Systematic Review on Chemical Diversity and Biological Activities of Essential Oils from the Genus *Blumea* (Asteraceae)

Wan Mohd Nuzul Hakimi Wan Salleh[1,2] ✉
Abubakar Siddiq Salihu[1,3]

[1] Department of Chemistry
Faculty of Science and Mathematics
Universiti Pendidikan Sultan Idris
Tanjong Malim, Perak, Malaysia

[2] Center of Biodiversity and Conservation
Faculty of Science and Mathematics
Universiti Pendidikan Sultan Idris
Tanjong Malim, Perak, Malaysia

[3] Department of Pure and Industrial Chemistry
Faculty of Natural and Applied Sciences
Umaru Musa Yar'adua University
Katsina, Nigeria

✉ CORRESPONDING AUTHOR:
E-mail: wmnhakimi@fsmt.upsi.edu.my
Phone: +605-4507123

Received: December 24, 2022
Accepted: July 17, 2023

Essential oils from plants have been widely used in the prevention and treatment of numerous human diseases in many parts of the world for thousands of years.. Plants of the genus *Blumea* comprise about 80 species and are distributed in tropical and subtropical Asia, Africa, and Oceania; thirty of which are distributed in the southern provinces of China. The genus has been used locally in the treatment of bronchitis, blood diseases, fevers, and to alleviate a burning sensation. Over the last years, *Blumea* species have attracted great interest due to the variety of their essential oils, bioactive compounds, and pharmacological activities. This work provides comprehensive information regarding the essential oils from *Blumea* species concerning their medicinal uses, chemical composition, and bioactivities. The relevant information about the genus *Blumea* was gathered through electronic databases from 1989 to 2022, including Pubmed, SciFinder, Scopus, Google Scholar, and Web of Science. Based on existing studies of the genus *Blumea*, a total of eighteen species have been reported on the composition of the essential oil. The essential oils are mainly composed of β-caryophyllene, germacrene D, and borneol as the most abundant components. Moreover, essential oils also possess a wide spectrum of pharmacology such as larvicidal, antimicrobial, anti-inflammatory, cytotoxicity, and fumigant toxicity. As a source of traditional folk medicine, the *Blumea* genus has high medicinal value, and they are widely used in medicine. Therefore, further systematic, and comprehensive research on the genus *Blumea* is still required to provide a scientific basis for its clinical applications.

Keywords: Asteraceae, *Blumea*, essential oil, caryophyllene, larvicidal

1. INTRODUCTION

The Asteraceae is the largest family of flora in the world, comprising about 1550 genera and about 23,000 species. It comprises 10% of all flowering plant species. Most species of Asteraceae are annual, biennial, or perennial herbaceous plants, but there are also shrubs, vines, and trees [1]. The family has a widespread distribution, from subpolar to tropical regions in a wide variety of habitats. The largest proportion of the species occurs in the arid and semi-arid regions of subtropical and lower temperate latitudes. Besides, Asteraceae is an economically important family, providing food staples, garden plants, and herbal medicines [2].

Blumea is a genus of flowering plants of the family Asteraceae. *Blumea* is a genus with ca. 80 species and is classified in the subtribe Matricariinae of Anthemideae. It is mainly found in tropical and subtropical Asia, Africa, and Oceania. It is a small tree and shrub, characterised by disciform capitula with outer filiform female florets and inner tubular bisexual florets, tailed anthers, and cypsela wall epidermis with one large oxalate crystal in each cell [3]. This genus includes some important medicinal plants largely used in traditional medicine. Some members of this genus are also used as herbal teas and condiments both in fresh and dried form due to their distinct aroma [4]. In the southern regions of China, thirty different species were reported, among which two of them, *B. balsamifera* and *B. riparia,* are utilised as conventional herbal remedies [5].

Since 1900s, more than 70 constituents have been isolated from the genus *Blumea*, including flavonoids, monoterpenes, sesquiterpenes, acetylenic thiophenes, triterpenoids, xanthenes, and diterpenes, and successfully exhibited significant bioactivities such as insecticidal, hepatoprotective, antitumor, antifungal, and antioxidant activities [6].

Essential oils from *Blumea* plants have shown a wide range of pharmacological activities, such as antimicrobial, antioxidant, and insecticidal. Recently, the volatile oil from *B. balsamifera* has been used to make over-the-counter medications, such as Jinhoujian spray, and used in China to treat throat sores and canker sores for decades. Besides those with throat sores, some patients in China who had larynx and hypopharynx cancer have taken Jinhoujian spraying as a part of their treatment. In addition, due to its unique scent, the *B. balsamifera* oil has been used as a cosmetics additive. For example, gynaecological lotions and shampoo liquids containing essential oils have been selling well in Southeast Asia for the last few years [7-8]. Also, the essential oil from *B. membranacea* produces a marked and long-lasting fall in the blood pressure of anaesthetised dogs, exerts a direct depressant action on frog hearts, and has a spasmolytic effect on rabbit ilea [9].

Recently, essential oils and other aromatic compounds sourced from plants and used as alternative medicine are gaining interest. Hence, the review regarding *Blumea* essential oils needs to be carried out 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 *Blumea* 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) [10] (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 this study. This systematic review was conducted through searches using Scopus, PubMed, Science Direct, SciFinder, and Google Scholar. The keywords used were '*Blumea*', 'essential oil', and 'biological activity' articles over the period from the beginning of the database until December 2022.

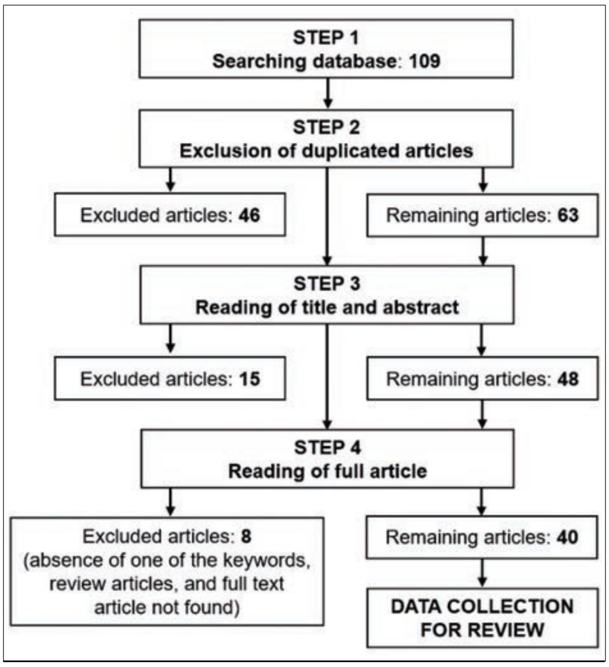

Figure 1 - PRISMA flow diagram of included studies

The inclusion of articles considered the following criteria: (1) type of publication - original research articles, (2) only articles in English, (3) articles must have the chemical composition of *Blumea* essential oils, (4) articles must discuss the bioactivity of the essential oils. As exclusion criteria, the following were used: (1) articles that did not have 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 have the essential oil composition.

3. MEDICINAL USES

The *Blumea* genus includes some key medicinal plants largely used in traditional medicine. Among the *Blumea* species, *B. balsamifera* is one of the best-known species and it is very often cultivated locally where it is known as 'sambong'. It has been widely used as medicine for thousands of years in Southeast Asia countries, such as China, Malaysia, Thailand, Vietnam, and the Philippines. In China, it is generally used as incense due to its richness of essential oils. Besides, the leaves were used as a crude Chinese traditional medicinal material to treat eczema, dermatitis, beriberi, lumbago, menorrhagia, rheumatism, and skin injury, and as an insecticide [6]. Table I shows the medicinal uses of several *Blumea* species [11-28].

4. ESSENTIAL OILS ANALYSIS

Generally, the volatile components of *Blumea* spp. were identified by Gas Chromatography (GC-FID) and Gas Chromatography-Mass Spectrometry (GC-MS). The plant parts, studies focused on many materials such as leaves, flowers, stems, twigs as well as aerial part. Data analysis of the GC-FID results were conducted using the calculation of Kovats index of homologous alkane (e.g., C7 to C20, while GC-MS mass spectrum was identified by comparison with integrated NIST library and Adams.

In previous studies, eighteen *Blumea* species were described on the composition of the essential oils [29-53]. These were *B. lacera* [12, 29-31], *B. sinuata* [12], *B. riparia* [13], *B. paniculata* [32], *B. balsamifera* [33-40], *B. lanceolaria* [41], *B. eriantha* [17, 42], *B. malcolmii* [43], *B. mollis* [44, 45], *B. densiflora* [46], *B. perrottetiana* [47], *B. megacephala* [48], *B. martiniana* [20], *B. gariepina* [49], *B. brevipes* [50], *B. lanceolaria* [51], *B. virens* [52], and *B. oxyodonta* [53].

Most of the species were reported from China, India, and Vietnam, in addition to Bangladesh, Kenya, Nepal, Nigeria, and Zambia. The highest yield was shown by the *B. balsamifera* leaf oil from China which gave 3.25-3.42% [35, 38].

5. ESSENTIAL OILS COMPOSITION

Investigation of chemical components identified in *Blumea* essential oils shows that the oil consists of several groups of components, which are monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, oxygenated sesquiterpenes, ester, and ketone. Besides, *B. lacera* essential oil from Nepal [30] reported the highest chemical components, consisting in 72 components. Table II shows the major components identified in *Blumea* essential oils from various localities.

Table I - Medicinal uses of several *Blumea* species

Species	Medicinal uses	References
B. lacera	Used as an expectorant, diuretic, astringent, antispasmodic, antipyretic, antioxidant, antidiarrheal, liver tonic, and stimulant.	[11]
B. sinuata	Its leaves and stems are used to treat boils, remove toxins from the body, and stop bleeding.	[12]
B. riparia	In Chinese traditional medicine, the plant is used to treat headaches, hypertension, colic, and gynecological diseases. In Malaysia, root decoction is used to treat cough, stomachache, and edema.	[13]
B. paniculata	The whole plant is used for the treatment of diarrhea, fever, and parasites, while the roots are used to control stomachache. In veterinary medicine, leave and fruit paste is used as a wound healing of cattle.	[14]
B. balsamifera	The leaves have been employed for the treatment of eczema, beriberi, menorrhagia, dermatitis, lumbago, rheumatism, and skin injury.	[15]
B. lanceolaria	The leaves are used for the treatment of bronchitis, aphthae, and asthma. In India, the plant is used as an anti-cancer agent, and leaves juice is useful for wound healing, chronic ulcers, and infusion of leaves to control dysentery.	[16]
B. membranacea	The essential oil led to blood pressure reduction.	[9]
B. eriantha	The juice extracted from this herb has been reported as a carminative, while the warm leaf infusion is used as sudorific, and the cold infusion is considered as a diuretic and herbal emmenagogue.	[17]
B. densiflora	This plant is used to drive away mosquitoes by burning, and its juice used to prevent mosquito bites in South China because of its light, borneol-like odor	[18]
B. megacephala	The plant is edible and used for malaria, bronchitis, puerperal metrorrhagia, puerperal edema, and barrenness.	[19]
B. martiniana	It has been used for the treatment of parasites and rheumatism in folklore medicine of Yunnan, China.	[20]
B. perrottetiana	It is a common aromatic weed of savannah farms and has been used as an insect repellent and as an anthelmintic.	[21]
B. mollis	The leaf of the plant is traditionally used for skin diseases and the boiled herb is used to treat diarrhea.	[22]
B. brevipes	The plant is traditionally administered after birth and in the treatment of the sexual disorder.	[23]
B. laciniata	In Bangladesh, this herb is used as a folk medicine to treat a range of ailments, including respiratory and blood diseases, fevers, ulcers, and burning sensations. It is also used in Indian and Chinese traditional medicine systems.	[24]
B. aromatica	It has been widely used as traditional Chinese medicine for the treatment of rheumatism, arthralgia, and eczema.	[25]
B. axillaris	The plant is used in the treatment of skin diseases, wounds, external parasites, diarrhea, asthma, and dropsy.	[26]
B. oxyodonta	The decoction of the roots is used for the treatment of impotency and spermatorrhea.	[14]
B. obliqua	It is used as remedies for malaria, influenza, bronchitis, and asthma.	[27]
B. arfakiana	The leaves are used in the traditional medicine of Papua New Guinea for the treatment of stomach pains, insect bites, and anemia.	[28]

Table II - Major chemical components identified from *Blumea* essential oils

Species	Locality	Part	Yield (%)	Identification (No. %)	Major components	References
B. lacera	Vietnam	Floral	1.10	32, 97.7	(*E*)-Caryophyllene (23.8%), germacrene D (18.5%), thymohydroquinone dimethyl ether (5.0%), γ-curcumene (5.9%), ar-curcumene (8.0%), and α-zingiberene (4.7%)	[12]
		Leaf	1.56	36, 97.3	(*E*)-Caryophyllene (27.2%), germacrene D (21.0%), thymohydroquinone dimethyl ether (4.1%), γ-curcumene (7.7%), ar-curcumene (3.7%), and α-zingiberene (7.1%)	[12]
		Stem	0.35	38, 94.7	(*E*)-Caryophyllene (11.7%), germacrene D (11.2%), thymohydroquinone dimethyl ether (28.4%), γ-curcumene (4.7%), ar-curcumene (1.9%), and α-zingiberene (4.6%)	[12]
		Aerial parts	0.06-0.5	49, 99.0	β-Caryophyllene (8.3-12.0%), thymolhydroquinon-dimethylether (6.6-11.9%), and caryophyllene oxide (11.9-21.7%)	[29]
	Nepal	Aerial parts	1.00	77, 98.2	(*Z*)-Lachnophyllum ester (25.5%), (*Z*)-lachnophyllic acid (17.0%), germacrene D (11.0%), (*E*)-β-farnesene (10.1%), bicyclogermacrene (5.2%), (*E*)-caryophyllene (4.8%), and (*E*)-nerolidol (4.2%)	[30]
	Nigeria	Leaf	NM	13, 63.0	Thymoquinol dimethyl ether (33.9%), β-caryophyllene (10.7%), α-humulene (4.6%)	[31]
B. sinuata	Vietnam	Aerial parts	0.16	65, 97.8	Thymohydroquinone dimethyl ether (29.4%), (*E*)-caryophyllene (19.7%), α-pinene (8.8%), germacrene D (7.8%), and α-humulene (4.3%)	[12]
B. riparia	Vietnam	Leaf	0.1-0.2	36, 91.8	Germacrene D (33.6%), (*E*)-β-caryophyllene (11.2%), bicyclogermacrene (9.3%), and caryophyllene oxide (5.9%)	[13]
		Twig	0.1-0.2	30, 94.2	germacrene D (42.6%), bicyclogermacrene (12.1%), and (*E*)-β-caryophyllene (11.6%)	[13]
B. paniculata	India	Leaf	0.09	39, 95.8	Germacrene D (46.9%), β-caryophyllene (5.9%), caryophyllene oxide (3.9%), and hexadecanoic acid (3.5%)	[32]
		Stem	0.50	46, 96.3	Germacrene D (48.1%), α-humulene (4.9%), β-caryophyllene (4.8%), *epi*-α-cadinol (4.7%), α-cadinol (4.3%), and α-pinene (4.2%)	
		Flower	0.80	40, 95.1	Germacrene D (39.6%), α-humulene (8.9%), β-caryophyllene (7.7%), and *epi*-α-cadinol (4.7%)	
B. balsamifera	China	Leaf	NM	39, 86.0	Borneol (25.3%), *trans*-caryophyllene (24.4%), camphor (8.9%), and caryophyllene oxide (5.8%)	[33]
				35, 85.0	Caryophyllene (18.54%), borneol (18.33%), (+)-2-bornanone (11.28%), and α-gurjunene (6.73%)	[34]
		Leaf	3.42	51, 86.3	Caryophyllene (22.5%), xanthoxylin (20.2%), and γ-eudesmol (12.2%)	[35]
		Leaf	0.88	27, 99.23	1,8-Cineole (20.98%), borneol (11.98%), β-caryophyllene (10.38%), camphor (8.06%), terpinen-4-ol (6.49%), α-terpineol (5.91%), and caryophyllene oxide (5.35%)	[36]
		Leaf	NM	49, 97.59	Borneol (43.55%), camphor (9.54%), and β-caryophyllene (6.51%)	[37]

Table II - Continue

Species	Locality	Part	Yield (%)	Identification (No. %)	Major components	References
		Leaf	3.25	42, 97.65	Caryophyllene (19.28%), 1,7,7-trimethyl-(1S-endo)-bicyclo[2.2.1] heptan-2-ol (15.54%), caryophyllene oxide (11.20%), thujopsene (10.36%), 3-t-butyl-4-methoxyphenol methyl derivative (6.04%), and guaiol (5.03%)	[38]
		Leaf	NM	67, 98.56	Caryophyllene (26.47%), thujopsene-I3 (14.45%), 1,7,7-trimethyl-(1*S*-endo)-bicyclo[2.2.1]heptan-2-ol (9.07%), 3-t-butyl-4-methoxyphenol methyl derivative (6.91%), 1*R*,4*R*,7*R*,11*R*-1,3,4,7-tetramethyl-tricyclo[5.3.1.0(4,11)]undec-2-ene (6.03%), and caryophyllene oxide (5.38%)	[39]
	Bangladesh	Leaf	0.40	50, 99.07	Borneol (33.22%), caryophyllene (8.24%), ledol (7.12%), tetracyclo[6,3,2,0,(2.5).0(1,8) tridecan-9-ol, 4,4-dimethyl (5.18%), phytol(4.63%), caryophyllene oxide(4.07%), and thujopsene-13 (4.42%)	[40]
B. lanceolaria	India	Leaf	0.02	36, 97.3	β-Pinene (82.3%), terpinen-4-ol (4.1%), γ-terpinene (2.5%), and sabinene (2.2%)	[41]
B. eriantha	India	Leaf	NM	34, 94.2	(4*E*,6*Z*)-*allo*-Ocimene (12.8%), carvotanacetone (10.6%), and dodecyl acetate (8.9%)	[17]
	India	Leaf	NM	72, 96.83	(4*E*,6*Z*)-Ocimene (13.72%), caryophyllene (9.71%), caryophyllene oxide (5.76%), and carvotanacetone (5.36%)	[42]
B. malcolmii	India	Aerial parts	0.27	18, 99.2	Carvotanacetone (92.1%), carvomenthone (2.3%), and β-caryophyllene (1.1%)	[43]
B. mollis	India	Leaf	NM	22, 92.3	β-Caryophyllene (24.54%), γ-cadinene (16.29%), α-zingiberene (9.34%), β-sesquiphellandrene (7.64%), and α-curcumene (7.49%)	[44]
	India	Leaf	0.50	39, 99.96	Linalool (19.43%), γ-elemene (12.19%), copaene (10.93%), estragole (10.81%), *allo*-ocimene (10.03%), γ-terpinene (8.28%), and *allo*-aromadendrene (7.44%)	[45]
B. densiflora	China	Aerial parts	NM	46, 98.63	Borneol (11.43%), germacrene D (8.66%), β-caryophyllene (6.68%), γ-terpinene (4.35%), sabinene (4.34%), and β-bisabolene (4.24%)	[46]
B. perrottetiana	Nigeria	Aerial parts	0.27	34, 99.9	2,5-Dimethoxy-p-cymene (30.0%), 1,8-cineole (11.0%), sabinene (8.1%), δ-cadinene (5.3%), and β-caryophyllene (3.9%)	[47]
B. megacephala	China	Aerial parts	0.72	65, 94.86	Borneol (13.6 %), β-caryophyllene (9.56 %), germacrene D (9.09 %), sabinene (6.37 %), and α-humulene (4.78 %).	[48]
B. martiniana	China	Aerial parts	0.64	68, 98.55	Linalool (10.36%), germacrene D (9.09%), borneol (6.24%), and γ-terpinene (5.38%)	[20]
B. gariepina	Zambia	Leaf	0.70	8, 97.7	Thymyl acetate (85.4%) and thymol (6.9%)	[49]
B. brevipes	Kenya	Flower	0.70	68, 94.0	Terpinen-4-ol (27.6%), germacrene-D (15.4%), sabinene (8.0%), and γ-terpinene (5.5%)	[50]
B. lanceolaria	Vietnam	Leaf	0.24	12, 99.9	Methyl thymol (94.9%) and *p*-cymene (3.28%)	[51]
B. virens	India	Aerial parts	0.20	52, 97.8	2,5-Dimethoxy-p-cymene (27.6%), hinesol (20.2%), α-pinene (6.9%), and hexadecanoic acid (4.3%)	[52]
B. oxyodonta	India	Aerial parts	0.02	61, 98.8	β-Caryophyllene (23.5%), 2,5-dimethoxy-p-cymene (14.7%), and germacrene D (13.2%)	[53]

β-Caryophyllene has been indicated as a major component in most *Blumea* essential oils. Its abundance was recognised in the essential oils of *B. lacera* [12, 29], *B. riparia* [13], *B. paniculata* [32], *B. balsamifera* [35, 38, 39], *B. mollis* [44], and *B. oxyodonta* [53]. The highest amount of β-caryophyllene was reported from the leaf oil of *B. lacera* from Vietnam which contributed with 27.2% [12]. β-Caryophyllene is found in numerous edible plants that are ingested daily, and it is approved as a food additive by the Food and Drug Administration. This compound can change the inflammatory processes in humans through the endocannabinoid system [54]. Furthermore, this compound could increase the intracellular accumulation of anticancer agents, thereby potentiating their cytotoxicity due to the absorption of 5-fluorouracil across human skin. β-Caryophyllene facilitates the passage of paclitaxel through membranes and thus potentiates its anticancer activity [55].

Germacrene D has been reported to be the major component in several *Blumea* essential oils such as *B. riparia* [12] from Vietnam and *B. paniculata* [32] from India. Both species presented in high amounts which is more than 30%. Germacrene D is one of the most common plant volatiles considered to be a biogenetic precursor of many sesquiterpenes such as cadinane, muurolane and amorphane derivatives. This metabolite is involved in plant-insect interaction acting as a pheromone on receptor neurons ones [56]. It was also shown as an important deterrent and insecticidal agent against different parasites such as mosquitos, aphids, and ticks [57].

In another study, the borneol richness was also found in *B. balsamifera* [37] from China and Bangladesh [40], as well as *B. densiflora* [46] and *B. megacephala* [48], both from China. Borneol was recently reported to exhibit an antibacterial activity [58]. It was also reported to have neuroprotective effects, as well as vasorelaxant properties [59].

Carvotanacetone was also found as a major component in *B. malcolmii* [43] and *B. eriantha* [17] essential oils from India. Previously, the essential oil containing carvotanacetone has been reported to possess a strong bactericidal activity, moderate cytotoxic activity, and an acetylcholinesterase inhibitory effect [60].

Furthermore, oxygenated monoterpenes were found in several *Blumea* essential oils. 1,8-Cineole was identified dominantly in the leaf oil of *B. balsamifera* [36], β-pinene from the leaf oil of *B. lanceolaria* [41], as well as terpinen-4-ol from the flower oil of *B. brevipes* [50]. In addition, linalool was also found in a high percentage in the leaf oil of *B. mollis* [45] and the aerial parts oil of *B. martiniana* [20].

Generally, the chemical variations discovered between the *Blumea* species might have possibly relied on the environment in which the plant existed and was collected in addition to seasonal variations at the time. These factors influence the plant's biosynthetic pathways and consequently, the relative proportion of the main characteristic components [61].

6. BIOLOGICAL ACTIVITIES

The literature study reveals that *Blumea* essential oils have been reported in various biological activities mainly for larvicidal, antimicrobial, anti-inflammatory, cytotoxicity, and fumigant toxicity. The biological activities of *Blumea* essential oils are illustrated in Table III.

Most of the studies focused on the larvicidal activity of *Blumea* essential oils. A larvicide is a type of insecticide used to control mosquitoes, by killing mosquito larvae before they can grow into adults. Among them, *B. sinuata* essential oil [12] showed strong larvicidal activities with 24-h LC_{50} values of 23.4 and 29.1 μg/mL against *Aedes aegypti* and *Aedes albopictus*, respectively, as well as 48-h LC_{50} values of 17.4 and 12.4 μg/mL. In addition, *B. eriantha* essential oil [17] also gave high toxicity against *Anopheles stephensi* (LC_{50} 41.61 μg/mL), *Aedes aegypti* (LC_{50} 44.82 μg/mL), *Culex quinquefasciatus* (LC_{50} 48.92 μg/mL), *Anopheles subpictus* (LC_{50} 51.21 μg/mL), *Aedes albopictus* (LC_{50} 56.33 μg/mL) and *Culex tritaeniorhynchus* (LC_{50} 61.33 μg/mL). Meanwhile, the essential oils of *B. lacera* [12], *B. densiflora* [46], *B. martiniana* [20], *B. mollis* [45], and *B. perrottetiana* [47] also exerted significant activity against various mosquito species.

For the antimicrobial activity, the essential oils act to inhibit the growth of bacterial cells and also inhibit the production of toxic bacterial metabolites. The *Blumea* essential oil were found to display antimicrobial activity against various microbial strains, which includes food spoilage and common human/plant pathogenic bacterial and yeast strains. The most known and basic methods are the disk-diffusion and broth or agar dilution methods. The *B. balsamifera* essential oil [64] appeared to impose an extremely strong inhibition on *Haemophilus parasuis* with MIC and MBC values found to be 0.625 and 1.25 μg/mL, respectively. In addition, *B. mollis* essential oil [66] also showed a strong activity against *Bacillus pumilus*, *Staphylococcus aureus*, and *Streptococcus pyogenes*, each with MIC value of 62.5 μg/mL. In another study, *B. balsamifera* essential oil [36] possessed a strong fumigant toxicity against *Sitophilus zeamais* with LC_{50} value 10.71 mg/L air.

7. CONCLUSION

This article's objective was to provide significant literature on the medicinal uses, chemical compositions, and biological activity evidence of the *Blumea* essential oils. Read together, the results above indicate that the chemical composition of the essential oils of *Blumea* species comprises a diverse group of components that could be considered promising

Table III - Biological activities from *Blumea* essential oils.

Bioactivities	Species	Description	References
Larvicidal	*B. lacera*	The essential oil showed moderate *Aedes* larvicidal activities with 24-h LC_{50} values of 64.7 and 116.7 µg/mL against *Aedes aegypti* and *Aedes albopictus*, respectively, as well as 48-h LC_{50} values of 55.1 and 99.4 µg/mL.	[12]
	B. sinuata	The essential oil showed very good *Aedes* larvicidal activities with 24-h LC_{50} values of 23.4 and 29.1 µg/mL against *Aedes aegypti* and *Aedes albopictus*, respectively, as well as 48-h LC_{50} values of 17.4 and 12.4 µg/mL.	[12]
	B. eriantha	The essential oil showed high toxicity against 3rd instar larvae of six important mosquito species: *Anopheles stephensi* (LC_{50} 41.61 µg/mL), *Aedes aegypti* (LC_{50} 44.82 µg/mL), *Culex quinquefasciatus* (LC_{50} 48.92 µg/mL), *Anopheles subpictus* (LC_{50} 51.21 µg/mL), *Aedes albopictus* (LC_{50} 56.33 µg/mL) and *Culex tritaeniorhynchus* (LC_{50} 61.33 µg/mL).	[17]
	B. densiflora	Toxic effect against fourth-instar larvae of *Anopheles anthropophagus* (LC_{50} 22.32 ppm and LC_{90} 54.04 ppm, 12 h; LC_{50} 10.55 ppm and LC_{90} 33.56 ppm, 24 h).	[46]
	B. martiniana	The essential oil exerted significant activity against *Anopheles anthropophagus* with LC_{50} values of 46.86, 35.87, 44.61, 35.89, and 29.21 mg/L, respectively.	[20]
	B. mollis	The essential oil showed significant toxic effect against early fourth-instar larvae of *Culex quinquefasciatus* with LC_{50} value 71.71 ppm and LC_{90} value 143.41 ppm, after 24 h.	[45]
	B. perrottetiana	The essential oil showed notable activity against the red flour beetle, *Tribolium Castaneum* (73.3% mortality, 12 h and 93.3% mortality, 24 h).	[47]
Antimicrobial	*B. riparia*	The twig oil possessed an MIC value of 100 µg/mL against *Bacillus subtilis*, whereas the leaf oil had MIC values of 50 and 100 µg/mL against *Fusarium oxysporum* and *Saccharomyces cerevisiae.*	[13]
	B. lacera	The essential oil showed potential activity against *Erwinia herbicola* and *Pseudomonas putida* with MIC values of 4.0 and 8.0 µg/mL, respectively.	[62]
	B. eriantha	The essential oil showed a significant activity against *Streptococcus pyogenes* with MIC and MBC values 0.09% and 0.39%, respectively.	[63]
	B. megacephala	The essential oil (1000 µg/disc) has promising effects against several pathogens, giving inhibition zone diameter values (21.5, 21.6, 23.4, 23.8, 21.9) and MIC values (125, 125, 62.5, 125, 125 µg/mL) against *Pseudomonas aeruginosa*, *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus*, and *Hansenula anomala*, respectively.	[48]
	B. balsamifera	The essential oil appeared to impose extremely strong inhibition on *Haemophilus parasuis* in vitro and the MIC was found to be 0.625 µg/mL, and the MBC was 1.25 µg/mL.	[64]
		The essential oil was the most potent with a MIC of 150 µg/mL against *Bacillus cereus* and an MIC of 1.2 µg/mL against *Staphylococcus aureus* and *Candida albicans.*	[65]
	B. mollis	The essential oil showed strong activity against *Bacillus pumilus*, *Staphylococcus aureus*, and *Streptococcus pyogenes*, each with MIC value of 62.5 µg/mL.	[66]
Anti-inflammatory	*B. balsamifera*	The essential oil can significantly reduce the LPS-induced pro-inflammatory elements TNF-α, IL-1β, IL-6, and inflammatory mediator COX-2 in RAW264.7 cells ($p<0.01$). Additionally, it can significantly inhibit the expression of proteins in the NF-κB signaling pathway, such as CD14, TLR4, MyD88, TAK-1, p-IκBα, and NLRP3 inflammasome ($p<0.05$, $p<0.01$).	[33]
		The essential oil can effectively alleviate the skin erythema and epidermal thickening caused by UV-B radiation, via the down-regulation of TNF-a, IL-6 and IL-10, thereby alleviating the damage of UV-B radiation to cells and tissues, and promoting the healing of injury skin.	[34]
Cytotoxicity	*B. lacera*	The essential oil showed promising activity against MDA-MB-231, MCF-7, and 5637 cell lines, with IC_{50} values of 11.2, 27.7, and 22.0 µg/mL.	[30]
Fumigant toxicity	*B. balsamifera*	The essential oil possessed strong fumigant toxicity against *Sitophilus zeamais* with LC_{50} value 10.71 mg/L air.	[36]

for applications in different industries, including the food and pharmaceutical industries. In addition, the essential oil isolated from *Blumea* species may bear the potential for a drug development due to its high concentration of β-caryophyllene, germacrene D, and borneol. Considering the great diversity of chemical components and functional properties of these essential oils, further investigations should focus on the effect of the extraction technique on the quality and extraction yield of the essential oils from *Blumea* species and the use of these oils in various applications such as food products.

REFERENCES

[1] E. Piątkowska, W. Biel, R. Witkowicz, J. Kępińska-Pacelik, Chemical composition and antioxidant activity of Asteraceae family Plants. Appl. Sci. 12(23), 12293 (2022).

[2] M. Jayasundera, S. Florentine, K.U Tennakoon, B.S. Chauhan, Medicinal value of three agricultural weed species of the Asteraceae family: A review. Pharmacogn. J. 13(1), 264-277 (2021).

[3] P. Pornpongrungrueng, F. Borchsenius, M. Englund, A.A. Anderberg, M.H.G. Gustafsson, Phylogenetic relationships in *Blumea* (Asteraceae: Inuleae) as evidenced by molecular and morphological data. Syst. Evol. 269, 223-243 (2007).

[4] I.H. Burkill, A Dictionary of the Economic Products of the Malay Peninsula, Vol. 1, Ministry of Agriculture and Cooperatives, Kuala Lumpur (1966).

[5] L.M. Perry, Medicinal plants of East and Southeast Asia, Harvard University, Cambridge, MA (1980).

[6] M. Chen, H.Z. Jin, W.D. Zhang, S.K. Yan, Y.H. Shen, Chemical constituents of plants from the genus *Blumea*. Chem. Biodiver. 6, 809-817 (2009).

[7] Y.X. Pang, Z.W. Fan, D. Wang, Q. Yang, K. Wang, X.L. Chen, X. Hu, F.L. Yu, Z.X. Chen, External application of the volatile oil from *Blumea balsamifera* may be safe for liver - a study on its chemical composition and hepatotoxicity. Molecules 19, 18479-18492 (2014).

[8] Y. Pang, D. Wang, Z. Fan, X. Chen, F. Yu, X. Hu, K. Wang, L. Yuan, *Blumea balsamifera* - a phytochemical and pharmacological review. Molecules 19(7), 9453-9477 (2014).

[9] S.C. Mehta, H. Vardhan, S.P. Saxena, Some pharmacological actions of the essential oil of *Blumea membranacea*. Indian J. Physiol. Pharmacol. 30, 149-154 (1986).

[10] D. Moher, A. Liberati, J. Tetzlaff, G.A. Douglas, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Ann. Intern. Med. 151, 264-269, (2009)

[11] M.R. Habib, Y. Igarashi, M.A. Rabbi, Phytochemical composition of *Blumea lacera* leaf and its inhibitory effects on the activity of enzymes related to metabolic diseases. Pharm. Sci. Asia 49, 265-272 (2022).

[12] T.M. Hoi, P. Satyal, L.T. Huong, D.V. Hau, T.D. Binh, D.T.H. Duyen, D.N. Dai, N.G. Huy, H.V. Chinh, V.V. Hoa, N.H. Hung, W.N. Setzer, Essential oils from Vietnamese Asteraceae for environmentally friendly control of *Aedes mosquitoes*. Molecules, 27(22), 7961 (2022).

[13] S.N. The, A.L. Tuan, T.D.T. Thu, N.D. Luyen, T.T. Thi, Essential oils of the Asteraceae plants *Blumea riparia* DC. and *Pluchea pteropoda* Hemsl. ex Hemsl. growing in Vietnam. Nat. Prod. Commun. 17(6), 1-6 (2022).

[14] U. Quattrocchi, CRC world dictionary of medicinal and poisonous plants, common names, scientific names, eponyms, synonyms, and etymology. Boca Raton (FL): CRC Press (2012).

[15] N. Ruangrungsi, P. Tantivatana, P. Tappayuthpijarn, R.P. Borris, G.A. Cordell, Traditional medicinal plants of Thailand VI: isolation of cryptomeridiol from *Blumea balsamifera* (Compositae). Sci. Asia, 11, 47-50 (1985).

[16] K.C.T. Phi, G.N. Kim, H.D. Jang, In vitro and intracellular antioxidant capacity of thymyl methyl ether as a major component in *Blumea lanceolaria* (Roxb.) Druce leaf oil. Food Chem. Toxicol. 50(5), 1583-1588 (2012).

[17] G. Benelli, M. Govindarajan, M. Rajeswary, S. Senthilmurugan, P. Vijayan, N.S. Alharbi, S. Kadaikunnan, J.M. Khaled, Larvicidal activity of *Blumea eriantha* essential oil and its components against six mosquito species, including Zikavirus vectors: the promising potential of (4*E*,6*Z*)-allo-ocimene, carvotanacetone and dodecyl acetate. Parasitol. Res. 116(4), 1175-1188 (2017).

[18] S.C. Gupta, U.M. Khanolkar, O. Koul, B.P. Saxena, Pyrethrin synergistic activity by the essential oils of a few *Blumea* species. Curr. Sci. 46, 304-305 (1977).

[19] D. Tan, Q. Yan, Flavonoids from the aerial parts of *Blumea megacephala*. Chem. Nat. Compd. 55(5), 927-928 (2019).

[20] L. Zhu, Y.J. Tian, Chemical composition and larvicidal effects of essential oil of *Blumea martiniana* against *Anopheles anthropophagus*. Asian Pacific J. Trop. Med. 4(5), 371-374 (2011).

[21] J.C.T. Uphof, Dictionary of Economic Plants, 2nd Ed. Verlag von J. Cramer. Lehre, Germany (1968).

[22] D.N. Guha Bakshi, P. Sensarma, D.C. Pal, A lexicon of medicinal plants in India, Vol. 1. Naya Prokash, Calcutta (1999).

[23] A.D.Q. Agnew, Upland Kenya Wild Flowers, Oxford University Press, London (1974).

[24] A.H.M.M. Rahman, Assessment of angiosperm

weeds of Rajshahi, Bangladesh with emphasis on medicinal plants. Res. Plant Sci. 1, 62-67 (2013).
[25] M.S. Lan, C. Luo, C.H. Tan, L. Chen, S. Wei, D.Y. Zhu, Study on chemical constituents of the ethyl acetate extract from *Blumea aromatica*. J. Chin. Med. Mater. 35, 229-231 (2012).
[26] K.P. Sreelekha, T.P. Ajeesh Krishna, T.P. Adarsh Krishna, P.E. Deepa, D. Udayan, S. Juliet, S.N. Nair, R. Ravindran, Pharmaco-chemical characterization of leaves of *Blumea mollis* (D.Don) Merr. from Western Ghats of Wayanad region of Kerala, India. J. Pharmacogn. Phytochem. 6(4), 319-323 (2017).
[27] V.U. Ahmad, N. Alam, New antifungal bithienylacetylenes from *Blumea obliqua*. J. Nat. Prod. 58(9), 1426-1429 (1995).
[28] G. Rucker, G. Paulini, H. Sakulas, B. Lawong, F. Goeltenboth, Medicinal plants from Papua New Guinea: Graniline-esters and germacranolides from *Blumea arfakiana*. Planta Med. 57(3), 278-281 (1991).
[29] L.V. Hac, T.T. Muoi, N.X. Dung, Essential oils of *Blumea lacera* (Burm. f) DC. (asteraceae) produced from aerial parts of plants grown in central of Vietnam. J. Essent. Oil-Bearing Pl. 6(1), 36-40 (2003).
[30] P. Satyal, B.K. Chhetri, N.S. Dosoky, S. Shrestha, A. Poudel, W.N. Setzer, Chemical composition of *Blumea lacera* essential oil from Nepal. Biological activities of the essential oil and (*Z*)-lachnophyllum ester. Nat. Prod. Commun. 10 (10), pp. 1749-1750 (2015).
[31] I. Laakso, T. Seppänen-Laakso, R. Hiltunen, O. Ekundayo, Composition of the essential oil of *Blumea lacera* DC. (Asteraceae) leaves from Nigeria. Flav. Fragr. J. 4(2), 73-75 (1989).
[32] R.K. Joshi, Sesquiterpenoid-rich leaf, stem, and flower essential oil of the traditional herb *Blumea paniculata* (Willd.) M.R. Almeida from India. Nat. Prod. Res. *in press* (2021).
[33] J. Liao, X. Xie, W. Wang, Y. Gao, Y. Cai, J. Peng, T. Li, Q. Yi, C. He, L. Wang, Anti-inflammatory activity of essential oil from leaves of *Blumea balsamifera* (L.) DC through Inhibiting TLR4/NF-kB signalling pathways and NLRP3 inflammasome activation in LPS-induced RAW264.7 macrophage cells. J. Essent. Oil-Bearing Pl. 24(2), 160-176 (2021).
[34] B. Zhang, M. Tang, W. Zhang, C. Zhang, Y. Ai, X. Liang, Y. Shi, Y. Chen, L. Zhang, T. He, Chemical composition of *Blumea balsamifera* and *Magnolia sieboldii* essential oils and prevention of UV-bradiation-induced skin photoaging. Nat. Prod. Res. 35(24), 5977-5980 (2021).
[35] Y.H. Wang, X.Y. Yu, Biological activities and chemical compositions of volatile oil and essential oil from the leaves of *Blumea balsamifera*. J. Essent. Oil-Bearing Pl. 21(6), 1511-1531 (2018).
[36] S.S. Chu, S.S. Du, Z.L. Liu, Fumigant compounds from the essential oil of Chinese *Blumea balsamifera* leaves against the maize weevil (Sitophilus zeamais). J. Chem. 289874 (2013).
[37] Y. Yuan, M. Huang, Y.X. Pang, F.L. Yu, C. Chen, L.W. Liu, Z.X. Chen, Y.B. Zhang, X.L. Chen, X. Hu, Variations in essential oil yield, composition, and antioxidant activity of different plant organs from *Blumea balsamifera* (L.) DC. at different growth times. Molecules 21(8), 1024 (2016).
[38] Z.L. Jiang, Y. Zhou, W.C. Ge, K. Yuan, Phytochemical compositions of volatile oil from *Blumea balsamifera* and their biological activities. Phcog. Mag. 10(30), 346-352 (2014).
[39] Y.X. Li, X.H. Pei, D.Q. Jiang, K. Yuan, Phytochemical compositions of the essential oil from *Blumea balsamifera*. Asian J. Chem. 25(11), 6361-6365 (2013).
[40] N.I. Bhuiyan, J.U. Chowdhury, J. Begum, Chemical components in volatile oil from *Blumea balsamifera* (L.) DC. Bangladesh J. Bot. 38(1), 107-109 (2009).
[41] R.K. Joshi, GC-MS analysis of volatile organic constituents of traditionally used medicinal plants from the Western Ghats of India: *Blumea lanceolaria* (Roxb.) Druce. *Heliotropium indicum* L. and *Triumfetta rhomboidea* Jacq. J. Mex. Chem. Soc. 64(2), 1-9 (2020).
[42] P.P. Pednekar, R.V. Dhumal, A.G. Datar, G.R. Vanage, In vivo dermal absorption and sub-acute toxicity studies of essential oil from *Blumea eriantha* DC. Int. J. Pharm. Pharm. Sci. 5(3), 351-358 (2013).
[43] R.K. Joshi, S.R. Pai, Reinvestigation of carvotanacetone after 100 years along with minor terpenoid constituents of *Blumea malcolmii* Hook. F. essential oil. Nat. Prod. Res. 30(20), 2368-2371 (2016).
[44] T. Tamilarasi, R. Thirugnanasampandan, Antioxidant activity evaluation of essential oil and RAPD analysis of in vitro regenerated *Blumea mollis* (D. Don) Merr. Acta Physiol. Plant. 36(6), 1593-1598 (2014).
[45] A. Senthilkumar, K. Kannathasan, V. Venkatesalu, Chemical constituents and larvicidal property of the essential oil of *Blumea mollis* (D. Don) Merr. against *Culex quinquefasciatus*. Parasitol. Res. 103(4), 959-962 (2008).
[46] L. Zhu, Y. Tian, Chemical composition and larvicidal activity of *Blumea densiflora* essential oils against *Anopheles anthropophagus*: A malarial vector mosquito. Parasitol. Res. 109(5), 1417-1422 (2011).
[47] M.S. Owolabi, L. Lajide, H.E. Villanueva, W.N. Setzer, Essential oil composition and insecticidal activity of *Blumea perrottetiana* growing in southwestern Nigeria. Nat. Prod. Commun. 5(7), 1135-1138 (2010).
[48] L. Zhu, Y.J. Tian, L. Yang, J.G. Jiang, Chemical

composition and antimicrobial activities of essential oil of *Blumea megacephala*. EXCLI J. 10, 62-68 (2011).

[49] E.H. Chisowa, D.R. Hall, D.I. Farman, Chemical composition of the essential oil of *Blumea gariepina* DC. J. Essent. Oil Res. 10(3), 337-338 (1998).

[50] J.W. Mwangi, K.J. Achola, W. Lwande, A. Hassanali, R. Laurent, Constituents of the essential oil of *Blumea brevipes* (Oliv. & Hiern) willd. Flav. Fragr. J. 9(5), 233-235 (1994).

[51] N.X. Dung, D.T. Loi, D.T. Hung, P.A. Leclercq, Chemical composition of the oil of *Blumea lanceolaria* (Roxb.) Druce from Vietnam. J. Essent. Oil Res. 3(4), 285-286 (1991).

[52] R.K. Joshi, Chemical composition of *Blumea virens* roots from India. Chem. Nat. Compd. 54(3), 584-585 (2018).

[53] R.K. Joshi, Terpenoids of *Blumea oxyodonta* essential oil. Chem. Nat. Compd. 54(2), 377-379 (2018).

[54] E.J. Corey, R.B. Mitra, H. Uda, Total synthesis of d,l-caryophyllene and d,l-isocaryophyllene. J. Am. Chem. Soc. 86(3), 485-492 (1964).

[55] J. Legault, A. Pichette A, Potentiating effect of beta-caryophyllene on anticancer activity of alpha-humulene, isocaryophyllene and paclitaxel. J. Pharm. Pharmacol. 59(12), 1643-1647 (2007).

[56] M. Stranden, A.K. Borg-Karlson, H. Mustaparta, Receptor neuron discrimination of the germacrene D enantiomers in the moth helicoverpa armigera. Chem. Senses 27(2), 143-152 (2002).

[57] M.A. Birkett, S. Al Abassi, T. Krober, K. Chamberlain, A.M. Hooper, P.M. Guerin, J. Pettersson, J.A. Pickett, R. Slade, L.J. Wadhams, Antiectoparasitic activity of the gum resin, gum haggar, from the East African plant, *Commiphora holtziana*. Phytochemistry 69(8), 1710-1715 (2008).

[58] N.F. Leite-Sampaio, C. Gondim, R.A.A. Martins, A. Siyadatpanah, R. Norouzi, B. Kim, C.E. Sobral-Souza, G.E.C. Gondim, J. Ribeiro-Filho, H.D.M. Coutinho, Potentiation of the activity of antibiotics against ATCC and MDR bacterial strains with (+)-α-pinene and (–)-borneol. Biomed. Res. Int. 8217380 (2022).

[59] S.E. Santos, F. Ribeiro, P.M.N. Menezes, L.A.M. Duarte-Filho, J.S.S. Quintans, L.J. Quintans-Junior, F.S. Silva, L.A.A. Ribeiro, New insights on relaxant effects of (–)-borneol monoterpene in rat aortic rings. Fundam. Clin. Pharmacol. 33, 148-158 (2019).

[60] N.A. Ali, F.S. Sharopov, M. Alhaj, G.M. Hill, A. Porzel, N. Arnold, W.N. Setzer, J. Schmidt, L. Wessjohann, Chemical composition and biological activity of essential oil from *Pulicaria undulata* from Yemen. Nat. Prod. Commun. 7, 257-260 (2012).

[61] N.M. Shakri, W.M.N.H.W. Salleh, N.A.M. Ali, Chemical composition and biological activities of the essential oils of genus *Xylopia* L. (Annonaceae) - a review. Riv. Ital. Sostanze Grasse 97(4), 25-34 (2020).

[62] A.K. Pandey, M. Mohan, P. Singh, U.T. Palni, N.N. Tripathi, Chemical composition, antibacterial and antioxidant activity of essential oil of *Eupatorium adenophorum* Spreng. from Eastern Uttar Pradesh, India. Food Biosci. 7, 80-87 (2014).

[63] P.P. Pednekar, B.V. Vakil, R.T. Sane, A.G. Datar, Antimicrobial activity of essential oil of *Blumea eriantha* against skin pathogens. Int. J. Pharm. Pharm. Sci. 4(4), 296-299 (2012).

[64] C. He, P. Yang, L. Wang, X. Jiang, W. Zhang, X. Liang, L. Yin, Z. Yin, Y. Geng, Z. Zhong, X. Song, Y. Zou, L. Li, C. Lv, Antibacterial effect of *Blumea balsamifera* DC. essential oil against *Haemophilus parasuis*. Arch. Microbiol. 202(9), 2499-2508 (2020).

[65] U. Sakee, S. Maneerat, T.P.T. Cushnie, W. De-Eknamkul, Antimicrobial activity of *Blumea balsamifera* (Lin.) DC. extracts and essential oil. Nat. Prod. Res. 25(19), 1849-1856 (2011).

[66] A. Senthilkumar, K. Kannathasan, V. Venkatesalu, Antibacterial activity of the leaf essential oil of *Blumea mollis* (D. Don) Merr. World J. Microbiol. Biotech. 25(7), 1297-1300 (2009).