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A comprehensive review of the botany, phytochemistry, pharmacology, and toxicology of Murrayae Folium et Cacumen

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Ethnopharmacological relevance: Murrayae Folium et Cacumen (MFC) is a plant considered to be a traditional Chinese medicine with culinary value as well. The dry leaves and twigs of *Murraya paniculata* and *M. exotica* are used to treat stomach aches, rheumatism, toothaches, swelling, and insect and snake bites. They are also used to prepare spicy chicken dishes.

Aim of the review: This review comprehensively summarizes the available information on the botanical characterization, phytochemistry, pharmacological activities, pharmacodynamics, pharmacokinetics, and toxicity of MFC.

Methods: Relevant scientific literature up to August 2023 was included in the study. Chinese and English studies on MFC were collected from databases, including PubMed, Elsevier, Web of Science, Springer, Science Direct, Wiley, ACS, and CNKI (Chinese). Doctoral and Master's dissertations were also included.

Results: In total, 720 compounds have been identified and reported in the literature, including flavonoids, coumarins, alkaloids, sterols, phenylpropenols, organic acids, spirocyclopentenones, and volatile oils. Flavonoids and coumarins are the two most important bioactive compounds responsible for these pharmacological activities. MFC has anti-inflammatory, anti-bacterial, anti-microbial, anti-diabetic, anti-tumor, anti-oxidant, anti-depressant, potential anti-Alzheimer's disease, chondroprotective, and analgesic properties. The pharmacological effects include interrupting the STAT3/NF-κB/COX-2 and EGFR signaling pathways,

Abbreviations: AChE, acetylcholinesterase; AD, Alzheimer's disease; BChE, butyrylcholinesterase; COX-2, cyclooxygenase-2; GC-FID, gas chromatography-flameionization detection; Foxo3a, Forkhead box class O 3a; GC-MS, gas chromatography-mass spectrometry; IC_{50}, half maximal inhibitory concentration; IL, interleukin; iNOS, nitric oxide synthase; LC_{50}, lethal concentration 50; LPS, lipopolysaccharide; MFC, Murrayae Folium et Cacumen; MIC, minimum inhibitory concentration; MIC_{50}, half minimal inhibitory concentration; MMP, matrix metalloproteinase; NF-κB, nuclear factor-kappa B; NO, nitric oxide; PGE2, and prostaglandin E2; PMFs, polymethoxyflavones; TFMP, total flavonoids extracted from *Murraya paniculata*; TNF-α, tumor necrosis factor alpha; SOD, superoxidase dismutase.

downregulating EpCAM expression, inhibiting NF-κB and ERK signals, inhibiting the EP/cAMP/PKA signaling pathway and miR-29a/Wnt/β-catenin signaling activity, and upregulating Foxo3a expression.

Conclusion: This review demonstrates that the chemical constituents, pharmacological activities, pharmacodynamics, pharmacokinetics, and toxicity of MFC support its use in traditional Chinese botanical medicines. MFC contains a wide range of chemical compounds. Flavonoids and coumarins promote strong pharmacological activity and, are low-toxicity natural phytomedicines that are widely used in medicine, food, ornamentation, and cosmetics, making MFC a promising compound for development and use in the treatment of several medical conditions.

KEYWORDS

Murrayae Folium et Cacumen, *Murraya paniculata*, *Murraya exotica*, phytochemistry, pharmacology, toxicology

1 Introduction

The genus *Murraya* comprises 21 accepted species (http://www.worldfloraonline.org). *Murraya paniculata* (L.) Jack and *M. exotica* L. (Rutaceae) are the most widely used *Murraya* species listed in the Chinese Pharmacopoeia (Chinese Pharmacopoeia Commission, 2020). Murrayae Folium et Cacumen (MFC), a traditional Chinese medicine, consists of dry leaves and twigs of *M. paniculata* and *M. exotica* (Lu et al., 2021a). It promotes qi, relieves pain, activates blood, and removes blood stasis and is used mainly to treat stomach pain, rheumatism, arthralgia, toothache, tumefaction, and snakebites (Chinese Pharmacopoeia Commission, 2020). MFC is the main ingredient in Sanjiu Weitai granules, a well-known Chinese-patented medicine used for the treatment of gastric conditions (Lu et al., 2021b). In addition, it is also used in the *Baihu Dan* in the *Jingyue Complete Book* to treat swelling of the head, face, limbs and eyes, and *Zhitong Jing* in the *Compilation of Chinese Medicine* to promote circulation and relieve pain.

The leaves of *Murraya paniculata* are used as a spice by the people of India, Southeast Asia, Pakistan, and Malaysia in a variety of food preparations. Malaysians typically use *M. paniculata* leaves to prepare soups, fish, and meat. *M. paniculata* has also been used to prepare spicy chicken dishes in popular fast-food restaurants (Ng et al., 2012; Saqib et al., 2015). In ancient China, India, and Indonesia, *M. paniculata* was used as a botanical medicine for numerous healthcare purposes. In the Chinese Pharmacopoeia, *M. paniculata* is reported to have analgesic effects and the potential to treat microbial infections and inflammatory diseases (Zhang et al., 2011). The ground stem bark of *M. paniculata* is used as an antidote for snake bites, whereas the ground roots are used to treat body pain. The leaves are irritating and astringent and are used by the Indonesian community to relieve diarrhea and dysentery (Saqib et al., 2015). *M. paniculata* has also been used to treat coughs, hysteria, and rheumatism (Gautam et al., 2012a). It is used to treat snake bites and as a detergent for other types of bites. The roots and bark are chewed and rubbed against the skin to treat pain. Crushed leaves are applied to fresh wounds and as a remedy for alcohol-related fluid retention. *M. paniculata* can be used to treat toothaches, stomach-aches, and gout. It is also used for abortion and to treat venereal diseases (Kinoshita and Firman, 1996a; Rahman et al., 2010). Terpenoid volatile oils extracted from the flowers of *M. paniculata* are used in the cosmetic industry (Rout et al., 2007; Rehman et al., 2013).

Murraya exotica is a dwarf tree or evergreen shrub commonly cultivated as an ornamental plant in many tropical and subtropical areas because of its glossy green leaves and clusters of fragrant white flowers (Sharma and Arora, 2015). It has also been used for the treatment of analgesia, anesthesia, abdominal pain, and rheumatism. The leaves of *M. exotica* are rich in coumarins, which exhibit anti-oxidant, anti-tumor, anti-mycobacterial, anti-fungal, anti-viral, and anti-inflammatory properties. The roots of *M. exotica* are rich in coumarins and alkaloids, such as paniculidines (A–F) (He et al., 2017).

Previous phytochemical studies on MFC (*M. paniculata* and *M. exotica*) have indicated the main bioactive compounds as coumarins, flavonoids, alkaloids, and volatile oils, of which the alkaloids are mainly present in the roots of plants. Pharmacological studies have demonstrated that MFC possesses anti-inflammatory, analgesic, anti-bacterial, anti-oxidant, and insecticidal properties (Lu et al., 2021a). To date, there have been no systematic reports on MFC. Therefore, it is necessary to summarize the phytochemistry, pharmacology, pharmacodynamics, pharmacokinetics, and toxicology of MFC to guide clinical use in the Chinese Pharmacopoeia.

2 Botanical characterization

2.1 Plant description

Murraya paniculata are 1.8–12 m tall shrubs or trees. Older branchlets are grayish-white to pale yellowish-gray. The leaves are 2–5 foliolate, and leaflet blades are mostly suborbicular to ovate to elliptical, margin entire or crenulate, and apex rounded to acuminate (http://www.worldfloraonline.org) (Figure 1A).

Murraya exotica are 2–8 m tall shrubs or trees. Older branchlets are grayish-white to pale yellowish-gray. The leaves are 3–7 foliolate, petiolules are rather short, leaflet blades are elliptic-obovate or

FIGURE 1
(A) *M. paniculata*; **(B)** *M. exotica*; **(C, D)** Murrayae Folium et Cacumen.

TABLE 1 Vernacular name of MFC.

Species	Local name	Country	References
M. paniculata	Kemuning Putih; orange jasmine	Malaysia	Ng et al. (2012)
M. paniculata	Daun kumning	Indonesia	Kinoshit and Firman, (1996a)
M. paniculata	Chinese box	America; Canada	Aziz et al. (2010)
M. paniculata	Qianlixiang; jiulixiang	China	Zhang et al. (2011)
M. paniculata	Orange jasmine; honey bush; kamini	India	Gautam et al. (2012a), Rehman et al. (2013)
M. paniculata	Orange jasmine	Pakistan	Rehman et al. (2013)
M. paniculata	Bajardante	Nepal	Dosoky et al. (2016)
M. paniculata	Nguyet que	Vietnam	Cuong et al. (2014)
M. paniculata	Kaew	Thailand	Rodanant et al. (2015)
M. paniculata	Orange jasmine	Brazil	Menezes et al. (2017)
M. exotica	Jiulixiang; qianlixiang	China	Wu et al. (2010)
M. exotica	Marwa	Pakistan	Siddiqua et al. (2023)

obovate, and margins are entire, apex rounded, or obtuse (http://www.worldfloraonline.org) (Figure 1B).

2.2 Vernacular names

Vernacular names—in other words, local, common, or non-Latin names for a plant or animal—are derived from common native languages and are distinct from binomial nomenclature. The name is derived from the plant's morphology, habits, habitats, organoleptic properties, and therapeutic uses (Hossain et al., 2021). The vernacular names of MFC are listed in Table 1.

3 Materials and methods

This review focuses on the research advances in the phytochemical constituents, pharmacological activities, pharmacodynamics, pharmacokinetics, and toxicology of MFC. Related scientific literature up to August 2023 was collected from the following databases: PubMed, Elsevier, Web of Science, Springer, Science Direct, Wiley, ACS, and CNKI (Chinese). Doctoral and Master′s dissertations were also included in the analysis. We used the terms (all fields) "Murrayae Folium et Cacumen," "*Murraya paniculata*," "*Murraya exotica*," and "*Murraya*" and collated all published works from the China Medical University Library. Only

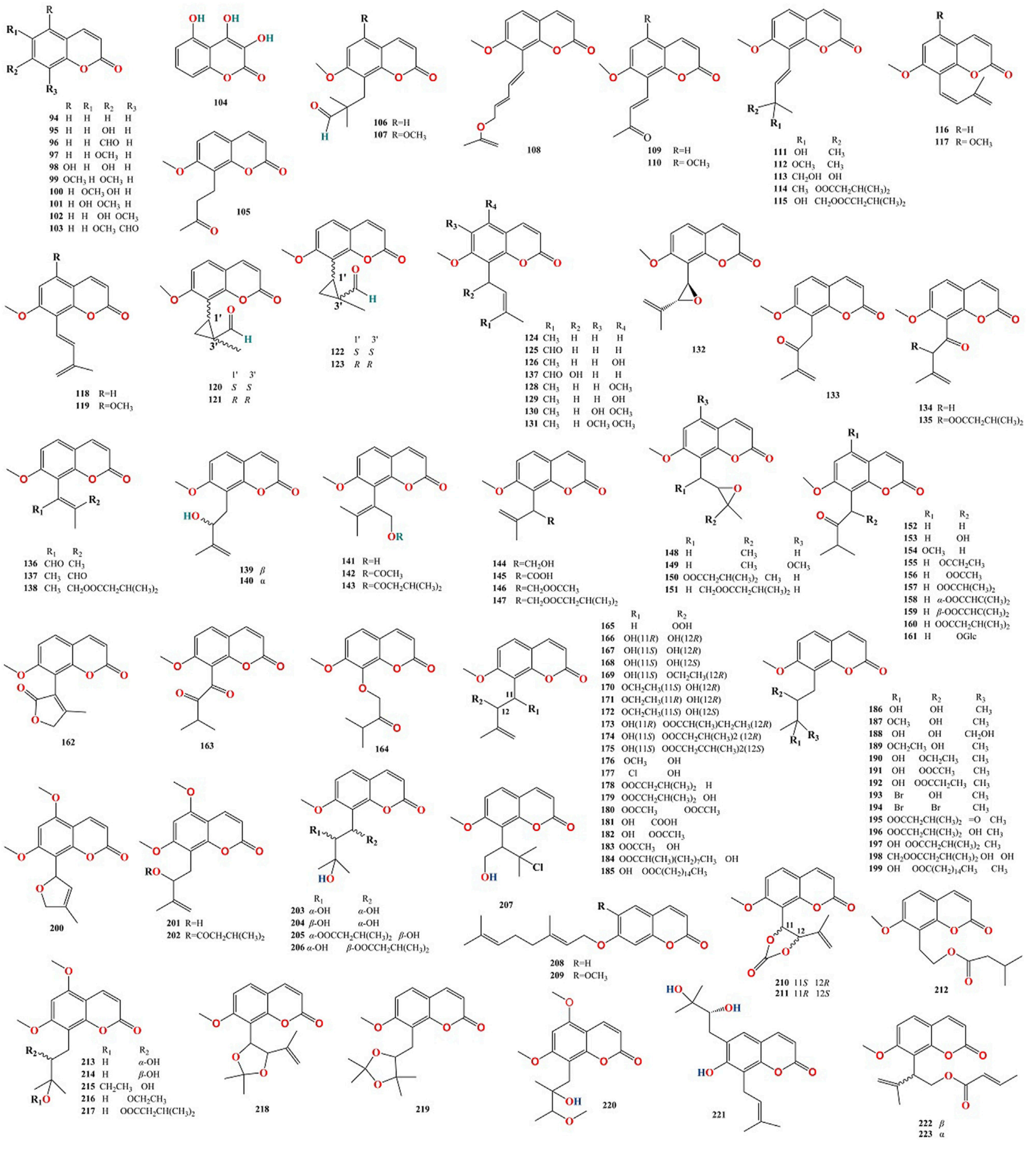

FIGURE 2
Chemical structures of flavonoids isolated from Murrayae Folium et Cacumen.

data published in English or Chinese were included in the analysis. ChemDraw 20.0 was used to extract the chemical compounds. The PubChem database (https://pubchem.ncbi.nlm.nih.gov) was used to confirm the chemical classifications and structures. World Flora Online (http://www.worldfloraonline.org/) was used to verify the names of the plants.

3.1 Inclusion and exclusion criteria

Firstly, duplicate articles, review articles, conference abstracts; non-English and non-Chinese articles were excluded. Further exclusions were duplicate articles and articles unrelated to the topic. Finally, 125 eligible articles were included.

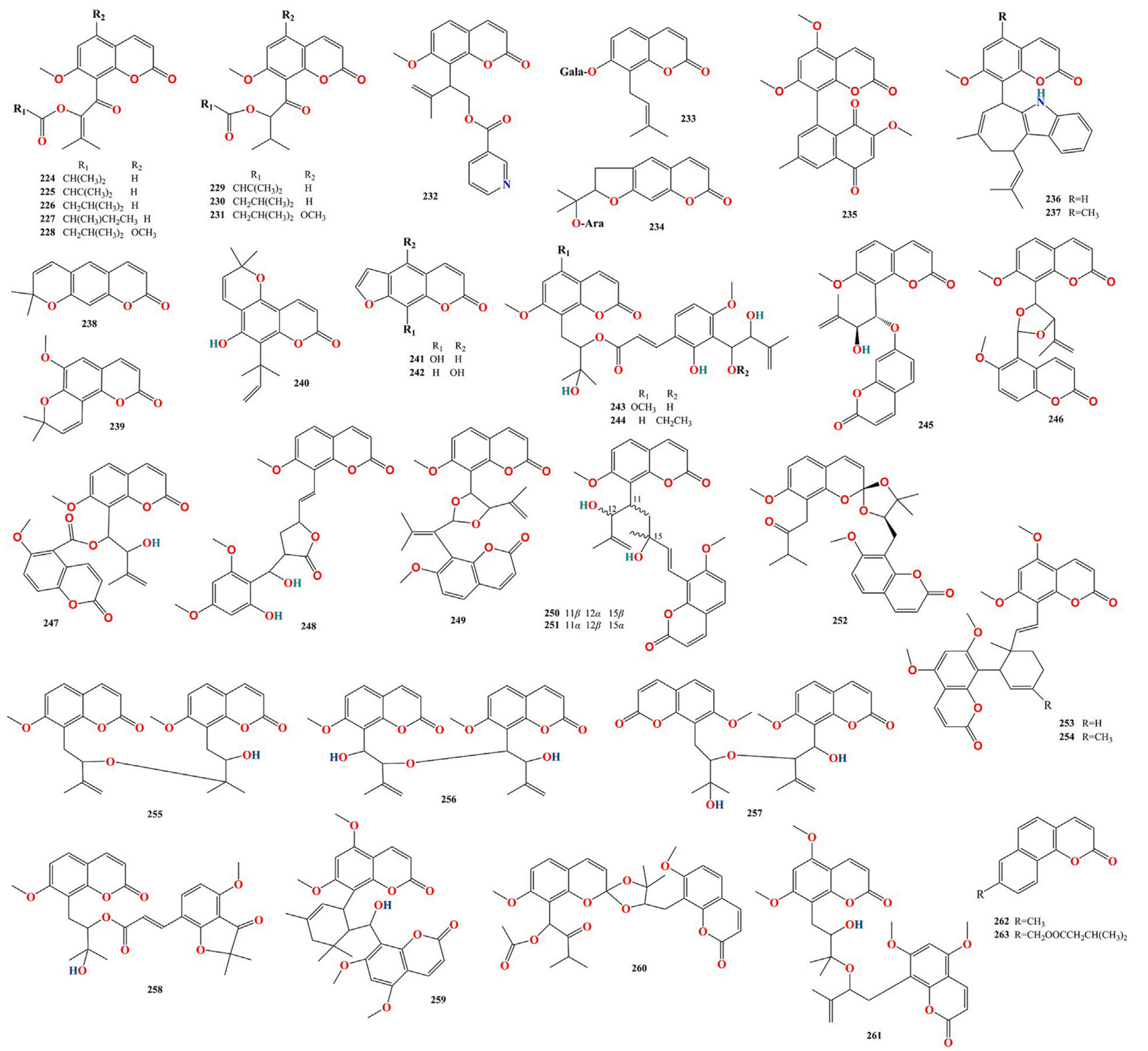

FIGURE 3
Chemical structures of coumarins isolated from Murrayae Folium et Cacumen.

4 Phytochemistry

To date, 316 compounds have been identified in MFC, including flavonoids, coumarins, alkaloids, sterols, phenylpropanoids, organic acids, spirocyclopentenones, and 404 volatile oils. These have been identified using thin layer chromatography (TLC), high-performance liquid chromatography (HPLC), ultra- performance liquid chromatography (UPLC), nuclear magnetic resonance (NMR), ultraviolet (UV), mass spectrometry (MS), NMR-MS, ultra-performance liquid chromatography-electrospray ionization-mass spectrometry (UPLC-ESI-MS), HR-FAB-MS, heteronuclear multiple-bond correlation (HMBC), heteronuclear multiple-quantum correlation (HMQC), and gas chromatography-mass spectrometry (GC-MS) (Kong Y. et al., 1985; Liu et al., 2015a; Kaur et al., 2016; Liang et al., 2020c; Saikia et al., 2021). Flavonoids are the main compounds of *M. paniculata*, whereas coumarins are the main compounds of *M. exotica*. Alkaloids mainly exist in the roots of plants but rarely in the twigs and leaves (Lu et al., 2021a). A detailed list of these chemical compounds and their classes is presented in Figures 2–5, and Tables 2–5 and Supplementary Table S.

4.1 Flavonoids

Ninety-three flavonoids (**1–93**, Table 2) have been identified in MFC. Of these, 72 compounds belong to the polymethoxylated flavonoid family, 90 were isolated from *M. paniculata*, and 24 were

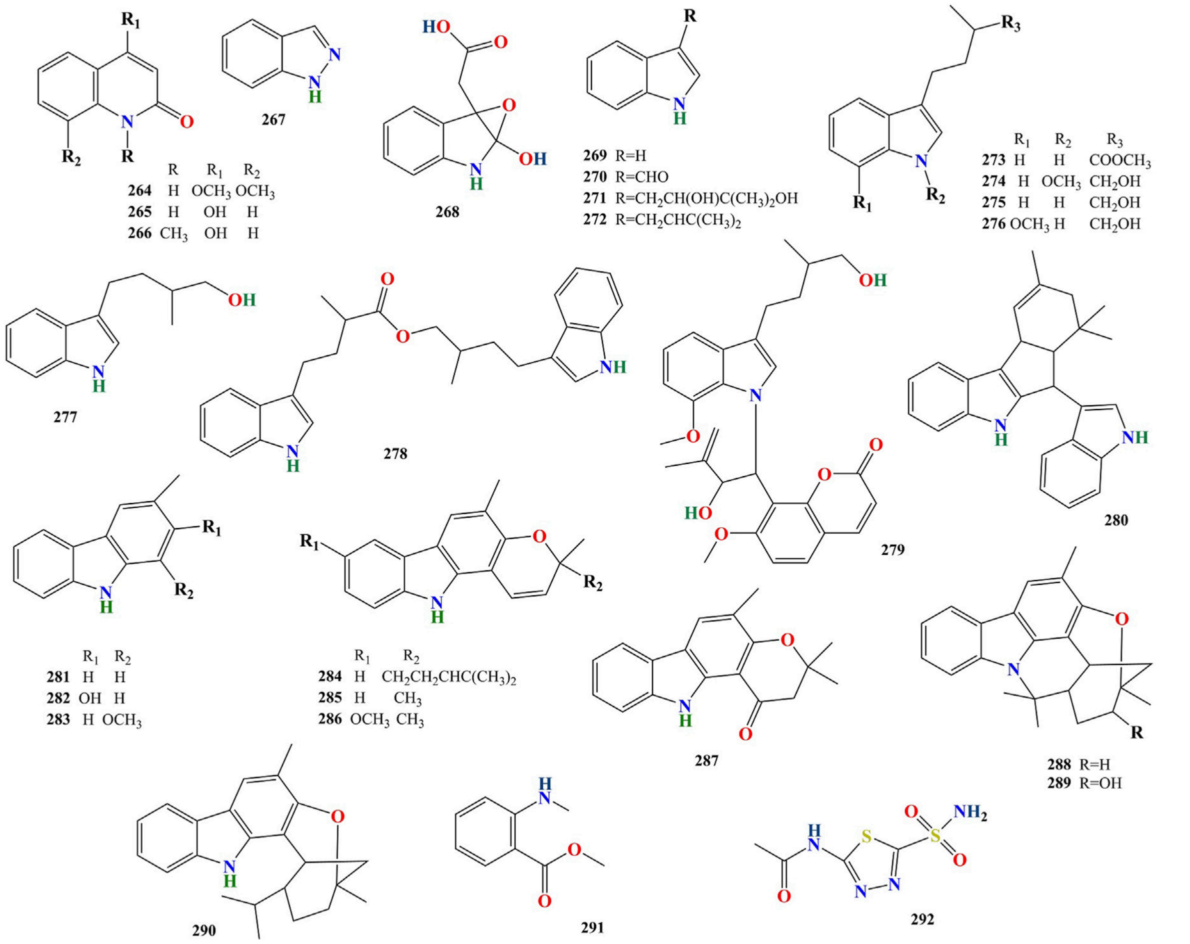

FIGURE 4
Chemical structures of alkaloids isolated from Murrayae Folium et Cacumen.

isolated from *M. exotica*, confirming that flavonoids were isolated mainly from *M. paniculata* (Lu et al., 2021a). Twenty-one compounds were isolated from *M. paniculata* and *M. exotica* (Negi et al., 2015; Sangkaew et al., 2020). Depending on their structure, flavonoids can be divided into six types: flavones, flavonols, flavanones, flavan-3-ols, chalcones, and isoflavones; of these, flavones are the primary structures of flavonoids in MFC (Figure 3).

4.2 Coumarins

One hundred and seventy coumarins (**94–263**, Table 3) have been identified in MFC. Of these, 89 compounds were isolated from *M. paniculata*, 130 compounds were isolated from *M. exotica*, and 49 were isolated from both *M. paniculata* and *M. exotica* (Liu et al., 2018; Wang X. et al., 2019; Wang Y. et al., 2019). Depending on their structure, coumarins can be classified into six types: simple coumarins, prenylated coumarins, pyranocomarins, furanocoumarins, dimeric coumarins, and benzocoumarins (Figure 4).

4.3 Alkaloids

Twenty-nine alkaloids (**264–292**, Table 4) have been identified in MFC. Of these, 17 compounds were isolated from *M. paniculata,* and 12 compounds were isolated from *M. exotica*. No alkaloids have been isolated in both *M. paniculata* and *M. exotica.* Depending on their structure, alkaloids can be divided into six types: quinoline, indazole, indole, carbazole, organic amine, and other alkaloids (Figure 5).

4.4 Sterols

Six sterols (**293–298**, Table 5) have been isolated from MFC (Desoky, 1995; Saeed et al., 2011) (Figure 5).

4.5 Phenylpropenols

Four phenylpropenols (**299–302**, Table 5) have been isolated from the roots of *M. exotica* (Liu et al., 2018), compounds **300** and **301** of which are isomers (Figure 5).

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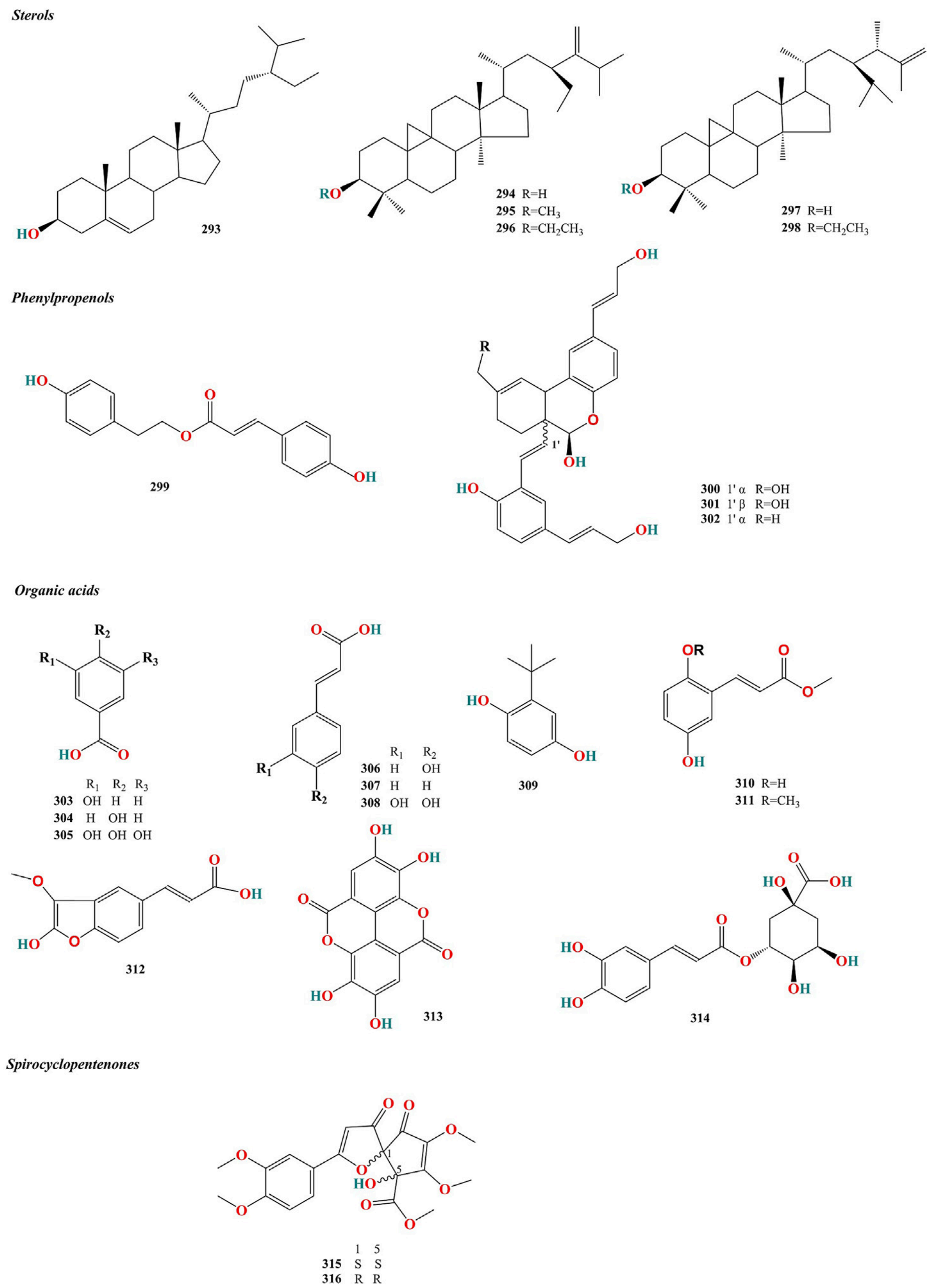

FIGURE 5
Chemical structures of sterols, pehylpropenols and other constituents isolated from Murrayae Folium et Cacumen.

4.6 Organic acids

Twelve organic acids (**303–314**, Table 5) have been isolated from MFC (Rahman et al., 1997; Saeed et al., 2011; Kaur et al., 2016; Menezes et al., 2017) (Figure 5).

4.7 Spirocyclopentenones

Two spirocyclopentenones (**315** and **316**, Table 5) have been isolated from *M. paniculata* (Liang et al., 2020a), including (1*S*, 5*S*)-murrayaspiroketone (**315**) and (1*R*, 5*R*)-murrayaspiroketone (**316**). Compounds **315** and **316** are enantiomers (Figure 5).

4.8 Volatile oils

Four-hundred and four volatile oils (**317–711**, Supplementary Table S) have been isolated from MFC (Pino et al., 2006; Raina et al., 2006; Krishnamoorthy et al., 2015; Silva et al., 2020; Saikia et al., 2021). The major volatile organic compounds dominated by benzenoids, sesquiterpenes, diterpenoids, triterpenoids, coumarins, and phenylethanoids in hydrodistillation and pentane, *n*-hexane, and

TABLE 2 Flavonoids isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
Flavones								
1	5,6,7,8,3′,4′,5′-Heptamethoxyflavone	*M. paniculata*	$C_{22}H_{24}O_9$	432.4	72815	Methanol	Leaves	Sangkaew et al. (2020)
		M. exotica				Acetone	Branches	Negi et al. (2015)
2	5,6,7,8,3′,4′-Hexamethoxyflavone; nobiletin	*M. paniculata*	$C_{21}H_{22}O_8$	402.4	72344	Methanol	Leaves	Zhang et al. (2012a)
3	5,6,7,3′,4′,5′-Hexamethoxyflavone	*M. paniculata*	$C_{21}H_{22}O_8$	402.4	185670	Methanol	Leaves	Sun et al. (2015)
		M. paniculata				Dichloromethane	Peel of fresh ripe fruits	Santos et al. (2009)
		M. exotica				Acetone	Branches	Negi et al. (2015)
4	6,7,8,3′,4′,5′-Hexamethoxyflavone	*M. paniculata*	$C_{21}H_{22}O_8$	402.4		Chloroform	Leaves	Kinoshita and Firman (1996b)
5	5,7,8,3′,4′,5′-Hexamethoxyflavone	*M. paniculata*	$C_{21}H_{22}O_8$	402.4		Methanol	Leaves	Zhang et al. (2013b)
		M. paniculata				Dichloromethane	Peel of fresh ripe fruits	Santos et al. (2009)
		M. exotica				Methanol	Leaves	Zhang et al. (2014)
6	5,6,7,3′,4′-Pentamethoxyflavone; sinensetin	*M. paniculata*	$C_{20}H_{20}O_7$	372.4	145659	Ethanol	Leaves	Li et al. (2018)
		M. exotica				Acetone	Branches	Zhang et al. (2013a)
7	5,7,8,3′,4′-Pentamethoxyflavone	*M. paniculata*	$C_{20}H_{20}O_7$	372.4	632135	Methanol	Leaves	Zhang et al. (2013b)
8	5,7,3′,4′,5′-Pentamethoxyflavone	*M. paniculata*	$C_{20}H_{20}O_7$	372.4	493376	Ethanol	Stems, leaves	Wu et al. (2015)
		M. exotica				Ethanol	Leaves, twigs	Peng et al. (2010)
9	5,7,3′,4′-Tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_6$	342.3	631170	Ethanol	Leaves	Li et al. (2018)
		M. exotica				Ethanol	Leaves	Huang et al. (2019)
10	7,3′,4′,5′-Tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_6$	342.3		Ethyl acetate	Leaves	Rodanant et al. (2015)
11	6,8,3′,4′-Tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_6$	342.3		Methanol	Leaves	Wang et al. (2010)
12	7,3′,4′,5′-Tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_6$	342.4		Ethyl acetate	Leaves	Rodanant et al. (2015)
13	5,3′,5′-Trihydroxy-6,7,8,4′-tetramethoxyflavone; gardenin E	*M. paniculata*	$C_{19}H_{18}O_9$	390.3	3084508	Chloroform	Leaves	Kinoshita and Firman (1996b)
14	5, 3′-Dihydroxy-6,7,4′,5′-tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_8$	374.3	183329	Ethanol	Leaves, twigs	Liang et al. (2020c)
15	5,3′-Dihydroxy-7,4′,5′-trimethoxyflavone	*M. paniculata*	$C_{18}H_{16}O_7$	344.3	5496476	Ethanol	Leaves, twigs	Liang et al. (2020c)
16	5,3′-Dihydroxy-7, 8,4′-trimethoxyflavone	*M. paniculata*	$C_{18}H_{16}O_7$	344.3		Ethyl acetate	Leaves, twigs	Li, (2022)
17	5,3′-Dihydroxy-7,4′-dimethoxyflavone	*M. paniculata*	$C_{17}H_{14}O_6$	314.3		Ethanol	Leaves	Shan et al. (2010)
18	5,3′-Dihydroxy-7,8,4′,5′-tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_8$	374.3	44258624	Methanol	Leaves	Zhang et al. (2013b)
19	5,3′-Dihydroxy-6,7,8,4′,5′-pentamethoxyflavone; gardenin C	*M. paniculata*	$C_{20}H_{20}O_9$	404.4	3084507	Chloroform	Leaves	Kinoshita and Firman (1996b)

(Continued on following page)

TABLE 2 (*Continued*) Flavonoids isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
20	3′,5′-Dihydroxy-5,7,4′-trimethoxyflavone	*M. paniculata*	$C_{18}H_{16}O_7$	344.3	134822350	Ethanol	Leaves	Li et al. (2018)
21	5, 4′-Dihydroxy-7,3′, -dimethoxyflavone	*M. paniculata*	$C_{17}H_{14}O_6$	314.3		Ethyl acetate	Leaves	Zhang et al. (2010)
22	7,4′-Hydroxy-5,3′-dimethoxyflavone	*M. paniculata*	$C_{17}H_{14}O_6$	314.3		Ethanol	Leaves	Li et al. (2018)
23	5-Hydroxy-6,7,8,3′,4′,5′-hexamethoxyflavone; gardenin A	*M. paniculata*	$C_{21}H_{22}O_9$	418.4		Methanol	Leaves	Zhang et al. (2012a)
24	5-Hydroxy-6,7,3′,4′,5′-pentamethoxyflavone	*M. paniculata*	$C_{20}H_{20}O_8$	388.4		Methanol	Leaves	Zhang et al. (2013b)
25	5-Hydroxy-6,7,8,3′,4′-pentamethoxyflavone	*M. paniculata*	$C_{20}H_{20}O_8$	388.4	358832	Ethanol	Leaves, stems	Wu et al. (2015)
		M. exotica				Ethanol	Leaves, twigs	Peng et al. (2010)
26	5-Hydroxy-7,8,3′,4′-tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_7$	358.3	9950661	Ethanol	Leaves, twigs	Liang et al. (2020c)
27	5-Hydroxy-6,7,3′,4′-tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_7$	358.3		Methanol	Leaves	Zhang et al. (2012b)
		M. exotica				Ethanol	Leaves, twigs	Peng et al. (2010)
28	5-Hydroxy-7,3′,4′-trimethoxyflavone	*M. paniculata*	$C_{18}H_{16}O_6$	328.3		Methanol	Leaves	Zhang et al. (2011)
29	3′-Hydroxy-5,6,7,4′,5′-pentamethoxyflavone	*M. paniculata*	$C_{20}H_{20}O_8$	388.4		Ethanol	Leaves, twigs	Liang et al. (2020c)
30	3′-Hydroxy-5,7,4′,5′-tetramethoxyflavone	*M. paniculata*	$C_{19}H_{18}O_7$	358.3	72703223	Ethanol	Leaves	Li et al. (2018)
31	3′-Hydroxy-5,7,4′-trimethoxyflavone	*M. paniculata*	$C_{18}H_{16}O_6$	328.3	13964545	Ethanol	Leaves	Li et al. (2018)
32	7-Hydroxy-5,3′,4′-trimethoxyflavone	*M. paniculata*	$C_{18}H_{16}O_6$	328.3		Ethanol	Leaves	Li et al. (2018)
33	4′-Hydroxy-5,6,7,3′,5′-pentamethoxyflavone	*M. paniculata*	$C_{20}H_{20}O_8$	388.4	44258535	Ethanol	Leaves, twigs	Liang et al. (2020c)
34	4′-Hydroxy-5,7,3′-trimethoxyflavone	*M. paniculata*	$C_{18}H_{16}O_6$	328.3	13964546	Ethanol	Leaves	Li et al. (2018)
35	5,7,3′,4′-Tetrahydroxyflavone; luteolin	*M. paniculata*	$C_{15}H_{10}O_6$	286.2	5280445	Hydroalcoholic	Leaves	Menezes et al. (2017)
36	5,3′-Dihydroxy-6,7,4′-trimethoxyflavone-8-*O*-*β*-glucopyranoside	*M. paniculata*	$C_{24}H_{26}O_{13}$	522.5		Ethanol	Leaves, shoots	Zhang et al. (2012a)
		M. exotica				Methanol	Leaves	Zhang et al. (2014)
37	5,3′-Dihydroxy-6,4′-dimethoxyflavone-7-*O*-*β*-glucopyranoside	*M. exotica*	$C_{23}H_{24}O_{12}$	492.4		Methanol	Leaves	Zhang et al. (2014)
38	5-Hydroxy-6,3′,4′-trimethoxyflavone-7-*O*-*β*-glucopyranoside	*M. paniculata*	$C_{24}H_{26}O_{12}$	506.5		Ethanol	Leaves	Li et al. (2018)
39	5,4′-Dihydroxy-3′-methoxyflavone-7-*O*-*β*-glucopyranoside	*M. paniculata*	$C_{22}H_{22}O_{11}$	462.4		Ethanol	Leaves	Li et al. (2018)
40	5,4′-Dihydroxy-6,3′-dimethoxyflavone-7-*O*-*β*-D-glucopyranoside	*M. paniculata*	$C_{23}H_{24}O_{12}$	492.4		Methanol	Leaves	Zhang et al. (2013b)

(Continued on following page)

TABLE 2 (*Continued*) Flavonoids isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
41	5-Hydroxy-6,7,3′,4′,-tetramethoxyflavone-8-*O*-*β*-D-glucopyranoside	*M. paniculata*	$C_{25}H_{28}O_{13}$	536.4		Methanol	Leaves	Zhang et al. (2013b)
Flavonols								
42	3,5,6,7,8,3′,4′,5′-Octamethoxyflavone; exoticin	*M. paniculata*	$C_{23}H_{26}O_{10}$	462.4	389000	Ethyl acetate	Leaves and twigs	Li, (2022)
43	3,5,6,7,3′,4′,5′-Heptamethoxyflavone	*M. paniculata*	$C_{22}H_{24}O_9$	432.4	389001	Methanol	Leaves	Sangkaew et al. (2020)
		M. paniculata				Dichloromethane	Pulp of fresh ripe fruits	Santos et al. (2009)
		M. exotica				Methanol	Stems, branches, twigs, leaves	Liu et al. (2015a)
44	3,5,7,8,3′,4′,5′-Heptamethoxyflavone	*M. paniculata*	$C_{22}H_{24}O_9$	432.4	5318050	Methanol	Leaves	Sangkaew et al. (2020)
		M. paniculata				Methanol	Peel and pulp of ripe fruits	Santos et al. (2009)
		M. exotica				Acetone	Branches	Negi et al. (2015)
45	3,5,6,8,3′,4′,5′-Heptamethoxyflavone	*M. exotica*	$C_{22}H_{24}O_9$	432.4		Petrol	Leaves	Braik et al. (1983b)
46	3,5,6,7,8,3′,4′-Heptamethoxyflavone	*M. paniculata*	$C_{22}H_{24}O_9$	432.4	150893	Methanol	Leaves, twigs	Liang et al. (2021)
		M. exotica				Methanol	Leaves, twigs	Liang et al. (2021)
47	3,5,7,3′,4′,5′-Hexamethoxyflavone	*M. paniculata*	$C_{21}H_{22}O_8$	402.4	634113	Methanol	Leaves	Sangkaew et al. (2020)
		M. paniculata				Chloroform	Flowers	Kinoshita and Firman (1997)
48	3,5,7,8,3′,4′-Hexamethoxyflavone	*M. paniculata*	$C_{21}H_{22}O_8$	402.4	146093	Dichloromethane	Peel and pulp of ripe fruits	Ferracin et al. (1998)
49	5-Hydroxy-3,7,8,3′,4′,5′-hexamethoxyflavone	*M. paniculata*	$C_{21}H_{22}O_9$	418.4		—	Leaves	Alam et al. (2021)
		M. paniculata				Dichloromethane	Peel of fresh ripe fruits	Santos et al. (2009)
50	5-Hydroxy-3,7,8,3′,4′-pentamethoxyflavone	*M. paniculata*	$C_{20}H_{20}O_8$	388.4	10200272	Dichloromethane	Peel and pulp of ripe fruits	Ferracin et al. (1998)
51	8-Hydroxy-3,5,7,3′,4′,5′-hexamethoxyflavone	*M. paniculata*	$C_{21}H_{22}O_9$	418.4		—	Leaves	Alam et al. (2021)
		M. paniculata				Dichloromethane	Peel of fresh ripe fruits	Santos et al. (2009)
52	Quercetin	*M. paniculata*	$C_{15}H_{10}O_7$	302.2	5280343	Hydroalcoholic	Leaves	Menezes et al. (2017)
		M. exotica				Ethanol	Leaves	Kaur et al. (2016)
53	Kaempferol	*M. paniculata*	$C_{15}H_{10}O_6$	286.2	5280863	Hydroalcoholic	Leaves	Menezes et al. (2017)
		M. exotica				Ethanol	Leaves	Kaur et al. (2016)
54	Kaempferide	*M. exotica*	$C_{16}H_{12}O_6$	300.3	5281666	_	_	Li et al. (2022)

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TABLE 2 (*Continued*) Flavonoids isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
55	Quercetin-3-*O*-rhamnoside; quercitrin	*M. paniculata*	$C_{21}H_{20}O_{11}$	448.4	5280459	Hydroalcoholic	Leaves	Menezes et al. (2017)
56	Quercetin-3-*O*-rutinoside (rutin)	*M. paniculata*	$C_{27}H_{30}O_{16}$	610.5	5280805	Hydroalcoholic	Leaves	Menezes et al. (2017)
		M. exotica				Ethanol	Leaves	Kaur et al. (2016)
Flavanones								
57	5,6,7,3′,4′,5′-Hexamethoxyflavanone	*M. paniculata*	$C_{21}H_{24}O_{8}$	404.4	42608106	Ethanol	Leaves, twigs	Liang et al. (2020b)
58	6,7,8,3′,4′,5′-Hexamethoxyflavanone	*M. paniculata*	$C_{21}H_{24}O_{8}$	404.4		Ethanol	Leaves, twigs	Liang et al. (2020b)
59	5,6,7,3′,4′-Pentamethoxyflavanone	*M. paniculata*	$C_{20}H_{22}O_{7}$	374.4		Methanol	Leaves	Zhang et al. (2013b)
		M. exotica				Methanol	Leaves	Zhang et al. (2014)
60	5,7,3′,4′,5′-Pentamethoxyflavanone	*M. paniculata*	$C_{20}H_{22}O_{7}$	374.4	4692111	Chloroform	Leaves	Kinoshita and Firman (1997)
		M. paniculata				Dichloromethane	Peel and pulp of ripe fruits	Ferracin et al. (1998)
		M. exotica				Methanol	Leaves	Zhang et al. (2014)
61	5,7,8,3′,4′-Pentamethoxyflavanone	*M. paniculata*	$C_{20}H_{22}O_{7}$	374.4		Ethanol	Leaves	Shan et al. (2010)
62	6,7,8,3′,4′-Pentamethoxyflavanone	*M. paniculata*	$C_{20}H_{22}O_{7}$	374.4		Ethanol	Leaves	Yao et al. (2013)
63	5,7,3′,4′-Tetramethoxyflavanone	*M. paniculata*	$C_{19}H_{20}O_{6}$	344.4	91212489	Ethanol	Leaves, twigs	Liang et al. (2020b)
64	3-Hydroxy-5,7,3′,4′,5′-pentamethoxyflavanone	*M. paniculata*	$C_{20}H_{22}O_{8}$	390.4		Chloroform	Leaves	Kinoshita and Firman (1997)
65	3-Hydroxy-5,7,3′,4′-tetramethoxyflavanone	*M. paniculata*	$C_{19}H_{20}O_{7}$	360.4		Ethanol	Leaves, twigs	Liang et al. (2020b)
66	4′-Hydroxy-5,7-dimethoxyflavanone	*M. paniculata*	$C_{17}H_{16}O_{5}$	300.3	5271551	Ethanol	Leaves, twigs	Liang et al. (2020b)
67	5,6,7,3′,4′,5′-Hexamethoxyflavanone-8-*O*-[rhamnopyranosyl-(1→4)-rhamnopyranoside	*M. paniculata*	$C_{33}H_{44}O_{17}$	712.7		Ethanol	Twig	Shi et al. (2017)
Flavan-3-ols								
68	(−)-Epicatechin; epicatechin	*M. paniculata*	$C_{15}H_{14}O_{6}$	290.3	72276	Hydroalcoholic	Leaves	Menezes et al. (2017)
		M. exotica				Ethanol	Leaves	Kaur et al. (2016)
69	Catechin	*M. paniculata*	$C_{15}H_{14}O_{6}$	290.3	9064	Hydroalcoholic	Leaves	Menezes et al. (2017)
		M. exotica				Ethanol	Leaves	Kaur et al. (2016)
Chalcones								
70	2′-Hydroxy-3,4,4′,6′-tetramethoxychalcone	*M. paniculata*	$C_{19}H_{20}O_{6}$	344.4	5373259	Ethanol	Leaves, twigs	Liang et al. (2020b)
71	2′-Hydroxy-3,4,5,4′,6′-pentamethoxychalcone	*M. paniculata*	$C_{20}H_{22}O_{7}$	374.4	5374858	Chloroform	Leaves	Kinoshita and Firman (1997)

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TABLE 2 (*Continued*) Flavonoids isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
72	2′-Hydroxy-3,4,3′,4′,6′-pentamethoxychalcone	*M. paniculata*	$C_{20}H_{22}O_7$	374.7		Ethanol	Leaves, twigs	Liang et al. (2020b)
73	2′-Hydroxy-3,4,5,3′,4′,6′-hexamethoxychalcone	*M. paniculata*	$C_{21}H_{24}O_8$	404.4	129823511	Ethanol	Leaves	Yao et al. (2013)
74	2′,4-Dihydroxy-3,5,4′,6′-tetramethoxychalcone	*M. paniculata*	$C_{19}H_{20}O_7$	360.4		Ethanol	Leaves, twigs	Liang et al. (2020b)
75	6′-Hydroxy-3,4,5,2′,3′,4′-hexamethoxychalcone	*M. paniculata*	$C_{21}H_{24}O_8$	404.4		Methanol	Leaves	Zhang et al. (2011)
76	6′-Hydroxy-3,4,5,2′,4′,5′-hexamethoxychalcone	*M. paniculata*	$C_{21}H_{24}O_8$	404.4		Methanol	Leaves	Zhang et al. (2013b)
		M. exotica				Methanol	Leaves	Zhang et al. (2014)
77	6′-Hydroxy-3,4,5,2′,5′-pentamethoxychalcone	*M. paniculata*	$C_{20}H_{22}O_7$	374.4		Methanol	Leaves	Zhang et al. (2013b)
		M. exotica				Methanol	Leaves	Zhang et al. (2014)
78	6′-Hydroxy-3,4,5,2′,4′-pentamethoxychalcone	*M. paniculata*	$C_{20}H_{22}O_7$	374.4		Methanol	Leaves	Zhang et al. (2011)
Isoflavones								
79	Genistein	*M. paniculata*	$C_{15}H_{10}O_5$	270.2	5280961	Methanol	Leaves	Lapčík et al. (2004)
80	Formononetin	*M. paniculata*	$C_{16}H_{12}O_4$	268.3	5280378	Methanol	Leaves	Lapčík et al. (2004)
81	Prunetin	*M. paniculata*	$C_{16}H_{12}O_5$	284.3	5281804	Methanol	Leaves	Lapčík et al. (2004)
82	Biochanin A	*M. paniculata*	$C_{16}H_{12}O_5$	284.3	5280373	Methanol	Leaves	Lapčík et al. (2004)
83	Daidzein	*M. paniculata*	$C_{15}H_{10}O_4$	254.2	5281708	Methanol	Leaves	Lapčík et al. (2004)
84	Daidzin	*M. paniculata*	$C_{21}H_{20}O_9$	416.4	107971	Methanol	Leaves	Lapčík et al. (2004)
85	Glycitin	*M. paniculata*	$C_{22}H_{22}O_{10}$	446.4	187808	Methanol	Leaves	Lapčík et al. (2004)
86	Genistin	*M. paniculata*	$C_{21}H_{20}O_{10}$	432.4	5281377	Methanol	Leaves	Lapčík et al. (2004)
87	Daidzin-6″-*O*-malonate	*M. paniculata*	$C_{24}H_{22}O_{12}$	502.4	9913968	Methanol	Leaves	Lapčík et al. (2004)
88	Glycitin-6″-*O*-malonate	*M. paniculata*	$C_{25}H_{24}O_{13}$	532.4	23724657	Methanol	Leaves	Lapčík et al. (2004)
89	Daidzin-6″-*O*-acetate	*M. paniculata*	$C_{23}H_{22}O_{10}$	458.4	156155	Methanol	Leaves	Lapčík et al. (2004)
90	Glycitin-6″-*O*-acetate	*M. paniculata*	$C_{24}H_{24}O_{11}$	488.4	10228095	Methanol	Leaves	Lapčík et al. (2004)
91	Genistin-6″-*O*-malonate	*M. paniculata*	$C_{24}H_{22}O_{13}$	518.4	15934091	Methanol	Leaves	Lapčík et al. (2004)
92	Genistin-6″-*O*-acetate	*M. paniculata*	$C_{23}H_{22}O_{11}$	474.4	22288010	Methanol	Leaves	Lapčík et al. (2004)
93	Sissotrin	*M. paniculata*	$C_{22}H_{22}O_{10}$	446.4	5280781	Methanol	Leaves	Lapčík et al. (2004)

Note: —Refer to "Not mention", the same below.

TABLE 3 Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
Simple coumarins								
94	Coumarin	*M. exotica*	$C_9H_6O_2$	146.1	323	_	_	Li et al. (2022)
95	Umbelliferone	*M. paniculata*	$C_9H_6O_3$	162.1	5281426	Ethyl acetate	Aerial parts	Saeed et al. (2011)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Acetone	Leaves	Xu et al. (2016)
96	7-Coumarincarboxaldehyde	*M. exotica*	$C_{10}H_6O_3$	174.2		Dichloromethane	Roots	Liu et al. (2018)
97	7-Methoxycoumarin	*M. exotica*	$C_{10}H_8O_3$	176.2	10748	Acetone	Leaves	Xu et al. (2016)
98	5,7-Dihydroxycoumarin	*M. exotica*	$C_9H_6O_4$	178.1	5324654	_	_	Li et al. (2022)
99	5,7-Dimethoxycoumarin	*M. exotica*	$C_{11}H_{10}O_4$	206.2	2775	_	_	Li et al. (2022)
100	Scopoletin	*M. paniculata*	$C_{10}H_8O_4$	192.2	5280460	Ethyl acetate	Aerial part	Saeed et al. (2011)
		M. paniculata				Chloroform	Root bark	Imai et al. (1989)
		M. exotica				Acetone	Branches	Negi et al. (2015)
		M. exotica				Ethanol	Leaves	Wu et al. (2010)
101	Isoscopoletin	*M. exotica*	$C_{10}H_8O_4$	192.2	69894	Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Acetone	Branches	Negi et al. (2015)
102	7-Hydroxy-8-methoxycoumarin	*M. paniculata*	$C_{10}H_8O_4$	192.2		Ethyl acetate	Leaves, twigs	Li, (2022)
103	7-Methoxy-8-formylcoumarin	*M. exotica*	$C_{11}H_8O_4$	204.2	11275724	Acetone	Leaves	Ito and Furukawa (1987b)
		M. exotica				Acetone	Branches	Negi et al. (2015)
104	Trihydroxy coumarin	*M. exotica*	$C_9H_6O_5$	194.2		Dichloromethane	Leaves	He et al. (2017)
105	Hassanon	*M. paniculata*	$C_{14}H_{14}O_4$	246.3		Chloroform	Roots	Wang et al. (2019a)
106	7-Methoxy-8-(2′-methyl-2′-formylpropyl)-coumarin	*M. exotica*	$C_{15}H_{16}O_4$	260.3	5319433	Dichloromethane	Leaves	He et al. (2017)
107	Seselinal	*M. paniculata*	$C_{16}H_{18}O_5$	290.3		Chloroform	Roots	Wang et al. (2019a)
108	7-Methoxy-8-(5-(prop-1-en-2-yloxy) enta-1,3-dien-1-yl)-coumarin	*M. exotica*	$C_{18}H_{18}O_4$	298.3		Ethanol	Root	Jiang et al. (2015)
109	*cis*-Osthenon	*M. paniculata*	$C_{14}H_{12}O_4$	244.3		Acetone	Leaves	Ito and Furukawa (1987a)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
110	Toddalenone	*M. paniculata*	$C_{15}H_{14}O_5$	274.3	101893838	Chloroform	Leaves	Aziz et al. (2010)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
Prenylated coumarins								
111	Murraol	*M. exotica*	$C_{15}H_{16}O_4$	260.3	15593213	Acetone	Leaves	Ito and Furukawa (1987b)
112	3′-*O*-Methylmurraol	*M. exotica*	$C_{16}H_{18}O_4$	274.3	102337145	Ethyl acetate	Leaves, twigs	Li, (2022)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
113	Casegravol	*M. exotica*	$C_{15}H_{16}O_5$	276.3	6440521	Acetone	Leaves	Ito and Furukawa (1987b)
114	Murraexotin A	*M. exotica*	$C_{21}H_{26}O_4$	342.4		Ethyl acetate	Leaves, twigs	Li, (2022)
115	Casegravol isovalerate	*M. paniculata*	$C_{20}H_{24}O_6$	360.4	14429495	Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Methanol	Leaves, twigs	Liang et al. (2021)
116	*cis*-Dehydroosthol	*M. exotica*	$C_{15}H_{14}O_3$	242.3	13917397	Acetone	Leaves	Ito and Furukawa (1987b)
117	*cis*-Dehydrocoumarrayin	*M. paniculata*	$C_{16}H_{16}O_4$	272.3		Chloroform	Leaves	Kinoshita and Firman (1996a)
118	*trans*-Dehydroosthol	*M. paniculata*	$C_{15}H_{14}O_3$	242.3		Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Acetone	Leaves	Ito and Furukawa (1987b)
119	*trans*-Gleinadiene	*M. paniculata*	$C_{16}H_{16}O_4$	272.3		Chloroform	Leaves	Aziz et al. (2010)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
120	(1′*S*, 3′*S*)-Murratin A	*M. exotica*	$C_{15}H_{14}O_4$	258.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
121	(1′*R*, 3′*R*)-Murratin A	*M. exotica*	$C_{15}H_{14}O_4$	258.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
122	(1′*S*, 3′*R*)-Murratin B	*M. exotica*	$C_{15}H_{14}O_4$	258.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
123	(1′*R*, 3′*S*)-Murratin B	*M. exotica*	$C_{15}H_{14}O_4$	258.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
124	Osthol	*M. paniculata*	$C_{15}H_{16}O_3$	244.3	10228	Chloroform	Roots	Wang et al. (2019a)
		M. paniculata				Ethyl acetate	Leaves, twigs	Li, (2022)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Acetone	Leaves	Ito and Furukawa (1987b)
125	7-Methoxy-8-(3′-formylbut-2′-enyl) coumarin	*M. paniculata*	$C_{15}H_{14}O_4$	258.3		Chloroform	Roots	Wang et al. (2019a)
126	Sibiricol	*M. paniculata*	$C_{15}H_{16}O_4$	260.3	13917413	Ethyl acetate	Leaves, twigs	Li, (2022)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Acetone	Leaves	Ito and Furukawa (1987b)
127	Panial	*M. paniculata*	$C_{15}H_{14}O_5$	274.3		Acetone	Leaves	Ito and Furukawa (1987a)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
128	Coumurrayin	*M. paniculata*	$C_{16}H_{18}O_4$	274.3	176911	Chloroform	Roots	Wang et al. (2019a)
		M. paniculata				Ethyl acetate	Leaves, twigs	Li, (2022)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Ethyl acetate	Leaves, twigs	Li, (2022)
129	Sibirinol	*M. exotica*	$C_{16}H_{18}O_5$	290.3		Dichloromethane	Roots	Liu et al. (2018)
130	6-Hydroxycoumurrayin	*M. paniculata*	$C_{16}H_{18}O_5$	290.3	133561628	Ethanol	Twigs, leaves	Li et al. (2016)
131	Muralatin C	*M. exotica*	$C_{17}H_{20}O_5$	304.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
132	Phebalosin	*M. paniculata*	$C_{15}H_{14}O_4$	258.3	188300	Methanol	Leaves	Jiwajinda et al. (2000)
		M. paniculata				Acetone	Roots	Ito et al. (1990)
		M. exotica				Ethanol	Leaves	Yan et al. (2018)
		M. exotica				Acetone	Branches	Negi et al. (2015)
133	Murrayone	*M. paniculata*	$C_{15}H_{14}O_4$	258.3	5319964	Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Dichloromethane	Leaves	He et al. (2017)
134	Micropubescin	*M. paniculata*	$C_{15}H_{14}O_4$	258.3	14185882	Ethyl acetate	Leaves	Rodanant et al. (2015)
135	Murpanitin D	*M. paniculata*	$C_{20}H_{23}O_6$	359.4		Ethanol	Leaves, stems	Liang et al. (2020a)
136	Murralongin	*M. paniculata*	$C_{15}H_{14}O_4$	258.3	179620	Chloroform	Roots	Wang et al. (2019a)
		M. paniculata				Ethyl acetate	Leaves, twigs	Li (2022)
		M. exotica				Acetone	Leaves	Ito and Furukawa (1987b)
		M. exotica				Acetone	Branches	Negi et al. (2015)
137	Murralonginal	*M. exotica*	$C_{15}H_{14}O_4$	258.3		Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
138	Murraexotin C	*M. exotica*	$C_{20}H_{24}O_5$	344.4		Ethyl acetate	Leaves, twigs	Li, (2022)
139	Auraptenol	*M. exotica*	$C_{15}H_{16}O_4$	260.3	13343541	Dichloromethane Chloroform	Roots	Liu et al. (2018)
		M. exotica					Leaves	Barik et al. (1983b)
140	(*S*)-Auraptenol	*M. exotica*	$C_{15}H_{16}O_4$	260.3	13343540	Acetone	Leaves	Xu et al. (2016)
141	Murralonginol	*M. paniculata*	$C_{15}H_{16}O_4$	260.3		Chloroform	Roots	Wang et al. (2019a)
142	Murratin M	*M. exotica*	$C_{17}H_{18}O_5$	302.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
143	Murralonginol isovalerate	*M. paniculata*	$C_{20}H_{24}O_6$	360.4		Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Ethyl acetate	Leaves, twigs	Li, (2022)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
144	Isomurralonginol	*M. paniculata*	$C_{15}H_{16}O_4$	260.3		Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
145	Isomurralonginoic acid	*M. exotica*	$C_{15}H_{14}O_5$	274.3		Acetone	Branches	Negi et al. (2015)
146	Isomurralonginol acetate	*M. paniculata*	$C_{17}H_{18}O_5$	302.3	13917402	Ethyl acetate	Leaves, twigs	Li, (2022)
		M. exotica				Acetone	Leaves	Ito and Furukawa (1987b)
147	Isomurralonginol isovalerate	*M. paniculata*	$C_{20}H_{24}O_6$	360.4	45359775	Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Acetone	Branches	Negi et al. (2015)
148	Meranzin	*M. exotica*	$C_{15}H_{16}O_4$	260.3	1803558	Ethanol	Leaves	Yan et al. (2018)
149	Sibiricin	*M. paniculata*	$C_{16}H_{18}O_5$	290.3	12315526	Chloroform	Roots	Wang et al. (2019a)
150	Panitin E	*M. paniculata*	$C_{20}H_{24}O_6$	360.4		Chloroform	Roots	Wang et al. (2019a)
151	Muralatin P	*M. exotica*	$C_{20}H_{24}O_6$	360.4		Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
152	Isomeranzin	*M. paniculata*	$C_{15}H_{16}O_4$	260.3	473252	Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Acetone	Leaves	Xu et al. (2016)
		M. exotica				Acetone	Branches	Negi et al. (2015)
153	Murranganon	*M. paniculata*	$C_{15}H_{16}O_5$	276.3	5319956	Methanol	Leaves	Choudhary et al. (2002)
		M. exotica				Acetone	Branches	Negi et al. (2015)
154	Isosibiricin	*M. paniculata*	$C_{16}H_{18}O_5$	290.3	5316871	Chloroform	Leaves	Kinoshita and Firman (1996a)
		M. exotica				Chloroform	Root barks	He et al. (2017)
		M. exotica				—	—	Wang et al. (2019b)
155	7-Methoxy-8-(1′-acetoxy-2′-oxo-3′-methylbutyl)coumarin	*M. exotica*	$C_{17}H_{20}O_5$	304.4		Acetone	Leaves	Ito and Furukawa (1987b)
156	Hainanmurpanin	*M. paniculata*	$C_{17}H_{18}O_6$	318.3	5317952	Ethyl acetate	Aerial parts	Saied et al. (2008)
		M. exotica				Ethanol	Leaves	Yan et al. (2018)
		M. exotica				Acetone	Branches	Negi et al. (2005)
157	Murpanitin C	*M. paniculata*	$C_{19}H_{23}O_6$	347.3		Ethanol	Leaves, stems	Liang et al. (2020a)
158	Epimurpaniculol senecioate	*M. exotica*	$C_{20}H_{22}O_6$	358.4		Ethanol	Leaves, twigs	Liang et al. (2020b)
159	Murranganonsenecioate	*M. paniculata*	$C_{20}H_{22}O_6$	358.4		Ethyl acetate	Leaves	Rodanant et al. (2015)
		M. exotica				Acetone	Branches	Negi et al. (2015)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
160	Paniculatin	*M. paniculata*	$C_{20}H_{24}O_6$	360.4	5320400	Ethanol	Leaves, stems	Liang et al. (2020a)
		M. exotica				Acetone	Branches	Negi et al. (2015)
161	Murratin F	*M. exotica*	$C_{21}H_{26}O_{10}$	438.4		Ethanol	Leaves, twigs	Liang et al. (2020b)
162	Microminutin	*M. paniculata*	$C_{15}H_{12}O_5$	272.3	5319827	Chloroform	Leaves, stems	Liang et al. (2020a)
163	Muralatin I	*M. paniculata*	$C_{15}H_{14}O_5$	274.3		Ethyl acetate	Leaves, twigs	Li, (2022)
164	8-(2′-Oxo-3′-methyl) butoxy-7-methoxycoumarin	*M. paniculata*	$C_{15}H_{16}O_5$	276.3		Methanol	Aerial parts	Rahman et al. (1997)
165	Peroxyauraptenol	*M. exotica*	$C_{15}H_{16}O_5$	276.3	13917394	Acetone	Leaves	Ito and Furukawa (1987b)
166	Murrangatin	*M. paniculata*	$C_{15}H_{16}O_5$	276.3		Ethanol	Leaves, stems	Liang et al. (2020a)
		M. paniculata				Chloroform	Root bark	Imai et al. (1989)
		M.exotica				Dichloromethane	Roots	Liu et al. (2018)
		M.exotica				Acetone	Leaves	Xu et al. (2016)
167	Minumicrolin	*M. paniculata*	$C_{15}H_{16}O_5$	276.3	389002	Ethanol	Leaves, stems	Liang et al. (2020a)
		M.exotica				Dichloromethane	Roots	Liu et al. (2018)
		M.exotica				Acetone	Leaves	Xu et al. (2016)
168	Murpanidin	*M. exotica*	$C_{15}H_{16}O_5$	276.3	6426907	Methanol	Leaves, twigs	Liang et al. (2021)
169	2′-*O*-Ethylmurrangatin	*M. paniculata*	$C_{17}H_{20}O_5$	304.3		Ethanol	Leaves, stems	Liang et al. (2020a)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
170	Muralatin K	*M. paniculata*	$C_{17}H_{20}O_5$	304.3		Ethanol	Leaves, stems	Liang et al. (2020a)
		M. exotica				Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
171	(+)-Murraxocin	*M. exotica*	$C_{17}H_{20}O_5$	304.3	188750	Dichloromethane	Roots	Zhou et al. (2020)
172	(−)-Murraxocin	*M. paniculata*	$C_{17}H_{20}O_5$	304.3		Ethanol	Leaves, stems	Liang et al. (2020a)
		M. exotica				Dichloromethane	Roots	Zhou et al. (2020)
		M. exotica				Acetone	Leaves	Xu et al. (2016)
173	Panitin F	*M. paniculata*	$C_{20}H_{24}O_6$	360.4		Chloroform	Roots	Wang et al. (2019a)
174	Fisovalerate	*M. paniculata*	$C_{20}H_{24}O_6$	360.4		Ethanol	Leaves, stems	Liang et al. (2020a)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
175	Murrangatin 2′- isovalerate	*M. paniculata*	$C_{20}H_{24}O_6$	360.4		Ethanol	Leaves, stems	Liang et al. (2020a)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Acetone	Branches	Negi et al. (2015)
176	Murracarpin	*M. paniculata*	$C_{16}H_{18}O_5$	290.3	5319464	Methanol	Leaves	Cuong et al. (2014)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Ethanol	Leaves	Wu et al. (2010)
177	Chloculol	*M. paniculata*	$C_{15}H_{15}ClO_4$	294.7	183084	Acetone	Roots	Ito et al. (1990)
178	7 -Methoxy-8-(2′-isovaleryloxy-3-butenyl-3-methyl)coumarin	*M. paniculata*	$C_{20}H_{24}O_5$	344.4		Hexane	Stem barks	Srivastava et al. (1996)
179	Murrangatin 1′-isovalerate	*M. exotica*	$C_{20}H_{24}O_6$	360.4		Acetone	Branches	Negi et al. (2015)
180	Murrangatin diacetate	*M. exotica*	$C_{19}H_{20}O_7$	360.4	389004	Acetone	Leaves	Xu et al. (2016)
181	Murrangatin 2′-formate	*M. exotica*	$C_{16}H_{16}O_6$	304.3		Acetone	Branches	Negi et al. (2015)
182	Murrangatin 2′-acetate	*M. paniculata*	$C_{17}H_{18}O_6$	318.3		Ethyl acetate	Leaves	Rodanant et al. (2015)
		M. exotica				Acetone	Branches	Negi et al. (2015)
183	Murrangatin 1′-acetate	*M. exotica*	$C_{17}H_{18}O_6$	318.3		Acetone	Branches	Negi et al. (2015)
184	Paniculacin	*M. paniculata*	$C_{26}H_{36}O_6$	444.6		Ethyl acetate	Aerial part	Saeed et al. (2011)
185	Murrangatin palmitate	*M. paniculata*	$C_{31}H_{46}O_6$	514.7		Chloroform	Root barks	Imai et al. (1989)
		M. exotica				Acetone	Branches	Negi et al. (2015)
186	Meranzin hydrate	*M. paniculata*	$C_{15}H_{18}O_5$	278.3	5070783	Methanol	Leaves, twigs	Liang et al. (2021)
		M. exotica				Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
187	Yuehgesin B	*M. exotica*	$C_{16}H_{20}O_5$	292.3		Ethyl acetate	Leaves, twigs	Li, (2022)
188	(2′S, 3′S) -Murratin G	*M. exotica*	$C_{15}H_{18}O_6$	294.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
189	Yuehgesin C	*M. exotica*	$C_{17}H_{22}O_5$	306.4	5319451	Acetone	Leaves	Xu et al. (2016)
190	Meranzin hydrate acetate	*M. exotica*	$C_{17}H_{22}O_5$	306.4		Petroleum ether	Leaves	Barik et al. (1983a)
191	2′-Acetoxy-3′-dihydroxyl-osthol	*M. exotica*	$C_{17}H_{20}O_6$	320.3		Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
192	Murratin J	*M. exotica*	$C_{18}H_{22}O_6$	334.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
193	7-Methoxy-8-(2′-hydroxy-3′bromo)-coumarin	*M. exotica*	$C_{15}H_{17}BrO_4$	341.2		Acetone	Leaves	Xu et al. (2016)
194	7-Methoxy-8-(2′,3′-dibromo)-coumarin	*M. exotica*	$C_{15}H_{16}Br_2O_3$	404.4		Acetone	Leaves	Xu et al. (2016)
195	Paniculonol isovalerate	*M. paniculata*	$C_{20}H_{24}O_6$	360.4		Methanol	Leaves, twigs	Liang et al. (2021)
		M. exotica				Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
196	Muralatin M	*M. paniculata*	$C_{20}H_{26}O_6$	362.4		Ethyl acetate	Leaves, twigs	Li, (2022)
197	Murrayatin	*M. paniculata*	$C_{20}H_{26}O_6$	362.4	621354	Methanol	Aerial parts	Rahman et al. (1997)
		M. exotica				Acetone	Branches	Negi et al. (2015)
198	Exotimarin G	*M. exotica*	$C_{20}H_{26}O_7$	378.2		Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
199	Meranzin hydrate-2′-palmitate	*M. exotica*	$C_{32}H_{50}O_7$	546.7	101245396	Acetone	Branches	Negi et al. (2015)
200	Panitin G	*M. paniculata*	$C_{16}H_{17}O_6$	289.3		Chloroform	Roots	Wang et al. (2019a)
201	Omphamurin	*M. paniculata*	$C_{16}H_{18}O_5$	290.3	11778953	Chloroform	Roots	Wang et al. (2019a)
202	Omphamurin isovalerate	*M. paniculata*	$C_{21}H_{26}O_6$	374.4	10643130	Methanol	Leaves, twigs	Liang et al. (2021)
203	Murratin H	*M. exotica*	$C_{15}H_{18}O_6$	294.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
204	Murratin I	*M. exotica*	$C_{15}H_{18}O_6$	294.3		Ethanol	Leaves, twigs	Liang et al. (2020b)
205	Murratin K	*M. exotica*	$C_{20}H_{26}O_7$	378.2		Ethanol	Leaves, twigs	Liang et al. (2020b)
206	Murratin L	*M. exotica*	$C_{20}H_{26}O_7$	378.2		Ethanol	Leaves, twigs	Liang et al. (2020b)
207	Chloticol	*M. exotica*	$C_{15}H_{17}ClO_4$	296.8		Acetone	Branches	Negi et al. (2015)
208	Auraptene	*M. paniculata*	$C_{19}H_{22}O_3$	298.4	1550607	Petroleum ether	Leaves	Aziz et al. (2010)
209	7-Geranyloxy-6-methoxycoumarin	*M. paniculata*	$C_{20}H_{24}O_4$	328.4	5319406	Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Ethanol	Leaves, twigs	Liang et al. (2020b)
210	(11*S*, 12*R*)-Murpanitin A	*M. paniculata*	$C_{16}H_{14}O_6$	302.3		Ethanol	Leaves, stems	Liang et al. (2020a)
211	(11*R*, 12*S*)-Murpanitin A	*M. paniculata*	$C_{16}H_{14}O_6$	302.3		Ethanol	Leaves, stems	Liang et al. (2020a)
212	Murraexotin B	*M. exotica*	$C_{17}H_{20}O_5$	304.3		Ethyl acetate	Leaves, twigs	Li, (2022)
213	Mexoticin	*M. paniculata*	$C_{16}H_{20}O_6$	308.3	176970	Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Acetone	Branches	Negi et al. (2015)
214	Isomexoticin	*M. paniculata*	$C_{16}H_{20}O_6$	308.3	4465807	Ethanol	Leaves	Yang and Su (1983)
		M.exotica				Dichloromethane	Roots	Liu et al. (2018)
215	5,7-Dimethoxy-8-(2-hydroxyl-3-ethoxy-3-methylbutyl) coumarin	*M. paniculata*	$C_{18}H_{24}O_6$	336.4		Chloroform	Roots	Wang et al. (2019a)
216	Exotimarin I	*M. paniculata*	$C_{18}H_{24}O_6$	336.4		Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
217	5-Methoxymurrayatin	*M. paniculata*	$C_{21}H_{28}O_7$	392.4	10644213	Ethanol	Leaves, stems	Liang et al. (2020a)
218	Minumicrolin acetonide	*M. paniculata*	$C_{18}H_{20}O_5$	316.3		Chloroform	Leaves, stems	Liang et al. (2020a)
		M. exotica				Acetone	Branches	Negi et al. (2015)
219	Pranferin	*M. exotica*	$C_{18}H_{22}O_5$	318.3	101967153	Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
220	Omphalocarpin	*M. paniculata*	$C_{17}H_{22}O_6$	322.4	101988840	Methanol	Leaves	Sangkaew et al. (2020)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
221	6-(2′,3′-Dihydroxy-3-methylbutyl)-8-prenylumbelliferone	*M. paniculata*	$C_{19}H_{24}O_5$	332.4		Chloroform	Roots	Wang et al. (2019a)
222	Isomurralonginol senecioate	*M. paniculata*	$C_{20}H_{22}O_5$	342.4		Ethyl acetate	Leaves, twigs	Li, (2022)
		M. exotica				Acetone	Branches	Negi et al. (2015)
223	2-(7-Methoxy-2-oxochromen-8-yl)-3-methylbut-2-enyl] 3-methylbut-2-enoate	*M. exotica*	$C_{20}H_{22}O_5$	342.4	45783081	Ethanol	Leaves, twigs	Liang et al. (2020b)
224	Murpanitin B	*M. paniculata*	$C_{19}H_{21}O_6$	345.3		Ethanol	Leaves, stems	Liang et al. (2020a)
225	Kimcuongin	*M. paniculata*	$C_{20}H_{20}O_6$	356.4	102141971	Methanol	Leaves	Cuong et al. (2014)
		M. exotica				Methanol	Leaves, twigs	Liang et al. (2021)
226	Exotimarin H	*M. paniculata*	$C_{20}H_{22}O_6$	358.4		Ethanol	Leaves, stems	Liang et al. (2020a);
		M. exotica				Ethanol	Roots	Liu et al. (2018)
227	Panitin C	*M. paniculata*	$C_{20}H_{22}O_6$	358.4		Chloroform	Roots;	Wang et al. (2019a)
		M. paniculata				Ethanol	Leaves, stems	Liang et al. (2020a);
		M. exotica				Ethanol	Leaves, twigs	Liang et al. (2020b)
228	Panitin D	*M. paniculata*	$C_{21}H_{24}O_7$	388.2		Chloroform	Roots	Wang et al. (2019a)
229	Isomurranganon senecioate	*M. exotica*	$C_{20}H_{22}O_6$	358.4		Acetone	Leaves	Ito and Furukawa (1987b)
230	Muralatin O	*M. paniculata*	$C_{20}H_{24}O_6$	360.4		Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
231	Panitin B	*M. paniculata*	$C_{21}H_{26}O_7$	390.2		Chloroform	Roots	Wang et al. (2019a)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
232	Isomurralonginol nicotinate	*M. paniculata*	$C_{21}H_{19}NO_5$	375.4		Ethyl acetate	Leaves, twigs	Li, (2022)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
233	8-(Butenyl-3′-methyl)-7 –*O*-*β*-D-galactopyranoside	*M. paniculata*	$C_{19}H_{22}O_9$	378.2		Hexane	Stem barks	Srivastava et al. (1996)
234	Marmesin-4′-*O*-*α*-L-arabinopyranoside	*M. paniculata*	$C_{20}H_{22}O_9$	406.4		Hexane	Stem barks	Srivastava et al. (1996)
235	Toddacoumaquinone	*M. paniculata*	$C_{23}H_{18}O_7$	406.4	10046907	Chloroform	Roots	Wang et al. (2019a)
236	Exotines A	*M. exotica*	$C_{28}H_{27}NO_3$	425.2		Ethanol	Roots	Liu et al. (2015b)
237	Exotines B	*M. exotica*	$C_{29}H_{29}NO_4$	455.6		Ethanol	Roots	Liu et al. (2015b)
Pyranocoumarins								
238	Xanthyletin	*M. exotica*	$C_{14}H_{12}O_3$	228.2	65188	Dichloromethane	Roots	Liu et al. (2018)
239	Braylin	*M. exotica*	$C_{15}H_{14}O_4$	258.3	618370	Ethyl acetate	Leaves, twigs	Li, (2022)
240	Nordentatin	*M. exotica*	$C_{19}H_{20}O_4$	312.4	5320206	Dichloromethane	Roots	Liu et al. (2018)
Furanocoumarins								
241	Xanthotoxol	*M. exotica*	$C_{11}H_6O_4$	202.2	65090	—	—	Li et al. (2022)
242	Bergaptol	*M. exotica*	$C_{11}H_6O_4$	202.2	5280371	—	—	Li et al. (2022)
Coumarin dimers								
243	(10′*R*,11′*R*,12*R*)-Exotimarin F	*M. exotica*	$C_{31}H_{36}O_{11}$	584.6		Dichloromethane	Roots	Liu et al. (2018)
244	5-Demethoxy-10′-ethoxyexotimarin F	*M. exotica*	$C_{32}H_{38}O_{10}$	582.3		Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
245	(11*R*,12*R*) -Exotimarin A	*M. exotica*	$C_{24}H_{20}O_7$	420.4		Dichloromethane	Roots	Liu et al. (2018)
246	Cladimarin A	*M. paniculata*	$C_{26}H_{22}O_8$	462.4	12108777	Ethyl acetate	Leaves, twigs	Li, (2022)
247	Cladimarin B	*M. paniculata*	$C_{26}H_{22}O_9$	478.4	101271041	Chloroform	Roots	Wang et al. (2019a)
		M. exotica				Dichloromethane	Roots	Liu et al. (2018)
		M. exotica				Acetone	Branches	Negi et al. (2015)
248	Exotimarin D	*M. exotica*	$C_{26}H_{26}O_9$	482.4		Dichloromethane	Roots	Liu et al. (2018)
249	Exotimarin B	*M. exotica*	$C_{30}H_{28}O_8$	516.6		Dichloromethane	Roots	Liu et al. (2018)
250	(+)-Exotimarin C	*M. exotica*	$C_{30}H_{30}O_8$	518.6		Dichloromethane	Roots	Liu et al. (2018)
251	(−)-Exotimarin C	*M. exotica*	$C_{30}H_{30}O_8$	518.6		Dichloromethane	Roots	Liu et al. (2018)
252	Murratin E	*M. exotica*	$C_{30}H_{32}O_8$	520.6		Ethanol	Leaves, twigs	Liang et al. (2020b)
253	Toddasin	*M. paniculata*	$C_{31}H_{30}O_8$	530.6	101999460	Chloroform	Leaves	Kinoshita and Firman (1996a)
254	Mexolide	*M. exotica*	$C_{32}H_{32}O_8$	544.6	54598332	Benzene	Stem barks	Chakraborty et al. (1980)

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TABLE 3 (*Continued*) Coumarins isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
255	Murradimerin A	*M. exotica*	$C_{30}H_{32}O_8$	520.6	12146410	Ethyl acetate	Leaves, twigs	Xia-Hou et al. (2022)
256	Bismurrangatin	*M. exotica*	$C_{30}H_{30}O_9$	534.6		Acetone	Branches	Negi, et al. (2005)
257	Murrmeranzin	*M. paniculata*	$C_{30}H_{32}O_9$	536.6		Ethyl acetate	Aerial parts	Saied et al. (2008)
258	Exotimarin E	*M. exotica*	$C_{30}H_{32}O_{10}$	552.6		Dichloromethane	Roots	Liu et al. (2018)
259	Toddalosin	*M. exotica*	$C_{32}H_{34}O_9$	562.6	15071281	Dichloromethane	Roots	Liu et al. (2018)
260	Murramarin A	*M. exotica*	$C_{32}H_{34}O_{10}$	578.6		Acetone	Branches	Negi et al. (2005)
261	Panitin A	*M. paniculata*	$C_{32}H_{36}O_{10}$	580.6		Chloroform	Roots	Wang et al. (2019a)
Benzocoumarins								
262	8-Methylbenzo [*h*]coumarin	*M. exotica*	$C_{14}H_{10}O_2$	210.2		Ethanol	Leaves, twigs	Liang et al. (2020b)
263	8-(3-Methylbutanoyloxy) methylbenzo [*h*] coumarin	*M. exotica*	$C_{19}H_{18}O_4$	310.3		Ethanol	Leaves, twigs	Liang et al. (2020b)

dichloromethane extracts using GC-MS and gas chromatography-flame ionization detection (GC-FID). Of these, 287 compounds were isolated from *M. paniculata,* 244 compounds from *M. exotica*, and 127 from both *M. paniculata* and *M. exotica.* Sesquiterpenes are the predominant constituents of the essential oils from MFC. The main compounds are *β*-caryophyllene, spathulenol, *α*-zingiberene, *α*-copaene, germacrene D, and methyl palmitate (Lv et al., 2013; Dosoky et al., 2016; Silva et al., 2019).

5 Pharmacological activities

Modern pharmacological research has indicated that MFC has anti-inflammatory, anti-bacterial, anti-microbial, anti-diabetic, anti-tumor, and anti-oxidant properties (Lu et al., 2021a). The mechanisms of the compounds, extracts, and fractions from MFC are summarized in Table 6 and discussed in subsequent sections. Figure 6 summarizes the pharmacological mechanisms of MFC.

5.1 Anti-inflammatory activity

Gastric ulcers promote the release of inflammatory factors leading to acute and chronic gastric mucosal lesions (Wu et al., 2015). MFC is the main crude material of a patented Chinese drug compound "Sanjiu Weitai," indicated for gastritis therapy (Lu et al., 2021a), indicating that MFC could exert anti-inflammatory effects.

A pharmacodynamical study demonstrated that the levels of interleukin (IL)-6, tumor necrosis factor-alpha (TNF-*α*), and prostaglandin E2 (PGE2) in the plasma of rats were significantly decreased at 300 and 600 mg/kg of *M. paniculata* and *M. exotica*, respectively, and there was no statistical difference in the inhibition of inflammatory cytokines between *M. paniculata* and *M. exotica* at the same dose, indicating a good anti-inflammatory effect (Lu et al., 2021a).

Prenylated phenylpropenols and coumarin derivatives from MFC exhibit anti-inflammatory effects by inhibiting lipopolysaccharide (LPS)-induced nitric oxide (NO) production in BV-2 microglial cells (Liu et al., 2018; Wang X. et al., 2019). The total flavonoids of *M. paniculata* leaves efficiently exert anti-inflammatory effects by inhibiting high glucose-induced expression of TNF-*α* and IL-6 in H9c2 cells (Zou et al., 2021). Coumarin derivatives isolated from the extracts of *M. exotica* leaves and twigs show anti-inflammatory activity by inhibiting the release of NO via the nitric oxide synthase (iNOS) protein (Liang et al., 2020b). Wu et al. (2010) evaluated the anti-inflammatory activity models of ethanol extracts and coumarin compounds of *M. exotica* and reported that the mechanism of action may involve proinflammatory cytokines, such as IL-1β and TNF-α. Murracarpin (**176**) shows the most potential for anti-inflammatory activity.

Isosibiricin (**154**), a natural bioactive coumarin compound isolated from MFC, markedly inhibits the release of NO and production of TNF-α and IL-6 and reduces the expression of cyclooxygenase-2 (COX-2) and inducible iNOS in a concentration-dependent manner to exert anti-inflammatory effects (Kinoshita and Firman, 1996a; Wang Y. et al., 2019). Isomeranzin (7-methoxy-8-(3-methyl-2-oxobutyl) coumarin, **152**) isolated from MFC produces the greatest inhibitory effect on proinflammatory factors, such as IL-1β and IL-6 mRNA expression and NO release. This suggests that compound **152** exerts anti-inflammatory effects primarily by selectively targeting macrophages via the inhibition of nuclear factor-kappa B (NF-*κ*B) and extracellular signal-regulated kinase signals (Xu et al., 2016). The 2′-*O*-Ehylmurrangatin (**169**) isolated from *M. paniculata* leaves promotes moderate respiratory burst inhibition, which could have potential anti-inflammatory effects (Shaikh and Choudhary, 2011).

Murrangatin (**166**), murrangatin 2′-acetate (**182**), murranganonsenecionate (**159**), micropubescin (**134**), and 3′,4′,5′,7-tetramethoxyflavone (**10**) isolated from the leaves of the

TABLE 4 Alkaloids isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
Quinoline alkaloids								
264	Edulitine	*M. paniculata*	$C_{11}H_{11}NO_3$	205.2	826073	Chloroform	Root bark	Imai et al. (1989)
265	2,4-Quinolinediol	*M. exotica*	$C_9H_7NO_2$	162.2	5280371	—	—	Li et al. (2022)
266	4-Hydroxy-1-methyl-2-quinolone	*M. exotica*	$C_{10}H_9NO_2$	175.2	54686436	—	—	Li et al. (2022)
Indazole alkaloids								
267	Indazole	*M. paniculata*	$C_7H_6N_2$	118.1	9221	Ethyl acetate	Leaves, twigs	Li, (2022)
Indole alkaloids								
268	Murrayaculatine	*M. paniculata*	$C_{10}H_9NO_4$	207.2	101416188	Butanol	Flowers	Wu et al. (1994)
269	1H-indole	*M. exotica*	C_8H_7N	117.2	798	—	—	Li et al. (2022)
270	Indol-3-carbaldehyde	*M. paniculata*	C_9H_7NO	145.2	10256	Chloroform	Roots	Wang et al. (2017)
271	Tanakine	*M. paniculata*	$C_{13}H_{17}NO_2$	219.3	57357311	Chloroform	Roots	Wang et al. (2017)
272	3-Prenylindole	*M. paniculata*	$C_{13}H_{15}N$	185.3	10867041	Acetone	Roots	Ito et al. (1990)
273	Paniculidine A	*M. paniculata*	$C_{14}H_{17}NO_2$	231.3	14166401	Chloroform	Roots	Wang et al. (2017)
274	Paniculidine B	*M. paniculata*	$C_{14}H_{19}NO_2$	233.3	14070748	Chloroform	Roots	Wang et al. (2017)
275	Paniculidine C	*M. paniculata*	$C_{13}H_{17}NO$	203.3	11264158	Chloroform	Roots	Wang et al. (2017)
276	Paniculidine D	*M. paniculata*	$C_{14}H_{19}NO_2$	233.3		Chloroform	Roots	Wang et al. (2017)
277	Paniculol	*M. paniculata*	$C_{13}H_{17}NO$	203.3		Acetone	Roots	Ito et al. (1990)
278	Paniculidine E	*M. paniculata*	$C_{26}H_{30}N_2O_2$	402.5		Chloroform	Roots	Wang et al. (2017)
279	Paniculidine F	*M. paniculata*	$C_{29}H_{33}NO_6$	491.3		Chloroform	Roots	Wang et al. (2017)
280	Yuehchukene	*M. paniculata*	$C_{26}H_{26}N_2$	366.5	126009	Chloroform	Roots	Wang et al. (2017)
Carbazole alkaloids								
281	3-Methyl-9H-carbazole	*M. exotica*	$C_{13}H_{11}N$	181.2	20746	—	—	Li et al. (2022)
282	3-Methyl-9H-carbazol-2-ol	*M. exotica*	$C_{13}H_{11}NO$	197.2	3459141	—	—	Li et al. (2022)
283	1-Methoxy-3-methyl-9H-carbazole	*M. exotica*	$C_{14}H_{13}NO$	211.3	375150	—	—	Li et al. (2022)
284	Mahanimbine	*M. exotica*	$C_{23}H_{25}NO$	331.4	167963	Petroleum ether	Stem barks	Bhattacharyyaet al. (1978)
285	Girinimbine	*M. exotica*	$C_{18}H_{17}NO$	263.3	96943	Petroleum ether	Stem barks	Roy and Bhattacharyya (1981)
286	Koenimbine	*M. exotica*	$C_{19}H_{19}NO_2$	293.4	97487	Petroleum ether	Stem barks	Roy and Bhattacharyya (1981)
287	Euchrestifoline	*M. paniculata*	$C_{18}H_{17}NO_2$	279.3	25172103	Methanol	Leaves	Rehman et al. (2013)
288	Murrayazoline	*M. exotica*	$C_{23}H_{25}NO$	331.4	21770913	Petroleum ether	Stem barks	Bhattacharyyaet al. (1978)
289	Murrayazolinol	*M. exotica*	$C_{23}H_{25}NO_2$	347.4	180314	—	—	Ahmad, (1994)
290	Exozoline	*M. exotica*	$C_{23}H_{27}NO$	333.5	101324894	Ethanol	Leaves	Ganguly and Sarkar (1978)

(Continued on following page)

TABLE 4 (*Continued*) Alkaloids isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
Organic amine alkaloid								
291	Methyl N-methyl anthranylate	*M. paniculata*	$C_9H_{11}NO_2$	165.2	6826	Chloroform	Root barks	Imai et al. (1989)
Other alkaloid								
292	Acetazolamide	*M. paniculata*	$C_4H_6N_4O_3S_2$	222.3	1986	Methanol	Leaves	Sangkaew et al. (2020)

ethyl acetate extract of *M. paniculata* also show strong anti-inflammatory activity via LPS-stimulated macrophages to produce the inhibitory effect (Rodanant et al., 2015). Three flavonoids (**8**, **9**, **25**) isolated from the dried stems and leaves of *M. paniculata* mainly suppress LPS-activated production of NO and IL-6 with little cytotoxicity in a dose-dependent manner. Wu et al. (2015) suggested that the C-2, 3 double bond might have an important inhibitory effect on the production of NO and IL-6 by LPS-activated RAW 264.7 cells and mouse peritoneal macrophages.

5.2 Anti-bacterial and anti-microbial activities

To date, studies on anti-bacterial and anti-microbial activities have been focused on *M. paniculata*, not *M. exotica*.

Murrangatin (**166**), murrangatin 2′-acetate (**182**), murranganonsenecionate (**159**), micropubescin (**134**), and 3′,4′,5′,7-tetramethoxyflavone (**10**) isolated from the leaves of ethyl acetate extract of *M. paniculata* are active against *Porphyromonas gingivalis*. Compounds **166** and **182** show better anti-bacterial potency than the crude extract, indicating that coumarins are the main constituents responsible for the anti-bacterial effects (Rodanant et al., 2015). Different extracts of *M. paniculata* used against different strains of human pathogenic bacteria have exhibited a broad spectrum of anti-bacterial activities. The ethanol and hydroalcoholic extracts show mild-to-moderate activity against human pathogenic bacteria. The methanol extract of *M. paniculata* leaves shows obvious antibacterial activities against Gram-positive and Gram-negative bacteria. Anti-bacterial properties against human pathogens with high phenol and flavonoid content have been reported (Gautam et al., 2012a). One study reported that the ethanol extract of *M. paniculata* leaf showed broad-spectrum activity in inhibiting the growth of *Staphylococcus aureus* (half minimal inhibitory concentration [MIC_{50}] = 406 μg/mL) (Panda et al., 2020).

Saikia et al. (2021) reported that volatile oils showed promising anti-bacterial activity against *Mycobacterium smegmatis* (MIC_{50} = 4 μg/mL) and *Pseudomonas aeruginosa* (MIC_{50} = 4 μg/mL). Twenty-nine compounds in the volatile oils of *M. paniculata* leaves were identified using GC-MS. Most of the volatile oils were sesquiterpene hydrocarbons (80%); the major compound was caryophyllene (20.93%). Silva et al. (2020) reported that volatile oils were also effective against *Mycobacterium kansasii* (MIC_{50} = 250 μg/mL) and moderately active against *Mycobacterium tuberculosis,* demonstrating anti-streptococcal and anti-mycobacterial activities (MIC_{50} = 500 μg/mL). GC-FID and GC-MS were used to analyze the volatile oils of *M. paniculata* leaves using hydrodistillation. Anti-fungal tests *in vitro* showed that essential oils had a 91.2% inhibitory effect on the growth of mycelia in *Sclerotinia sclerotiorum*. Eighteen compounds were identified using GC-MS in the volatile oils of *M. paniculata* leaves obtained using hydrodistillation. Rodríguez et al. (2012) reported that the volatile oils exerted moderate inhibitory effects against *Klebsiella pneumoniae* and *Bacillus subtilis*. GC-MS analysis of fresh leaf extract of *M. paniculata* by hydrodistillation identified 13 compounds using GC-MS analyses, including 99.3% sesquiterpenes and 0.3% monoterpenes. The major compounds were *β*-caryophyllene (**320**), *α*-zingiberene (**325**), and *α*-caryophyllene (**336**). Another study indicated that the volatile oils and *β*-caryophyllene (**320**) exhibited moderate anti-bacterial activity (MIC_{50} < 1.0 mg/mL) (Selestino Neta et al., 2017).

5.3 Anti-tumor (cytotoxic) activity

Polymethoxyflavones (PMFs) exhibit a wide range of biological activities, including anti-inflammatory, anti-carcinogenic, and anti-tumor activities. Owing to the hydrophobicity of the methoxyl groups relative to the hydroxyl groups, PMFs are more lipophilic and inhibit tumor cell growth compared with hydroxylated flavonoids (Pan et al., 2007). The roots of *M. paniculata* and *M. exotica* are rich in coumarins, which exhibit cytotoxic activity in tumor cell lines (Shao et al., 2016; He et al., 2017). The leaves of *M. paniculata* also exhibits cytotoxic activity (Selestino Neta et al., 2017; Saikia et al., 2021).

The 5, 6, 7, 3′, 4′, 5′-hexamethoxyflavanone-8-*O*-[rhamnopyranosyl-(1→4)-rhamnopyranoside] (**67**) isolated from 75% ethanol extract of twigs of *M. paniculata* inhibited the adhesion, migration and invasion of lung adenocarcinoma A549 cells *in vitro.* Compound **67** blocked the adhesion of A549 cells to human pulmonary microvascular endothelial cells by targeting COX-2, matrix metalloproteinase (MMP)-2, and MMP-9 and blocked the NF-*κ*B/signal transducer and activator of transcription 3 and epidermal growth factor receptor/phosphatidylinositol 3-kinase/protein kinase B signaling pathways, thereby blocking the invasion and migration of targeted cancer cells and downregulating their epithelial–mesenchymal transition phenotype. Compound **67** inhibited the adhesion of cancer cells to abnormal endothelial cells by regulating the cellular microenvironment (Shi et al., 2017).

The raw methanol/dichloromethane extracted fraction (containing flavonoids and coumarins) of *M. paniculata* had a

TABLE 5 Sterols, phenylpropenols, organic acids and spirocyclopentenones isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
Sterols								
293	*β*-Sitosterol	*M. paniculata*	$C_{29}H_{50}O$	414.7	222284	Ethyl acetate	Aerial parts	Saeed et al. (2011)
294	(23*S*)-23-Ethyl-24-methyl-cycloart-24(24^1)-en-3*β*-ol	*M. exotica*	$C_{33}H_{56}O$	468.8		Cyclohexane	Leaves	Desoky, (1995)
295	3*β*-Methoxy-(23*S*)-23-ethyl-24-methyl-cycloart-24(24^1)-en-3*β*-ol	*M. exotica*	$C_{34}H_{58}O$	482.8		Cyclohexane	Leaves	Desoky, (1995)
296	(23*S*)-23-Ethyl-24-methyl-cycloart-24(24^1)-3*β*-yl acetate	*M. exotica*	$C_{35}H_{60}O$	496.8		Cyclohexane	Leaves	Desoky, (1995)
297	(23ζ)-23-Isopropyl-24-methyl-cycloart-25-en-3*β*-ol	*M. exotica*	$C_{34}H_{58}O$	482.8		Cyclohexane	Leaves	Desoky, (1995)
298	(23ζ)-23-Isopropyl-24-methyl-cycloart-25-en-3*β*-yl acetate	*M. exotica*	$C_{36}H_{62}O$	510.9		Cyclohexane	Leaves	Desoky, (1995)
Phenylpropenols								
299	2-(*p*-Hydroxyphenyl)ethyl *p*-coumarate	*M. exotica*	$C_{17}H_{16}O_4$	284.3		Dichloromethane	Roots	Liu et al. (2018)
300	Exotiacetal A	*M. exotica*	$C_{28}H_{30}O_6$	462.5		Dichloromethane	Roots	Liu et al. (2018)
301	Exotiacetal B	*M. exotica*	$C_{28}H_{30}O_6$	462.5		Dichloromethane	Roots	Liu et al. (2018)
302	Exotiacetal C	*M. exotica*	$C_{28}H_{30}O_5$	446.5		Dichloromethane	Roots	Liu et al. (2018)
Organic acids								
303	3-Hydroxybenzoic acid	*M. exotica*	$C_7H_6O_3$	138.1	7420	—	—	Li et al. (2022)
304	4-Hydroxybenzoic acid	*M. paniculata*	$C_7H_6O_3$	138.1	135	Ethyl acetate fraction	Aerial parts	Saeed et al. (2011)
305	Gallic acid	*M. paniculata*	$C_7H_6O_5$	170.1	370	Ethanol	Leaves	Kaur et al. (2016)
		M. exotica				Hydroalcoholic	Leaves	
306	Coumaric acid	*M. exotica*	$C_9H_8O_3$	164.2	637542	Ethanol	Leaves	Menezes et al. (2017)
307	*trans*-Cinnamic acid	*M. paniculata*	$C_9H_8O_2$	148.2	444539	Ethylacetate	Aerial parts	Kaur et al. (2016)
308	Caffeic acid	*M. paniculata*	$C_9H_8O_4$	180.2	689043	Ethanol	Leaves	Saeed et al. (2011)
		M. exotica				Hydroalcoholic	Leaves	
309	tert-Butylhydroquinone	*M. exotica*	$C_{10}H_{14}O_2$	166.2	16043	Ethanol	Leaves	Kaur et al. (2016)
310	Methyl 2,5-dihydroxycinnamate	*M. paniculata*	$C_{10}H_{10}O_4$	194.2	5353609	Methanol	Aerial parts	Menezes et al. (2017)
311	Methyl 2-methoxy-5-hydroxycinnamate	*M. paniculata*	$C_{11}H_{12}O_4$	208.1		Methanol	Aerial parts	Kaur et al. (2016)
312	Murraxonin	*M. exotica*	$C_{13}H_{13}O_5$	249.2		Chloroform	Leaves	Rahman et al. (1997)
313	Ellagic acid	*M. paniculata*	$C_{14}H_6O_8$	302.2	5281855	Ethanol	Leaves	Rahman et al. (1997)
		M. exotica				Hydroalcoholic	Leaves	
314	Chlorogenic acid	*M. paniculata*	$C_{16}H_{18}O_9$	354.3	1794427	Ethanol	Leaves	Braik and Kundu (1987)
		M. exotica				Hydroalcoholic	Leaves	

(Continued on following page)

TABLE 5 (*Continued*) Sterols, phenylpropenols, organic acids and spirocyclopentenones isolated from Murrayae Folium et Cacumen.

No.	Name	Species	Formula	Weight	PubChem CID	Extract	Parts of the plant	References
Spirocyclopentenones								
315	(1*S*, 5*S*)-Murrayaspiroketone	*M. paniculata*	$C_{20}H_{21}O_{10}$	421.1		Ethanol	Leaves, stems	Menezes et al. (2017)
316	(1*R*, 5*R*)-Murrayaspiroketone	*M. paniculata*	$C_{20}H_{21}O_{10}$	421.1		Ethanol	Leaves, stems	Kaur et al. (2016)

high adhesion inhibition rate, and the inhibition effect on human endothelial cells HT29 was concentration-dependent (1–30 μg/mL). In addition, this fraction inhibited the invasion and migration of HT29 cells. Oral administration of the fraction substantially inhibited lung metastasis in immunized mice inoculated with murine melanoma cells, without obvious side effects (Jiang et al., 2016).

Phebalosin (**132**) and murralongin (**136**), isolated from 80% acidic ethanol extracts of *M. paniculata* roots, inhibited the adhesion of cancer cells to the vascular intima because they specifically targeted cell–cell adhesion at low concentrations (Shao et al., 2016). Pharmacodynamic experiments showed that coumarin extracts from *M. exotica* roots had low cytotoxicity and high resistance to HT-29 tumor cells and could substantially inhibit the migration of tumor cells (Jiang et al., 2015). The root extracts of *M. exotica* were more efficient in restraining cell migration and had a slightly lower inhibition of cell adhesion in MDA-MB-231 cells than the leaf extracts *in vitro*. Compounds isolated from the roots of *M. exotica* show obvious inhibitory effects on the adhesion and migration of tumor cells (He et al., 2017).

The volatile oils from fresh leaves of *M. paniculata* exhibited a half maximal inhibitory concentration (IC50) value of 63.73 μg/mL for tumorous cells of hepatocytes in a study by Selestino Neta et al. (2017). Twenty-nine compounds in the essential oil of M. paniculata leaf were identified using GC-MS. The major compound was caryophyllene (20.93%), which had an obvious inhibitory effect on HeLa, MIAPaCa2, and PA1 cell lines (Saikia et al., 2021).

5.4 Anti-diabetic activity

The total flavonoids extracted from *M. paniculata* (TFMP) effectively alleviated kidney damage in diabetic rats. The effects of TFMP on diabetic nephropathy may involve the regulation of glucose, lipid metabolism, oxidative stress, and inflammatory cytokines (Zou et al., 2014). Zou et al. (2021) found that TFMP could decrease the occurrence of diabetic cardiomyopathy in type 2 diabetic rats, and the protective effect may upregulate the expression of the NF-E2-related factor 2 and heme oxygenase-1 genes, inhibiting oxidative stress, inflammation, and apoptosis (Zou et al., 2021). The extract of *M. paniculata* leaves decreases glucose levels in alloxan-induced diabetic rats, effectively treating diabetes-related complications, such as hypercholesterolemia and hypertriglyceridemia, and reducing the damage associated with diabetic status. The hypoglycemic effect is similar to that of glibenclamide and metformin, which are related to the inhibition of ATP-sensitive potassium channels (Menezes et al., 2017).

The flavones extracted from *M. paniculata* leaf mainly include 5, 6, 7, 3′, 4′, 5′-hexamethyl flavone (**3**), 5, 6, 7, 3′, 4′-pentamethoxyl flavone (**6**), 5, 7, 3′, 4′, 5′-pentamethoxyl flavone (**8**), 5, 7, 3′, 4′-tetramethoxy flavone (**9**), and 7-hydroxyl-5, 3′, 4′-trimethyl flavone (**32**). A patent disclosed that the flavonoids could remarkably reduce blood glucose; improve the disturbance of lipid metabolism; increase the C-peptide level and the content of insulin in the serum; improve the excretion index of β cells of insulin and insulin resistance; reduce the insulin resistance index, malondialdehyde content in the blood serum, and contents of IL-1β, IL-6, and TNF-α; and improve superoxidase dismutase (SOD) activity (Jin et al., 2008).

5.5 Anti-oxidant activity

Various *in vitro* studies have shown that 50% ethanol extract of *M. paniculata* leaves possessed strong anti-oxidant activity (Gautam et al., 2012b). GC-MS was used to identify 18 compounds in volatile oils of *M. paniculata* leaves obtained via hydrodistillation. These volatile oils showed strong anti-oxidant activity, and the main component is *β*-caryophyllene (**320**) (Rodríguez et al., 2012).

Research has shown that ethyl acetate fraction of *M. exotica* leaves, which is rich in polyphenols and flavonoids, exhibits the highest anti-oxidant activity of the different parts obtained using the sequential extraction method (Kaur et al., 2016). The methanol extract of *M. exotica* leaves has been reported to contain numerous flavonoids and polyphenols, and these compounds show marked anti-oxidant activity (Khatun et al., 2014).

5.6 Chondroprotective activity

Wu and coworkers (2010) found the 70% ethanol extract of *M. exotica* leaves significantly reduced iNOS activity and IL-1β and TNF-α contents, increaseed SOD activity, decreaseed NO production, protected cartilage and chondrocytes from destruction, and maintained the normal function of femoral condyle cartilage and the arrangement of different layers of chondrocytes. Another study demonstrated that 70% ethanol extracts of *M. exotica* decreased the contents of TNF-α and IL-1β in rat osteoarthritis synovial fluid by inhibiting the *β*-catenin signaling pathway, and reduced chondrocyte apoptosis *in vitro* (Wu et al., 2013). 5,7,3′,4′-Tetramethoxyflavone (**9**) has been demonstrated to improve chondrocyte apoptosis by inhibiting Wnt/*β*-catenin signaling *in vivo* and *in vitro* (Wu et al., 2014).

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TABLE 6 Pharmacological Mechanism, models of compounds and various extracts in Murrayae Folium et Cacumen.

Activities	Resource	Compounds/ extracts	*In vivo*/*in vitro* and Dosage	Experimental Model (Animals/Cell lines)	Mechanisms of action	References
Anti-inflammatory	*M. exotica*	Isosibiricin (**154**)	*In vitro* Dose range: 0–50 μm	BV-2 cell, Balb/c mice; Positive control: Sultopride	Inhibiting TNF-α and IL-6 production, reducing COX-2 and iNOS expression	Wang et al. (2019b)
	M. exotica	Isomeranzin (**152**)	*In vivo*: 10 and 30 mg/kg *In vitro*: 3, 10, and 30 μm	Female C57BL/6 mice; murine Raw 264.7 cells	Inhibiting the expression of IL-1β and IL-6 mRNA and NO release via the inhibition of NF-κB and ERK signals	Xu et al. (2016)
	M. paniculata	5,7,3′,4′,5′-pentamethoxyflavone (**8**), 5,7,3′,4′-tetramethoxyflavone (**9**), 5-hydroxy-6,7,8,3′,4′-pentamethoxyflavone (**25**) (70% Ethanol extract of stems and leaves)	*In vitro*: 0.01, 0.1, 1, 10, and 100 μm IC_{50}: 53.40 μm (**8**) 120.98 μm (**9**) 10.73 μm (**25**)	RAW 264.7, GES-1 cells	Reducing NO production and IL-6 production	Wu et al. (2015)
	M. paniculata	Total flavonoids (Ethanol extract of leaves)	*In vitro*: 25, 50, 75, 100, and 200 μg/mL; *In vivo*: 35 and 70 mg/kg	H9c2 cells; Male Wistar rats	Inhibiting HG-induced expression of TNF-α and IL-6	Zou et al. (2021)
	M. paniculata	3′,4′,5′,7-tetramethoxyflavone (**10**), micropubescin (**134**), murranganonsenecionate (**159**), Murrangatin (**166**), murrangatin 2′-acetate (**182**) (Ethyl acetate extract of leaves)	*In vitro*: 20 and 50 μg/mL	HGFs and U937 cells Positive controls: 0.5 μg/mL Dexamethasone and 0.5 μg/mL LPS Negative control: 1% DMSO	Suppressing the IL-1β production through LPS-stimulated macrophage	Rodanant et al. (2015)
	M. exotica	*cis*-osthenon (**109**), *trans*-dehydroosthol (**118**), sibirinol (**129**), Exotiacetal A (**300**) (95% Aqueous EtOH extract of roots)	*In vitro* IC_{50}: 16.9 ± 1.0 μm (**109**) 11.8 ± 0.9 μm (**118**) 15.5 ± 0.9 μm (**129**) 8.6 ± 0.9 μm (**300**)	BV-2 microglial cells	Inhibiting against LPS-induced NO production	Liu et al. (2018)

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TABLE 6 (*Continued*) Pharmacological Mechanism, models of compounds and various extracts in Murrayae Folium et Cacumen.

Activities	Resource	Compounds/ extracts	*In vivo*/*in vitro* and Dosage	Experimental Model (Animals/Cell lines)	Mechanisms of action	References
	M. paniculata	*trans*-dehydroosthol (**118**), exotimarin I (**216**), Panitin D (**228**) (95% Aqueous EtOH extract of roots)	*In vitro* IC_{50}: 12.4 ± 0.9 μm (**118**) 26.9 ± 0.8 μm (**216**) 19.6 ± 2.3 μm (**228**)	BV-2 microglial cells	Inhibiting against LPS-induced NO production	Wang et al. (2019a)
	M. exotica	70% Ethanol extract of leaves	*In vivo*: 50, 100, and 200 mg/kg	Male mice; rats Positive control: 0.5 mg/kg Hexadecadrol	Inhibiting the production of iNOS, decreasing IL-1β and TNF-α and elevating the activity of SOD	Wu et al. (2010)
	M. exotica	CH_2Cl_2 fraction (95% Aqueous EtOH extract of leaves and twigs)	*In vitro* Positive control: IC_{50} = 15.7 ± 1.1 μm	RAW 264.7 Positive control: Dexamethasone	Inhibiting the release of NO by inhibiting iNOS protein	Liang et al. (2020b)
	M. paniculata/ *M. exotica*	Ethanol extract of twigs and leaves	*In vivo*: 100, 300, and 600 mg/kg	ICR mice, SD rats Positive controls: 5 mg/kg Dexamethasone 5 mg/kg Domperidone	Decreasing the TNF-*α* and PGE2 in plasma	Lu et al. (2021a)
Antibacterial and antimicrobial	*M. paniculata*	3′,4′,5′,7-tetramethoxyflavone (**10**), micropubescin (**134**), murranganonsenecionate (**159**), Murrangatin (**166**), murrangatin 2′-acetate (**182**) (Ethyl acetate extract of leaves)	*In vitro*: 100 μg/mL	*Prophyromonas gingivalis* Positive control: 2% Chlorhexidine Negative control: DMSO	Exhibiting antibacterial activity against *P. gingivalis*	Rodanant et al. (2015)
	M. paniculata	Volatile oils (Leaves by hydrodistillation)	*In vitro*: 10 μL MIC = 4 μg/mL	*Pseudomonas aeruginosa* *Mycobacterium smegmatis*	Exhibiting against *Pseudomonas aeruginosa* and *Mycobacterium smegmatis*	Saikia et al. (2021)
	M. paniculata	Volatile oils (Leaves by hydrodistillation)	*In vitro*	Bacterial species	Inhibiting *Klebsiella pneumoniae* and *Bacillus subtilis*	Rodríguez et al. (2012)
	M. paniculata	Volatile oils (Ripe and unripe fruits by hydrodistillation)	*In vitro* Dose range: 400–3.9 μg/mL *Mycobacterium kansasii* (MIC = 250 μg/mL) *M. tuberculosis* (MIC = 500 μg/mL)	Bacterial strains Positive controls: Chlorhexidine dihydrochloride; Isoniazid	Inhibiting *Mycobacterium kansasii* and *M. tuberculosis*	Silva et al. (2020)

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TABLE 6 (*Continued*) Pharmacological Mechanism, models of compounds and various extracts in Murrayae Folium et Cacumen.

Activities	Resource	Compounds/ extracts	*In vivo/in vitro* and Dosage	Experimental Model (Animals/Cell lines)	Mechanisms of action	References
Antitumor activity	*M. paniculata*	5,6,7,3′,4′,5′-Hexamethoxyflavanone-8-*O*-[rhamnopyranosyl-(1→4)-rhamnopyranoside] (**67**) (75% Ethanol extract of twigs)	*In vitro* Dose range: 1–100 μg/mL	A549, PC9 cells	Interrupting the STAT3/NF-κB/COV-2 and EGFR signaling pathways	Shi et al. (2017)
	M. paniculata	Phebalosin (**132**), murralongin (**136**) (Ethyl acetate extract of roots)	*In vitro* Dose range: 1–100 μg/mL	HCT116 cells Positive control: Warfarin	Down-regulating EpCAM expression	Shao et al. (2016)
	M. paniculata	Volatile oils (Leaves by hydrodistillation)	*In vitro* HeLa cells: IC_{50} = 6.28 ± 1.82 μg/mL L6 cells: IC_{50} = 13.62 ± 4.02 μg/mL MIA-PaCa2 cells: IC_{50} = 55.12 ± 0.77 μg/mL PA1 cells: IC_{50} = 13.14 ± 1.56 μg/mL	L6, MIA-PaCa2, PA1 and Hela cells	Inhibiting HeLa, L6, MIAPaCa2 and PA1 cell lines	Saikia et al. (2021)
	M. paniculata	Volatile oils (Fresh leaves by hydrodistillation)	*In vitro* Dose range: 7.8–500 μg/mL IC_{50} = 63.7 μg/mL	Hepa 1c1c7 cells	Inhibiting Hepa 1c1c7 cells	Selestino Neta et al. (2017)
	M. exotica	Chloroform and methylene chloride extracts of roots and leaf parts, respectively	*In vitro*: 1, 10, 50, and 100 μg/mL	MDA-MB-231 cells	Inhibiting IL-1β, inducing VCAM-1 expression	He et al. (2017)
	M. exotica	Ethyl acetate extract of roots and leaves	*In vitro*: 1, 10, 50, and 100 μg/mL	HT-29 cells	Inhibiting HT-29 tumor cells	Jiang et al. (2015)
	M. paniculata	Dichloromethane fractions (75% Refluxing ethanol extract of twigs)	*In vitro* Dose range: 1–200 μg/mL IC_{50} = 145.8 μg/mL EC_{50} = 18.43 μg/mL	HT29 cell lines	Down-regulating the expression of integrin β1, α6, CD44 in HT-29 cells and E-selectin in endothelial cells	Jiang et al. (2016)

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TABLE 6 (*Continued*) Pharmacological Mechanism, models of compounds and various extracts in Murrayae Folium et Cacumen.

Activities	Resource	Compounds/ extracts	*In vivo*/*in vitro* and Dosage	Experimental Model (Animals/Cell lines)	Mechanisms of action	References
Antidiabetic activity	*M. paniculata*	5,6,7,3′,4′,5′-Hexamethyl flavone (**3**), 5,6,7,3′, 4′-pentamethoxyl flavone (**6**), 5,7,3′,4′, 5′-pentamethoxyl flavone (**8**), 5,7,3′, 4′-tetramethoxy flavone (**9**), 7-hydroxyl-5,3′, 4′-trimethyl flavone (**32**)		Rats	Reducing the blood glucose level	Jin et al. (2008)
	M. paniculata	Total flavonoids (95% Ethanol extract of air-dried leaves)	*In vivo*:	Male Wistar rats	Decreasing the expression of TGF-β1 and CTGF protein	Zou et al. (2014)
			35 and 70 mg/kg	Positive control:		
				10 mg/kg Captopril		
	M. paniculata	Total flavonoids (95% Ethanol extract of dried leaves)	*In vivo*:	H9c2 cells;	Increasing Nrf2 and HO-1 gene expression	Zou et al. (2021)
			35 and 70 mg/kg	Male Wistar rats		
			In vitro:	Negative control:		
			25, 50, 75, 100, and 200 μg/mL	0.5%CMC-Na		
	M. paniculata	50% Ethanol extract of leaves	*In vivo*:	Male Wistar rats	Reducing the blood glucose, TGs, and cholesterol levels	Menezes et al. (2017)
			100, 200, and 400 mg/kg	Positive controls:		
				5 mg/kg Glibenclamide		
				50 mg/kg Metformin		
Antioxidant activity	*M. paniculata*	Volatile oils of leaves	*In vitro*	Positive controls:	Showing strong antioxidant activity	Rodríguez et al. (2012)
				Thymol;		
				Butylated hydroxyanisole;		
				Butylated hydroxytoluene;		
				Propyl gallate		
	M. exotica	Ethanol extract of fresh leaves (Polyphenols and flavonoids)	*In vitro*		Exhibiting the antioxidant activity	Kaur et al. (2016)
			10–1,000 μg/mL			
	M. exotica	Methanol extract of leaves	*In vitro*:	Positive control:	Indicating the marked antioxidant activity	Khatun et al. (2014)
			1, 5, 10, 50, and 100 μg/mL IC_{50} = 1.25 μg/mL; IC_{90} = 4.4 μg/mL	Ascorbic acid		
			Positive control:			
			IC_{50} = 0.01 μg/mL; IC_{90} = 3.58 μg/mL			

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TABLE 6 (*Continued*) Pharmacological Mechanism, models of compounds and various extracts in Murrayae Folium et Cacumen.

Activities	Resource	Compounds/ extracts	*In vivo/in vitro* and Dosage	Experimental Model (Animals/Cell lines)	Mechanisms of action	References
Chondroprotective activity	*M. exotica*	5,7,3′,4′-Tetramethoxyflavone (**9**)	*In vivo*: 25, 50 and 100 mg/kg *In vitro*: 5, 10, and 20 μg/mL	Rats; Joint cartilage cells	Inhibiting EP/cAMP/PKA signaling pathway and β-catenin signaling pathway	Wu et al. (2014)
	M. exotica	5,7,3′,4′-Tetramethoxyflavone (**9**)	*In vivo*: 25 and 100 mg/kg *In vitro*: 5 and 20 μg/mL	Rats; Joint cartilage cells	Up-regulating Foxo3a expression and inhibiting miR-29a/Wnt/β-catenin signaling activity	Huang et al. (2019)
	M. exotica	70% Ethanol extracts of leaves	*In vivo*: 50, 100, and 200 mg/kg	Rats	Decreasing the IL-1β and TNF-α contents through inhibiting *β*-catenin signaling pathway	Wu et al. (2013)
	M. exotica	70% Ethanol extracts of leaves	*In vivo*: 50, 100, and 200 mg/kg	Rats	Increasing the SOD activity, inhibiting the NO activity, and decreasing the IL-1β and TNF-α contents	Wu et al. (2010)
Potential anti-Alzheimer activity	*M. paniculata*	murranganone (**153**), (**160**), 2′-*O*-ethylmurrangatin (**169**) (Methanolic extract of air-dried leaves)	*In vitro* Positive control (IC_{50}): Tacrine 0.021 μm (AChE) 0.025 μm (BChE) Galanthamine 0.45 μm (AChE) 32.5 μm (BChE) Murranganone 79.1 μm (AChE) 74.3 μm (BChE) Paniculatin 31.6 μm (AChE) >100 μm (BChE)	-	Inhibiting AChE and BChE activities	Khalid et al. (2023)
	M. paniculata	Germacrene D, α-zingiberene, δ-elemene (Leaves by hydrodistilation)	*In vitro* IC_{50}: 5.1 ± 0.3 μg/mL (BChE) 13.2 ± 0.9 μg/mL (AChE)	-	Inhibiting AChE and BChE activities	El-Shiekh et al. (2023)

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TABLE 6 (*Continued*) Pharmacological Mechanism, models of compounds and various extracts in Murrayae Folium et Cacumen.

Activities	Resource	Compounds/extracts	*In vivo*/*in vitro* and Dosage	Experimental Model (Animals/Cell lines)	Mechanisms of action	References
Analgesic activity	*M. paniculata*	Barks extracts of petroleum ether, ethyl acetate and methanol in equal proportions	*In vivo*:	Mice	Inhibiting the writhing and extending the tail flicking time	Podder et al. (2011)
			200 and 400 mg/kg	Positive control:		
				2 mg/kg Morphine		
				50 mg/kg Aminopyrine		
Other activities	*M. paniculata*	Yuehchukene (**280**) (Chloroform extract of roots)	*In vivo*:	SD rats	having the anti-implantation and estrogenic activities	Kong et al. (1985a)
			2.5 and 3 mg/kg			
	M. paniculata	Chloroform fraction and ethanol extracts of leaves	*In vivo*:	Laca mice	Showing significant anxiolytic and antidepressant activities	Sharma et al. (2017)
			100, 200, and 400 mg/kg	Positive control:		
				2 mg/kg Diazepam		
				10 mg/kg Imipramine		
	M. paniculata	Chloroform extract of leaves	*In vitro*	-	Exhibiting moderate anti-giardial activity *in vitro*	Sawangjaroen et al. (2005)
			MIC = 250 μg/mL			
			IC_{50} = 144.87 ± 19.45 μg/mL			
	M. paniculata	Chloroform extract of leaves	*In vitro*	Positive control:	Showing moderate anti-amoebic activity	Sawangjaroen et al. (2006)
			Dose range:	Metronidazole		
			31.25–1,000 μg/mL			
			IC_{50} = 116.5 ± 3.5 μg/mL			
			Positive control:			
			IC_{50} = 1.1 ± 0.1 μg/mL			

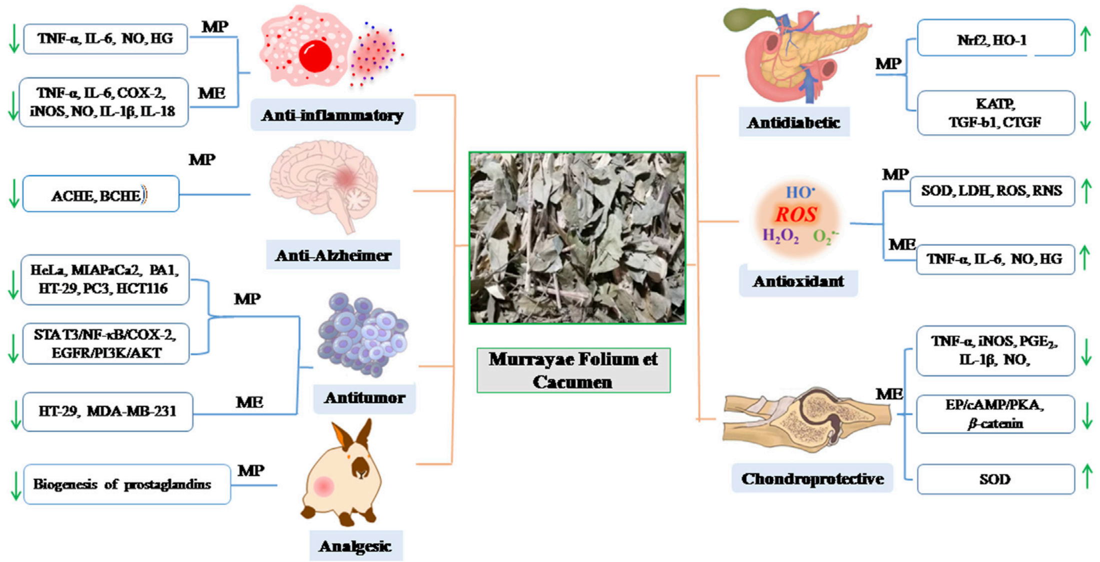

FIGURE 6
The pharmacological activity mechanism of Murrayae Folium et Cacumen (MP: *Murraya. Paniculata*; ME: *M. exotica*).

Further studies show that compound **9** from *M. exotica* exhibits chondroprotective activity by upregulating Foxo3a expression and inhibiting miR-29a/Wnt/*β*-catenin signaling activity (Huang et al., 2019).

5.7 Potential anti-Alzheimer's disease activity

Alzheimer's disease (AD) is a neurodegenerative disease that causes progressive loss of neuronal structure and function, leading to cognitive decline and dementia (Kabir et al., 2021). Some natural products have promising anti-AD properties. Acetylcholinesterase/butyrylcholinesterase (AChE/BChE) inhibitors are desirable because they improve cognition with minimal side effects (Wojtunik-Kulesza et al., 2021). In one study, the essential oil of *M. paniculata* leaves was the most potent selective BChE inhibitor with an IC_{50} of 5.1 ± 0.3 μg/mL and showed strong inhibitory activity against AChE (IC_{50} = 13.2 ± 0.9 μg/mL). Germacrene D (**324**), α-zingiberene (**325**), and δ-elemene (**333**) had a high affinity for BChE. These volatiles, with their *in vitro* cholinesterase inhibitory potential, have demonstrated a novel and safe treatment for AD (El-Shiekh et al., 2023). Experimentally, paniculatin (**160**) is most potent against AChE (IC_{50} = 31.6 μM), whileas murranganone (**153**) is the most potent against BChE (IC_{50} = 74.3 μM); neither compound shows selectivity toward any of the two enzymes. Paniculatin (**160**) is a mixed-type inhibitor of both AChE and BChE, whereas murranganone (**153**) promotes pure noncompetitive inhibition of AChE and BChE. Compound 2′-*O*-ethylmurrangatin (**169**) has no inhibitory effect on AChE but has a very weak inhibitory effect on BChE. These three coumarins represent a new class of natural coumarins that are active against cholinesterases. Therefore, they can be considered potential candidates for AD treatment. These coumarins show non-selective, moderate-to-good *in vitro* activity against both AChE and BChE via a mixed-type inhibitory mechanism (Khalid et al., 2023).

5.8 Analgesic activity

The bark extract of *M. paniculata* (200 and 400 mg/kg) has an obvious inhibitory effect on the writhing bodies of mice, and the degree of the inhibitory effect increases with increasing dose. The results at both doses are comparable to those of the standard drug aminopyrine. A similar analgesic activity was observed using the radiant heat method (Podder et al., 2011).

5.9 Other activities

Yuehchukene (**280**) from *M. paniculata* has been shown to exhibit long-standing anti-implantation and estrogenic activity (Kong YC. et al., 1985).

M. paniculata is widely used to treat mental health disorders. The chloroform (200 mg/kg) and ethanol (400 mg/kg) extracts of *M. paniculata* leaves demonstrate marked anxiolytic and anti-depressant activities, respectively (Sharma et al., 2017). The chloroform extract of *M. paniculata* leaves showed a moderate level of anti-giardial and anti-amoebic activity *in vitro* in patients with AIDS in southern Thailand (Sawangjaroen et al., 2005; Sawangjaroen et al., 2006).

Cuong et al. (2014) reported that the chloroform fraction of the methanol extract of *M. paniculata* leaves had the most potent vasorelaxing effect on rat aortic rings contracted using 60 mM K^+. Kimcuongin (**225**) and murracarpin (**176**) isolated from the chloroform fraction showed vasorelaxant activity with IC_{50} values of 37.7 μM and 139.3 μM, respectively, suggesting that *M. paniculata* has an anti-hypertensive effect (Cuong et al., 2014).

6 Pharmacodynamics and pharmacokinetics

6.1 Pharmacodynamics

One pharmacodynamic study of MFC indicated that both *M. exotica* and *M. paniculata* markedly inhibited the writhing reaction induced by acetic acid in mice and the paw swelling induced by carrageenan in rats; decreased IL-6, TNF-*α*, and PGE2 levels in the plasma of rats with swollen paws; and increased the gastric emptying rate and intestinal propulsive rate in a dose-dependent manner. *M. exotica* and *M. paniculata* did not indicate marked differences at the same dose and are therefore considered to have similar anti-inflammatory, analgesic, and gastrointestinal motion-promoting effects (Lu et al., 2021a). The authors compared the preventive effects of *M. exotica* and *M. paniculata* against alcohol-induced gastric lesions. MFC effectively attenuated ethanol-HCl-induced gastric diseases by reversing inflammatory development and preventing ethanol-HCl-induced necrosis and apoptosis (Lu et al., 2021b).

6.2 Pharmacokinetics

A novel, fast, and sensitive UPLC–tandem mass spectrometry method with a sample preparation procedure, low limit of quantitation, short run time, and good accuracy was used to easily detect murrayone (**133**) extracted from *M. paniculata* in rat plasma. This method has been successfully applied in pharmacokinetic studies. Zhai et al. (2020) studied Sprague-Dawley rats administered with 20, 50, or 125 mg/kg murrayone intra-gastrically or 20 mg/kg murrayone via intravenous bolus injection. The mean T_{max} values of the relevant pharmacokinetic parameters ranged from 0.75 h to 1 h for all doses, indicating rapid murrayone absorption. The mean $T_{1/2}$ was 3.52–5.97 h for all dose groups, indicating that the rate of murrayone elimination was also rapid. The relatively high Vd/F indicated that murrayone was widely distributed in the body and combined with tissues. The absorption rate of murrayone was high, and the absolute bioavailability of murrayone was 22.72%–37.81% in rats. The exposure level of murrayone was positively correlated with the dose administered, indicating that the *in vivo* pharmacokinetic behavior of murrayone is linear (Zhai et al., 2020).

7 Toxicology

The constituents and extracts of MFC have been studied for their pharmacological activity. However, studies on the potential toxicology of these compounds are limited.

In male and female Swiss mice, acute toxicity was assessed using a single oral dose of the hydroethanolic extract of *M. paniculata* leaves (2,000 and 5,000 mg/kg bw/day). No abnormal signs of toxicity (e.g., piloerection, diarrhea, or alteration in locomotor activity) or death were observed during the 14 days of observation (Menezes et al., 2015). The aqueous extracts of *M. paniculata* leaves against *Artemia salina* were presented as total phenolic compounds. The percentage mortality of brine shrimp increased with the concentration of the aqueous extract of *M. paniculata*, which has been shown to have a significant effect on brine shrimp (Bovornvattanangkul and Jiraungkoorskul, 2016). Liaqat et al. (2018) studied Wistar rats with free access to food and water that were administered with 400 mg/kg volatile oils of *M. paniculata*. The MIC and MBC results showed that the oils of *M. paniculata* were active against Gram-positive strains. Moreover, elevation in packed cell volume and depletion in mean corpuscular volume were observed; therefore, the volatile oils of *M. paniculata* are considered safe for internal use (Liaqat et al., 2018). The half lethal concentration (LC_{50}) and 90% lethal concentration (LC_{90}) values of petroleum ether extract and crude methanol extract from *M. paniculata* leaves were 0.471 ± 0.72 μg/mL and 0.773 ± 0.19 μg/mL, respectively, showing high cytotoxic activity in a brine shrimp lethal test (Mita et al., 2013). Another study showed that the ethanol extract (250 and 500 mg/kg dosages) of *M. paniculata* leaves produced strong anti-nociceptive activity and was toxic to brine shrimp (half lethal dose [LD_{50}] = 32 μg/mL) (Sharker et al., 2009).

Khatun et al. (2014) identified the methanol extract from *M. exotica* leaves using a brine shrimp lethality assay. After 24 h, the LC_{50} and LC_{90} values of the extract were 1.27 μg/mLand 5.09 μg/mL, respectively, indicating cytotoxic effects ($p < 0.01$). The volatile oils of *M. exotica* possessed fumigant toxicity against *Sitophilus zeamais* and *Tribolium castaneum* adults, with LC_{50} values of 8.29 and 6.84 mg/L, respectively. The essential oils also showed contact toxicity against *S. zeamais* and *T. castaneum* adults with LD_{50} values of 11.41 and 20.94 μg/adult, respectively (Li et al., 2010).

8 Conclusion and future perspectives

MFC contains at least 720 components, 404 of which are volatile oils. Crude extracts and their chemical compounds have been shown to exert anti-inflammatory, anti-bacterial and anti-microbial, antitumor, anti-oxidant, anti-diabetic, anti-Alzheimer, and analgesic effects. Flavonoids, coumarins, and volatile oils are the most important bioactive compounds with pharmacological activity.

The compounds of *M. paniculata* and *M. exotica* differ in that flavonoids are the main compounds in *M. paniculata*, whereas coumarins are the main compounds in *M. exotica*. Flavonoid compounds, particularly polymethoxyflavones, exhibit anti-inflammatory, anti-bacterial, anti-microbial, antitumor, and chondroprotective effects. Coumarin compounds, especially prenylated coumarins, exhibit anti-inflammatory, anti-bacterial, anti-microbial, antitumor, potential anti-Alzheimer, chondroprotective, anti-implantation, estrogenic, and anti-hypertensive properties. Studies on volatile oil compounds have primarily focused on their anti-bacterial, anti-microbial and potential anti-Alzheimer effects.

Despite the remarkable outcomes of previous studies on MFC (*M. paniculata* and *M. exotica*), some questions remain, and further research is needed to bridge the current scientific gap. First, although MFC demonstrates considerable pharmacological activity, little is known about the active parts and components, and further research and exploration are warranted. Second, we focused more on the analysis of polymethoxyflavones and coumarins and less on the quality control of MFC. A quality control assessment of MFC is needed to ensure quality. Third, there are many studies on the pharmacological activities of *M. paniculata* and *M. exotica*; however, only two comparative studies on the pharmacodynamics have shown no statistical differences between *M. paniculata* and *M. exotica.*

Meanwhile, in pharmacological studies, most of the studies are limited to *in vitro* cell studies, while *in vivo* studies are rarely involved. So far, only two studies are related to clinical indications, which limits the further clinical use of MFC. In view of these gaps and challenges, we should focus on *in vivo* pharmacological research, the relationship between efficacy and mechanism of action, and activity research on the structure-activity relationship of compounds in the future. Fourth, the antitumor activity of MFC has been described as cytotoxic, but no *in vivo* model is currently available and further *in vivo* model and clinical tumor patient studies are needed. Fifth, there are no systematic reports on the mechanisms of MFC. MFC is mainly used in the treatment of stomach pain, rheumatism, arthralgia, toothache, and tumefaction; however, the underlying mechanisms remain unclear, except for the protective effects on gastric lesions. Volatile oils are the most abundant and promote important insecticidal activity; however, their composition varies markedly depending on their origin. Therefore, there is an urgent need to establish quality standards for MFC.

At present, the phenomenon of "heterogeneous equivalence" is widespread in many multisource traditional Chinese medicines. Therefore, several problems are associated with its clinical application, such as efficacy equivalence and quality control (Lu et al., 2021b). To ensure its efficacy and safety, it is necessary to study the rationality of two source plants, *M. paniculata* and *M. exotica,* used as the same kind of MFC. Therefore, we conducted a comprehensive review of the phytochemistry, pharmacology, pharmacodynamics, pharmacokinetics, and toxicity of *M. paniculata* and *M. exotica*. This systematic review of MFC provides a material and theoretical basis for rational and effective utilization and also provides direction for in-depth research.

In conclusion, although there have been many studies on the phytochemical and pharmacological effects of MFC, there are still many aspects that require further research and control to lay a theoretical foundation for their heterogeneous use.

Author contributions

YQ: Writing–review and editing. LW: Writing–review and editing. NW: Writing–review and editing. SW: Writing–review and editing. XZ: Writing–review and editing. TZ: Writing–review and editing. QJ: Funding acquisition, Writing–review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fphar.2024.1337161/full#supplementary-material

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