Magnolia genus - A systematic review on the composition and biological properties of its essential oils

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The genus *Magnolia* comprises approximately 219 species and is widely distributed in the Asian and American regions. The plants in the Magnolia genus posess unique ornamental values, strong anti-pollution properties, and significant economic and medicinal relevance due to the chemical diversity and biological potentials of their essential oils. The current review includes 24 *Magnolia* species from around the world and the chemical and biological properties of their essential oils. The data were collected from scientific electronic databases, including Scopus, PubMed, Scielo, ScienceDirect, SciFinder, and Google Scholar. Chemically, major components identified in most *Magnolia* essential oils were eucalyptol, linalool, limonene, β-eudesmol, β-elemene, β-pinene, and caryophyllene. Additionally, the essential oils displayed various biological activities, including antioxidant, antimicrobial, antibacterial, antiphotoaging, antifungal, cytotoxic, antidermatophytic, and nematocidal properties. The review emphasises *Magnolia* species' chemical and biological properties and provides guidance for selecting accessions or species with the best chemical profiles. The review also identifies species that were not yet studied and the potentials of their essential oils.

Keywords: Essential oil; *Magnolia*; eucalyptol; linalool; antioxidant; antimicrobial

1. INTRODUCTION

Magnoliaceae is a family of *Magnolia* in the Magnoliales order consisting of around 17 genera and 300 species. *Magnolia*, *Liriodendron Alcimandra*, *Lirianthe*, *Manglietia*, *Michelia*, *Pachylarnax*, *Parakmeria*, *Talauma*, and *Yulania* are some genera that are well-known [1]. About 219 species in the genus *Magnolia* are woody plants with primitive flowers. The species are widely distributed in the tropical and subtropical regions, mainly in Southeast United States (US), Mexico, Central America, the Caribbean, and Southeast Asia [2]. The most common *Magnolia* species, *M. salicifolia, M. kobus*, *M. macrophylla*, *M. ashei*, *M. acuminata*, *M. grandiflora, M. virginiana*, and *M. liliiflora*, are native to Japan, Korea, Southeast US, Mexico, and China, respectively [3].

The *Magnolia* genus encompasses deciduous and evergreen trees and shrubs that are nine to 31 meters tall, with most species having thin and smooth barks and soft and light-coloured woods, which are commonly used to produce crates, boxes, and furniture [3]. The *Magnolia* seeds are usually reddish and often hang pendulously with slender threads [3]. Additionally, the species is valued for its large and fragrant white, yellow, pink, and purple flowers, frequently smooth and shiny leaves, and cone-like fruits. The flowers, usually cup-like and fragrant, are located at the tips of branches, and have three sepals, 6 to 12 petals arranged in two to four series, and numerous spirally arranged stamens. Moreover, the *Magnolia* species have unique ornamental values, strong anti-pollution abilities, are widely adaptable, especially in China, Japan, Thailand, and India [4], and are economically important as natural aromatic and bioactive compounds [5].

Essential oils are composed of secondary metabolites commonly concentrated in the leaves, barks, and fruits of aromatic plants. Essential oils have been used since ancient times and are currently used in the food and chemical industries, medicine, cigarettes, candy, and cosmetics [6-7]. Studies reported that essential oils from different *Magnolia* species contain bioactive chemicals, including nerolidol, β-myrcene, β-elemene, and linalool. The bioactive components indicated anti-inflammatory, anticancer, antiarthritic, antiangiogenic, antioxidant, and neuroprotective properties [5].
Recently, essential oils and other aromatic compounds resourced from plants used as alternative medicine are gaining interest. The essential oils from the *Magnolia* genus have been extensively studied, with the most reported species being *M. grandiflora*, *M. liliflora*, and *M. officinalis* [8]. The current review on *Magnolia* essential oils aimed to simplify and compile the information available thus far. The information was obtained via electronic searches in Scopus, PubMed, Scielo, ScienceDirect, SciFinder, and Google Scholar. Additionally, the review provided an overview of the chemical compositions, biological activities, and medicinal uses of previously published reports on *Magnolia* essential oils.

2. SEARCH STRATEGY

The systematic review was conducted through searches using Scopus, PubMed, Scielo, ScienceDirect, SciFinder, and Google Scholar. The keywords used were '*Magnolia*', 'essential oil', and 'biological activity'. Articles covering the period from the beginning of the database until May 2021 were all viewed.
The protocol for performing the current study was developed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (PRISMA) [9]. Figure 1 displays the flow diagram for the identification and selection of articles. First, duplicate articles were excluded, titles and abstracts were then read, and the inclusion and exclusion criteria were applied. Lastly, all the articles resulting from the previous stages were fully read, and the inclusion and exclusion criteria were applied again. At the end of the final step, the articles that fulfilled all criteria were selected for this study. Additionally, manual search of the reference lists of the included studies were conducted. Articles on the genus of *Magnolia* that reported traditional uses, essential oils, and their biological activities were covered.
The inclusion criteria for the current review were original research articles in English, Portuguese, and Spanish, articles that presented the chemical compositions of the essential oils, and articles that discussed the biological activities of the essential oils. The exclusion criteria were articles without the search terms in their title and abstract, review articles, articles without its full-text available, articles without one of the keywords, and articles without the compositions of the essential oils.

3. MEDICINAL USES

Herbal medicines are used as complementary or alternative medicine worldwide, including in many developed countries, to treat various health concerns. Earlier studies reported that *Magnolia* species had been used as traditional medicine in various parts of the world [10-27]. In ancient Chinese and Japanese medication, the *Magnolia* bark was one of the ingredients in *Hange-koboku-to* and *Saiboku-to,* used to decrease anxiety and nervousness and to boost sleep [28]. Additionally, some researchers reported that *Magnolia* barks and flower buds were employed for weight loss, digestion, constipation, inflammation, anxiety, stress, depression, fever, headache, stroke, and asthma [28]. Furthermore, *Magnolia* plants are marketed as fresh or dried products to cater to consumers' preferences and use [29]. Therefore, the *Magnolia* species have an economic importance as forest products such as timber and as one of the sources for herbal medicine. Table I illustrates the medicinal uses of several *Magnolia* species.

4. CHEMICAL COMPOSITIONS

The chemical components identified in *Magnolia* essential oils have been documented since 1968. As of May 2021, 24 *Magnolia* species were reported as the sources of *Magnolia* essential oils [30-69]. Most of the species reported were from China (nine studies) with six species from Korea and Japan, five from the United States of America (USA), four from Vietnam, and one each from Thailand, Brazil, and Taiwan. Ta-

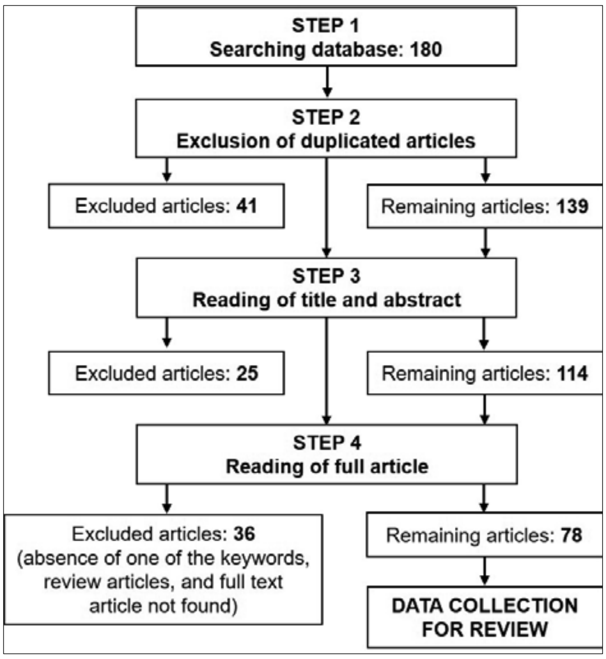

Figure 1 - PRISMA flow diagram of included studies

Table I - Medicinal uses of several *Magnolia* species

Species	Traditional uses
M. acuminata	Remedy for toothache, stomachache, and cramps [10]
M. coco	Prevent age-related diseases and photoaging [12].
M. grandiflora	Prepare bitter tonics to prevent malaria, cold, headache, and stomachache [13].
	Used as stimulants, diaphoretic, anti-inflammatory, and antiseptic agents and to control pain, anxiety, and nervous disturbances [14].
	Remedy against itchiness [15].
	Treatment for cardiovascular diseases and cancer [16].
M. insignis	Treat chest, abdominal pain, indigestion, asthma, and dysentery [17].
M. kobus	Treatment for headaches and colds [18].
M. obovata	Treatment for gastrointestinal disorders, anxiety, allergic diseases, and bronchial asthma [19].
	Relaxes muscle tension to improve vitality [20].
M. officinalis	Treatment for thrombotic stroke, typhoid fever, headache, and alleviate gastric, and abdominal distension [21].
	Treatment for digestive disturbances, reduce the symptoms of cough and asthma [21].
	Treat syndromes caused by emotional distress and turmoil [21].
	Treat abdominal distention, vomiting, diarrhea, food accumulation, constipation, phlegm, fluid retention, and cough resulting from asthma [22].
	Used as deobstruent, tonic, stomachic, quieting, and anthelmintic [23].
M. ovata	Treat fever, cough, scabies, toothache, stomachache, rheumatism, and diabetes [5].
M. sieboldii	Treat inflammatory diseases such as rhinitis, pneumonia, and endometritis [24].
M. virginiana	Treat various ailments, and an ingredient in tonics for autumnal fever, and rheumatism [25].
	Used as a laxative and sudorific in a warm decoction or as an agent against paroxysms of intermittent fever in cold decoctions, powder, or tinctures [25].
	Used to prevent chills, colds, and warm the blood [26].
	Used as a diaphoretic in the treatment of rheumatism, pleurisy, cough, consumption, utilized against remittent, intermittent, and typhoidal fever [27].

ble II demonstrates the major components identified in several *Magnolia* essential oils of various origin, while Figure 2 shows the chemical structures of selected major components.

M. grandiflora from the USA has received the most attention and have been widely investigated. The essential oils mainly were extracted from the leaves, flowers, and flower buds of the plants. Nevertheless, the fruits, barks, twigs, buds, branchlets, shoots, seeds, peels, arils, stems, and trunks were also studied. The essential oil from *M. grandiflora* flowers had the highest number of chemical components (118) [40], while the flower buds of *M. biondii* showed the highest percentage of oil, about 99.91% [35]. Analysis of the chemical components identified in *Magnolia* essential oils included monoterpene hydrocarbons, monoterpenoids, sesquiterpene hydrocarbons, and sesquiterpenoids.

In another study, Zheng et al. [46] reported that the aril oil of *M. kwangsiensis* con-

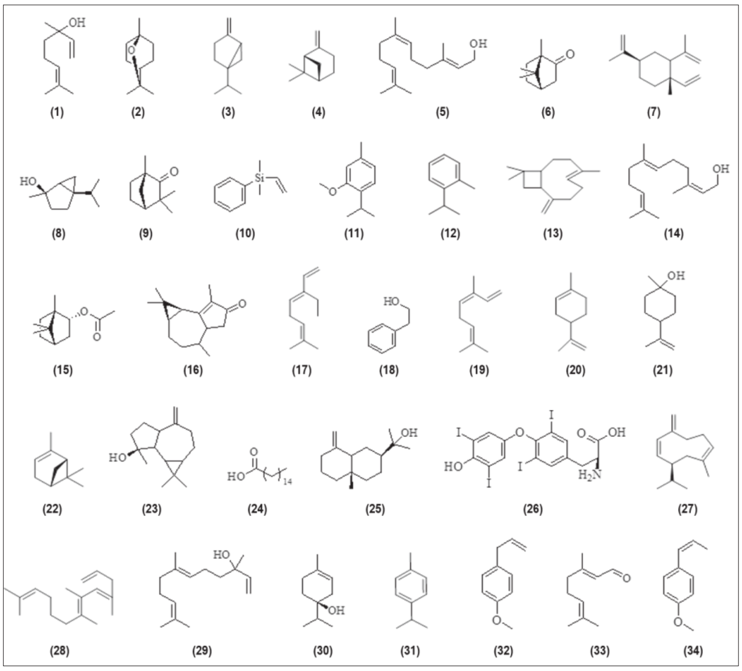

Figure 2 - Chemical structures of major components from *Magnolia* essential oils

Table II - Major components identified in several *Magnolia* essential oils

Species	Locality	Part	Total components (No., %)	Major Groups (%)	Major components (%)
M. hookeri	Vietnam	Leaves	35 (96.50%)	Monoterpenoids (41.50%)	Linalool (**1**) (21.30%), (*E*)-nerolidol (12.20%), *neo*-intermedeol (13.50%), geraniol (8.40%), α-selinene (5.50%) [30]
		Twig	59 (97.40%)	Monoterpenoids (45.10%)	Linalool (**1**) (17.10%), eucalyptol (1,8-cineole) (13.30%), β-eudesmol (5.70%), α-eudesmol (5.70%), bulnesol (6.80%) [30]
M. insignis	Vietnam	Leaves	54 (96.60%)	Monoterpenoids (46.50%)	Linalool (**1**) (24.10%), geraniol (14.90%), (*E*)-nerolidol (22.50%) [30]
		Twig	56 (95.20%)	Monoterpenoids (56.30%)	Eucalyptol (**2**) (9.50%), linalool (26.90%), geraniol (8.50%) [30]
M. sirindhorniae	Thailand	Bud	30 (83.50%)	Monoterpenes and monoterpenoids (62.10%)	Linalool (**1**) (58.90%), β-elemene (4.40%), β-caryophyllene (3.50%) [5]
		Flower	30 (83.20%)	Monoterpenes and monoterpenoids (53.00%)	Linalool (**1**) (51.00%), β-elemene (7.50%), β-caryophyllene (6.40%) [5]
M. coco	Vietnam	Leaves	34 (94.50%)	Monoterpene hydrocarbons (69.50%)	Sabinene (**3**) (35.40%), β-pinene (16.30%), α-pinene (7.10%), β-elemene (6.20%), β-caryophyllene (6.20%) [31]
M. biondii	China	Bud	26 (96.65%)	NM	β-Pinene (**4**) (28.60%), eucalyptol (19.30%), α-pinene (14.90%), γ-terpinene (11.00%), α-myrcene (9.00%) [32]
		Flower bud	80 (97.13%)	NM	Eucalyptol (**2**) (14.20%), (*E,E*)-farnesol (13.05%), α-phellandrene (6.27%), α-pinene (6.22%), terpineol (5.34%) [33]
		NM	50 (NM)	NM	Eucalyptol (**2**) (28.92%), β-pinene (12.39%), α-terpineol (8.28%) [16]
		Flower bud	25 (97.68%)	Sesquiterpene hydrocarbons (62.26%)	Farnesol (**5**) (34.54%), eucalyptol (21.03%), α-cadinol (13.95%), β-pinene (12.23%), α-cadinene (11.04%) [34]
		Flower bud	56 (99.91%)	Monoterpenes (78.72%)	Camphor (**6**) (43.26%), eucalyptol (38.02%), α-terpineol (12.29%), α-cadinene (15.15%) [35]
	Korea	Flower bud	55 (85.40%)	Monoterpene hydrocarbons (63.72%)	Eucalyptol (**2**) (34.93%), camphor (25.43%), farnesol (9.59%), β-pinene (9.36%), sabinene (7.89%), α-terpineol (7.37%), α-pinene (5.37%) [36]
M. sieboldii	China	Leaves	33 (87.91%)	NM	β-Elemene (**7**) (29.10%), γ-terpinene (17.01%), (*E*)-β-ocimene (11.69%), germacrene D (9.57%) [37]
		Leaves	26 (91.33%)	Terpene hydrocarbons (85.95%)	β-Elemene (**7**) (57.55%), β-phellandrene (19.12%), τ-cadinol (8.24%), *trans*-β-ocimene (5.06%) [38]
		Leaves	21 (85.40%)	NM	4-Thujanol (**8**) (31.17%), phenyldimethylvinyl silane (11.51%), copaene (9.44%), α-terpineol (5.93%) [7]
		Flower	19 (84.00%)	NM	Fenchone (**9**) (24.67%), phenyldimethylvinyl silane (15.51%), 10-hydroxytricyclo-dec-3-en-9-one (11.10%), 2,6-dimethyl-2,4,6-octatriene (7.87%), 3,6-dimethoxy-4-nitropyridazine1-oxide (5.47%) [7]
		Twig	25 (82.50%)	NM	Phenyldimethylvinyl silane (**10**) (35.06%), 10-hydroxytricyclo-dec-3-en-9-one (12.97%), fenchone (8.12%), 2,6-dimethyl-2,4,6-octatriene (6.40%), 4-thujanol (5.34%) [7]
		Stem bark	27 (83.00%)	NM	2-Isopropyl-5-methyl anisole (**11**) (21.56%), δ-3-carene (15.85%), cosmene (5.88%) [7]

Continua Tabella II

Species	Locality	Part	Total components (No., %)	Major Groups (%)	Major components (%)
		Root bark	24 (84.10%)	NM	*O*-Cymene (**12**) (28.24%), δ-3-carene (20.53%) (Sun et al., 2014)
	Korea	Flower	60 (91.50%)	Hydrocarbons (74.60%)	β-Elemene (**7**) (18.00%), α-terpinene (14.83%), β-myrcene (12.72%), eremophilene (6.00%) [39]
M. grandiflora	USA	Leaves	34 (78.10%)	Monoterpene hydrocarbons (30.90%)	β-Pinene (**4**) (23.00%), β-elemene (13.60%), α-pinene (6.30%) [8]
		Flower	46 (93.00%)	Monoterpene hydrocarbons (43.80%)	β-Pinene (**4**) (32.30%), α-pinene (8.00%), β-elemene (7.70%) [8]
		Immature fruit	44 (86.30%)	Sesquiterpene hydrocarbons (32.00%)	β-Elemene (**7**) (12.90%), β-pinene (12.70%), β-caryophyllene (7.90%), α-terpineol (5.10%) [8]
		Mature fruit	45 (84.10%)	Oxygenated monoterpenes (36.90%)	Eucalyptol (**2**) (12.20%), caryophyllene oxide (7.20%), β-pinene (6.90%), β-elemene (5.70%) [8]
		Seed	52 (85.20%)	Sesquiterpene hydrocarbons (31.50%)	β-Caryophyllene (**13**) (8.80%), β-phellandrene (7.30%), 1-octanol (6.20%), *p*-cymene (5.50%) [8]
		Flower	118 (92.30%)	Sesquiterpene hydrocarbons (52.80%)	β-Elemene (**7**) (14.30%), bicyclogermacrene (10.30%), germacrene D (7.60%) [40]
		Flower	65 (99.00%)	Oxygenated monoterpenes (27.80%)	(2*Z*,6*E*)-Farnesol (**14**) (18.0%), 2-phenylethanol (10.8%), benzene acetaldehyde (8.50%) [41]
		Leaves	28 (93.60%)	Sesquiterpene hydrocarbons (45.70%)	Bornyl acetate (**15**) (20.90%), (*E*)-β-caryophyllene (15.10%), germacrene D (8.40%), α-guaiene (6.80%), camphor (5.50%) [42]
		Flower	71 (96.90%)	Sesquiterpene hydrocarbons (70.70%)	Cyclocolorenone (**16**) (39.60%), bicyclogermacrene (25.20%), germacrene D (23.80%), isobornyl acetate (16.00%), methyl myristate (15.30%), (2*Z*,6*E*)-farnesol (15.00%), β-pinene (14.60%), β-elemene (12.80%), (2*Z*,6*E*)-farnesol (12.50%), (*Z*)-β-ocimene (6.40%) [43]
		Seed	16 (90.97%)	Monoterpenoids and sesquiterpenoids (40.91%)	β-Caryophyllene (**13**) (19.36%), eucalyptol (10.70%), equilenin (8.02%) [22]
		Flower	67 (66.80%)	NM	β-Pinene (**4**) (10.50%), geraniol (7.40%), germacrene D (6.20%) [13]
		Flower	34 (100.00%)	NM	(*E*)-β-Ocimene (**17**) (24.60%), geraniol (18.90%), β-elemene (11.20%), germacrene D (9.90%) [13]
		Fruit	20 (83.80%)	Monoterpenes and sesquiterpenes (15.50%)	β-Elemene (**7**) (12.10%), β-caryophyllene (7.40%) [44]
		Flower	17 (83.00%)	Sesquiterpene hydrocarbons (80.00%)	β-Caryophyllene (**13**) (34.80%), β-cedrene (8.10%), (*Z*)-β-farnesene (6.40%), γ-elemene (5.70%) [45]
M. virginiana	USA	Flower	49 (98.00%)	Aromatic (45.90%)	2-Phenylethanol (**18**) (39.90%), methyl myristate (11.50%) [41]
M. kwangsiensis	China	Peel	22 (87.51%)	Monoterpene hydrocarbons (69.70%)	(*Z*)-β-Ocimene (**19**) (30.80%), *p*-menth-1-ene (17.76%), α-terpinene (10.15%), β-myrcene (7.03%), α-terpineol (5.18%) [46]
		Aril	23 (94.42%)	Monoterpene hydrocarbons (86.59%)	(*Z*)-β-Ocimene (**19**) (56.03%), β-phellandrene (10.96%), α-terpinene (6.37%), α-phellandrene (6.16%), β-myrcene (6.04%) [46]

Continua Tabella II

Species	Locality	Part	Total components (No., %)	Major Groups (%)	Major components (%)
		Male flower	31 (99.20%)	Monoterpene hydrocarbons (48.30%)	Limonene (**20**) (18.50%), α-terpinene (13.00%), α-cadinol (12.20%), τ-muurolol (9.90%), *cis*-β-ocimene (8.10%), δ-cadinene (7.20%), β-myrcene (6.40%), α-amorphene (6.20%) [46]
		Female flower	27 (98.50%)	Monoterpene hydrocarbons (54.00%)	Limonene (**20**) (20.80%), α-cadinol (11.50%), *cis*-β-ocimene (9.50%), δ-cadinene (8.50%), τ-muurolol (8.40%), α-terpinene (7.10%), β-myrcene (6.60%), *p*-menth-1-ene (5.90%) [47]
		Leaf	26 (96.20%)	Monoterpene hydrocarbons (44.60%)	β-Terpineol (**21**) (28.90%), γ-terpinene (18.10%), β-myrcene (15.90%), α-terpineol (5.40%) [47]
M. hypolampra	Vietnam	Leaf	40 (99.20%)	Monoterpene hydrocarbons (69.70%)	α-Pinene (**22**) (23.70%), β-pinene (36.50%), germacrene D (14.60%) [48]
		Twig	41 (98.20%)	Monoterpene hydrocarbons (80.50%)	β-Pinene (**4**) (41.30%), α-pinene (24.40%), germacrene D (5.80%) [48]
M. ovata	Japan	Leaves	87 (98.00%)	Sesquiterpene hydrocarbons (23.70%)	(*E*)-β-Caryophyllene (**13**) (23.70%), α-humulene (11.60%), geraniol (9.10%), borneol (7.00%) [49]
			58 (99.70%)	Sesquiterpene hydrocarbons (48.90%)	(*E*)-β-Caryophyllene (**13**) (48.90%), α-humulene (15.70%) [49]
	Brazil	Fruit	43 (80.30%)	Sesquiterpenes (66.60%)	Spathulenol (**23**) (19.30%), β-eudesmol (8.00%), hexadecanoic acid (7.60%), germacrene D (6.40%) [50]
			31 (89.70%)	Aliphatic (66.70%)	Hexadecanoic acid (**24**) (52.00%), β-eudesmol (7.60%), 1-hexadecanol (4.30%) [50]
M. obovata	Japan	Bark	90 (79.00%)	Sesquiterpenoid (62.67%)	β-Eudesmol (**25**) (23.61%), cadalene (17.21%), γ-eudesmol (7.32%), bornyl acetate (6.40%) [51]
M. liliflora	China	Flower	57 (94.03%)	NM	β-Pinene (**4**) (21.16%), eucalyptol (16.59%), camphor (9.86%), α-terpineol (7.13%), terpinen-4-ol (6.51%), α-pinene (6.31%), camphene (6.03%) [52]
	Korea	Flower bud	67 (87.80%)	Monoterpene hydrocarbons (84.99%)	Eucalyptol (**2**) (23.46%), β-myrcene (28.87%), β-pinene (12.56%), limonene (6.18%), sabinene (11.31%), α-pinene (6.32%), linalool (5.07%) [36]
	Korea	Leaves	52 (78.07%)	NM	Levoxine (**26**) (15.59%), methycyclopropane (24.26%), phenyethyl alcohol (15.87%), β-pinene (5.30%) [53]
	China	Leaf	32 (95.00%)	NM	Germacrene D (**27**), santolina triene, caryophyllene, 1,3,7-octatriene, nerol, camphene [54]
	Japan	Leaf	65 (100.00%)	Sesquiterpene hydrocarbons (72.5%)	*trans*-α-Farnesene (**28**) (72.50%), *cis*-3-hexenol (6.40%) [55]
		Branchlet	84 (100.00%)	NM	*trans*-α-Farnesene (**28**) (20.50%), δ-cadinene (20.50%), δ-cadinol (5.20%) [55]
		Flower bud	76 (99.80%)	NM	*trans*-α-Farnesene (**28**) (50.10%), δ-cadinene (9.90%), germacrene D (8.20%) [55]
Magnolia sp.	China	Flower bud	54 (99.00%)	NM	Eucalyptol (**2**) (21.55%), β-pinene (11.07%), limonene (8.93%), α-pinene (7.86%), camphor (6.46%), β-terpinene (5.30%), γ-terpinene (5.10%) [56]
Flos Magnolia	China	Bud	52 (97.35%)	NM	Eucalyptol (**2**) (38.38%), β-pinene (10.27%), (*E*)-farnesol (7.22%), α-terpinol (6.46%), β-phellandrene (6.72%) [57]

Continua Tabella II

Species	Locality	Part	Total components (No., %)	Major Groups (%)	Major components (%)
		NM	74 (98.74%)	Monoterpenes (42.01%)	Camphor (**6**) (32.62%), eucalyptol (21.08%), *p*-cymene (13.98%), camphene (8.33%), β-pinene (5.97%), limonene (5.07%) [58]
M. officinalis	China	Stem	90 (84.03%)	Oxygenated sesquiterpenes (47.66%)	β-Eudesmol (**25**) (27.34%), γ-eudesmol (13.57%), α-eudesmol (6.75%) [21]
		Branch	82 (83.68%)	Oxygenated sesquiterpenes (36.74%)	β-Eudesmol (**25**) (22.02%), γ-eudesmol (9.39%), α-eudesmol (5.33%) [21]
		Root bark	76 (83.10%)	Oxygenated sesquiterpenes (36.31%)	β-Eudesmol (**25**) (18.56%), α-eudesmol (10.24%), γ-eudesmol (7.51%) [21]
		Bark	28 (77.50%)	NM	β-Eudesmol (**25**) (40.74%), *p*-cymene (9.37%), δ-selinene (9.21%), caryophyllene oxide (5.19%) [59]
		Bark	26 (93.80%)	Monoterpenoids and sesquiterpenoids (40.70%)	β-Eudesmol (**25**) (17.40%), cardinol (14.60%), guaiol (8.70%), *p*-cymene (7.80%), 1,4-cineole (5.60%), caryophyllene (5.00%) [60]
M. denudata	Korea	Flower bud	69 (91.90%)	Monoterpene hydrocarbons (84.92%)	Eucalyptol (**2**) (29.71%), β-pinene (15.42%), sabinene (16.63%), α-terpineol (10.88%), β-myrcene (10.83%), terpinen-4-ol (6.62%), α-pinene (6.61%), limonene (6.60%) [36]
	Japan	Leaf	51 (99.30%)	NM	*trans*-Nerolidol (**29**) (25.90%), β-caryophyllene (18.43%), β-myrcene (10.00%), α-humulene (8.40%), β-bourbonene (5.30%) [61]
		Branchlet	40 (99.40%)	NM	Terpinen-4-ol (**30**) (18.20%), eucalyptol (17.60%), sabinene (11.00%), α-terpineol (10.90%), β-eudesmol (7.00%), linalool (6.70%), *trans*-nerolidol (5.30%) [61]
		Bark	40 (97.80%)	NM	Eucalyptol (**2**) (43.50%), β-eudesmol (16.70%), terpinen-4-ol (8.00%), α-terpineol (7.30%) [61]
		Flower bud	44 (100.00%)	NM	Eucalyptol (**2**) (57.20%), sabinene (11.50%), α-terpineol (8.30%), β-caryophyllene (5.0%) [61]
		Flower	44 (98.70%)	NM	Eucalyptol (**2**) (36.10%), sabinene (30.00%), pentadecane (9.10%), α-terpineol (7.60%), β-eudesmol (5.50%) [61]
M. kobus	Korea	Flower bud	56 (90.00%)	Monoterpene hydrocarbons (81.84%)	Limonene (**20**) (18.81%), eucalyptol (15.44%), β-pinene (9.95%), γ-terpinene (9.14%), *p*-cymene (7.15%), sabinene (5.87%), β-myrcene (5.05%) [36]
		Fresh fruit	12 (97.30%)	Monoterpene hydrocarbons (71.80%)	α-Pinene (**22**) (31.60%), β-pinene (27.90%), limonene (8.60%), β-caryophyllene (8.10%) [62]
		Dried fruit	16 (96.30%)	Monoterpene hydrocarbons (62.80%)	α-Pinene (**22**) (26.70%), β-pinene (20.20%), limonene (10.00%), heptadecane (6.10%), caryphyllene oxide (8.10%) [62]
	Japan	Shoot	21 (100.00%)	NM	Limonene (**20**) (39.30%), eucalyptol (34.10%), camphor (26.50%), α-terpineol (11.70%), *p*-cymene (8.60%), β-pinene (8.00%), terpinen-4-ol (5.20%) [63]
		Branchlet	15 (98.60%)	NM	Limonene (**20**) (57.60%), α-terpineol (12.60%), camphor (12.50%), terpinen-4-ol (6.40%) [63]

Continua Tabella II

Species	Locality	Part	Total components (No., %)	Major Groups (%)	Major components (%)
		Shoot	30 (100.00%)	NM	*p*-Cymene (**31**) (41.30%), δ-nerolidol (28.00%), *trans*-linalool oxide (20.90%), eucalyptol (18.80%), caryophyllene (15.30%), limonene (14.40%), camphor (12.40%), elemol (6.80%), β-pinene (6.70%), α-pinene (6.40%), α-terpineol (6.20%), citronellol (5.50%) [64]
		Shoot	27 (99.70%)	NM	*p*-Cymene (**31**) (34.00%), limonene (22.60%), camphor (14.00%), δ-nerolidol (8.30%), eucalyptol (8.00%), β-pinene (5.10%), camphene (5.00%) [65]
		Bud	5 (74.90%)	NM	Camphor (**6**) (69.00%), eucalyptol (47.00%), linalool (5.90%), neral (5.30%), geranial (5.10%) [66]
M. fraseri	USA	Fruit	23 (80.40%)	Monoterpenes and sesquiterpenes (19.40%)	β-Pinene (**4**) (26.30%), β-myrcene (13.10%), limonene (6.30%), bornyl acetate (5.70%), α-pinene (5.70%), germacrene D (5.70%), terpinene-4-ol (5.10%) [44]
M. tripetala	USA	Fruit	22 (87.10%)	Monoterpenes and sesquiterpenes (52.60%)	β-Caryophyllene (**13**) (21.00%), bornyl acetate (17.00%), α-humulene (11.20%) [44]
M. acuminata	USA	Fruit	21 (67.50%)	Monoterpenes and sesquiterpenes (14.00%)	*trans*-Nerolidol (**29**) (20.00%), 9-oxofarnesol (11.00%), bornyl acetate (5.30%) [44]
M. fargesii	Taiwan	Bud	NM	Oxygenated monoterpenes (47.16%)	Farnesol (**5**) (42.23%), camphor (19.25%), eucalyptol (14.23%), oplopanone (10.61%), α-terpineol (9.50%) [67]
M. sprengeri	China	Flower bud and twig	32 (NM)	NM	Sabinene (**3**) (12.18%), bornyl acetate (9.50%), *trans*-caryophyllene (8.25%), β-eudesmol (7.43%), caryophyllene oxide (6.90%), *p*-cymene (7.31%), β-pinene (5.81%) [67]
M. salicifolia	Japan	Shoot	27 (99.90%)	NM	Methyl chavicol (**32**) (84.10%), geranial (6.70%), limonene (5.00%) [68]
		Leaf	18 (99.00%)	NM	Methyl chavicol (**32**) (91.40%), *trans*-anethole (2.90%), geranial (1.90%), neral (1.00%) [68]
		Branchlet	25 (99.60%)	NM	Geranial (**33**) (30.20%), eucalyptol (23.80%), neral (19.70%), methylchavicol (7.00%) [68]
		Flower bud	25 (99.60%)	NM	Geranial (**33**) (38.10%), neral (22.60%), methyl chavicol (10.00%), *trans*-anethole (5.60%) [68]
		Flower	25 (99.80%)	NM	Geranial (**33**) (43.30%), neral (24.20%), methyl chavicol (8.50%) [68]
		Shoot	29 (99.90%)	NM	*trans*-Anethole (**34**) (64.80%), geranial (11.40%), neral (7.00%) [69]
		Trunk	19 (99.40%)	NM	Eucalyptol (**2**) (34.00%), geranial (27.60%), neral (20.20%), terpinen-4-ol (5.40%) [69]
		Flower bud	7 (87.90%)	NM	Geranial (**33**) (52.00%), neral (28.00%), linalool (28.00%), safrole (27.00%), *trans*-asarone (18.00%), camphor (10.00%), methyleugenol (9.80%) [66]

NM – not mentioned

tained the highest amount of monoterpene hydrocarbons (86.59%), which constituted *cis*-β-ocimene, β-phellandrene, α-terpinene, α-phellandrene, and β-myrcene. Furthermore, the study also reported the presence of limonene (18.5-20.8%) as the primary component in the flower oil of the same species [47] and *M. kobus* [36].

Other investigations illustrated other monoterpenes,

Table III - Biological activities of *Magnolia* essential oils

Bioactivities	Description
Antioxidant	The flower oil demonstrated maximum scavenging in the DPPH radical assay with 96.04% inhibition, whereas bud oil displayed 75.33% inhibition [5].
	The leaf oil presented low DPPH scavenging activity with an IC_{50} value of 10.11 µg/ml [71].
	The flower oil displayed minimum scavenging activity in DPPH and ABTS radical assays with more than 1% and 0.05% inhibition, respectively [72].
	The flower oil illustrated low DPPH radical scavenging activity with TEAC and IC_{50} values of 3.14 µmol TE/g and 2300 µg/mL, respectively [40].
	The flower oil displayed moderate ABTS and FRAP radical scavenging activity with TEAC and IC_{50} values of 95.02, 24.4 µmol TE/g and 216.5 µg/mL, respectively [40].
	The seed oil exhibited significant proliferation of HL-60 with a cell proliferation rate of 44.8% at the concentration of 27.7 µg/mL [22].
	The seed oil had sharp increases in the serum GSH-Px activity, 38.62%, 61.68%, and 62.86%, at doses 50, 100, and 200 mg/kg, respectively [22].
	The flower oil displayed weak DPPH radical scavenging activity at 20 µg/mL or more [73].
	The leaf oil exhibited low DPPH radical scavenging activity at 250 µg/mL by reducing 4% chemically [42].
Antimicrobial	The leaf (IC_{50} value 278 µg/mL and MIC value 1024 µg/mL) and twig (IC_{50} value 491 µg/mL and MIC value 2048 µg/mL) oils presented strong inhibitory effects against *Lactobacillus fermentum* [30].
	The leaf (IC_{50} value 9.3 µg/mL and MIC value 512 µg/mL) and twig (IC_{50} value 25 µg/mL and MIC value 512 µg/mL) oils illustrated strong inhibitory effects against *Candida albicans* [30].
	The flower oil demonstrated high efficacy against *Klebsiella pneumoniae* and *Staphylococcus aureus* with 25% and 32% growth inhibition, respectively [5].
	The leaf oil displayed strong growth inhibition against *Candida albican*s with an IC_{50} value of 64.0 µg/mL and MIC value of 32.33 µg/mL [31].
	The leaf oil exhibited strong inhibitory effects against *Staphylococcus aureus, Salmonella enterica, Escherichia coli,* and *Candida albicans* with MIC value of 4.1 each mg/mL, and the twig oil also displayed strong inhibitory effects against *Staphylococcus aureus* with the MIC value of 2.0 mg/mL [48].
	The flower oil illustrated strong inhibition capacity against *Rhodotorula* in the medium of red yeast growth [73].
	The leaf oil displayed low inhibitory concentration with 500 and 125 µg/mL MIC values against *Staphylococcus aureus* and *Streptococcus pyogenes*, respectively [42].
Antibacterial	The bud and flower oils demonstrated 17 mm and 30 mm growth inhibition zones against *Staphylococcus aureus*, respectively [5].
	The leaf oil illustrated low efficacy against *Streptococcus mutans* and *Streptococcus sobrinus* with 10.50 mm and 11.65 mm of growth inhibitions, respectively [74].
	The leaf (18.5 mm, 30.5 mm, and 27.5 mm) and twig (45.5 mm, 45.5 mm, and 46 mm) oils exhibited strong inhibitory effects against *Escherichia coli, Staphylococcus aureus*, and *Candida albicans* [48].
	The leaf oil demonstrated the highest efficacy against *Listeria monocytogenes* with 18 mm growth inhibition and MIC value of 125 µg/mL [71].
Antiphotoaging	The leaf oil inhibited skin photoaging by down-regulating the expression of inflammatory factors, including tumor necrosis factor-alpha, interleukin 6, and interleukin 10 through the skin injury models [37].
Antifungal	The flower oil presented weak activity against *Aspergillus fumigatus* and *Candida albicans* with IC_{50} values 0.097% and 0.108%, respectively [72].
	The leaf oil demonstrated good growth inhibition against *M. gypseum*, *T. mentagrophyte*, *T. tonsurans,* and *T. rubrum* with inhibition zone values of 20 mm, 25 mm, and 27 mm, respectively [42].
	The oil displayed a strong effect against *Fusarium solani* with a growth inhibition percentage of 65.60% and MIC value of 125 µg/mL [75].
Antidermatophytic	The oil demonstrated moderate activity against *Trichophyton* and *Microsporum spp* with MIC values that ranged from 62.5 to 500 and 250 to 2000 µg/mL, respectively [71].
Nematocidal	The bark oil illustrated strong activity against *Bursaphelenchus xylophilus* with mean mortality values of 71.8, 82.3, and 85.3% at 24, 48, and 72 hours, respectively [76].
Toxicity	The leaf oil displayed decreased cell viability against human lung (A549) and skin (Detroit551) cells with IC_{50} values of 0.43 and 0.04 µg/mL, respectively [77].
	Immature and mature oils exhibited high toxicity against *Aedes aegypti* with IC_{50} values of 49.4 and 48.9 ppm, respectively [8].
Cytotoxicity	The oil presented no measurable effects against dendritic cells [58].
	The flower oil displayed no cytotoxic selectivity response against A375, MDA-MB 231, and T98G cell lines with IC_{50} values of 36.86, 36.81, and 34.49 µg/mL, respectively [40].
Cytokine	The oil illustrated a strong inhibitory effect against interleukin-12 with 60–85% inhibition [58].

sabinene [31, 70], α-pinene [48, 62], β-pinene [8, 13, 32, 44, 52], o-cymene [7], and β-ocimene [13, 46] as the major components in *Magnolia* essential oils. About 47.16% of the bud oil in *M. fargesii* were oxygenated monoterpenes and characterised as farnesol, camphor, eucalyptol, and α-terpineol [67]. Additionally, eucalyptol was in most *Magnolia* essential oils, such as in *M. biondii* [36, 16, 33], *M. grandiflora*

[8], *Magnolia sp.* [56], *Flos Magnoliae* [57], *M. denudata* [61] [36], and *M. salicifolia* [66].

The flower oil of *M. grandiflora* was about 80% sesquiterpene hydrocarbons, which were dominantly β-caryophyllene, *β*-cedrene, γ-elemene, and germacrene D [45]. Both *M. sieboldii* [37-39] and *M. grandiflora* [44] contained mainly *β*-elemene. Moreover, sesquiterpenoids were found mainly in several *Magnolia* essential oils, such as spathulenol in *M. ovata* fruit oil [50], *trans*-nerolidol in *M. denudata* [61] and *M. acuminata* [44], and β-eudesmol in *M. obovata* [50] and *M. officinalis* [21, 59-60].

5. BIOLOGICAL ACTIVITIES

The diverse pharmacological impacts [71-79], in particular the discrepant force caused by the various bioactive compounds of *Magnolia* essential oil, translated to its high value and attracted the attention of researchers. The biological activities of *Magnolia* essential oils are illustrated in Table III.

Most studies focused on the antioxidant properties of *Magnolia* essential oils. Several assays, such as 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging, 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) free radical scavenging, and ferric-reducing antioxidant power (FRAP), were used to determine the antioxidant potentials of the essential oils. For example, the DPPH assay of flower and bud oils of *M. sirindhorniae* demonstrated maximum scavenging activity of 96.04% and 75.33%, respectively [5]. The significant antioxidant inhibition abilities of the flower oils might be due to the combination of terpenoids and benzenoids volatiles.

Besides being appreciated for the pleasant floral smell of the extracted oils, the components serve as attractants of plant pollinators [78]. The leaf and twig oils of *M. insignis* and the leaf oil of *M. coco* displayed strong inhibitory effects with minimum inhibitory concentration (MIC) values of 512 μg/mL [30] and 32.33 μg/mL [31], respectively, against *Candida albicans*. The significant activities of essential oils might be due to sabinene and β-pinene, the two primary compounds of *M. coco* [31].

Moreover, Ha et al. [48] reported that the leaf and twig oils of *M. hypolampra* illustrated strong inhibitory effects against *Staphylococcus aureus* (inhibition zone 30.5 mm) and *Candida albicans* (inhibition zone 46.0 mm). The strong inhibitory effect might result from the actions of the major components of the oil, α-pinene and β-pinene. Other biological activities of *Magnolia* essential oils reported were antiphotoaging, antifungal, antidermatophytic, cytotoxic, nematocidal, toxicity, and cytokine properties.

6. CONCLUSION

The current review provided an overview of Magnolia essential oils' medicinal uses, chemical compositions, and bioactivities. The essential oils from *Magnolia* species revealed high eucalyptol, β-elemene, linalool, β-eudesmol, methyl chavicol, caryophyllene, camphor, limonene, α-pinene, and β-pinene contents. However, variations in the chemical compositions within the same species obtained from different origins were observed. Different species of the *Magnolia* genus also illustrated variations in chemical compositions. More pharmacological investigations should be performed to unravel the full therapeutic potentials of the *Magnolia* species. Preclinical analyses and clinical trials for essential oils are also required to evaluate the potentials of essential oils from the *Magnolia* species for drug development.

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