) [45]
		Stem	38; 95.5%	Hydrodistillation (0.18%)	Sabinene (15.5%), bicyclogermacrene (12.3%), α-copaene (8.1%), α-pinene (7.8%) and β-caryophyllene (7.1%) [45]
P. stylosum	Terengganu	Leaf	50; 89.2%	Hydrodistillation (0.08%)	Aromadendrene (26.6%), β-caryophyllene (11.5%) and sabinene (13.8%) [46]
		Stem	45; 88.8%	Hydrodistillation (0.07%)	Aromadendrene (18.8%), β-caryophyllene (17.9%) and sabinene (6.7%) [46]
P. ribesioides	Terengganu	Leaf	60; 87.0%	Hydrodistillation (0.03%)	β-Caryophyllene (20.0%), camphene (16.3%) and δ-cadinene (4.4%) [46]
		Stem	39; 82.9%	Hydrodistillation (0.04%)	β-Caryophyllene (14.4%), camphene (12.3%) and δ-cadinene (7.8%) [46]
P. muricatum	Terengganu	Whole plant	40; 90.8%	Hydrodistillation (0.46%)	Aromadendrene (16.2%), β-caryophyllene (8.8%), germacrene D (7.9%), γ-cadinene (7.9%), elemol (5.4%), γ-elemene (4.9%) and bicyclogermacrene (4.4%) [47]

*NS- not stated

the essential oils of *Piper* species. The biological activities including anti-microbial, antioxidant and cytotoxicity activities have been reported in some works. Indeed, the genus *Piper* has been exploited traditionally, thus revealing the medicinal variation it possesses. In addition, several species that have been used traditionally to treat some types of ailments have not been investigated for their bioactivities at all. Thus, this is an opportunity to find new pharmacological properties from this genus, and the information on the qualification of the essential oils is very important to be applied in functional food and pharmaceutical areas.

In the case of Malaysian *Piper* essential oils, antimicrobial [33,35,39,44-47] and antioxidant [37,39,41,44,46] activities have been reported and the details are described in Table III and Table IV, respectively.

For antimicrobial activity activity, four *Piper* essential oils have shown a good activity towards Gram positive bacteria (*Bacillus cereus* and *Staphylococcus aureus*) which are *P. abbreviatum* [33], *P. arborescens* [35], *P. stylosum* [46], and *P. muricatum* [47]. Meanwhile, the essential oils of *P. magnibacum* [39], *P. officinarum* [44], and *P. porphyrophyllum* [45] have shown significant activity towards Gram negative bacteria; *Pseudomonas aeruginosa*, *Escherichia coli*, and *Pseudomonas putida*, respectively. On the other hand, *P. erecticaule* and *P. lanatum* have shown antifungal activity towards *Aspergillus niger* [33]. β-Caryophyllene, germacrene D, bicyclogermacrene,

Table III - Antimicrobial activities of the essential oils of Malaysian *Piper* species

Species	Description
P. erecticaule	The leaf oil showed activity towards *Aspergillus niger* with MIC value of 31.3 µg/mL [33]
P. lanatum	The leaf oil showed activity towards *Aspergillus niger* with MIC value of 62.5 µg/mL [33]
P. abbreviatum	The leaf oil showed activity towards *Bacillus cereus, Staphylococcus aureus*, and *Enterococcus faecalis* with MIC value of 250 µg/mL each [33]
P. arborescens	The leaf oil showed activity towards *Bacillus subtilis*, *Staphylococcus aureus* and *Aspergillus niger* with MIC values of 500, 250 and 500 µg/mL, respectively [35]
	The stem oil showed activity towards *Pseudomonas putida* and *Apergillus niger* with MIC value of 500 µg/mL each [35]
P. magnibacum	The leaf oil showed activity towards *Pseudomonas aeruginosa* with MIC value of 250 µg/mL [39]
	The stem oil showed activity towards *Pseudomonas aeruginosa, Bacillus cereus* and *Escherichia coli* with MIC value of 500 µg/mL [39]
P. officinarum	The leaf and stem oils showed activity towards *Escheric coli* and *Pseudomonas aeruginosa* with MIC value of 250 µg/mL each [44]
P. porphyrophyllum	The leaf and stem oils showed activity towards *Pseudomonas putida* with MBC values of 250 and 125 µg/mL, respectively [45]
	The leaf and stem oils showed activity towards *Pseudomonas putida* with MBC values of 500 and 250 µg/mL, respectively [45]
P. stylosum	The leaf and stem oils showed activity towards *Bacillus cereus* and *Staphylococcus aureus* with MIC value of 125 µg/mL [46]
P. muricatum	The leaf oil showed activity towards *Bacillus cereus, Streptococcus mutans* and *Pseudomonas aeruginosa* with MIC value of 250 µg/mL [47]

MIC – Minimum Inhibitory Concentration; MBC – Minimum Bactericidal Concentration

Table IV - Antioxidant activities of the essential oils of Malaysian *Piper* species

Species	Method	Description
P. caninum	DPPH	The leaf and stem oils showed activity with IC_{50} values of 187.6 and 452.4 mg/mL, respectively [37]
	β-carotene	The leaf and stem oils showed activity with percentage values of 103.5 and 114.9%, respectively [37]
P. magnibacum	DPPH	The leaf and stem oils showed activity with IC_{50} values of 20.5 and 17.5 µg/mL, respectively [39]
	ABTS	The leaf and stem oils showed activity with IC_{50} values of 11.7 and 12.9 µg/mL, respectively [39]
P. maingayi	ABTS	The stem and fruit oils showed activity with IC_{50} values of 12.6 and 13.9 µg/mL, respectively [41]
	DPPH	The stem and fruit oils showed activity with IC_{50} values of 14.9 and 20.8 µg/mL, respectively [41]
	TPC	The stem and fruit oils gave total phenolic content of 176.8 and 279.6 mg GA/g, respectively [41]
	β-carotene	The stem and fruit oils showed activity with percentage values of 91.8 and 83.6%, respectively [41]
P. officinarum	DPPH	The leaf and stem oils showed weak activity with IC_{50} values of 622.2 and 777.4 µg/mL, respectively [44]
P. stylosum	DPPH	The leaf and stem oils showed weak activity with IC_{50} values 605.8 and 623.2 µg/mL, respectively [46]
	TPC	The leaf and stem oils gave total phenolic content of 15.4 and 18.2 mg GA/g, respectively [46]
P. ribesiodes	DPPH	The leaf and stem oils showed activity with IC_{50} values of 831.5 and 692.4 µg/mL, respectively [46]
	TPC	The leaf and stem oils gave total phenolic content of 20.5 and 24.8 mg GA/g, respectively [46]

DPPH – 2,2-diphenyl-1-picrylhydrazyl; TPC – Total phenolic content; ABTS – 2,2'-Azinobis-(3-Ethylbenzthiazolin-6-Sulfonic Acid)

and aromadendrene are among the major components identified from the above *Piper* essential oils which have shown potential against Gram positive bacteria, Gram negative bacteria, and fungus.
For antioxidant activity, six *Piper* essential oils have been reported using DPPH assay. However, most of the essential oils showed weak activity. It could be due to the presence of sesquiterpenes as major components. β-Caryophyllene has been found as a major component from *P. magnibacum* [39], *P. maingayi* [41], *P. officinarum* [44], and *P. ribesioides* [46], as well as germacrene D from *P. magnibacum* [39] and aromadendrene from *P. stylosum* [46] essential oils.
In addition, the cytotoxicity activity was also reported from the leaf and stem oils of *P. magnibacum* [39] which showed an activity against A-549 with inhibition values of 88.0% and 77.3%, as well as against MCF-7 with inhibition values of 88.7% and 91.3%, respectively [39]. In another study, the leaf oil of *P. aduncum* exhibited a high activity against *Aedes albopictus* with ED_{50} and ED_{90} values of 1.5 and 17.6 μg/cm^2, respectively [48].

6. CONCLUSION

This article aims to give the relevant literature on the medicinal uses, chemical compositions, and bioactivity information of the Malaysian *Piper* essential oils. The studies managed to declare that the essential oils of *Piper* species contain monoterpenes and sesquiterpenes, which potentially stimulate bioactivities such as antioxidant and antimicrobial properties. The diversity of quantitative and qualitative components observed could be due to genetic differences or to the environmental conditions of the plant material based on different geographic locations. More pharmacological investigations into other pharmacological activities should be performed to unravel the full therapeutic potential of Piper species. Furthermore, preclinical analyses as well as clinical trials, as conducted for essential oils from other species, are required to evaluate the potential of essential oils from *Piper* species for drug development. This information is also critical when selecting species that have an economic potential for the pharmaceutical and cosmetics industries.

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