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Review Article

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Chemical profiles and biological activities of essential oils of *Arisaema* and *Homalomena* species (Araceae) – A review

Sao Mai Dam, Hong Thien Van*

Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, No. 12 Nguyen Van Bao Street, Ward 4, Go Vap District, Ho Chi Minh City, Vietnam

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***Corresponding author:**
Hong Thien Van
E-mail: vanhongthien@iuh.edu.vn

ABSTRACT

In this review, the chemical compositions and bioactivities of the essential oils isolated from *Arisaema* and *Homalomena* species, two large genera belonging to the Araceae family, have been reported for the first time. Accordingly, the essential oils isolated from the plants of two genera consisted of some chemical groups, including monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, and oxygenated sesquiterpenes, etc. In addition, the essential oils and their major compounds isolated from *Arisaema* and *Homalomena* plants possessed biological activities, including antimicrobial, insecticidal, nematicidal, antiproliferative, larvicidal and anthelmintic activities. This review mainly provides information on the *Arisaema* and *Homalomena* oils which are able to use as a guide for the collection of the species with the best chemical composition and biological activities.

KEYWORDS: Essential oils, *Arisaema*, *Homalomena*, phytochemicals, bioactivities

INTRODUCTION

Araceae, a family belonging to the monocototyledons, is one of the most diverse families with over 120 genera and 3800 species. This family is widely distributed from Himalayas and throughout tropical and subtropical Asia as far east as New Guinea and Australia (Croat, 1983; Mayo *et al.*, 1997; Croat, 1998; Coelho, 2000; Vargas, 2002; Boyce *et al.*, 2012). More than 800 Araceae species possess economic values (Pedralli 2002). Members of Araceae are also well-known for their medicinal values which used to deal with headaches, liver disorders, stomach, splenomegaly, etc. (Leaman *et al.*, 1995; Lahitte *et al.*, 1998; Blair & Madrigal, 2005; Lekana-Douki *et al.*, 2011; Kyei *et al.*, 2012). Furthermore, the essential oils isolated from the different parts of the Araceae species additionally contained numerous medicinal compounds, together with terpenes, ketones, flavonoids and phytoestrogens (Todorova *et al.*, 1998; Singh *et al.*, 2000; Wong *et al.*, 2006; Rana *et al.*, 2009; Zeng *et al.*, 2011; Policegoudra *et al.*, 2012; Zhu *et al.*, 2013; Liu *et al.*, 2014; Le *et al.*, 2017; Jia *et al.*, 2018; Rozman *et al.*, 2018; Li *et al.*, 2019; Huang *et al.*, 2019; Van *et al.*, 2020).

Arisaema Martius and *Homalomena* Schott are the two large genera belonging to the Araceae family (Pham, 2000; Gusman & Gusman, 2006; Li *et al.*, 2010; Boyce, 2012; Van, 2017). The first genus includes over 200 species whereas the later one has about 250 species which are widely distributed from the Himalayas, tropical Asia, New Guinea and Australia (Pham, 2000; Gusman & Gusman, 2006; Li *et al.*, 2010; Boyce, 2012; Van, 2017). Both genera are extensively used for traditional medicine in many countries. For instance, the extracts of the rhizomes or tubers of some *Arisaema* species, including *A. calcareum*, *A. serratum*, *A. asperatum*, *A. heterophyllum* and *A. amurense* were used as analgesic, antitumor and pesticide agents in traditional Chinese medicine (Zhao *et al.*, 2010). On the other hand, *H. occulta* and *H. aromatica*, two abundant species of *Homalomena* genus, have been used to treat many diseases such as stomach, skin infections, mosquito repellent, asthma, and liver diseases (Khan & Yadava, 2000; Delang, 2007; Rana *et al.*, 2009). Furthermore, the phytochemical composition and the biological activities of the essential oils which are isolated from the different parts of the *Arisaema* and *Homalomena* species have been shown by many previous studies (Todorova *et al.*, 1998; Singh *et al.*, 2000; Wong *et al.*, 2006; Rana *et al.*, 2009; Zeng *et al.*, 2011; Policegoudra *et al.*, 2012; Zhu *et al.*, 2013; Liu *et al.*, 2014; Le *et al.*, 2017; Jia *et al.*, 2018; Rozman *et al.*, 2018; Li *et al.*, 2019; Huang *et al.*, 2019; Van *et al.*, 2020). Thus, the present review aims to provide information regarding the chemical profiles and bioactivities of the essential oils isolated from the *Arisaema* and *Homalomena* plants.

Botanical Description

Arisaema is the deciduous or evergreen herbaceous plants and possess rhizomes or tubers. Leaves emerges with 1-3, the petiole and peduncle are usually sheathing into pseudostem at lower part, free above or this pseudostem sometime is absent. Leaf blade is trifoliolate with dark green above, pale green under side. The inflorescence emerges along with or after the leaves, solitary, monoecious or dioecious. Spathe of *Arisaema* species divides into two parts, including a spathe tube at the lower part and variously expanded above into a limb. Spadix is sessile, unisexual or bisexual. Infructescence grows upright or nodding. Berries is reddish and has several seeded (Figure 1). On the other hand, *Homalomena* genus is the evergreen herbaceous plants and possess rhizomes. The *Homalomena* species are the strong aromatic plants, especially rhizomes and leaves. Leaves are mostly spirally arranged and have long petiolate. Leaf blade is usually oblong, elliptic, lanceolate, deltoid or sagittate. The inflorescence is usually several together and emerges along with leaves. Spathe is persistent. Spadix is elongate shape; female flowers are usually each with an associated staminode; Male flowers are consisting of 2–6 stamens (Figure 1) (Pham, 2000; Gusman & Gusman, 2006; Li *et al*., 2010; Boyce *et al*., 2012; Van *et al*., 2015; Van *et al*., 2016a; Van *et al*., 2016b; Van *et al*., 2017; Van, 2017; Luu *et al*., 2020).

Chemical Profiles of *Homalomena* Essential Oils

Analysis of chemical profiles of the essential oils isolated from *Homalomena* species showed that the oils consisted of some chemical groups, including monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpene hydrocarbons, and oxygenated sesquiterpenes. Studies focused on two plant materials such as rhizomes and leaves (Todorova *et al*., 1998; Singh *et al*., 2000; Policegoudra *et al*., 2012; Van *et al*., 2020). The major components identified in *Homalomena* essential oils from various origins were presented in Table 1.

Homalomena aromatica (Spreng.) Schott. is the most common species of *Homalomena* genus throughout Bangladesh, India, Laos, Myanmar, Thailand and Vietnam (Li *et al*., 2000). It is a rhizomatous perennial herb and can grow up to 0.4-0.5 meter. *H. aromatica* is considered an ethnomedicinal plant (Kehie *et al*., 2017). For instance, leaf and rhizome of *H. aromatica* are commonly used to treat skin infections, joint-pains, asthma, common cold in infants, stomach pain and diarrhea, jaundice stomach and kidney problems (Kar & Borthakur, 2008; Khan & Yadava, 2010). The chemical compositions of essential oils of *H. aromatica* have been reported by previous studies. Accordingly, linalool and terpene-4-ol were the major components in the essential oils isolated from rhizomes of *H. aromatica* which collected from India, Bangladesh and Vietnam, followed by α-terpineol, α-pinene, δ-cadinene, t-muurolol, α-cadinol, viridiflorol (Todorova *et al*., 1998; Singh *et al*., 2000; Chowdhury *et al*., 2008; Rana *et al*., 2009; Policegoudra *et al*., 2012; Kehie *et al*., 2017).

Homalomena occulta (Lour.) Schott., another common species of *Homalomena* genus, has a wide distribution in several Asian countries, including China, Laos, Thailand and Vietnam (Pham, 2000; Li *et al*., 2010; Boyce *et al*., 2012; Van, 2017). In traditional Chinese medicine, the rhizome of this plant has been used to cure several diseases such as rheumatoid arthritis and stomach. Moreover, this species was also used as tonics and anti-inflammatory agent (Liu *et al*., 2014). According to the previous reports, the major constituents of essential oil from the rhizome of *H. occulta* collected from Anguo, Hebei Province, China, e.g. linalool (47.7%), terpene-4-ol (16.5%), α-terpineol (11.2%), geraniol (3.7%) (Liu *et al*., 2014) were remarkably different compared to those in this species collected in Guangxi Province, China, e.g. epi-α-cadinol (14.81%), α-cadinol (14.77%), α-terpineol (13.77%), linalool (11.08%), terpinen-4-ol (4.92%), δ-cadinene (4.91%) (Zeng et al., 2011) or in Vietnam, e.g. α-bisabolol (22.8%), benzyl benzoate (11.4%), linalool (8.6%), benzyl salicylate (4.9%), α-terpinolen (4.6%) (Le *et al*., 2017). Note that, the chemical components of plant essential oils were found to vary depending on the geographical regions where they are collected (Hassiotis *et al*., 2010; Devkota *et al*., 2013).

Homalomena pierreana Engl. is a rare species and endemic species in Vietnam. Engler and Krause discovered this species for the first time which the samples were collected from southern Vietnam (Engler & Krause, 1912). Recently, this species has been re-collected in Phu Quoc island, Kien Giang Province, Vietnam (Van *et al*., 2018). To date, there were two publications reported the chemical composition of essential oils of this species collected from Nghe An and Kien Giang Province, Vietnam which had differences in the major components of the rhizome oils collected in different regions. Accordingly, α-bisabolol (20.9%), bicyclogermacren (12.8%), (E)-nerolidol (8.0%), δ-cadinen (5.8%), α-muurolen (3.9%), α-terpinolen (3.6%) and benzyl benzoate (3.6%) were the main compounds of *H. pierreana* oils collected in Nghe An Province (North-Central Vietnam) (Le *et al*., 2017). On the other hand, the rhizome essential oil of this species collected from Phu Quoc island (Southern Vietnam) was found to be rich in aromadendrene (44%), δ-selinene (18.5%), cycloundecatriene (7.5%) while aromadendrene (48%), δ-selinene (13.5%), trans-α-bisabolene (12%) were the major compounds in the leaf oil (Van *et al*., 2020).

Homalomena cochinchinensis Engl. is a rare species and found in Southern China, Cambodia, Laos and Southern Vietnam. To date, only our previous publications reported the chemical composition and bioactivities of this species (Van *et al*., 2015; Van *et al*., 2021a; Van *et al*., 2021b). As a result, the essential oil isolated from the rhizome of *H. cochinchinensis* grown in Bu Gia Map National Park, Vietnam was characterized by the prominence of linalool (57.4%), terpinen-4-ol (10.6%), α-sabinene (4.2%) while the aerial part oil was found to be rich in myrcene (41.1%), sabinene (8.2%), D-limonene (9.1%) (Van *et al*., 2021a).

Homalomena pineodora Sulaiman & P.C.Boyce has been described as a new species from Peninsular Malaysia by

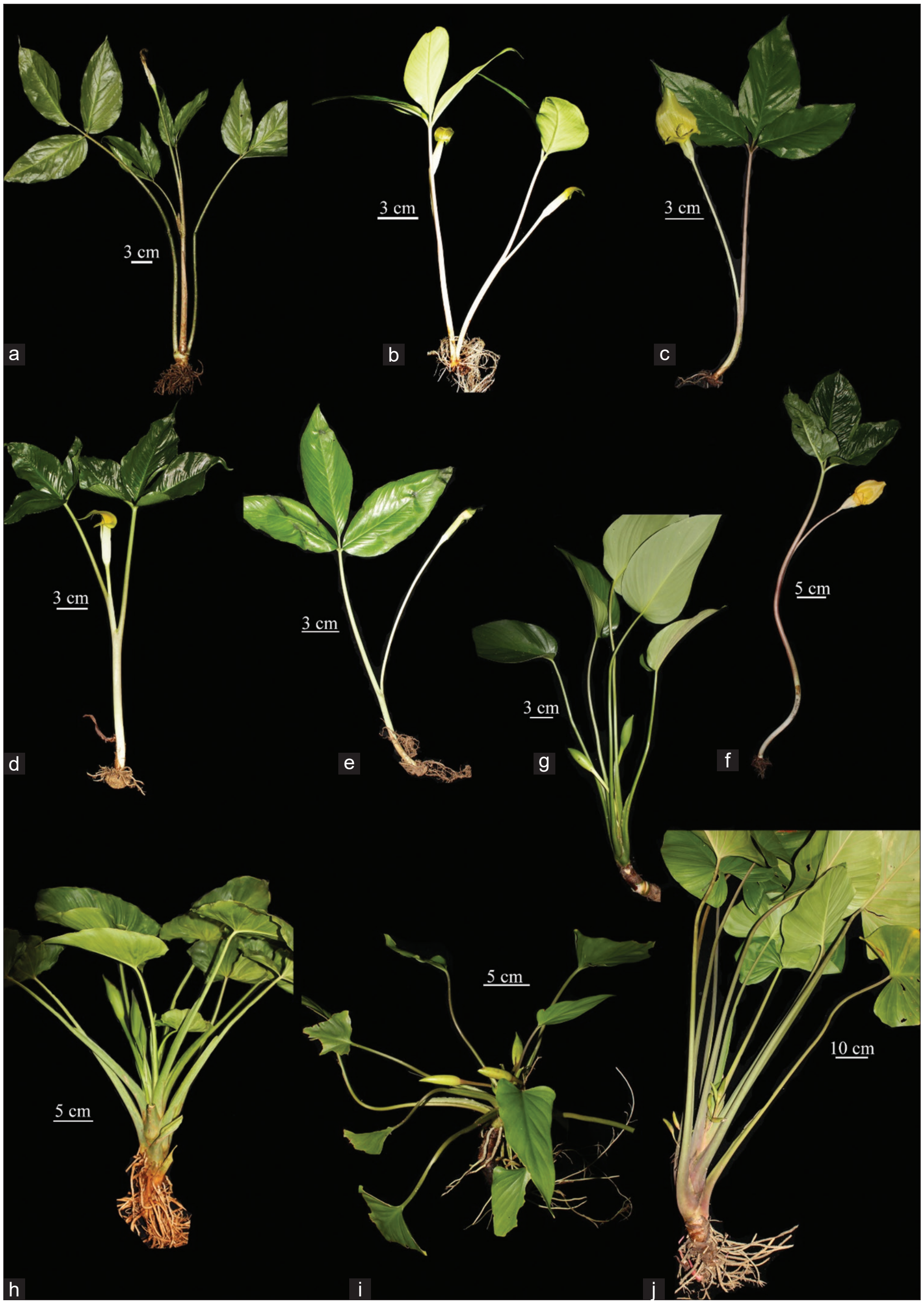

Figure 1: Some *Arisaema* and *Homalomena* species. a: *Arisaema langbiangense*, b: *A. roxburghii*, c: *A. liemana*, d: *A. condaoense*, e: *A. chauvanminhii*, f: *A. pierreanum*, g: *Homalomena vietnamensis*, h: *H. cochinchinensis*, i: *H. pierreana*, j: H. *H. occulta*. Photos by Hong Thien Van

Sulaiman and Boyce (2005) and one later study, Rozman *et al.* (2018) showed the chemical constituents of the essential oils isolated from the leaves of this species of which the major components were 2-octylcyclopentanone (53.8%), propyl decanoate (22.1%), 4-tridecanone (8.7%), 3-methyl-1-dodecyn-3-ol (6.7%), 2-undecanone (2.9%). On the other hand, the investigation on the chemical constituents of the essential oils isolated from *Homalomena sagittifolia* Jungh. ex Schott, another species collected in Malaysia, has been conducted by Wong *et al.* (2006). Accordingly, the major constituents from the rhizome essential oil of *H. sagittifolia* were found to be rich in linalool (61.9%), nonan-2-one (3.7%), α-cadinol (3.4%), terpinen-4-ol (2.5%), T-cadinol (2.1%) whereas the leaves were characterized by the following main compounds, α-pinene (22.2%), β-pinene (17.2%), neointermedeo (6.5%), germacrene D (5.9%), α-selinene (4.1%), δ-cadinene (2.5%), α-humulene (3.9%) (Wong *et al.*, 2006).

Currently, three *Homalomena* species, including *H. aromatica*, *H. cochinchinesis* and *H. occulta* still have different opinions

Table 1: Major components identifed from *Homalomena* essential oils

Species	Locality	Part	Major compounds	References
H. aromatica	Sonitpur, India	Rhizome	Linalool (62.5%), terpene-4-ol (7.08%), δ-cadinene (5.57%), T-muurolol (5.32%), α-cadinol (3.71%), viridiflorol (3.69%)	Policegoudra *et al.* (2012)
	Gopal Nagar, India	Rhizome	Linalool (62.1%), terpinen-4-ol (17.2%), α-terpineol (2.4%), γ-terpinene (1.9%)	Singh *et al.* (2000)
	Jiribum, Indian	Rhizome	Linalool (58.3%), terpinen-4-ol (16.7%), a-terpineol (1.8%). a-eadinol (1.7%)	Rana *et al.* (2009)
	Uttar Pradesh, India	Rhizome	Linalool (68.51%), terpinen-4-ol (8.26%), α-pinene (3.16%), terpineol (2.24%)	*Tiwari et al.* (2021)
	Bangladesh	Rhizome	linalool (69.5%), terpinen-4-ol (7.6%), 2-furanethanol-5-etheny Itetrahydro-a.(1-5-tri methy I (5.7%).	Chowdhury *et al.* (2008)
	Thanh Hoa, Vietnam	Rhizome	Linalool (71.2%), terpene-4-ol (4.6%), linalyl acetate (3.3%)	Todorova *et al.* (1988)
H. cochinchinensis	Bu Gia Map National Park, Vietmam	Rhizome	Linalool (57.4%), terpinen-4-ol (10.6%), α-sabinene (4.2%)	Van *et al.* (2021a)
		Aerial part	Myrcene (41.1%), sabinene (8.2%), D-limonene (9.1%)	Van *et al.* (2021a)
H. occulta	Hebei, China	Rhizome	Linalool (47.7%), terpene-4-ol (16.5%), α-terpineol (11.2%), geraniol (3.7%)	Liu *et al.* (2014)
	Hong Kong, China	Rhizome	Epi-α-cadinol (14.81%), α-cadinol (14.77%), α-terpineol (13.77%), linalool (11.08%), terpinen-4-ol (4.92%), δ-cadinene (4.91%)	Zeng *et al.* (2011)
	Nghe An, Vietnam	Rhizome	α-bisabolol (22.8%), benzyl benzoate (11.4%), linalool (8.6%), benzyl salicylate (4.9%), α-terpinolen (4.6%)	Le *et al.* (2017)
H. pierreana	Nghe An, Vietnam	Rhizome	α-bisabolol (20.9%), bicyclogermacren (12.8%), (E)-nerolidol (8.0%), δ-cadinen (5.8%), α-muurolen (3.9%), α-terpinolen (3.6%), benzyl benzoate (3.6%)	Le *et al.* (2017)
H. pierreana	Phu Quoc National park, Vietnam	Leaves	Aromadendrene (48%), δ-selinene (13.5%), trans-α-bisabolene (12%), α-terpinolen (3.0%), limonene (1.6%)	Van *et al.* (2020)
		Rhizome	Aromadendrene (44%), δ-selinene (18.5%), cycloundecatriene (7.5%), δ^3-carene (1.6%)	Van *et al.* (2020)
H. pineodora	Penang, Malaysia	Leaves	2-Octylcyclopentanone (53.8%), propyl decanoate (22.1%), 4-Tridecanone (8.7%), 3-methyl-1-dodecyn-3-ol (6.7%)	Rozman *et al.* (2018)
H. sagittifolia	Kedah, Malaysia	Leaves	α-Pinene (22.2%), β-pinene (17.2%), neointermedeo (6.5%), germacrene D (5.9%), α-selinene (4.1%)	Wong *et al.* (2006)
		Rhizomes	Linalool (61.9%), nonan-2-one (3.7%), α-cadinol (3.4%), terpinen-4-ol (2.5%), T-cadinol (2.1%)	Wong *et al.* (2006)

from botanists. For example, Hu (1968) and Li (1979) identified that *H. cochinchinesis* was a synonym of *H. occulta*, Nguyen (2017) had the same view as the two authors. However, Pham (2000) and Govaerts *et al.* (2002) showed that *H. cochinchinesis* and *H. occulta* were the two distinct species. Notably, based on the morphological and molecular data, Van (2017) demonstrated that *H. cochinchinesis* was a good species and obviously distinct from *H. occulta*. In addition, previous studies showed that *H. aromatica* and *H. occulta* were a unique species (Nguyen 2017). However, Van *et al.* (2019) provided that *H. aromatica* and *H. occulta* were the two distinct species based on the molecular data. The chemical compositions of rhizome essential oils of *H. aromatica*, *H. cochinchinesis* and *H. occulta* collected from different locations have been reported to be similar in terms of the major constituents. Accordingly, the major components of the rhizome oils of *H. aromatica* (from India, Bangladesh and Vietnam); *H. cochinchinesis* (Vietnam) and *H. occulta* (Hebei, China) were characterized by the prominence of linalool and terpene-4-ol (Todorova *et al.*, 1988; Singh *et al.*, 2000; Chowdhury *et al.*, 2008; Policegoudra *et al.*, 2012; Liu *et al.*, 2014; Tiwari *et al.*, 2021; Van *et al.*, 2021a). This result again reveals the close phylogenetic relationship among the 3 species, including *H. aromatica*, *H. cochinchinesis* and *H. occulta*.

Chemical Profiles of *Arisaema* Essential Oils

Table 2 presented the chemical compositions of essential oil isolated from *Arisaema* species. Accordingly, Li *et al.* (2019) investigated the chemical composition of the essential oils isolated from four parts of *Arisaema amuremse*, including tubers, petioles, leaves and fruits. The results showed that the tubers consisted of the following major compounds: 3-cyclohexyl-1-phenyl propane (14.86%); 2-pentadecanone (8.9%); perhydrofarnesyl acetone (6,10,14-trimethyl-2-pentadecanone (7.15%); heneicosane (6.27%); 9,12-octadecadienoic acid, ethyl ester (5.6%) and 2-furanmethanol (5.5%) whereas 7,9-di-tert-butyl-1-oxaspiro (4,5) deca-6,9-diene-2,8-dione (7.9%); 14-methylpentadecanoic acid methyl ester (7.7%); 1-hexadecanol acetate (4.05%) were the main constituents in petiole oils. Furthermore, the leave oils were characterized by the prominence of 6,10,14-trimethyl-2-pentadecanone (46.27%); hexadecanoic acid methyl ester (38.62%) and (Z)

Table 2: Major components identifed from *Arisaema* essential oils

Species	Locality	Part	Major compounds	References
A. amuremse	Changbai, China	Tubers	3-cyclohexyl-1-phenyl propane (14.86%); 2-pentadecanone (8.9%); perhydrofarnesyl acetone (6,10,14-trimethyl-2-pentadecanone (7.15%); Heneicosane (6.27%); 9,12-octadecadienoic acid, ethyl ester (5.6%); 2-furanmethanol (5.5%)	Li *et al.* (2019)
		Petioles	7,9-di-tert-butyl-1-oxaspiro (4,5) deca-6,9-diene-2,8-dione (7.9%); 14-methylpentadecanoic acid methyl ester (7.7%); 1-hexadecanol acetate (4.05%)	Li *et al.* (2019)
		Leaves	6,10,14-trimethyl-2-pentadecanone (46.27%); hexadecanoic acid methyl ester (38.62%); (Z) 9-octadecenoic acid methyl ester (12.27%)	Li *et al.* (2019)
		Fruits	Hexadecanoic acid methyl ester (53.45%); 13-octadecenoate (7.82%); (Z, Z)-9,12-octadecadienoic acid methyl ester (5.4%)	Li *et al.* (2019)
A. anurans	Wu-Tai, China	Aerial parts	Asarone (11.08%), cubenol (8.43%), guaiol (4.73%), eugenol (3.46%), linalool (3.41%), α-bisabolol (3.29%)	Jia *et al.* (2018)
A. fargesii	Hubei, China	Aerial parts	Linalool (12.38%), carvacrol (8.27%), eugenol (5.21%), β-selinene (5.36%);, β-caryophylen (4.32%), limonene (4.16%)	Huang *et al.* (2019)
A. franchetianum	Yunnan, China	whole plant	Linalool (8.89%); limonene (3.68%), β-selinene (3.65%), α-pinene (3.55%), caryophyllene oxide (3.43%), β-caryophyllene (2.37%)	Zhu *et al.* (2013)
A. lobatum	Yunnan, China	whole plant	Linalool (6.67%), limonene (4.28%), β-caryophyllene (3.21), α-pinene (2.68%), caryophyllene oxide (2.37%), β-selinene (2.02%)	Zhu *et al.* (2013)

9-octadecenoic acid methyl ester (12.27%) while the main constituents of the fruit oils were hexadecanoic acid methyl ester (53.45%); 13-octadecenoate (7.82%); (Z, Z)-9,12-octadecadienoic acid methyl ester (5.4%) and 9-Octadecenoic acid methyl ester (5.03%) (Li *et al.*, 2019).

Jia *et al.* (2018) investigated the essential oil extracted from the aerial parts of A. *anurans* and showed that the major components of the aerial part oils were asarone (11.08%), cubenol (8.43%), guaiol (4.73%), eugenol (3.46%), linalool (3.41%) and α-bisabolol (3.29%) while the aerial part oils of A. *fargesii* were found be rich in linalool (12.38%), carvacrol (8.27%), eugenol (5.21%), β-selinene (5.36%), β-caryophylen (4.32%) and limonene (4.16%) (Huang *et al.*, 2019). Zhu *et al.* (2013) investigated the chemical profiles of the essential oils isolated two endemic species in China, including A. *franchetianum* and A. *lobatum*. This study showed that A. *franchetianum* oils were linalool (8.89%), limonene (3.68%), β-selinene (3.65%), α-pinene (3.55%) and caryophyllene oxide (3.43%) as major constituents whereas the A. *lobatum* oils contained high presence of linalool (6.67%), limonene (4.28%), β-caryophyllene (3.21), α-pinene (2.68%), caryophyllene oxide (2.37%) and β-selinene (2.02%) (Zhu *et al.*, 2013).

Biological Activities of *Homalomena* Essential Oils

Antimicrobial activity

The antimicrobial activity of the essential oils isolated from different parts of the *Homalomena* plants have been documented in previous studies. For instance, Policegoudra *et al.* (2001) demonstrated that the essential oils extracted from *H. aromatica* rhizomes collected from Sonitpur, India had promising activity against six fungi, including *Trichophyton rubrum*, *T. mentagrophytes*, *Microsporum fulvum*, *M. gypseum*, *Trichosporon beigelii* and *Candida albicans* with MIC values ranging from 8 to 16 μg/ml. Similarly, Laishram *et al.* (2006) show that the essential oils from the rhizomes of *H. aromatica* grown in Sonitpur, India could inhibit antibacterial activity against five bacterial pathogens such as *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa* and *Proteus vulgaris*. Singh *et al.* (2000) demonstrated that the rhizome oils of *H. aromatica* from Gopal Nagar, India showed good antifungal activity against four fungi, including *Curvularia pallescens*, *Aspergillus niger*, *Fusarium solani* and *Fusarium graminearum*.

Rozman *et al.* (2018) reported that the essential oils of *H. pineodora* leaves exhibited significant inhibitory activity on 3 Gram positive bacteria (*Bacillus cereus*, *B. subtilis* and *Staphylococcus aureus*), 5 Gram negative bacteria (*Proteus mirabilis*, *Yersinia* sp., *Shigella boydii*, *Acinetobacter anitratus* and *Pseudomonas aeruginosa*) and 1 yeast (*Candida albicans*) with minimal inhibitory concentrations ranging from 156.25 to 1250 μg/ml. Rozman *et al.* (2020) showed that *H. pineodora* essential oils loaded-chitosan nanoparticles had an inhibitory effect on 13 oral microorganisms, including *Bacillus cereus*, *B. subtilis*, *Staphylococcus aureus*, *Proteus mirabilis*, *Yersinia* sp., *E. coli*, *Shigella boydii*, *Acinetobacter anitratus*, *Pseudomonas aeruginosa*, *Salmonella typhimurium*, *Klebsiella pneumonia*, *Candida albicans* and C. *utilis* with MIC values ranging from 9.75 to 78 μg/ml.

Furthermore, the rhizome and leaf oils of *H. pierreana* from Vietnam showed significant activity against *Staphylococcus aureus*, *Escherichia coli* and *Pseudomonas aeruginosa* (Van *et al.*, 2020). Recently, Van *et al.* (2021a) demonstrated that the rhizome essential oil of *H. cochinchinensis* collected from Vietnam possessed strong antibacterial activities against *Bacillus cereus*, *Staphylococcus aureus Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella enteritidis* and *Salmonella typhimurium* whereas the aerial part oil was found to be effective against five bacterial strains except for *S. enteritidis* (Van *et al.*, 2021a).

The antimicrobial activities of essential oils isolated from *Homalomena* species may be attributed to the chemical components present in the essential oils. For instance, terpinen-4-ol had an inhibitory effect on human pathogenic *yeast* species such as *Candida albicans*, *C. tropicalis*, *C. parapsilosis*, *C. krusei*, *C. glabrata*, *Cryptococcus neoformans*, *C. neoformans* and *Saccharomyces cerevisiae* (Mondello *et al.*, 2006). This compound was also found to be effective against many *Staphylococcus aureus* strains, including ATCC-13150, ATCC-25923, LM-02, LM-45, LM-116, LM-232, LM-222, LM-297 and LM-314 (Cordeiro *et al.*, 2020). In addition, linalool has been reported to possess strong antibacterial effects against many microorganisms, including *Prevotella intermedia*, *Porphylomonas gingivalis*, *P. nigrescens*, *Fusobacterium nucleatum* subsp. *nucleatum*, *F. nucleatum* subsp. *polymorphum*, *F. nucleatum* subsp. *vincentii*, *F. nucleatum* subsp. *fusiforme*, *F. nucleatum* subsp. *animalis*, *Streptococcus mutans*, *S. sobrinus*, *Aggregatibacter actinomycetemcomitans* (Park *et al*. 2012), *Pasteurella multocida*, *Listeria monocytogenes* (Gao *et al.*, 2019), *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Escherichia coli* and *Candida albicans* (Herman *et al.*, 2016).

α-Pinene was found to be effective against many bacteria and fungi such as S. *aureus*, *S. aureus*, *S. epidermidis*, *Streptococcus faecalis*, S. *pyogenes*, *Pseudomonas aeruginosa*, *Escherichia coli*, *Candida albicans*, *Sclerotinia sclerotiorum*, *Mycobacterium smegmatis*, *Cylindrocarpon mali*, *Aspergillus niger*, *Stereum purpureum*, *Cryptococcus neoformans* and *Rhizopus oryzae* (Prudent *et al.*, 1993; Leite *et al.*, 2007; Rivas *et al.*, 2012). Moreover, β-pinene has been reported to possess antibacterial and antifungal effects against *Staphylococcus aureus*, *S. epidermidis*, *Streptococcus pyogenes* and *S. pneumonia*, *Candida albicans*, *Cryptococcus neoformans* and *Rhizopus oryzae* (Leite *et al.*, 2007; Rivas *et al.*, 2012). β-myrcene had an inhibitory effect on *Enterococcus faecalis*, *Streptococcus salivarius* and *S. sanguinis* (Koziol *et al.*, 2014).

Insecticidal activity

In 2000, Singh *et al.* reported that the essential oils isolated from the rhizomes of *H. aromatica* showed insecticidal behavior against white termite *Odontotermes obesus* Rhamb. This report showed that the oil was found to be 90% insecticidal behavior against *O. obesus* at 3 μl dose oil after 2 hours while the percentage of mortality of *O. obesus* was 100% after 5 hours. On the other hand, the oil has been found to be highly toxic (100% mortality) towards *O. obesus* at 6 μl dose oil after 2 hours (Singh *et al.*, 2000). Hazarika *et al.* (2012) showed that the essential oils extracted from *H. aromatica* rhizomes could be repellent against the blackflies (*Simulium* sp.). According to this study, the oils showed protection from the blackflies bites for more than 2 hours at 5% concentration and above 5 hours at 10% concentration (Hazarika *et al.*, 2012). Furthermore, the insecticidal and repellency activity of the essential oil of *H. occulta* rhizomes against the red flour beetles (*Tribolium castaneum*) were also observed by Han *et al.* (2004).

The chemical constituents of the essential oils extracted from the members of *Homalomena* genus could be the main factor contributing to their insecticidal activity. Accordingly, α-pinene and β-pinene have been reported to display insecticidal activity against *Lasioderma serricorne*, *Rhodnius nasutus* and *Aedes aegypti* (Santos *et al.*, 2012; Wu *et al.*, 2014; Wu *et al.*, 2015; Souza *et al.*, 2018). Furthermore, terpinen-4-ol was found to be effective against hematophagous insects such as *Rhodnius nasutus* (Souza *et al.*, 2018).

Nematicidal activity

The nematicidal activity of the essential oils isolated from *Homalomena* species has been also reported. Accordingly, the rhizome oils of *H. occulta* collected from Anguo, Hebei Province, China, possessed strong nematicidal activity against *Meloidogyne incognita* with a LC_{50} value of 156.43 μg/ml. Also, linalool (47.7%), the most abundant component of *H. occulta* rhizomes, could inhibit against *M. incognita* with LC_{50} value of 180.36 μg/ml whereas the other major compounds, terpene-4-ol (16.5%) and α-terpineol (11.2%), were able to resist against *M. incognita* with LC_{50} values of 115.17 μg/ml and 103.41 μg/ml, respectively (Liu *et al.*, 2014).

Biological Activities of Arisaema Essential Oils

Antiproliferative activity

Li *et al.* (2019) demonstrated that the essential oils isolated from the tubers, petioles, leaves, and fruits of *A. amuremse* had strong antiproliferative activity on the cancer cell lines, including Hep2, HCT-116, A-549, SW-480, HepG-2 using MTT assay. Among four parts of this species, the essential oils extracted from tubers inhibited strong antiproliferative activity against HCT-116 cells (IC_{50} of 19.6 μg/ml), followed by HepG-2 (IC_{50} of 19.83 μg/ml), Hep2 (IC_{50} of 26.71 μg/ml), A-549 (IC_{50} of 27.44 μg/ml) and SW-480 (IC_{50} of 35.46 μg/ml). The petiole oils showed the highest antiproliferative activity against HepG-2 (IC_{50} of 17.6 μg/ml) whereas the IC_{50} values of HCT-116, A-549, HepG-2 and SW-480 were 19.52, 20.8, 32.6 and 27.72 μg/ml, respectively. The antiproliferative activity of the essential oils isolated from the leaves of *A. amuremse* showed the strongest inhibitory effect on HepG-2 (23.8 μg/ml), HCT-116 (36.75 μg/ml), Hep2 (51.79 μg/ml), A-549 (52.52 μg/ml) and SW-480 (138.1 μg/ml). Finally, the fruit oils were the most sensitive to SW-480 cells (IC_{50} of 30.23 μg/ml), followed by HepG-2 (40.14 μg/ml), Hep2 (50.47 μg/ml), HCT-116 (59.26 μg/ml), A-549 (105 μg/ml) (Li *et al.*, 2019).

Larvicidal activity

Aedes mosquitoes, secondary vectors of dengue virus, is currently considered the most invasive mosquito species in the world (Hira *et al.*, 2018). The recent studies showed that the essential oil isolated from plant sources has emerged as good candidates for larvicides or insect growth regulators because of its economic tools in vector management as well as eco-friendly agents (Pavela, 2015; Sarma *et al.*, 2019). Huang *et al.* (2019) demonstrated that the essential oil isolated from the aerial parts of *Arisaema fargesii* had larvicidal activity against two *Aedes* mosquitoes, including *Ae. aegypti* and *Ae. albopictus*. The results showed that the essential oils could be larvicidal activity against the early 4th instar larvae of *Ae. Aegypti* with LC_{50} value of 40.49 mg/L whereas the oil also had larvicidal activity against the larvae of *Ae. albopictus* with LC_{50} value of 47.01 mg/L. The larvicidal activity of *A. fargesii* essential oil may be attributed to the major components present in the essential oil. For instance, the four major compounds of the essential oils extracted from *A. fargesii*, including linalool, carvacrol, β-selinene and eugenol also possessed larvicidal activity against two *Aedes* mosquitoes. Among four compounds, carvacrol showed the strongest inhibitory effect on *Ae. aegypti* and *Ae. albopictus* with LC_{50} values of 32.78 and 39.08 mg/l, respectively, followed by eugenol (LC_{50} values of 56.34 and 52.07 mg/l), linalool (LC_{50} values of 70.56 and 82.34 mg/l) and β-Selinene (LC_{50} values of 136.03 and 151.74 mg/l) (Huang *et al.*, 2019).

Jia *et al.* (2018) demonstrated that the essential oils isolated from the aerial parts of *Arisaema anurans* and 2 major compounds, including asarone and cubenol exhibited evidence of acaricidal activity against *Rhipicephalus microplus*. The results showed that the essential oil, asarone and cubenol exhibited the oviposition reduction percentages of 36.3%, 44.2% and 17.7%, respectively whereas the hatching reduction percentages were 40.8%, 51.0% and 35.1%, respectively. The dose-dependent egg hatching test revealed that the oils, asarone and cubenol had promising activity against *R. microplus* with LC_{50} values (in w/v) of 0.174%, 0.180% and 0.381%, respectively. Finally, the oil, asarone and cubenol could inhibit the larval stage of *R. microplus* with LC_{50} values of 0.147%, 0.115% and 0.338%, respectively.

Anthelmintic Activity

Arisaema franchetianum and *Arisaema lobatum*, two endemic species in China, have been demonstrated that the essential oils extracted from the whole plants and one major constituent such as carvacrol had promising anthelmintic activity against three stages of *Haemonchus contortus*, including egg hatch, larval development and larval migration (Zhu *et al.*, 2013). In the egg hatch stage, carvacrol inhibited the strongest ovicidal activity with the CE_{50} value of 0.32 mg/ml whereas the CE_{50} values of *A. franchetianum* and *A. lobatum* oils were 1.63 mg/ml and 0.48 mg/ml, respectively. The larval development assay showed that *A. franchetianum* and *A. lobatum* oils possessed the anthelmintic activity with the CE_{50} values of 1.10 and 0.73 mg/ml, respectively while a lower a CE_{50} value (0.51 mg/ml) was recorded in carvacrol compound. In the larval migration stage, carvacrol showed the highest in anthelmintic activity with CE_{50} value of 0.30 mg/mL whereas the CE_{50} values of *A. franchetianum* and *A. lobatum* oils were 2.3 and 0.62 mg/mL, respectively (Zhu *et al.*, 2013).

CONCLUSION AND PERSPECTIVE

By using the various literature, the chemical composition and biological activities of the essential oils extracted from *Arisaema* and *Homalomena* species have been reviewed for the first time. A variety of phytochemicals isolated from the studied oils could be found to vary depending on the geographical regions where they are collected. Different essential oils and their major chemical components extracted from different parts of studied species have been found to produce dynamic biological activities, which include antimicrobial, insecticidal, nematicidal, antiproliferative, larvicidal and anthelmintic activities. The outcome of this review will provide more information for further application of the essential oils isolated from *Arisaema* and *Homalomena* plants.

However, some studies on the chemical components of essential oils extracted from *Arisaema* and *Homalomena* plants have not calculated the retention indices by using n-alkane standard. As a result, it is not really accurate to describe the chemical composition of the essential oil of studied species. In addition, some studies did not verify the origin and the authentication of the studied sample. For example, a sample purchased in the market will not have a scientific basis to determine the exact origin and distribution of the studied species, so it will be unreliable when comparing the chemical composition of the essential oil of the studied species with the same species distributed in other locations. Note that, the chemical constituents of plant essential oils could be found to vary depending on the geographical regions where they are collected.

Currently, studies on the chemical compositions and biological properties of essential oils from many rare or new species belonging to *Arisaema* and *Homalomena* genus are still unknown, including *Homalomena vagans* (Brunei), *H. vietnamensis*, *H. pendula* (Vietnam), *H. hainanensis*, *H. kelungensis* (China), *H. joanneae* (Malaysia), *Arisaema langianense*, *A. pierreanum*, *A. condaoense*, *A. liemiana*, *A. chauvanminh*, *A. honbaense* (Vietnam), *A. menghaiense*, *A. wangmoense* (China), etc. Future research, thus, should investigate the chemical components and bioactivities of essential oils isolated from these species.

REFERENCES

Blair, S., & Madrigal, B. (2005). Plantas antimaláricas de Tumaco: Costa Pacífca colombiana. (1st ed.). Medellin: University of Antioquia.
Boyce, P. C., Sookchaloem, D., Hetterscheid, W. L. A., Gusman, G., Jacobsen, N., Idei, T., & Nguyen, V. D. (2012). Araceae. *Flora of Thailand, 11*, 101-321.
Chowdhury, U., Yusuf, M., & Hossain, M. M. (2008). Aromatic Plants of Bangladesh: Constituents of rhizomes oil of *Homaiomena aromalica*. *Indian Perfumer, 52*(1), 33-34.
Coelho, N. M. A. (2000). *Philodendron* Schott (Araceae): Morfología e taxonomía das especies da Reserva da Macae da Cima–Nova Friburgo, Rio de Janeiro, Brasil. *Rodriguesia, 51*(78), 21-68. https://doi.org/10.1590/2175-7860200051787902
Cordeiro, L., Figueiredo, P., Souza, H., Tirosh, P., & Arber, N. (2020). Terpinen-4-ol as an antibacterial and antibiofilm agent against *Staphylococcus aureus*. *International Journal of Molecular Sciences, 21*, 1-14. https://doi.org/10.3390/ijms21124531
Croat, T. B. (1983). A revision of the genus *Anthurium* (Araceae) of Mexico and Central America. Part. I: Mexico and middle America.

Annals of the Missouri Botanical Garden, 70(2), 211-416. https://doi.org/10.2307/2399049

Croat, T. B. (1998). History and current status of systematic research with Araceae. *Aroideana, 21*, 26-145.

Delang, C. O. (2007). The role of medicinal plants in the provision of health care in Lao PDR. *Journal of Medicinal Plants Research, 1*, 50-59.

Devkota, A., Stefano, D. A., Stefano, C., Gabriella, I., & Pramod, K. J. (2013). Chemical Composition of Essential Oils of *Centella asiatica* (L.) Urban from different habitats of Nepal. *International Journal of Pharmaceutics, 4(2),* 300-304.

Engler, A., & Krause, K. (1912). *Araceae-Philodendroideae-Philodendreae*, Allgemeiner Teil, Homalomeninae und Schismatoglottidinae, pp. 1-134 in Pflanzenreich, vol. 55 (IV.23Da), ed. A. Engler. Leipzig: Engelmann.

Gao, Z., Van Nostrand, J. D., Zhou, J., Zhong, W., Chen, K., & Guo. J. (2019). Anti-listeria activities of linalool and its mechanism revealed by comparative transcriptome analysis, *Frontiers in Microbiology, 10*. https://doi.org/10.3389/fmicb.2019.02947

Govaerts, R., & Frodin, D. (2002). World checklist and bibliography of Araceae (and Acoraceae). Royal Botanic Gardens, Kew.

Gusman, G., & Gusman, L. (2006). The genus *Arisaema*. A Monograph for botanists and nature lovers. (2nd ed.). Ruggell, Germany: A.R.G. Gartner Verlag Kommanditgesellschaft.

Han, Q. X., Chen, J. L., Liu, B. R., & Tang, H. X. (2004). Toxic and repellent effects of several Chinese medicinal materials on the adults of *Triblium castaneum* (Coleoptera: Tenebrionidae). *Plant Protection, 30,* 60-63.

Hassiotis, C. N., Lazari, D. M., & Vlachonasios, K. E. (2010). The effects of habitat type and diurnal harvest on essential oil yield and composition of *Lavandula angustifolia* Mill. *Fresenius Environmental Bulletin, 19*(8), 1491-1498.

Hazarika, S., Dhiman, S., Rabhac, B., Bhola, R. K., & Singh, L. (2012). Repellent activity of some essential oils against *Simulium* species in India. *Journal of Insect Science, 12*(5). https://doi.org/10.1673/031.012.0501

Herman, A., Tambor, K., & Herman, A. (2016). Linalool affects the antimicrobial efficacy of essential oils. *Current Microbiology, 72*, 165-172. https://doi.org/10.1007/s00284-015-0933-4

Hira, F. S, Asad, A., Farrah, Z., Basit, R. S., Mehreen, F., & Muhammad, K. (2018). Patterns of occurrence of dengue and chikungunya, and spatial distribution of mosquito vector *Aedes albopictus* in Swabi district, Pakistan. *Tropical Medicine & International Health 23*, 1002-1013. https://doi.org/10.1111/tmi.13125

Huang, Y., Lin, M., Jia, M., Hu, J., & Zhu, L. (2019). Chemical composition and larvicidal activity against *Aedes* mosquitoes of essential oils from *Arisaema fargesii. Pest Management Science, 76*(2), 534-542. https://doi.org/10.1002/ps.5542

Hu, S. Y. (1968). Studies in the Flora of Thailand 41, Araceae. *Dansk Botanisk Arkiv, 23*, 409-457.

Jia, M., He, Q., Wang, W., Dai, J., & Zhu, L. (2018). Chemical composition and acaricidal activity of *Arisaema anurans* essential oil and its major constituents against *Rhipicephalus microplus* (Acari: Ixodidae). *Veterinary Parasitology, 15*(261), 59-66. https://doi.org/10.1016/j.vetpar.2018.08.006

Kar, K., & Borthakur, S. K. (2008). Wild vegetables of Karbi-anglong district, Assam. *Natural Product Radiance, 7*, 448-460.

Kehie, M., Kehie, P., & Pfoze, N. L. (2017). Phytochemical and ethnopharmacological overview of endangered *Homalomena aromatica* Schott: An aromatic medicinal herb of Northeast India. *Indian Journal of Natural Products and Resources, 8*(1), 18-31.

Khan, M. H., & Yadava, P. H. (2000). Herbal remedies of asthma in Thoubal district of Manipur in Northeast India. *Indian Journal of Natural Products and Resources, 1*, 80-84.

Koziol, A., Stryjewska, A., Librowski, T., Sałat, K., Gaweł, M., & Moniczewski, A. (2014). An overview of the pharmacological properties and potential applications of natural monoterpenes. *Mini-Reviews in Medicinal Chemistry, 14*, 1156-1168. https://doi.org/10.2174/1389557514666141127145820

Kyei, S., Koffuor, G. A., & Boampong, J. N. (2012). The efficacy of aqueous and ethanolic leaf extracts of *Pistia stratiotes* Linn. in the management of arthritis and fever. *Journal of Medical and Biomedical Sciences, 1*(2), 29-37.

Lahitte, H. J., Julio, A., & Valla, H. J. J. (1998). Plantas medicinales Rioplatenses. Buenos Aires: Editorial LOLA.

Laishram, S. K. S., Nath, D. R., Bailung, B., & Baruah, I. (2006). In vitro antibacterial activity of essential oil from rhizome of *Homalomena aromatica* against pathogenic bacteria. *Cell and Tissue Research, 6*(2), 849-851.

Le, T. H., Dao, T. M. C., Nguyen, V. H., Nguyen, C. T., & Do, N. D. (2017). Chemical composition of essential oils of *Homalomena occulta* (Lour.) Schott and *Homalomena pierreana* Engl. in Pu Mat National Park, Nghe An Province. 7th National Science Conference on Ecology and Biological Resources.

Leaman, D. J. J., Arnason, T., Yusuf, R., Sangat-Roemantyo, H., Soedjito, H., Angerhofer, C. K., & Pezzuto, J. M. (1995). Malaria remedies of the Kenyah of the Apo Kayan, East Kalimantan, Indonesian Borneo: a quantitative assessment of local consensus as an indicator of biological efficacy. *Journal of Ethnopharmacology, 49*, 1-16. https://doi.org/10.1016/0378-8741(95)01289-3

Leite, A. M., Lima, E. O., Souza, E. L., Diniz, M. F. F. M., Trajano, V. N., & Medeiros, I. A. (2007). Inhibitory effect of β-pinene, α-pinene and eugenol on the growth of potential infectious endocarditis causing Gram-positive bacteria. *Brazilian Journal of Pharmaceutical Sciences, 43*, 122-126. https://doi.org/10.1590/S1516-93322007000100015

Lekana-Douki, J. B., Bongui, J. B., Liabagui, S. L. O., Edou, S. E. Z., Zatra, R., Bisvigou, U., Druilhe, P., Lebibi, J., Fousseyni, S. T. N., & Maryvonne, K. (2011) In vitro antiplasmodial activity and cytotoxicity of nine plants traditionally used in Gabon. *Journal of Ethnopharmacology*, *133*, 1103-1108. https://doi.org/10.1016/j.jep.2010.11.056

Li, H., Zhu, G., & Murata, J. (2010). *Arisaema*. *Flora of China, 23*, 43-69.

Li, H. (1979). Araceae, Lemnaceae. In Wu Cheng Yih & Li Heng, *Fl Reip Pop Sinicae, 13*(2), 1-242.

Li, G., Jiang, Y., Li, Y., He, T., Wang, Y., Ji, T., Zhai, W., Zhao, L., & Zhou, X. (2019). Analysis and biological evaluation of *Arisaema amuremse* Maxim essential oil. *Open Chemistry, 17*, 647-654. https://doi.org/10.1515/chem-2019-0054

Liu, X. C., Bai, C. Q., Liu, Q. Z., & Liu, Z. L. (2014). Evaluation of nematicidal activity of the essential oil of *Homalomena occulta* (Lour.) Schott rhizome and its major constituents against *Meloidogyne incognita* (Kofoid and White) Chitwood. *Journal of Entomology and Zoology Studies, 2*(4), 182-186.

Luu, H. T., Nguyen, Q. D., Nguyen, H. C., Van, H. T., & Nguyen, V. D. (2020). Arisaema liemiana sp. nov. (Araceae: Arisaemateae), a new species from southern-central Vietnam. *Phytotaxa, 468*(2), 214-220. https://doi.org/10.11646/phytotaxa.468.2.5

Mayo, S. J., Bogner, J., & Boyce, P. (1997). The genera of Araceae. Kew (UK): Royal Botanic Garden.

Mondello, F., De Bernardis, F., Girolamo, A., Cassone, A., & Salvatore, G. (2006). In vivo activity of terpinen-4-ol, the main bioactive component of Melaleuca alternifolia Cheel (tea tree) oil against azole-susceptible and -resistant human pathogenic Candida species. *BMC Infectious Diseases, 6*. https://doi.org/10.1186/1471-2334-6-158

Nguyen, V. D. (2017). Araceae Juss. Flora of Vietnam 16. Publishing House for Science and Technology, Hanoi.

Park, S. N., Lim, Y. K., Freire, M. O., Cho, E., Jin, D., & Kook, J. K. (2012). Antimicrobial effect of linalool and α-terpineol against periodontopathic and cariogenic bacteria. *Anaerobe, 18*, 369-372. https://doi.org/10.1016/j.anaerobe.2012.04.001

Pavela, R. (2015). Essential oils for the development of eco-friendly mosquito larvicides: A review. *Industrial Crops and Products, 76*(15), 174-187. https://doi.org/10.1016/j.indcrop.2015.06.050

Pedralli, G. (2002). Dioscoreaceae e Araceae: aspectos taxonômicos, etnobotânicos e espécies nativas com potencial para melhoramento genético. In: Simpósio nacional sobre as culturas do inhame e do taro II. João Pessoa. Resumo, João Pessoa: EMEPA-PB.

Pham, H. H. (2000). Araceae. In: Pham-hoang H. (ed.), Cây cỏ Việt Nam: An Illustrated Flora of Vietnam.Ho Chi Minh City, Vietnam: Youth Publishing House.

Policegoudra, R. S., Goswami, S., Aradhya, S. M., Chatterjee, S., Datta, S., Sivaswamy, R., Chattopadhyay, P., & Singh, L. (2012). Bioactive constituents of *Homalomena aromatica* essential oil and its antifungal activity against dermatophytes and yeasts. *Journal of Medical Mycology,* 22, 83-87. https://doi.org/10.1016/j.mycmed.2011.10.007

Prudent, D., Perineau, F., Bessiere, J. M., Michel, G., & Bravo, R. (1993). Chemical analysis, bacteriostatic and fungistatic properties of the essential oil of the atoumau from martinique (*Alpinia speciosa* K. schum.). *Journal of Essential Oil Research, 5*, 255-264. https://doi.org/10.1080/10412905.1993.9698218

Rana, V. S., Pukhrambam, M., Singh, H. B., Verdeguer, M., & Blazquez, M. A. (2009). Essential oil composition of *Homalomena aromatica* roots. *Indian Perfumer, 53*, 43-45.

Rivas, A. C. S., Lopes, P. M., Barros, M. M. A, Machado, D. C. C., Alviano, C. S., & Alviano, D. S. (2012). Biological activities of α-pinene and β-pinene enantiomers. *Molecules, 17,* 6305-6316. https://doi.org/10.3390/molecules17066305

Rozman, N. A. S., Yenn, T. W., Tan, W. N., Ring, L. C., Yusof, F. A. M., & Sulaiman, B. (2018). *Homalomena pineodora,* a Novel Essential Oil Bearing Plant and Its Antimicrobial Activity Against Diabetic Wound Pathogens. *Journal of Essential Oil Bearing Plants, 21*(4), 963-971. https://doi.org/10.1080/0972060X.2018.1526129

Rozman, N. A. S., Tong, W. T., Leong, C. R., Anuar, M. R., Karim, S., Ong, S. K., Yusof, F. A. M., Tan, W. N., Sulaiman, B., Ooi, M. L., & Lee, K. C. (2020). *Homalomena pineodora* essential oil nanoparticle inhibits diabetic wound pathogens. *Scientific reports, 10,* 3307. https://doi.org/10.1038/s41598-020-60364-0

Santos, G. K. N., Dutra, K. A., Barros, R. A., Camara, C. A. G., Lira, D. D., & Gusmao, N. B. (2012). Essential oils from *Alpinia purpurata* (Zingiberaceae): Chemical composition, oviposition deterrence, larvicidal and antibacterial activity. *Industrial Crops and Products, 40*, 254-260. https://doi.org/10.1016/j.indcrop.2012.03.020

Sarma, R., Adhikari, K., Mahanta, S., & Khanikor, B. (2019). Combinations of plant essential oil Based terpene compounds as larvicidal and adulticidal agent against *Aedes aegypti* (Diptera: Culicidae), *Scientific reports, 9*, 9471. https://doi.org/10.1038/s41598-019-45908-3

Singh, G., Kapoor, I. P. S., Singh, O. P., Leclerecq, P. A., & Klinkby, N. (2000). Studies on essential oils. Part 28: chemical composition, antifungal and insecticidal activities of rhizome volatile oil of *Homalomena aromatica* Schott. *Flavors & Fragrances Journal*, *15*, 278-280. https://doi.org/10.1002/1099-1026(200007/08)15:4<278::AID-FFJ913>3.0.CO;2-L

Souza, T. A., Lopes, M. B. P., Ramos, A. S., Ferreira, J. L. P., Silva, J. R. A., & Queiroz, M. M. C. (2018). *Alpinia* essential oils and their major components against *Rhodnius nasutus*, a vector of chagas disease. *Scientific World Journal,* 2393858. https://doi.org/10.1155/2018/2393858

Sulaiman, B., & Boyce, P. C. (2005). A remarkable new species of *Homalomena* (Araceae: Homolomeneae) from Peninsular Malaysia, *Gard Bull Singapore, 57*, 7-11.

Tiwari, S., Upadhyay, N., Singh, B. K., Singh, V. K., & Dubey, N. K. (2021). Chemically characterized nanoencapsulated *Homalomena aromatica* Schott. essential oil as green preservative against fungal and aflatoxin B1 contamination of stored spices based on in vitro and in situ efficacy and favorable safety profile on mice. *Environmental Science and Pollution Research, 29*(2), 3091-3106. https://doi.org/10.1007/s11356-021-15794-2

Todorova, M., Tho, P. T. T., Ognyanov, I., & Lawrence, B. M. (1988). The composition of *Homalomena aromatica* Schott oil of Vietnamese origin, *Flavors & Fragrances Journal, 3*, 179-181.

Van, H. T., Nguyen, P. N., & Luu, H. T. (2015). Homalomena cochinchinensis: testing molecular markers for its taxomonic identity in the Araceae and identification of some chemical compounds. *Journal of Biotechnology, 15*(4A), 1329-1334.

Van, H. T., Nguyen, P. N., & Luu, H. T. (2016a). On the taxonomic identity of Arisaema pierreanum Engl. (Araceae) in Vietnam. STDJ. *Vietnam National University, 13*(4A), 52-56.

Van, H. T., Nguyen, P. N., & Luu, H. T. (2016b). A new species of Arisaema (Araceae) from Vietnam. *Phytotaxa, 227*(1), 090–094. https://doi.org/10.11646/phytotaxa.277.1.9

Van, H. T., Nguyen, P. N., & Luu, H. T. (2017). Taxonomic identity of Arisaema condaoense (Araceae) based on new morphological and molecular data, *Journal of Biotechnology, 15*(4), 1-8.

Van, H. T. (2017). Building phylogenetic trees for the Araceae in southern Vietnam based on morphological and molecular markers. PhD Doctoral thesis, Graduate University Science and Technology, Vietnam Academy of Science and Technology.

Van, H. T., Nguyen, P. N., & Luu, H. T. (2018). New distributions of three Aroids species (Araceae) in Southern Vietnam. *Journal of Science, HCMC University of Education, 15*(3), 66-79.

Van H. T., Nguyen, P. N., Luu, H. T., & Trinh, N. N. (2019). Identification of DNA barcode sequence for two Homalomena species (Araceae) in Vietnam. Journal of Science, HCMC University of Education, *39*B, 39-49.

Van, H. T., Le, B. T., Nguyen, T. L., Trinh, N. N., Pham, T. V., Nguyen, N. T., Tran, G. B., Nguyen, P. N., & Luu, H. T. (2020). Chemical composition and antibacterial activities of essential oils from *Homalomena pierreana* (Araceae). *Indian Journal of Natural Products and Resources, 11*(1), 30-37.

Van, H. T., Le, N. T., Huynh, N. T. A., Vo, H. S., Le, T. T., Chu, V. H., Truong, H. A. V., & Nguyen, Q. H. (2021a). Chemical composition and antibacterial activities of essential oils from rhizomes and aerial parts of *Homalomena cochinchinensis* (Araceae). *Natural Product Research*, 1-4. https://doi.org/10.1080/14786419.2021.1939333.

Van, H. T., Le, N. T., Nguyen, D. L., Tran, G. B., Huynh, N. T. A., Vo, H. S., Chu, V. H., Truong, H. A. V., & Nguyen, Q. H. (2021b). Chemical profile and antibacterial activity of acetone extract of Homalomena cochinchinensis Engl. (Araceae), *Plant Science Today 8*(1), 58-65. https://doi.org/10.14719/pst.2021.8.1.971

Vargas, W. G. (2002). Guía ilustrada de las plantas de las montañas del Quindío y los andes centrales. Manizales (Colombia): Centro ditorial Universidad de Caldas.

Wong, K. C., Lim, T. B., & Ali, D. M. H. (2006). Essential oil of *Homalomena sagittifolia* Jungh, *Flavour and Fragrance Journal, 21*, 786-788. https://doi.org/10.1002/ffj.1714

Wu, Y., Wang, Y., Li, Z. H., Wei, I. J., Li, X. L., & Wang, P. J. (2014). Composition of the essential oil from *Alpinia galanga* rhizomes and its bioactivity on *Lasioderma serricorne*. *Bulletin of Insectology, 67*, 247-255.

Wu, Y., Zhang, W. J., Huang, D. Y., Wang, Y., Wei, J. Y., & Li, Z. H. (2015). Chemical compositions and insecticidal activities of *Alpinia kwangsiensis* essential oil against *Lasioderma serricorne*. *Molecules, 20*, 21939-21945. https://doi.org/10.3390/molecules201219818

Zeng, L. B., Zhang, Z. R., Luo, Z. H., & Zhu, J. X. (2011). Antioxidant activity and chemical constituents of essential oil and extracts of Rhizoma *Homalomenae. Food Chemistry, 125*, 456-463. https://doi.org/10.1016/j.foodchem.2010.09.029

Zhao, F. W., Luo, M., Wang, Y. H., Li, M. L., Tang, G. H., & Long, C. L. (2010). A piperidine alkaloid and limonoids from *Arisaema decipiens*, a traditional antitumor herb used by the Dong people. *Archives of Pharmacal Research, 33*(11), 1735-1739. https://doi.org/10.1007/s12272-010-1104-6

Zhu, L., Dai, J., Yang, L., & Qiu, J. (2013). Anthelmintic activity of *Arisaema franchetianum* and *Arisaema lobatum* essential oils against *Haemonchus contortus. Journal of Ethnopharmacology, 148*, 311-316. https://doi.org/10.1016/j.jep.2013.04.034