Arabian Journal of Chemistry (2022) **15**, 104260

King Saud University

Arabian Journal of Chemistry

www.ksu.edu.sa
www.sciencedirect.com

REVIEW ARTICLE

Genus Chloranthus: A comprehensive review of its phytochemistry, pharmacology, and uses

Yuan-yuan Liu [1], Yu-ze Li [1], Shi-qi Huang, Hua-wei Zhang, Chong Deng, Xiao-mei Song, Dong-dong Zhang [*], Wei Wang [*]

School of Pharmacy, Shaanxi University of Chinese Medicine, Xian Yang, Shaanxi 712046, PR China

Received 30 June 2022; accepted 11 September 2022
Available online 17 September 2022

KEYWORDS

Chloranthus;
Traditional uses;
Chemical constituents;
Pharmacological;
Development and utilization;
Review

Abstract This paper is intended to review advances in the botanical, traditional uses, phytochemical, pharmacological and development and utilization studies of the genus *Chloranthus*. *Chloranthus*, a genus of the family Chloranthaceae, which is mainly distributed in the temperate and tropical regions of Asia, has been used as a folk remedy for swollen boils, snake bites and bruises. Up to now, **418** compounds have been reported from the genus *Chloranthus*, including **383** terpenoids, **4** coumarins, **6** lignans, **2** simple phenylpropanoids, **4** flavonoids, **6** amides, **5** organic acids and some other types of compounds. Among them, the main chemical constituents are sesquiterpenes and their diterpenoids. Modern pharmacological studies have shown that most of the *Chloranthus* plants possessed anticancer, anti-inflammatory, antibacterial, antiviral, and antimalarial activities. As one of the most important genera in China, *Chloranthus* should be paid further attention to gathering information about the pharmacological mechanism and value active compounds. This paper summarized the phytochemistry, pharmacology, and uses of genus *Chloranthus* in order to lay a foundation and provide reference for the follow-up research and wide application of the genus.

1. Introduction

The genus *Chloranthus* belongs to the family Chloranthaceae, and consists of 14 species in the world (Chloranthus Swartz in Flora of China @ efloras.org" eFlora). They are mainly distributed in temperate and tropical Asia (Lu et al., 2020). Among them, 13 species are reported in southwestern, southern, eastern and central China (Chloranthus Swartz in Flora of China @ efloras.org eFlora). As the country with the abundant resources of the genus *Chloranthus*, China has a long history of application of the genus *Chloranthus* plants. In traditional Chinese medicine (TCM) theory, their effects are defined as dispersing cold, dispelling wind and relieving pain, removing blood stasis and detoxifying (Zhang, 2016). According to the Dictionary of Traditional Chinese Medicine, Fujian Folk Herbal Medicine, Jiangxi Herbal Medicine and other local herbal standards, most of this genus plants can be

* Corresponding author at: School of Pharmacy, Shaanxi University of Chinese Medicine, No.1, Middle Section of Century Avenue, Qindu District, Xianyang, Shaanxi Province 712046, PR China (D.D. Zhang). School of Pharmacy, Shaanxi University of Chinese Medicine, No.1, Middle Section of Century Avenue, Qindu District, Xianyang, Shaanxi Province 712046, PR China (W. Wang).
E-mail addresses: zhangnatprod@163.com (D.-d. Zhang), 2051003@sntcm.edu.cn (W. Wang).
[1] These authors contributed equally: Yuan-yuan Liu, Yu-ze Li.

Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.arabjc.2022.104260
1878-5352 © 2022 The Author(s). Published by Elsevier B.V. on behalf of King Saud University.

used as folk herbal medicine to treat wind-cold cough, bruises and injuries, rheumatism and lumbago.

Due to the novelty of the chemical structure and the richness of biological activities, a large number of scholars at home and abroad have conducted in-depth studies on genus *Chloranthus*. Modern pharmacology has shown that this genus has excellent pharmacological activities in anticancer, antibacterial, anti-inflammatory and neuroprotective effect (Chen et al., 2021c; Huang et al., 2020). Phytochemical studies discovered the presence of sesquiterpenes, coumarins, lignans, simple phenylpropanoids, flavonoids and amides from this genus. Especially sesquiterpenes dimer macrocyclic compounds possess significant antitumor activity. Such as the types of chloranthalactone and shizukanolide, studies have shown that this class of compounds showed significant activity against A549 cells, human glioma U87 cells, and hepatocellular carcinoma SMMC-7721 cells (Zhang et al., 2021). It has a broad prospect in developing drugs against breast cancer and liver cancer. Eudesmane sesquiterpenes isolated from the *C. fortunei*, such as fortunilide A (**96**), sarglabolide J (**100**), chloraholide D (**103**), most of which exhibited antimalarial activity, which was comparable to the potency and selectivity index values of artemisinin (Zhou et al., 2017a).

This review summarized the research advancement of this genus in botanical, traditional uses, phytochemical, pharmacological and development and utilization studies at the past 30 years, in order to provide reference for further applications and research of the genus *Chloranthus*.

2. Search strategy

Comprehensive research and analysis of previously published literature were conducted for studies on the traditional use, distribution, chemistry, and pharmacological properties of the genus *Chloranthus*. The search was conducted using databases such as Sciencedirect, SciFinder, Medline PubMed, Google Scholar, Baidu Scholar, and CNKI by using the keywords such as *Chloranthus*, *Chloranthus. japonicus*, *Chloranthus. henryi* and *Chloranthus multistachys*. Part of the analyzed studies was got by a manual search of articles in the reference lists of the included studies. The chemical structures were drawn using ChemDraw Professional 20.0 software.

3. Botany, description and distribution

To date, about 13 species of the genus *Chloranthus* have been reported in China, inculding *Chloranthus elatior* Link, *Chloranthus spicatus* (Thunb.) Makino, *Chloranthus angustifolius* Oliv, *Chloranthus japonicus* Sieb, *Chloranthus fortunei* (A. Gray) Solms-Laub, *Chloranthus holostegius* (Hand.-Mazz.) Pei et Shan, *Chloranthus anhuiensis* K. F. Wu, *Chloranthus tianmushanensis* K. F. Wu, *Chloranthus serratus* (Thunb.) Roem. et Schult, *Chloranthus multistachys* Pei, *Chloranthus henryi* Hemsl, *Chloranthus sessilifolius* K. F. Wu and *Chloranthus oldhamii* Solms Laubach. Among them, about eight species of the genus are available for medicinal use in China. Among which *C. japonicus*, *C.* serratus, *C. multistachys* and *C. henryi* are extensively studied (*Chloranthus* in Flora of China @ efloras.org, 2020). Most of the plants in the genus commonly grow on mountain slopes in the forest understory and gully side grasses. They are subshrubs or perennial herbs. Leaves opposite or whorled, serrate; stipules tiny; petioles connected by a transverse ridge on stem. Inflorescences in spikes or branched, arranged in panicles, terminal or axillary. Flowers small, bisexual; perianth absent. Stamens usually 3, rarely 1, on 1 side of apical part of ovary; basal part of connective confluent, or free and connected or overlapped at base, ovoid or lanceolate, sometimes elongated to linear; anthers 1-or 2-loculed; if stamens 3, central anther 2-loculed or occasionally absent, lateral anthers 1-loculed, if stamen 1, anther 2-loculed. Ovary 1-loculed; ovule 1, pendulous, orthotropous; style usually absent, rarely present; stigma truncate or parted. Drupes globose, obovoid, or pyriform (*Chloranthus* in Flora of China @ efloras.org, 2020).

4. Traditional uses

Most of plants in the genus *Chloranthus* are used as folk herbal medicine and have a long history of medicinal use. It has the medicinal potencies of dispelling wind and cold, strengthening bones and tendons, activating blood circulation and dispersing blood stasis, removing swelling and relieving pain, and are commonly used to treat bruises, swelling and pain, rheumatic arthritis, boils, sores and swellings in the folk. Moreover, the resources of this genus are rich in species and reserves, and have a high value for development and utilization. In this paper, we have collected proprietary Chinese patent medicines or preparations on the genus *Chloranthus*, which include empirical prescriptions for folk use, in-hospital preparations and marketed drugs. (Table 3).

5. Phytochemistry and Pharmacology

Literature investigation revealed that *Chloranthus* include terpenoids, coumarins, amides and phenylpropanoids, among which sesquiterpenoids and diterpenoids are predominant structural types and active components. Up to now, **418** compounds have been reported from the genus *Chloranthus*, including **383** terpenoids, **4** coumarins, **6** lignans, **2** simple phenylpropanoids, **4** flavonoids, **5** organic acids, **6** amides, and **8** other compounds. Their specific compound names, structures and references are shown in Table 1 and Figs. 1–19.

5.1. Sesquiterpenes

Sesquiterpenoids are the main types of chemical constituents in the genus *Chloranthus*, as well as its main active ingredients. At present, **286** sesquiterpenes were isolated from this genus, mainly distributed in *C. japonicus*, *C. fortunei*, *C. holostegius* and *C. spicatus* plants, and the structural types include lindenane sesquiterpenes and their polymers (**1**–**161**), eudesmane sesquiterpenes (**162**–**226**), germacrane sesquiterpenes (**227**–**243**), cadinane sesquiterpenes (**244**–**256**), guaiane sesquiterpenes (**257**–**266**), acorane sesquiterpenes (**267**–**270**), eremophilane sesquiterpenes (**271**–**277**), oplopanone sesquiterpenes (**278**), drimane sesquiterpene (**279**), elemene sesquiterpene (**280**–**281**), brasilane sesquiterpene (**282**) and others sesquiterpene (Wang et al., 2015a; Xu, 2013).

Among them, lindenane sesquiterpenes, sesquiterpenes dimers and eudesmane sesquiterpenes are the most abundant. In particular, sesquiterpene dimers, as indicator components of this genus, which have diverse structural types and significant pharmacological activities (Ma et al., 2020). The specific compound names and structures are shown in Table 1 and Figs. 1–9.

Table 1 Chemical Constituents of the *Genus* Chloranthus.

No.	Name	Plant	Bioactivity	Part	References
Lindenane Sesquiterpenes and Their Polymers					
1	shizukanolide	E	Antitumor activity	Aerial	(Kawabata et al., 1981)
2	chloranthalactone A	E	Antitumor activity	Aerial	(Uchida et al., 1980) (Gong et al., 2021)
3	yinxiancaoside A	E	Antitumor activity	Whole	(Kuang et al., 2008)
4	chloranoside A	E		Whole	(Kuang et al., 2008)
5	chloranthalactone B	E	Antitumor activity	Whole	(Uchida et al., 1980) (Gong et al., 2021)
6	chloranthalactone C	EF		Whole	(Uchida et al., 1980)
7	chloranthalactone D	E		Whole	(Uchida et al., 1980)
8	chloranthalactone E	E		Whole	(Uchida et al., 1980)
9	9-hydroxy heterogorgiolide	E		Aerial	(Uchida et al., 1980)
10	chlojaponilactone B	E		Whole	(Yan et al., 2013)
11	chlojaponilactone C	E		Whole	(Yan et al., 2013)
12	chlojaponilactone D	E		Whole	(Yan et al., 2013)
13	chlorajapolide C	E		Whole	(Yan et al., 2013)
14	chlojaponilactones E	E		Whole	(Yan et al., 2013)
15	chlorajapolides F	E		Aerial	(Zhang et al., 2012a)
16	chlorajapolides G	E		Aerial	(Zhang et al., 2012a)
17	chlorajapolides H	E		Aerial	(Zhang et al., 2012a)
18	chlojaponilactones F	E		Whole	(Li et al., 2016)
19	chlojaponilactones H	E		Whole	(Li et al., 2016)
20	chlojaponilactones G	E		Whole	(Li et al., 2016)
21	chlojaponilactones I	E		Whole	(Li et al., 2016)
22	chlorajapolides A	E	Antitumor activity	Whole	(Wang et al., 2011)
23	chlorajapolides B	E	Antitumor activity	Whole	(Wang et al., 2011)
24	chlorajapolides C	E	Antitumor activity	Whole	(Wang et al., 2011)
25	chlorajapolides D	E	Antitumor activity	Whole	(Wang et al., 2011)
26	chlorajapolides E	E	Antitumor activity	Whole	(Wang et al., 2011)
27	chlorajaposide	E		Whole	(Wang et al., 2011)
28	chloranthalactone A	E		Roots	(Uchida et al., 1980)
29	shizukanolide C	F		Aerial	(Fang, 2011)
30	shizukanolide H	EFH	Neuroprotective activity	Whole	(Fang, 2011)
31	shizukanolide G	F	Anti-inflammatory activity	Aerial	(Wang et al., 2009) (Gong et al., 2021)
32	shizukanolide F	F		Aerial	(Wang et al., 2009)
33	lindenanolide H	G		Whole	(Kim et al., 2011)
34	(1*R*,3*S*,5*S*,8*S*,10*R*)-14-Acetylshizukanolide	H		Whole	(Xu et al., 2018)
35	isoshizukanolide	F		Whole	(Zhou et al., 2017b)
36	spicachlorantins G	C	Antiinflammatory activity	Roots	(Kim et al., 2011)
37	spicachlorantins H	C		Roots	(Kim et al., 2011)
38	spicachlorantins I	C		Roots	(Kim et al., 2011)
39	spicachlorantins A	C		Roots	(Kim et al., 2011)
40	spicachlorantins B	C	Antiinflammatory activity	Roots	(Kim et al., 2011)
41	spicachlorantins C	C		Roots	(Kim et al., 2011)
42	spicachlorantins D	C		Roots	(Kim et al., 2011)
43	chloramultilide A	CDF	Antineuroinflammatory activity Antimicrobial activity	Roots	(Kim et al., 2011) (Yang et al., 2014)
44	spicachlorantins E	C		Roots	(Kim et al., 2011)
45	spicachlorantins F	C		Roots	(Kim et al., 2011)
46	chloramultilide B	C	Antimicrobial activity	Whole	(Xu et al., 2007)
47	chloramultilide C	C	Antimicrobial activity	Whole	(Xu et al., 2007)
48	chloramultilide D	C		Whole	(Xu et al., 2007)
49	trichloranoids A	C	Antimalarial activity	Whole	(Zhou et al., 2021)
50	trichloranoids B	C		Whole	(Zhou et al., 2021)
51	trichloranoids C	C		Whole	(Zhou et al., 2021)
52	trichloranoids D	C	Antimalarial activity	Whole	(Zhou et al., 2021)
53	analogue	C	Antimalarial activity	Whole	(Zhou et al., 2021)
54	chlojapolides A	DE	Antiinflammatory activity	Whole	(Guo et al., 2016)
55	chlojapolides B	DE		Whole	(Guo et al., 2016)
56	chlojapolides C	DE		Whole	(Guo et al., 2016)
57	chlojapolides D	DE		Whole	(Guo et al., 2016)
58	chlojapolides E	DE		Whole	(Guo et al., 2016)

(*continued on next page*)

Table 1 (*continued*)

No.	Name	Plant	Bioactivity	Part	References
59	chlojapolides F	DE		Whole	(Guo et al., 2016)
60	shizukaol A	DEF	Antiinflammatory activity	Whole	(Guo et al., 2016) (Gong et al., 2021)
61	shizukaol A acetate	E		Roots	(Kawabata et al., 1990)
62	chlojapolides G	DE		Aerial	(Guo et al., 2016)
63	chlojapolides H	DE		Aerial	(Guo et al., 2016)
64	spicachlorantin H	DE		Aerial	(Guo et al., 2016)
65	shizukaol B	CDEFJ	Antitumor activity Antinflammatory activity Anti-viral Activity	Whole	(Zhang et al., 2012a) (Fang et al., 2011)
66	shizukaol F	DEFGJ	Antitumor activity HIV-1 RNase H inhibitor Anti-viral Activity	Whole	(Guo et al., 2016) (Xu, 2016) (Fang et al., 2011)
67	shizukaol G	DEF	Anti-inflammatory Anti-tumor activity	Aerial	(Guo et al., 2016)
68	shizukaol C	CDEFG	Anti-inflammatory activity Insecticidal activity Anti-tumor activity Anti-viral Activity	Aerial	(Zhang et al., 2012a) (Guo et al., 2016) (Gong et al., 2021) (Shi et al., 2015) (Fang, 2011)
69	shizukaol D	DEFJ	Anti-inflammatory activity Anti-tumor activity Hypoglycemic Activity	Aerial	(Guo et al., 2016) (Shi et al., 2015) (Zhang et al., 2012) (Hu et al., 2017)
70	shizukaol H	CE	Anti-viral Activity	Aerial	(Fang, 2011) (Fang et al., 2011)
71	chloramultilide B	DEF GJ	Anti-bacterial activity	Aerial	(Fang, 2011)
72	spicachlorantin B	DEF	Anti-neuroinflammatory activity	Aerial	(Zhou et al., 2017b)
73	chlorahololide C	DEF	Inhibiting K^+ channels	Aerial	(Guo et al., 2016) (Yang et al., 2008)
74	spicachlorantins J	C		Roots	(Guo et al., 2016)
75	henriol A	D	Antimicrobial activity	Aerial	(Xu, 2016) (Yang et al., 2014)
76	spicachlorantin A	DJ	Antimicrobial activity	Roots	(Yang et al., 2014)
77	tianmushanol	DJI	Inhibiting TYR activity Antimicrobial activity	Roots	(Yang et al., 2014)
78	8-O-methyltianmushanol	DIJ	Inhibiting TYR activity Antimicrobial activity	Roots	(Yang et al., 2014) (Wu et al., 2008)
79	chlojapolactone A	E	Anti-inflamma tory activity	Whole	(Guo et al., 2015)
80	multistalide C	E	Insecticidal activity	Whole	(Shi et al., 2015)
81	chlorajaponilide I.	E		Whole	(Zhuo et al., 2017)
82	spicachlorantin D	EF		Whole	(Zhuo et al., 2017)
83	chlorajaponilide C	EF	Antimalarial activity	Whole	(Zhuo et al., 2017) (Zhou et al., 2017b)
84	japonicones A	E		Whole	(Yan et al., 2019)
85	japonicones B	E		Whole	(Yan et al., 2019)
86	japonicones C	E		Whole	(Yan et al., 2019)
87	chlorajaponol	E		Whole	(Wang et al., 2011)
88	chloranthadimeric acid acetate	E		Roots	(Uchida et al., 1980)
89	chlorajaponilides A	E		Whole	(Fang, 2011)
90	chlorajaponilides B	E		Whole	(Fang, 2011)
91	chlorajaponilides D	E		Whole	(Fang, 2011)
92	chlorajaponilides E	E		Whole	(Fang, 2011)
93	cloramultilide C	E		Whole	(Fang, 2011)
94	yinxiancaol	EFG		Whole	(Fang, 2011)
95	chlorafortulide	F		Whole	(Zhang et al., 2012a)
96	fortunilide A	F	Antimalarial activity	Whole	(Zhou et al., 2017b)
97	fortunilide B	F		Whole	(Zhou et al., 2017b)
98	fortunilide C	F		Whole	(Zhou et al., 2017b)
99	sarglabolide I	F		Whole	(Zhou et al., 2017b)
100	sarglabolide J	F	Antimalarial activity	Whole	(Zhou et al., 2017b)
101	shizukaol K	F		Whole	(Zhou et al., 2017b)
102	shizukaol M	F		Whole	(Zhou et al., 2017b)

Table 1 (*continued*)

No.	Name	Plant	Bioactivity	Part	References
103	chloraholide D	FGJ	Inhibiting K^+ channels	Whole	(Zhou et al., 2017b) (Yang et al., 2008)
104	shizukaol N	F		Whole	(Zhou et al., 2017b)
105	sarcandrolide B	F		Whole	(Zhou et al., 2017b)
106	sarcandrolide A	F		Whole	(Zhou et al., 2017b)
107	sarcandrolide J	F		Whole	(Zhou et al., 2017b)
108	sarcandrolide E	F		Whole	(Zhou et al., 2017b)
109	fortunilides D	F		Whole	(Zhou et al., 2017b)
110	fortunilides E	F		Whole	(Zhou et al., 2017b)
111	fortunilides F	F		Whole	(Zhou et al., 2017b)
112	fortunilides G	F		Whole	(Zhou et al., 2017b)
113	fortunilides H	F		Whole	(Zhou et al., 2017b)
114	fortunilides I	F	Anti-inflammatory activity	Whole	(Zhou et al., 2017b)
115	fortunilides J	F		Whole	(Zhou et al., 2017b)
116	fortunilides K	F		Whole	(Zhou et al., 2017b)
117	fortunilides L	F		Whole	(Zhou et al., 2017b)
118	fortunoid A	F	Antimalarial activities	Whole	(Zhou et al., 2017b)
119	fortunoid B	F	Antimalarial activities	Whole	(Zhou et al., 2017b)
120	fortunoid C	F		Aerial	(Zhou et al., 2017b)
121	shizukaol P	F		Aerial	(Zhou et al., 2017b)
122	9-O-β-glucopyranosylcycloshizukaol A	F		Aerial	(Wang et al., 2009)
123	cycloshizulkaol A	F	Anti-tumor activity	Aerial	(Wang et al., 2009)
124	shizukaol L	F		Roots	(Gong et al., 2021)
125	shizukaol O	F	Anti-inflammatory activity Anti-tumor activity	Roots	(Gong et al., 2021) (Zhang et al., 2012a)
126	cihoranhtaol A	F		Whole	(Luo et al., 2009)
127	chioranthaol B	F		Whole	(Luo et al., 2009)
128	chioranthaol C	F		Whole	(Luo et al., 2009)
129	chloraholide G	G		Whole	(Xu, 2016)
130	chloraholide B	G	Inhibiting K^+ channels	Whole	(Xu, 2016)
131	chloramultiol D	G		Whole	(Xu, 2016)
132	chloraholide F	G	Inhibiting K^+ channels	Whole	(Xu, 2016) (Yang et al., 2008)
133	sarcandrolide D	G		Whole	(Xu, 2016)
134	henriol C	GJ		Roots	(Xu, 2016)
135	chlotrichenes A	G		Roots	(Chi et al., 2019)
136	chlotrichenes B	G	Anti-tumor activity	Roots	(Chi et al., 2019)
137	chololactone A	G	Anti-inflammatory activity	Roots	(Shen et al., 2017)
138	chololactone B	G	Anti-inflammatory activity	Roots	(Shen et al., 2017)
139	chololactone C	G	Anti-inflammatory activity	Roots	(Shen et al., 2017)
140	chololactone D	G	Anti-inflammatory activity	Roots	(Shen et al., 2017)
141	chololactone E	G	Anti-inflammatory activity	Roots	(Shen et al., 2017)
142	chololactone F	G	Anti-inflammatory activity	Roots	(Shen et al., 2017)
143	chololactone G	G	Anti-inflammatory activity	Roots	(Shen et al., 2017)
144	chololactone H	G	Anti-inflammatory activity	Roots	(Shen et al., 2017)
145	multistalides A	G		Whole	(Zhang et al., 2010)
146	multistalides B	G		Whole	(Zhang et al., 2010)
147	chloraserrtone A	J		Roots	(Bai et al., 2019)
148	chloraholide A	F	Inhibiting K^+ channels	Whole	(Zhou et al., 2017b)
149	chloraholide E	F	Inhibiting K^+ channels	Whole	(Zhou et al., 2017b) (Yang et al., 2008)
150	shizukaol	F		Whole	(Wang et al., 2009)
151	13′-acetylshizukaol C	F		Whole	(Gong et al., 2021)
152	chloramuhilide B	F		Whole	(Gong et al., 2021)
153	chlorahupetone A	L	Antitumor activity	Whole	(Zhang et al., 2021)
154	chlorahupetone B	L		Whole	(Zhang et al., 2021)
155	chlorahupetone C	L		Whole	(Zhang et al., 2021)
156	chlorahupetone D	L		Whole	(Zhang et al., 2021)
157	chlorahupetone E	L		Whole	(Zhang et al., 2021)
158	chlorahupetone F	L		Whole	(Zhang et al., 2021)
159	chlorahupetone G	L	Antitumor activity	Whole	(Zhang et al., 2021)
160	chlorahupetone H	L	Antitumor activity	Whole	(Zhang et al., 2021)
161	chlorahupetone I	L	Antitumor activity	Whole	(Zhang et al., 2021)

(*continued on next page*)

Table 1 (*continued*)

No.	Name	Plant	Bioactivity	Part	References
Eudesmane Sesquiterpenes					
162	serralactones A	J		Whole	(Teng et al., 2010)
163	serralactones B	J		Whole	(Teng et al., 2010)
164	serralactones C	J		Whole	(Teng et al., 2010)
165	serralactones D	J		Whole	(Teng et al., 2010)
166	neolitacumone B	J		Whole	(Teng et al., 2010)
167	1β,4β-dihydroxy-5α,8β(H)-eudesm-7(11)Z-en-8,12-olide	C		Aerial	(Yang et al., 2007a)
168	1β,4α-dihydroxy-5α,8β(H)-eudesm-7(11)Z-en-8,12-olide	C		Aerial	(Yang et al., 2007a)
169	homalomenol A	C		Aerial	(Yang et al., 2007a)
170	oplodiol	C		Aerial	(Yang et al., 2007a)
171	chlospicates A	C		Whole	(Yang et al., 2007a)
172	chlospicates B	C		Whole	(Yang et al., 2007a)
173	codonolactone	L		Whole	(Wang et al., 2014a)
174	5-eudesmene-1β,4α-diol	C		Whole	(Yang et al., 2007a)
175	4α,8β-dihydroxyeudesm-7(11)-en-8,12-olide	D	Antimicrobial activity	Roots	(Wang et al., 2014a)
176	4β,7β,11-enantioeudesmantriol	D		Roots	(Xu, 2016)
177	9α-hydroxycurcolonol	D	Antimicrobial activity	Roots	(Yang et al., 2014) (Wang et al., 2014a)
178	3α-hydroxy-4-deoxy-5-dehydrocurcolonol	D	Antimicrobial activity	Roots	(Yang et al., 2014) (Wang et al., 2014a)
179	9α-curcolonol	DFJ	Antimicrobial activity	Roots	(Yang et al., 2014) (Wang et al., 2014a)
180	4α-hydroxy5α,8β(H)-eudesm-7(11)-en-8,12-olide monohydrate	E		Whole	(Lu et al., 2015)
181	shizukafuranol	E		Whole	(Kawabata et al., 1984)
182	shizukolidol	E		Whole	(Kawabata et al., 1984)
183	1β,10β-dihydroxy-eremophil-7(11),8-dien-12,8-olide	E		Whole	(Lu et al., 2016)
184	8,12-epoxy-1β-hydroxyeudesm-3,7,11-trien-9-one	E		Whole	(Lu et al., 2016)
185	4α-hydroxy-5α(H)-8β-methoxy-eudesm-7(11)-en-12,8-olide	E		Whole	(Lu et al., 2016)
186	CJ-01	E	Antimicrobial activity	Whole	(Yim et al., 2008)
187	chlojaponilactone A	E		Whole	(Fang, 2011)
188	tsoongianolide D	E		Whole	(Yan et al., 2013)
189	tsoongianolide E	E		Whole	(Yan et al., 2013)
190	(10α)-10-hydroxy-1-oxoeremophila-7(11),8-dien-12,8-olide	E		Whole	(Yan et al., 2013)
191	chlorajapolides I	E		Aerial	(Zhang et al., 2012a)
192	chlojaponols A	E		Whole	(Li et al., 2016)
193	chlojaponols B	E	Antimicrobial activity	Whole	(Li et al., 2016)
194	chlorajapotriol	E		Whole	(Zhuo et al., 2017)
195	chloraeudolide	E	Antitumor activity	Whole	(Wang et al., 2011)
196	chlorantene B	E J		Whole	(Yuan et al., 2008)
197	chlorantene C	EJ	Neuroprotective activity	Whole	(Yuan et al., 2008) (Chen et al., 2021a)
198	chlorantene D	EJ	Antibacterial activity	Whole	(Yuan et al., 2008)
199	chlorantene G	E	Antibacterial activity	Whole	(Yuan et al., 2008)
200	atractylenolactam	F		Whole	(Wang et al., 2008)
201	curcodione	F	Neuroprotective activity	Whole	(Chen et al., 2021a)
202	1β,8β-dihydroxyeudesman −3,7(11)-dien-8α,12-olide	G		Whole	(Xu, 2016)
203	4(15)-eudesmene-1β,7α,11-triol	G		Whole	(Xu, 2016)
204	3,4,8α-trimethyl-4α,7,8,8α-tetrahydro-4α-naphto[2,3-*b*]furan-9-one	G		Whole	(Zhan et al., 2021)
205	(5*S*,10*S*)-9-Oxo-atractylon	H		Whole	(Xu et al., 2018)
206	chlorantene J	H		Whole	(Xu et al., 2018)
207	(7*R*,10*S*)-7-hydroxyeudesm-4-en-3,6-dione	H		Whole	(Xu et al., 2018)
208	1α-hydroxy-4αH,5αH-eudesma-7,11-diene-6,9-dione	H		Whole	(Xu et al., 2018)
209	4α-hydroxy-8,12-epoxyeudesma-7,11-diene-1,6-	H		Whole	(Xu et al., 2018)

Table 1 (*continued*)

No.	Name	Plant	Bioactivity	Part	References
	dione				
210	(3*R*)-3-hydroxyatractylenolide III	H		Roots	(Xu et al., 2010)
211	8β-hydroxy-1-oxoeudesma-3,7(11)-dien-12,8α-olide	H		Roots	(Xu et al., 2010)
212	chlorantene M	J		Whole	(Huang et al., 2021)
213	5α,7α(H)-6,8-cycloeudesma-1β,4β-diol	C		Aerial	(Yang et al., 2007a)
214	5α-(cinnamoyloxy)-8,12-epoxy-3-methoxy-7βH,8αH-eudesma-3,11-dien-6-one	E		Aerial	(Fang, 2011)
215	8β-(cinnamoyloxy)eudesma-4(14),7(11)-dien-12,8-olide	E		Aerial	(Fang, 2011)
216	8,12-epoxy-1α-hydroxy-4αH,5αH-eudesma-7,11-diene-6,9-dione	E		Aerial	(Fang, 2011)
217	8,12-epoxy-1α-methoxy-4αH,5αH-eudesma-7,11-diene-6,9-dione	E		Aerial	(Fang, 2011)
218	sarcaglaboside A	E	Hepatoprotective activity	Aerial	(Fang, 2011) (Li et al., 2006)
219	chlorajapodiolide	E		Whole	(Fang, 2011)
220	chloranholide A	G		Whole	(Zhan et al., 2021)
221	1α-methoxy-8,12-epoxyeudesma-4,7,11-trien-6-one	L		Steem	(Wu et al., 2008)
222	11,12,13-trihydroxyeudesma-4(15),8-dien-9-one	L		Steem	(Wu et al., 2008)
223	1α-hydroxy-8,12-epoxyeudesma-4,7,11-triene-3,6-dione	L		Roots	(Gan et al., 2009)
224	curcolone	L		Roots	(Gan et al., 2009)
225	endesm-4(15)-en-7α,11-diol	L		Roots	(Gan et al., 2009)
226	1α-hydroxy-8,12-epoxyeudesma-4,7,11-triene-6,9-dione	L	Antitumor activity	Whole	(Wu et al., 2006)
Germacrane Sesquiterpenes					
227	germacra-5*E*,10(14)-dien-1β,4β-diol	C		Whole	(Yang et al., 2012)
228	4α,5α-epoxy1(10),7(11)-dienegermacr-8α,12-olide	C		Whole	(Yang et al., 2012)
229	furanodienone	DE		Roots	(Yang et al., 2014)
230	glechomanolid	E		Aerial	(Kawabata et al., 1981)
231	isofuranodiene	E		Aerial	(Kawabata et al., 1981)
232	chlorantene E	EJ	Anti-bacterial activity	Whole	(Yuan et al., 2008)
233	chloranthatone	F		Roots	(Wang et al., 2008)
234	zederone	F	Neuroprotective activity	Whole	(Chen et al., 2021a)
235	(1*E*,4*Z*)-8-hydroxy-6-oxogermacra-1(10),4,7(11)-trieno-12,8-lactone	F	Neuroprotective activity	Whole	(Wu et al., 2008) (Chen et al., 2021a)
236	8-methoxy-6-oxogermacra-1(10),4,7(11)-trieno-12,8-lactone	L		Steem	(Wu et al., 2008)
237	zederone epoxide	F	Antitumor activity Anti-neuroinflammatory activity Neuroprotective activity	Whole	(Wang et al., 2014a) (Chen et al., 2021a)
238	4β,5α-dihydroxy-10(β)H-8,12-epoxygermacra-7,11-diene-9-one	G		Whole	(Xu, 2016)
239	curcuzederone	H		Whole	(Xu et al., 2018)
240	15-hydroxy-11βH-8-oxogermacra-1(10),4-dieno-12,6α-lactone	L		Steem	(Wu et al., 2008)
241	(1*S*,4*S*,5*S*,10*S*)-1,10:4,5-diepoxygermacrone	L		Whole	(Wang et al., 2014a)
242	chlogermacrone A	L		Roots	(Chen et al., 2020)
243	chlogermacrone C	L	Neuroprotective effects activity	Roots	(Chen et al., 2020)
Cadinane Sesquiterpenes					
244	(7*R*,9*S*,10*R*)-3,9-di-hidroxicalameneno	G		Whole	(Xu, 2016)
245	chloranholide B	G		Whole	(Zhan et al., 2021)
246	chloranholide C	G		Whole	(Zhan et al., 2021)
247	chloranholide D	G	Anti-inflammatory activity	Whole	(Zhan et al., 2021)
248	phacadinane E	H		Whole	(Xu et al., 2018)
249	chlomultin C	H		Whole	(Xu et al., 2018)
250	chlorantene N	K		Whole	(Huang et al., 2021)
251	(4α)-8-hydroxy-12-norcardina-6,8,10-trien-11-one	L		Whole	(Wang et al., 2014a)
252	(4α,11β)-8,11-dihydroxycadina-6,8,10-trien-12-	L		Whole	(Wang et al., 2014a)

(*continued on next page*)

Table 1 (*continued*)

No.	Name	Plant	Bioactivity	Part	References
	oic acid g-lactone				
253	4-epimer	L		Whole	(Wang et al., 2014b)
254	(8α)-6,8-dihydroxycadina-7(11),10(15)-dien-12-oic acid g-lactone1)	L	Anti-tumor activity	Steem	(Wu et al., 2007)
255	tanapraetenolide	L		Steem	(Wu et al., 2007)
256	dayejijiol	L	Anti-tumor activitity	Whole	(Wu et al., 2006)
Guaiane Sesquiterpenes					
257	(1*R*,4*S*,5*R*,8*S*,10*S*)-Zedoalactone A	K		Whole	(Liu et al., 2013)
258	multistalactone D	K		Whole	(Liu et al., 2013)
259	multistalactone E	K		Whole	(Liu et al., 2013)
260	multistalactone F	K		Whole	(Liu et al., 2013)
261	chlospicate D	C		Whole	(Yang et al., 2012)
262	chloraniolide A	H		Whole	(Xu et al., 2010)
263	chlospicates C	C		Whole	(Yang et al., 2012)
264	chlohenriol A	L	Neuroprotective activitity	Roots	(Chen et al., 2021c)
265	chlohenriol B	L	Neuroprotective activitity	Roots	(Chen et al., 2021c)
266	chlohenriol C	L	Neuroprotective activitity	Roots	(Chen et al., 2021c)
Acorane Sesquiterpenes					
267	shizuka-acoradienol	EF		Roots	(Kawabata et al., 1984)
268	spiro[4.5]dec-6-ene-8α,9β,15α-triol,4β-methyl-1α-isopropyl	G		Whole	(Xu, 2016)
269	Spiro[4.5]dec-6-ene-8β,9β,15α-triol,4β-methyl-1α-isopropyl	G		Whole	(Xu, 2016)
270	8-desmethylacor-6,9-dien-8-one-3α-ol	G		Whole	(Xu, 2016)
Eremophilane Sesquiterpenes					
271	(3*R*,4S,5*R*,10*S*,11*S*)-3-hydroxy-8-oxo-6-eremophilen-12-oic acid	H		Leaves	(Wu et al., 2010)
272	Anhuienol	H		Leaves	(Wu et al., 2010)
273	(3*R*,4*S*,5*R*,6*R*,8*R*,10*S*)-3,6,8-trihydroxy-7(11)-eremophilen-12,8-olide	H		Leaves	(Wu et al., 2010)
274	3*R*,6*R*-dihydroxy-8αH-7(11)-eremophilen-12,8-olide	H		Leaves	(Wu et al., 2010)
275	anhuienoside A	H		Leaves	(Wu et al., 2010)
276	6αH,8αH-7(11)-eremophilen-12,8:15,6-diolide	H		Leaves	(Wu et al., 2010)
277	(7α)-8-oxoeudesm-4(14)-en-12-oic acid	L		Leaves	(Wu et al., 2010)
Oplopanone Sesquiterpenes					
278	oplopanone	C		Aerial	(Yang et al., 2007a)
Drimane Sesquiterpene					
279	11- hydroxydrim-8,12-en-14-oic acid	L		Whole	(Gan et al., 2009)
Elemene Sesquiterpene					
280	curzerenone	F	Neuroprotective activity	Whole	(Chen et al., 2021a)
281	isogermafurenolide	H		Whole	(Xu et al., 2018)
Brasilane Sesquiterpene					
282	chlospicates E	C		Whole	(Yang et al., 2012)
Others Sesquiterpene					
283	chloranholides E	G		Whole	(Zhan et al., 2021)
284	chlorantolide A	H		Whole	(Xu et al., 2018)
285	(7*S*,1(10)Z)-4,5-secoguaia-1(10),11-diene-4,5-dione	L		Whole	(Wang et al., 2014b)
286	chlogermacrone B	L		Roots	(Chen et al., 2020)
Monoterpenes					
287	pressafonin	D		Roots	(Wang et al., 2014a)
288	(3*R*,4*S*,6*R*)- p-menth-1-en-3,6-diol	E		Whole	(Lu et al., 2016)
289	(*R*)-p-menth-1-en-4,7-diol	E		Whole	(Lu et al., 2016)
290	(–) loliolide	F		Whole	(Chen et al., 2021a)
Diterpenoids					
291	13-epitorulosol	FJ		Whole	(Chen et al., 2019)
292	(12*R*,13*E*)-15-(acetoxy)-12-hydroxylabda-8(20),13-dien-19-oic acid	H		Roots	(Xu et al., 2010)
293	(12*S*,13*E*)-15-(acetoxy)-12-dihydroxylabda-8(20),13-dien-19-oic acid	H		Roots	(Xu et al., 2010)
294	12*R*,13*S*-dihydroxylabda-8(17),14-dien-19-oic acid	J		Roots	(Chen et al., 2019)

Table 1 (*continued*)

No.	Name	Plant	Bioactivity	Part	References
295	henrilabdane A	J		Roots	(Chen et al., 2019)
296	henrilabdane C	J		Roots	(Chen et al., 2019)
297	12*S*,15-dihydroxylabda-8(17),13*E*-dien-19-oic acid	J		Roots	(Chen et al., 2019)
298	henrilabdane B	J		Roots	(Chen et al., 2019)
299	12,15-expoxylabda-8(17),13-dien-19-oic acid	J		Roots	(Chen et al., 2019)
300	serralabdanes A	J	Anti-inflammatory activity	Whole	(Zhang et al., 2013)
301	serralabdanes B	J	Anti-inflammatory activity	Whole	(Zhang et al., 2013)
302	serralabdanes C	J	Anti-inflammatory activity	Whole	(Zhang et al., 2013)
303	serralabdanes D	J	Anti-inflammatory activity	Whole	(Zhang et al., 2013)
304	serralabdanes E	J	Anti-inflammatory activity	Whole	(Zhang et al., 2013)
305	*ent*-17-hydroxyl-16-methoxyl-kauran-3-one	K		Whole	(Luo et al., 2014)
306	*ent*-17-acetoxyl-16-methoxyl-kauran-3-one	K		Whole	(Luo et al., 2014)
307	*ent*-17-hydroxylkaur-15-en-3-one	K		Whole	(Luo et al., 2014)
308	*ent*-3-acetoxyl-kaur-15-en-16, 17-diol	K		Whole	(Luo et al., 2014)
309	*ent*-kauran-3, 16, 17-triol	K		Whole	(Luo et al., 2014)
310	*ent*-3-acetoxyl-kauran-16, 17-diol	K		Whole	(Luo et al., 2014)
311	*ent*-kauran-16, 17-diol	K		Whole	(Luo et al., 2014)
312	abbeokutone	K		Whole	(Luo et al., 2014)
313	*ent*-17α-acetyl-16β-hydroxyl- kauran-3-one	K	Anti-tumor activity	Whole	(Luo et al., 2014)
314	15-norlabda-8(20),12E-diene-14-carboxalde-19-oic acid	C		Whole	(Yang et al., 2012)
315	12*R*,15-dihydroxy-8(17),13*E*-labdadien-19-oic acid	D		Roots	(Wang et al., 2014a)
316	chloranhenryin A	L		Whole	(Xie et al., 2015)
317	oryzalexin A	L		Whole	(Xie et al., 2015)
318	15-hydroxysessilifol F	L		Whole	(Xie et al., 2015)
319	decandrin B	L		Whole	(Xie et al., 2015)
320	sessilifol F	L	Anti-inflammatory activity	Whole	(Xie et al., 2015)
321	13-O-methylsessilifol D	L		Whole	(Xie et al., 2015)
322	sessilifol D	L		Whole	(Xie et al., 2015)
323	chloranhenryin B	L	Antibacterial activity	Whole	(Xie et al., 2015)
324	chloranhenryin C	L		Whole	(Xie et al., 2015)
325	15-O-methylsessilifol J	L		Whole	(Xie et al., 2015)
326	chloranhenryin D	L		Whole	(Xie et al., 2015)
327	chloranhenryin E	L		Whole	(Xie et al., 2015)
328	chloranhenryin F	L		Whole	(Xie et al., 2015)
329	15-ene-3α,8α-diol	L		Whole	(Xie et al., 2015)
330	*ent*-pimara-8(14),15-diene-3α,7β-diol	L	Antibacterial activity	Whole	(Xie et al., 2015)
331	3β-hydroxyabieta-8,11,13-trien-7-one	L	Antibacterial activity	Whole	(Xie et al., 2015)
332	3β,7α-dihydroxyabieta-8,11,13-triene	L	Antibacterial activity	Whole	(Xie et al., 2015)
333	sessilifol O	L		Whole	(Xie et al., 2015)
334	henrilabdanes A	L	Hepatoprotective activity	Roots	(Li et al., 2008)
335	henrilabdanes C	L	Hepatoprotective activity	Roots	(Li et al., 2008)
336	henrilabdanes B	L	Hepatoprotective activity	Roots	(Li et al., 2008)
337	(13*S*)-13-hydroxy-19-methoxy-5αH-8(17),14-labdadien	L		Whole	(Wu et al., 2006)
338	7β,12α-Dihydroxy-13-*epi*-manoyl oxide	L		Roots	(Gan et al., 2009)
339	7β,12α-Dihydroxymanoyl oxide	L		Roots	(Gan et al., 2009)
340	(12*R*)-Labda-8(17),13*E*-dien-12,15,19-triol	L		Roots	(Gan et al., 2009)
341	15-Nor-14-oxolabda-8(17),12*E*-dien-19-ol	L		Roots	(Gan et al., 2009)
342	12(*R*)-12,15-dihydroxylabda-8(17),13*E*-dien-19-oic acid	L		Roots	(Gan et al., 2009)
343	15-hydroxy-12-oxolabda-8(17),13*E*-dien-19-oic acid	L		Roots	(Gan et al., 2009)
344	15-nor-14-oxolabda-8(17),12*E*-dien-19-oic acid	L		Roots	(Gan et al., 2009)
345	(12*R*),(13*S*)-12,13-dihydroxylabda-8(17),14-dien-19-oic acid	L		Roots	(Gan et al., 2009)
346	(12*S*)-12,15-dihydroxylabda-8(17),13*E*-dien-19-oic acid	L		Roots	(Gan et al., 2009)
347	12,15-Epoxy-5αH,9βH-labda-8(17),13-dien-19-oic acid	L		Whole	(Wu et al., 2006)

(*continued on next page*)

Table 1 (*continued*)

No.	Name	Plant	Bioactivity	Part	References
348	14-methoxy-15,16-dinor-5αH,9αH-labda-13 (*E*),8(17)-dien-12-one	L	Antitumor activity	Whole	(Wu et al., 2006)
349	(3*R*,5*S*,9*R*,10*S*)-3-hydroxy-*ent*-podocarpa-8 (14)-ene-13-one	M		Whole	(Wang et al., 2015b)
350	3α-hydroxy-*ent*-torara-8-en-7,13-dione	M		Whole	(Wang et al., 2015b)
351	decandrin G	M		Whole	(Wang et al., 2015b)
352	3α,7β-dihydroxyabieta-8,11,13-triene	M	Anti-inflammatory activity	Whole	(Wang et al., 2015b)
353	decandrin B	M		Whole	(Wang et al., 2015b)
354	sessilifol A	M		Whole	(Wang et al., 2015b)
355	sessilifol B	M		Whole	(Wang et al., 2015b)
356	sessilifol C	M		Whole	(Wang et al., 2015b)
357	sessilifol G	M		Whole	(Wang et al., 2015b)
358	sessilifol H	M		Whole	(Wang et al., 2015b)
359	sessilifol I	M	Anti-inflammatory activity	Whole	(Wang et al., 2015b)
360	sessilifol J	M		Whole	(Wang et al., 2015b)
361	sessilifol K	M		Whole	(Wang et al., 2015b)
362	sessilifol M	M		Whole	(Wang et al., 2015b)
363	sessilifol N	M		Whole	(Wang et al., 2015b)
364	sessilifol P	M		Whole	(Wang et al., 2015b)
365	sessilifol Q	M		Whole	(Wang et al., 2015b)
366	chlorabietol A	N	Inhibition of PTP1B activity Hypoglycemic Activity	Roots	(Xiong et al., 2015) (Xiong et al., 2015)
367	chlorabietol B	N	Inhibition of PTP1B activity Hypoglycemic Activity	Roots	(Xiong et al., 2015) (Xiong et al., 2016)
368	chlorabietol C	N	Inhibition of PTP1B activity Hypoglycemic Activity	Roots	(Xiong et al., 2015) (Xiong et al., 2016)
369	19-Hydroxy-*ent*-abieta-7,13-diene	N		Roots	(Xiong et al., 2015)
370	chlorabietin A	N		Roots	(Xiong et al., 2016)
371	chlorabietin B	N	Anti-inflammatory activity	Roots	(Xiong et al., 2016)
372	chlorabietin C	N	Anti-inflammatory activity	Roots	(Xiong et al., 2016)
373	chlorabietin D	N		Roots	(Xiong et al., 2016)
374	chlorabietin E	N		Roots	(Xiong et al., 2016)
375	chlorabietin F	N	Anti-inflammatory activity	Roots	(Xiong et al., 2016)
376	chlorabietin G	N	Anti-inflammatory activity	Roots	(Xiong et al., 2016)
377	chlorabietin H	N		Roots	(Xiong et al., 2016)
378	chlorabietin I	N		Roots	(Xiong et al., 2016)
379	chlorabietin K	N		Roots	(Xiong et al., 2016)
Triterpenoids					
380	2β,9α-dihydroxy-5α-methoxyergosta-7,22-diene	JK		Whole	(Shen et al., 2016)
381	2β,6β-dihydroxy-5α-methoxyergosta-7,22-diene	JK		Whole	(Shen et al., 2016)
C_{25} Terpenoids					
382	hitorins A	E		Aerial	(Kim et al., 2016)
383	hitorins B	E		Aerial	(Kim et al., 2016)
Coumarins					
384	isofraxidin	DEH	choleretic activity	Whole	(Zhu et al., 2018)
385	scopoletin	E		Whole	(Kawabata et al., 1984) (Kawabata et al., 1984)
386	isoscopoletin	E		Whole	(Kawabata et al., 1984)
387	isofraxidin-7-O-β-D-glucopyranoside	E		Whole	(Heo et al., 2005)
Lignans					
388	(7*S*,8*R*)-dihydrodehydrodiconiferyl alcohol	E		Roots	(Kuang et al., 2009)
389	(7*S*, 8*R*)-urolignoside	E		Roots	(Kuang et al., 2009)
390	(7*S*,8*R*)-dihydrodehydrodiconiferyl alcohol-9-β-D-glucopyranoside	E		Roots	(Kuang et al., 2009)
391	(7*S*,8*R*)-dihydrodehydrodiconiferyl alcohol-9′-O-β-D-glucopyranoside	E		Roots	(Kuang et al., 2009)
392	(7*S*,8*R*)-5-methoxydihydrodehydrodiconiferyl alcohol-4-O-β-D-glucopyranoside	E		Roots	(Kuang et al., 2009)
393	(±)-*erythro*-guaiacyl-glycerol-β-O-4′-dihydroconiferylether	D		Aerial	(Du et al., 2017)
Simple phenylpropanoids					
394	(*E*)-cinnamic acid	D		Roots	(Wang et al., 2014a)
395	p-coumaric acid	F		Whole	(Chen et al., 2021a)

Table 1 (*continued*)

No.	Name	Plant	Bioactivity	Part	References
Flavonoids					
396	7,4′-dimethylnaringenin	F		Whole	(Chen et al., 2021a)
397	quercetin-3-O-α-L-rhamnopyranoside	F		Whole	(Chen et al., 2021a)
398	quercetin-3-O-β-D-glucopyranoside	F		Whole	(Chen et al., 2021a)
399	catechin	F		Whole	(Chen et al., 2021a)
Organic acids					
400	stearic acid	D		Roots	(Wang et al., 2014a)
401	vanillic acid	D		Roots	(Wang et al., 2014a)
402	4-Hydroxybenzoic acid	G		Whole	(Xu, 2016)
403	*trans*-4-Hydroxy-2-nonenoic acid	G		Whole	(Xu, 2016)
404	3,4,5-trimethoxybenzaldehyde	H		Leaves	(Wu et al., 2010)
Amide					
405	*N*-p-*trans*-coumaroyltyramine	D		Aerial	(Xu, 2016)
406	*N*-p-*trans*-feruloyltyramine	D		Aerial	(Xu, 2016)
407	cannabisin G	D		Aerial	(Xu, 2016)
408	thoreliamide A	D		Aerial	(Xu, 2016)
409	cannabisin F	D		Aerial	(Xu, 2016)
410	aurantiamide acetate	D		Aerial	(Xu, 2016)
Others compounds					
411	(*E*)-5-(4-methoxyphenyl)-4-ene-1,2,3-trihydroxyamyl	D		Aerial	(Du et al., 2017)
412	1-acetoxy-2,3,4,5-tetrahydroxy-5-p-metoxyphenylpentane	D		Aerial	(Du et al., 2017)
413	(−)-rosiridol	D		Aerial	(Du et al., 2017)
414	(4*S*)-p-menth-1-ene-4,7-diol	D		Aerial	(Du et al., 2017)
415	pisumionoside	E		Whole	(Kuang et al., 2008)
416	yinxiancaoside B	E	Antitumor activity	Whole	(Kuang et al., 2008)
417	yinxiancaoside C	E	Antitumor activity	Roots	(Kuang et al., 2008)
418	vomifoliol	F		Whole	(Chen et al., 2021a)

Note: B: *Chloranthus elatior* Link. C: *Chloranthus spicatus* (Thunb.) Makino.
D: *Chloranthus angustifolius* Oliv. E: *Chloranthus japonicus* Sieb.
F: *Chloranthus fortunei* (A. Gray) Solms-Laub. G: *Chloranthus holostegius* (Hand. -Mazz.) Pei et Shan.
H: *Chloranthus anhuiensis* K. F. Wu. I: *Chloranthus tianmushanensis* K. F. Wu.
J: *Chloranthus serratus* (Thunb.) Roem. et Schult. K: *Chloranthus multistachys* Pei.
L: *Chloranthus henryi* Hemsl. M: *Chloranthus sessilifolius* K. F. Wu.
N: *Chloranthus oldhamii* Solms Laubach.

5.2. Monoterpenes

Monoterpenes are less abundant in the genus *Chloranthus*, and four compounds **(287–290)** were reported. Wang *et al*. isolated a monoterpene lactone (**287**) pressafonin from *C. angustifoliu* (Wang et al., 2014a). Lu *et al*. obtained two monoterpenes (3*R*,4*S*,6*R*)-p-menth-1-en-3,6-diol and (*R*)-p-menth-1-en-4,7-diol from *C. japonicus* (Lu et al., 2016). (–) loliolide was first isolated from *C. fortunei* (Chen et al., 2021a). The specific compound names and structures are shown in Table 1 and Fig. 10.

5.3. Diterpenoids

Diterpenoids are abundant in the genus *Chloranthus* and they are an important source of activity in this genus. So far, a total of **88** compounds (**291–379**) were isolated from this genus, and the main structural types include abietane diterpenes, pimarane diterpenes, totarane diterpenes, labdane diterpenes and ring-opened chinane diterpenes (Chen et al., 2021b). Among them, the norditerpenoids are new diterpenoid structure types in this genus, and their carbon skeletons are mostly C_{18} and C_{19}. Xie et al. (2015). reported that chloranhenryin D (**326**) from *C. henryi* was a abietane-type diterpenoid at the absence of C-14 position. Wang et al. (2015c). isolated a new *ent*-podocarpane-type C_{17} norditerpenoid compound (3*R*,5*S*,9*R*,10*S*)-3-hydroxy-*ent*-podocarpa-8(14)-ene-13-one from *C. sessilifolius*. Furthermore, three new norditerpenoid compounds sessilifol O (**333**), sessilifol P (**364**)and sessilifol Q (**365**), were also isolated from *C. serratus* (Wang et al., 2015b). The specific compound names and structures are shown in Table 1 and Fig. 11.

5.4. Triterpenoids

Shen *et al*. identified two new triterpenoids, 2β, 9α-dihydroxy-5α-me-thoxyergosta-7,22-diene (**380**) and 2β, 6β-dihydroxy-5 α-methoxyergosta-7, 22-diene (**381**)from the leaves of *C. multistachys* (Shen et al., 2016). The specific compound names and structures are shown in Table 1 and Fig. 12.

5.5. C_{25} terpenoids

Two new C_{25} Terpenoids, hitorins A (**382**) and hitorins B (**383**), were identified from *C. japonicus*, which has a

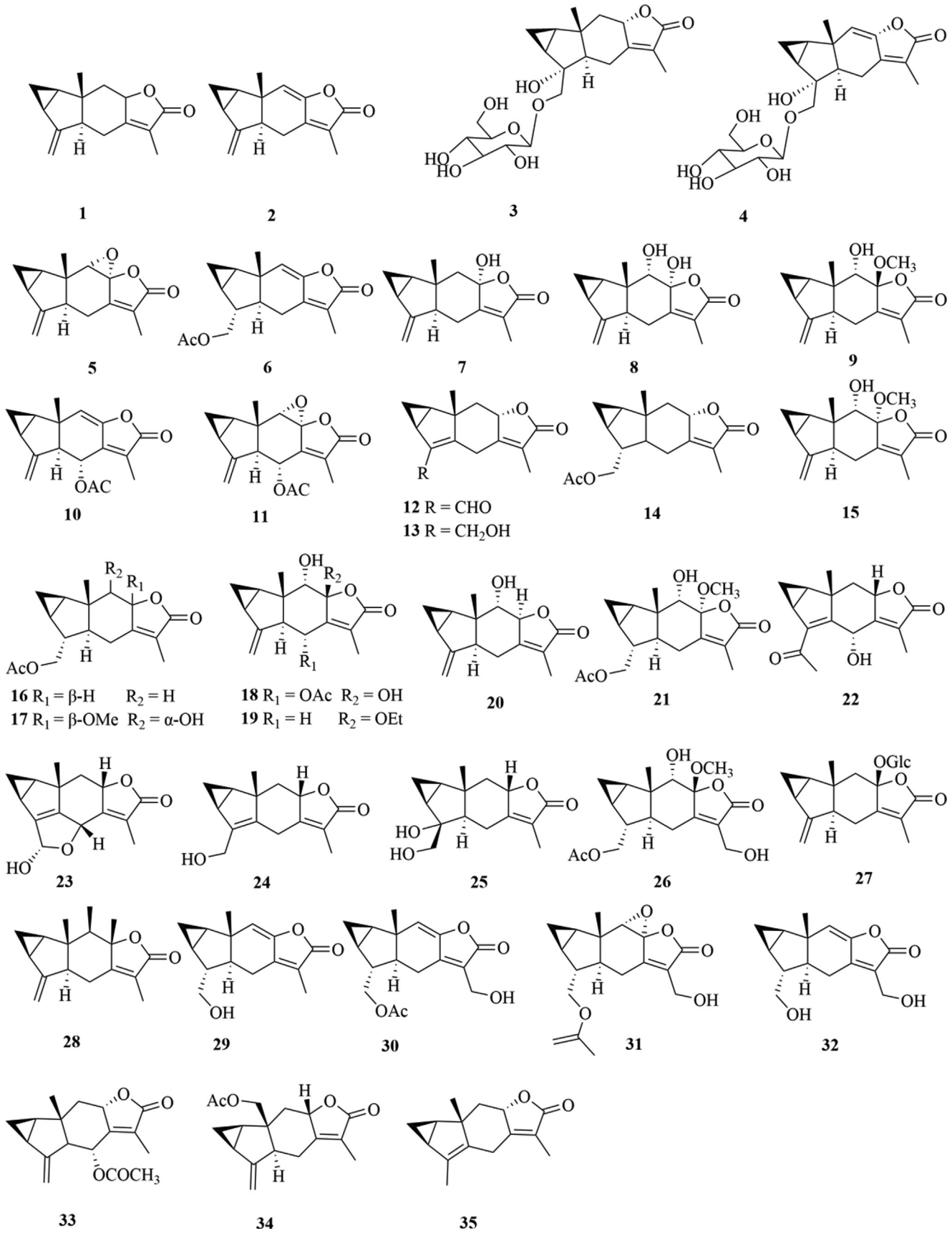
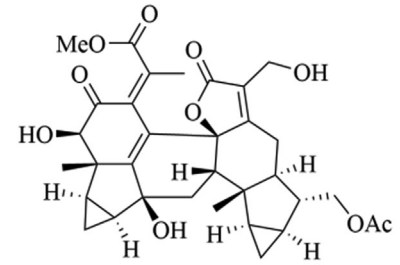
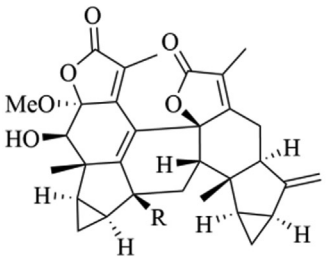


Fig. 1 Structures of lindenane sesquiterpenes and their polymers in genus *Chloranthus*.

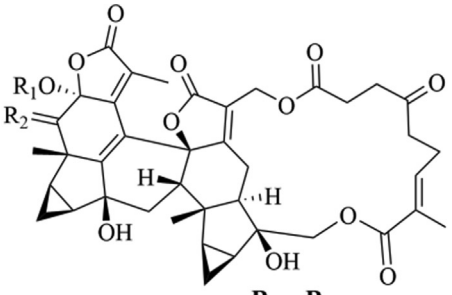


36

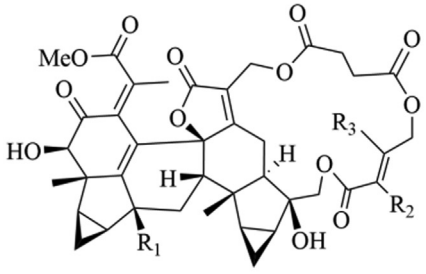


37 R = OH

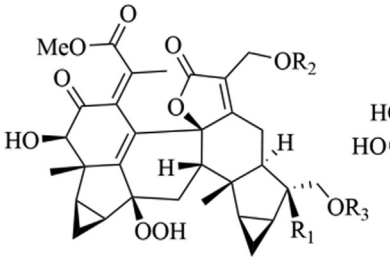
38 R = OOH



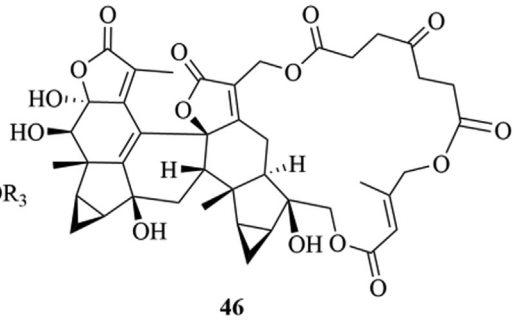
	R_1	R_2
39	H	O
40	Me	βOH,H



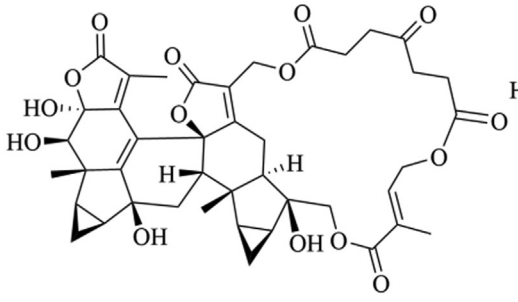
	R_1	R_2	R_3
41	OOH	Me	H
42	OOH	H	Me
43	OH	Me	H



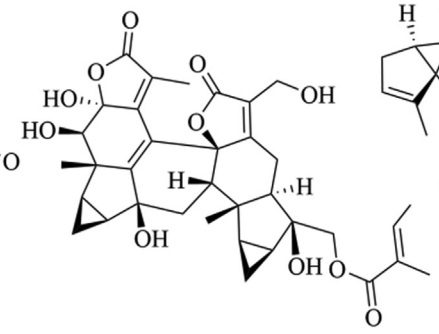
	R_1	R_2	R_3
44	OH	Ac	Tig
45	H	H	Ac



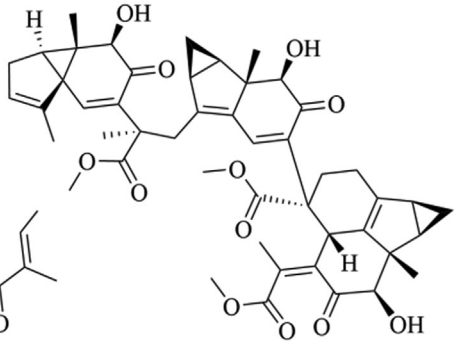
46



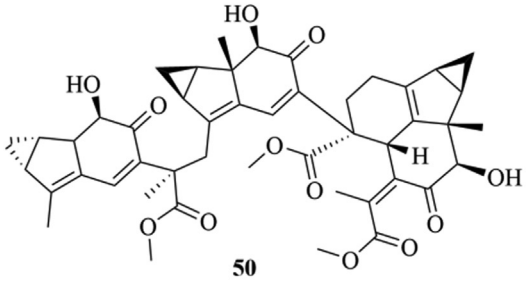
47



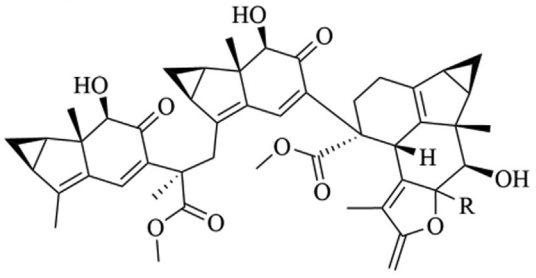
48



49

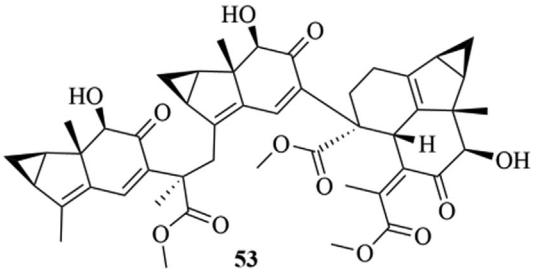


50

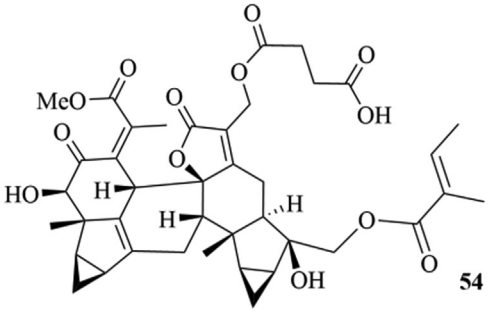


51 R = α-OMe

52 R = β-OH

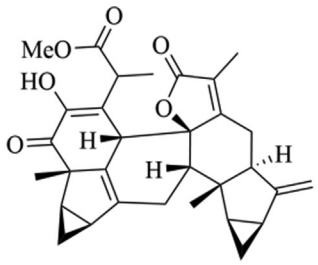


53

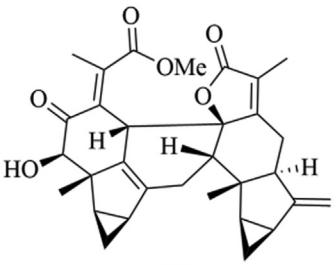


54

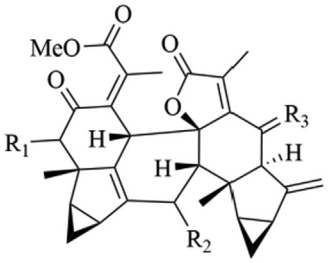
Fig. 1 (*continued*)



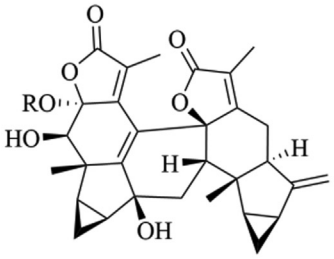
55



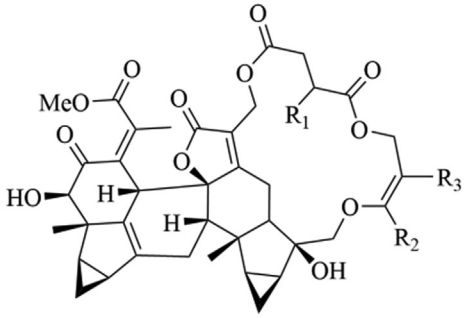
56



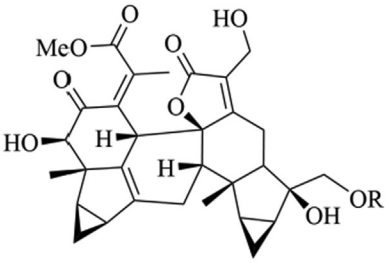
	R_1	R_2	R_3
57	β-OH	H	α-OAc
58	β-OH	β-OH	H
59	H	H	H
60	β-OH	H	H
61	β-OAc	H	H



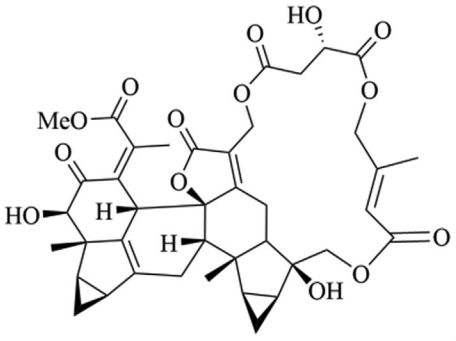
62 R= H
63 R= butyl
64 R=Me



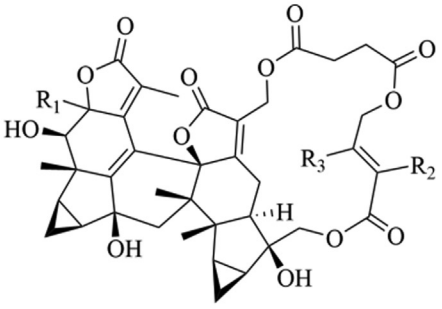
	R_1	R_2	R_3
65	H	Me	H
66	H	H	Me
67	OH	Me	H



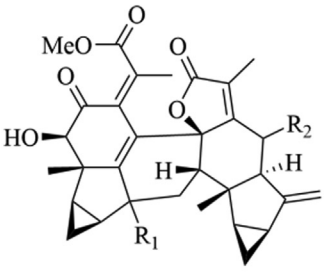
68 R=tiglate
69 R=acetyl



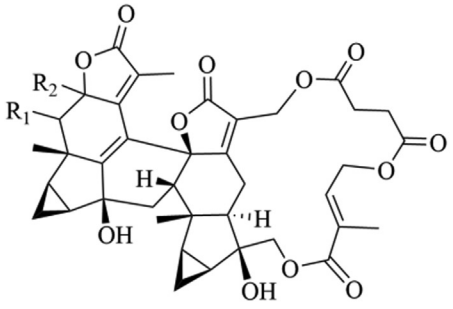
70



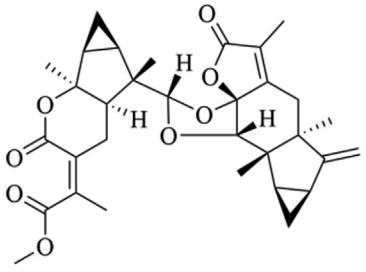
71 R_1= α-OH R_2= H R_3= Me
72 R_1= β-OMe R_2= Me R_3= H



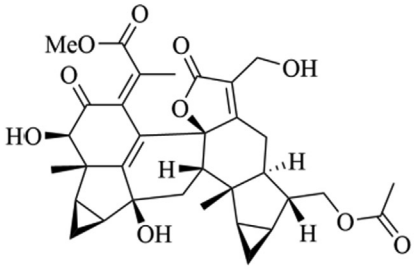
73 R_1 = β-OH R_2 = α-OAc
74 R_1 = β-OOH R_2 = H



	R_1	R_2
75	β-OH	α-OH
76	=O	α-OH
77	β-OH	β-OH
78	β-OH	β-OCH_3



79



80

Fig. 1 (*continued*)

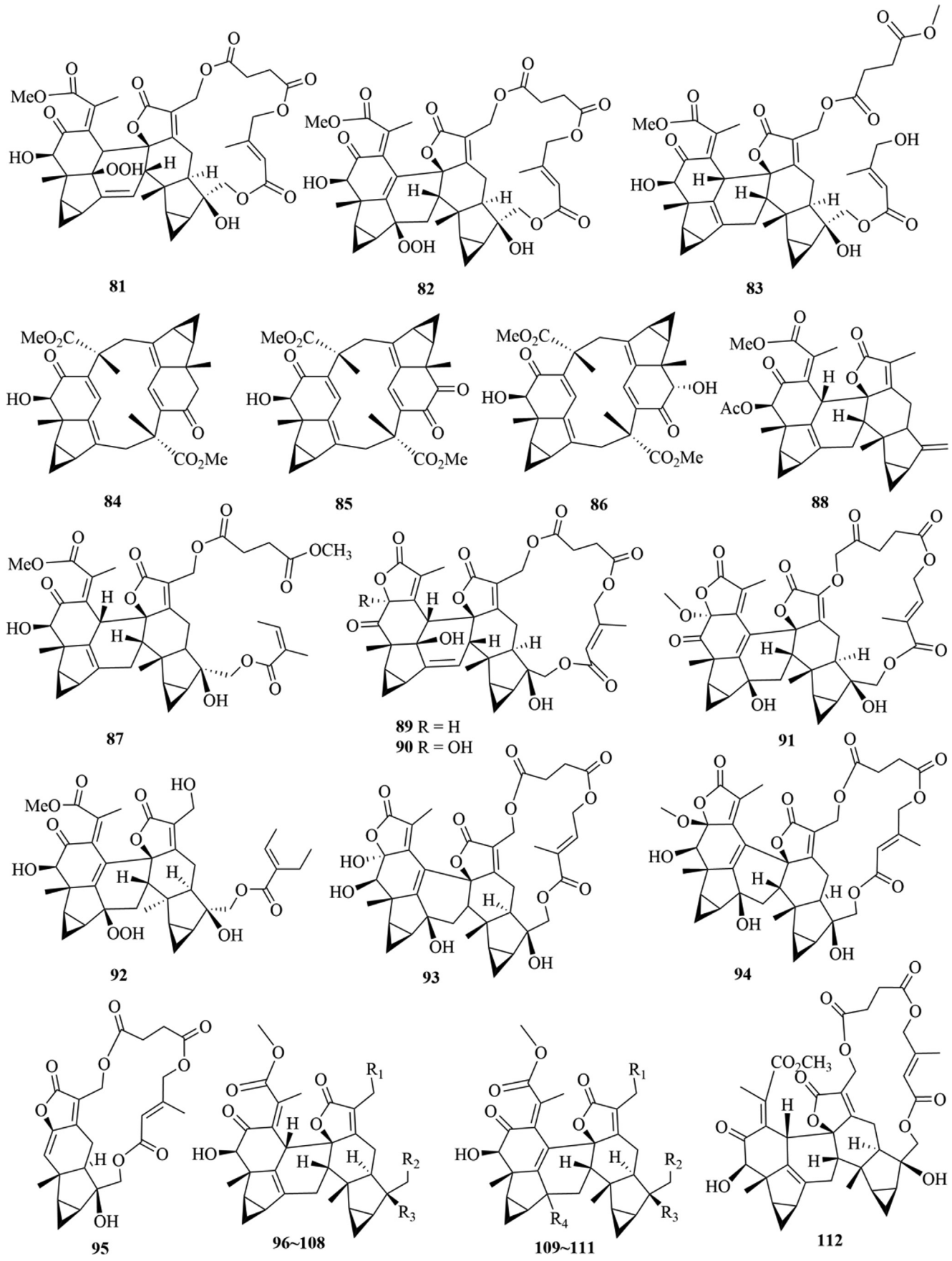


Fig. 1 (*continued*)

	R_1	R_2	R_3
96	F	B	OH
97	OH	J	OH
98	OH	A	OH
99	OH	OH	OH
100	G	E	OH
101	OAc	A	OH
102	H	C	OH
103	OAc	D	OH
104	OH	OAc	OH
105	OH	E	OH
106	H	D	OH
107	OH	OH	H
108	H	OAc	H

	R_1	R_2	R_3	R_4
109	OH	J	OH	OOH
110	F	C	OH	OOH
111	H	OH	OH	OOH

A= B= C= D= E= F= J=

113

114

115

116 R=H
117 R=F

118

119

120

121

122 R=glucosyl
123 R=H

124 R_1= g R_2= CH_3
125 R_1= h R_2= i

g h i

Fig. 1 (*continued*)

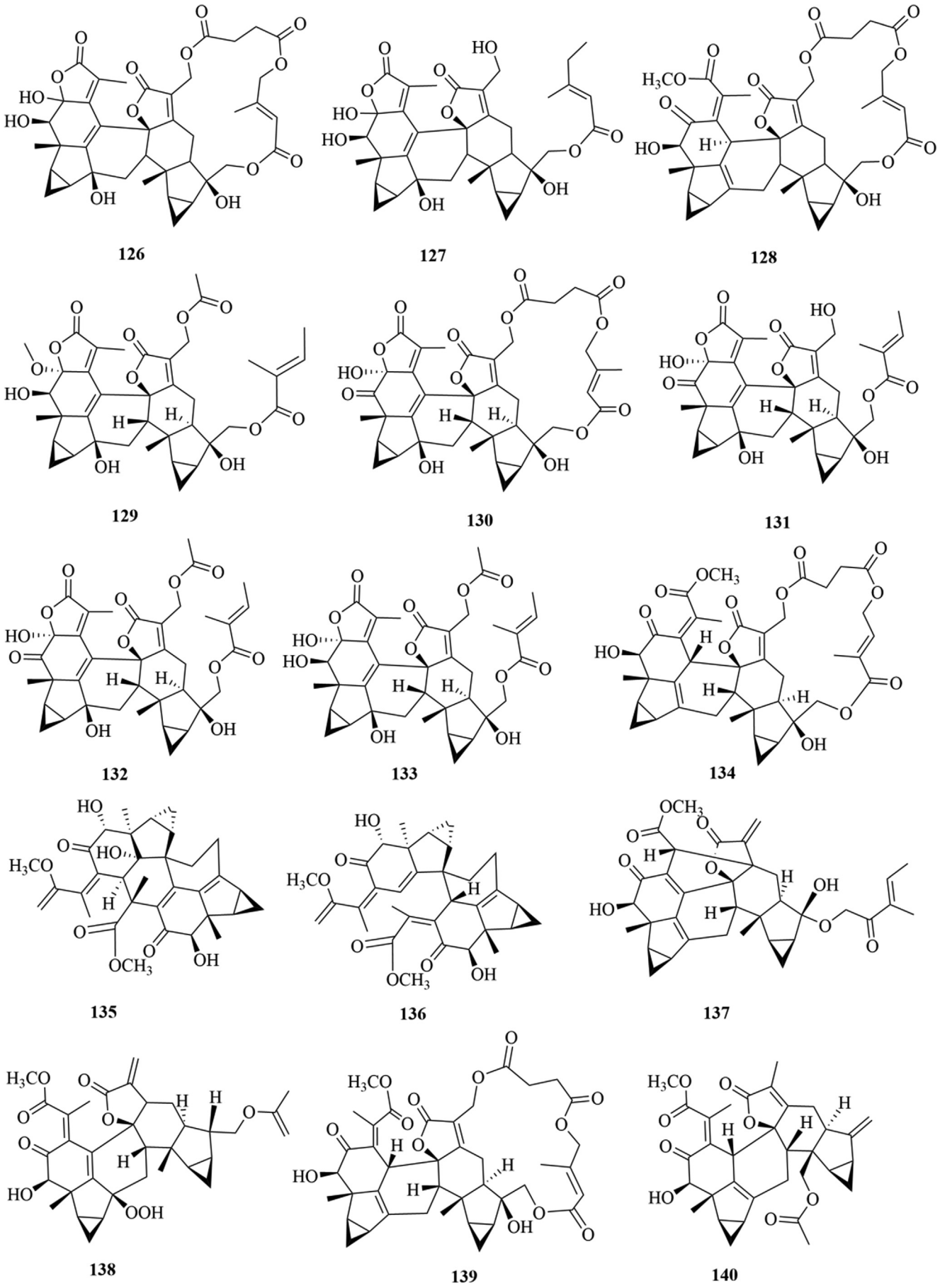


Fig. 1 (*continued*)

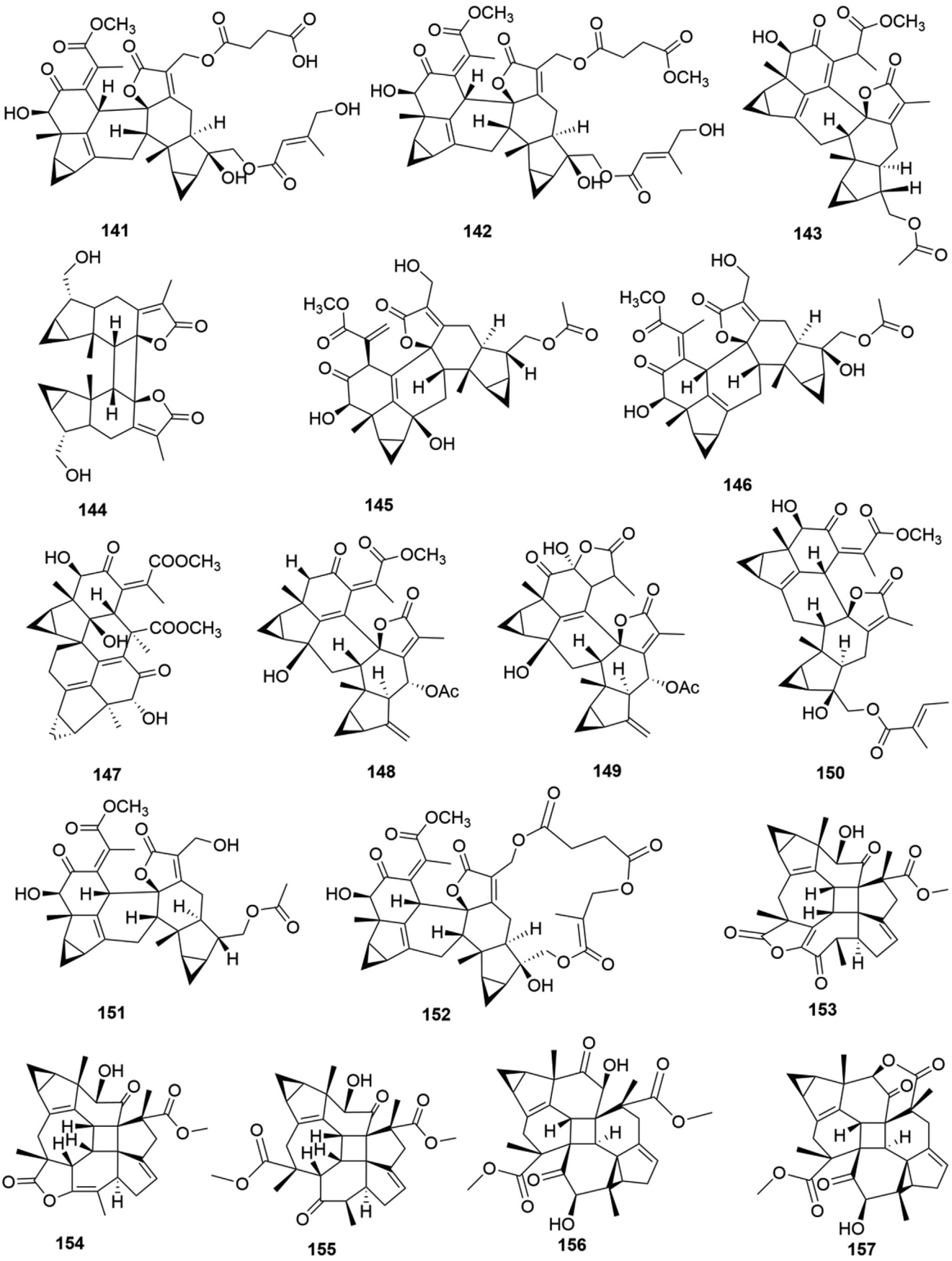


Fig. 1 (*continued*)

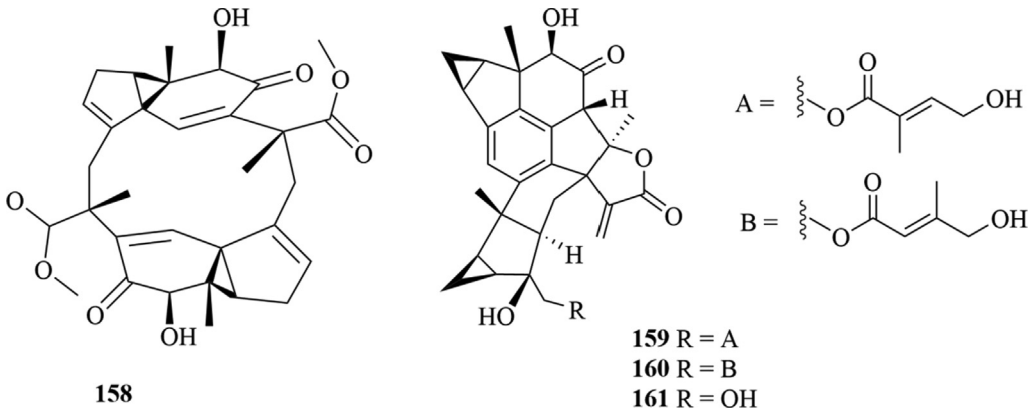


Fig. 1 (*continued*)

6/5/5/5/5/3 hexacyclic skeleton including one γ-lactone ring and two tetrahydrofuran rings (Kim et al., 2016). The specific compound names and structures are shown in Table 1 and Fig. 13.

5.6. Coumarins

A total of four coumarins isofraxidin (**384**), scopoletin (**385**), isoscopoletin (**386**) and isofraxidin-7-*O*-β-D-glucopyranoside (**387**) were isolated from the genus *Chloranthus*, and most of them were distributed in *C. japonicus* (Zhu et al., 2018; Kawabata et al., 1984; Heo et al., 2005). The specific compound names and structures are shown in Table 1 and Fig. 14.

5.7. Lignans

Kuang *et al.* and Du *et al.* isolated six new lignans (**388**–**393**) from the root parts of *C. japonicus* and aboveground parts of *C. angustifolius*, respectively (Kuang et al., 2009; Du et al., 2017). The specific compound names and structures are shown in Table 1 and Fig. 15.

5.8. Simple phenylpropanoids

At present, only two simple phenylpropanes, (*E*)-cinnamic acid (**394**) and p-coumaric acid (**395**), have been isolated from *C. angustifolius* and *C. fortunei* (Wang, 2014; Chen et al., 2021a). The specific compound names and structures are shown in Table 1 and Fig. 15.

5.9. Flavonoids

In recent years, there are relatively few reports on flavonoids in the genus *Chloranthus*. Chen *et al.* isolated four flavonoids (**396**–**399**) from *C. fortunei* for the first time (Chen et al., 2021a). The specific compound names and structures are shown in Table 1 and Fig. 16.

5.10. Organic acids

The content of organic acids in the genus *Chloranthus* is low, and five organic acids compounds (**400**–**404**) were found in *C. angustifolius* and *C. Holostegius* (Wang et al., 2014a; Xu, 2016; Wu et al., 2010). The specific compound names and structures are shown in Table 1 and Fig. 17.

5.11. Amides

Liu *et al.* isolated six amides (**405**–**410**) from *C. angustifolius*, all of which were found and reported for the first time in the genus *Chloranthus* (Liu et al., 2015). The specific compound names and structures are shown in Table 1 and Fig. 18.

5.12. Others compounds

Besides, eight other types of compounds were discovered in this genus. The specific compound names and structures are shown in Table 1 and Fig. 18.

5.13. Pharmacological activity

Modern pharmacological experiments indicated that most species of the genus *Chloranthus* have anti-cancer, antibacterial, antiviral, hypoglycemic anti-inflammatory, and antimalarial activities (Cao et al., 2008). The bioactivities of monomeric compounds in *Chloranthus* are listed in Table 2.

5.14. Antitumor activity

More and more research revealed that the genus *Chloranthus* exhibited strong toxicity against cancer cells. Tang et al. (2016). reported that shizukaol D (**69**) isolated from *C. serratus* could inhibit the growth of hepatocellular carcinoma cells by regulating the Wnt pathway. Many studies demonstrated that serralactones A (**162**) in *C. serratus* showed significant inhibition activity on LIM domain kinase 1 (LIMK1) by regulating the structure of the actin cytoskeleton of tumor cells in the invasion and metastasis, which may be a potential value in preventing the distant spread of cancer cells. Additionly, its IC_{50} values on MDA-MB-231 and MDA-MB-468 cells were 3.14 μM and 4.64 μM, respectively (Fu et al., 2018). Wang et al. (2014b) found that codonolactone (**173**) obtained from *C. henryi* exhibited potential antimetastatic properties against breast cancer cells using bioactivity-guided fractionation. Its mechanism may be associated with inhibiting the binding of Runx2 to the mmp-13 promoter through downregulation of

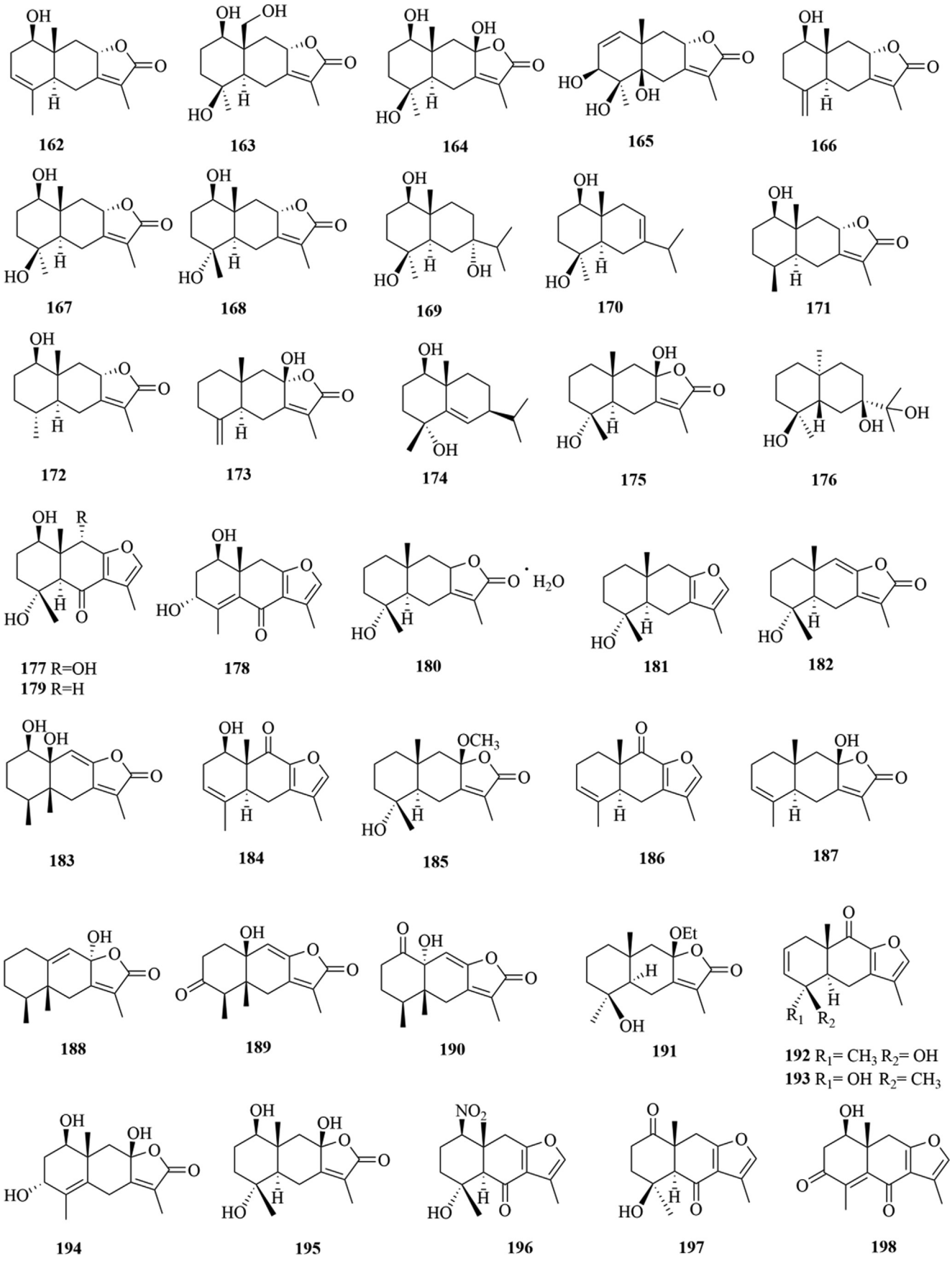


Fig. 2 Structures of eudesmane sesquiterpenes in genus *Chloranthus*.

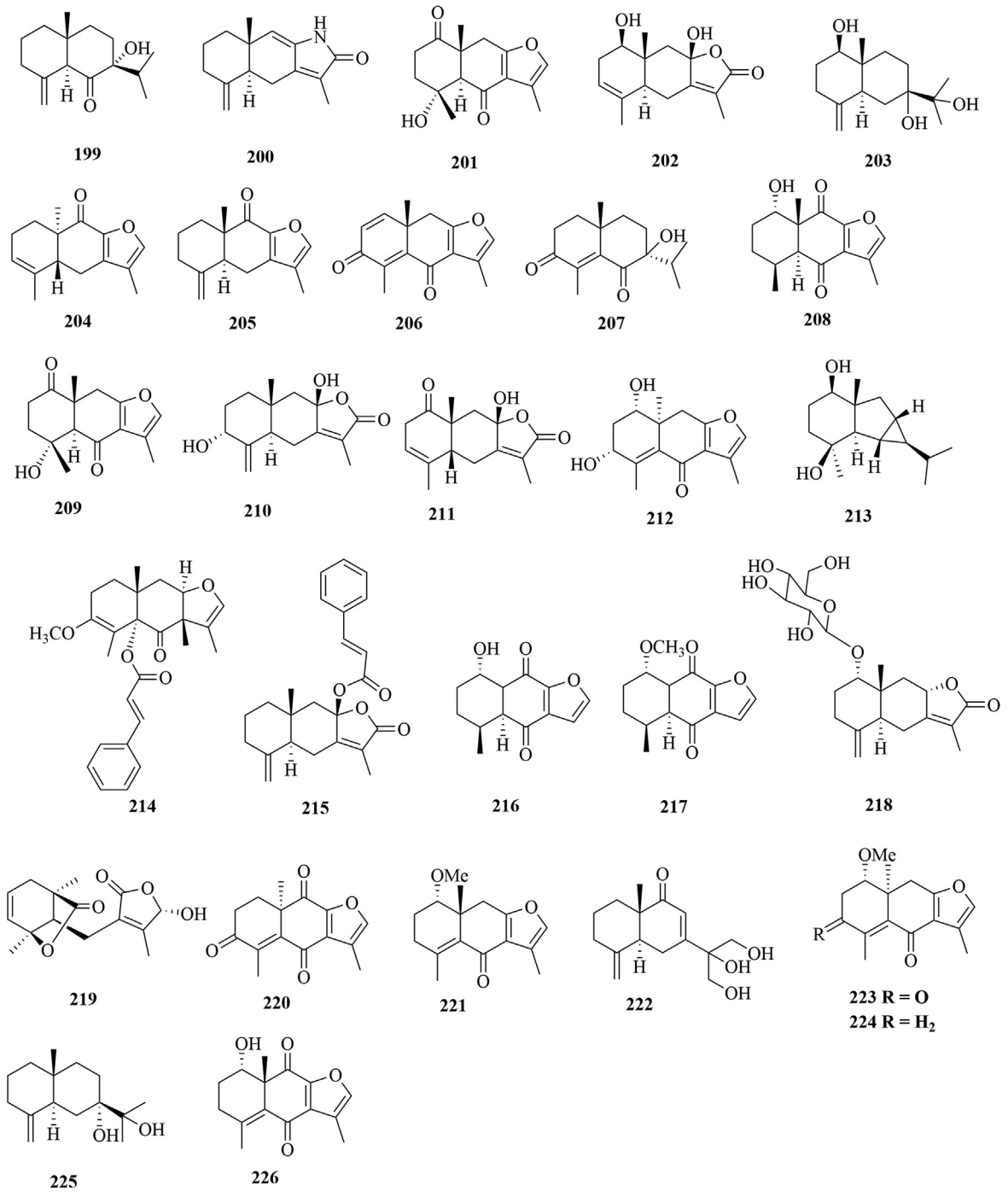


Fig. 2 (*continued*)

invasion and migration of MDA-MB-231 and MDA-MB-157 cells. Zhu Huilin (Zhu et al., 2018) discovered that compound **313** in *C. anhuiensis* exhibited moderate cytotoxicity on MDA-MB-231, 4 T1, and HepG2 cells with an IC_{50} value of 39.7 μM. Besides, the compounds yinxiancaoside A (**3**), yinxiancaoside B (**416**), chloranoside A (**4**), pisumionoside (**415**) and sarcaglaboside A (**218**) separated from *C. japonicus* exhibited antago-

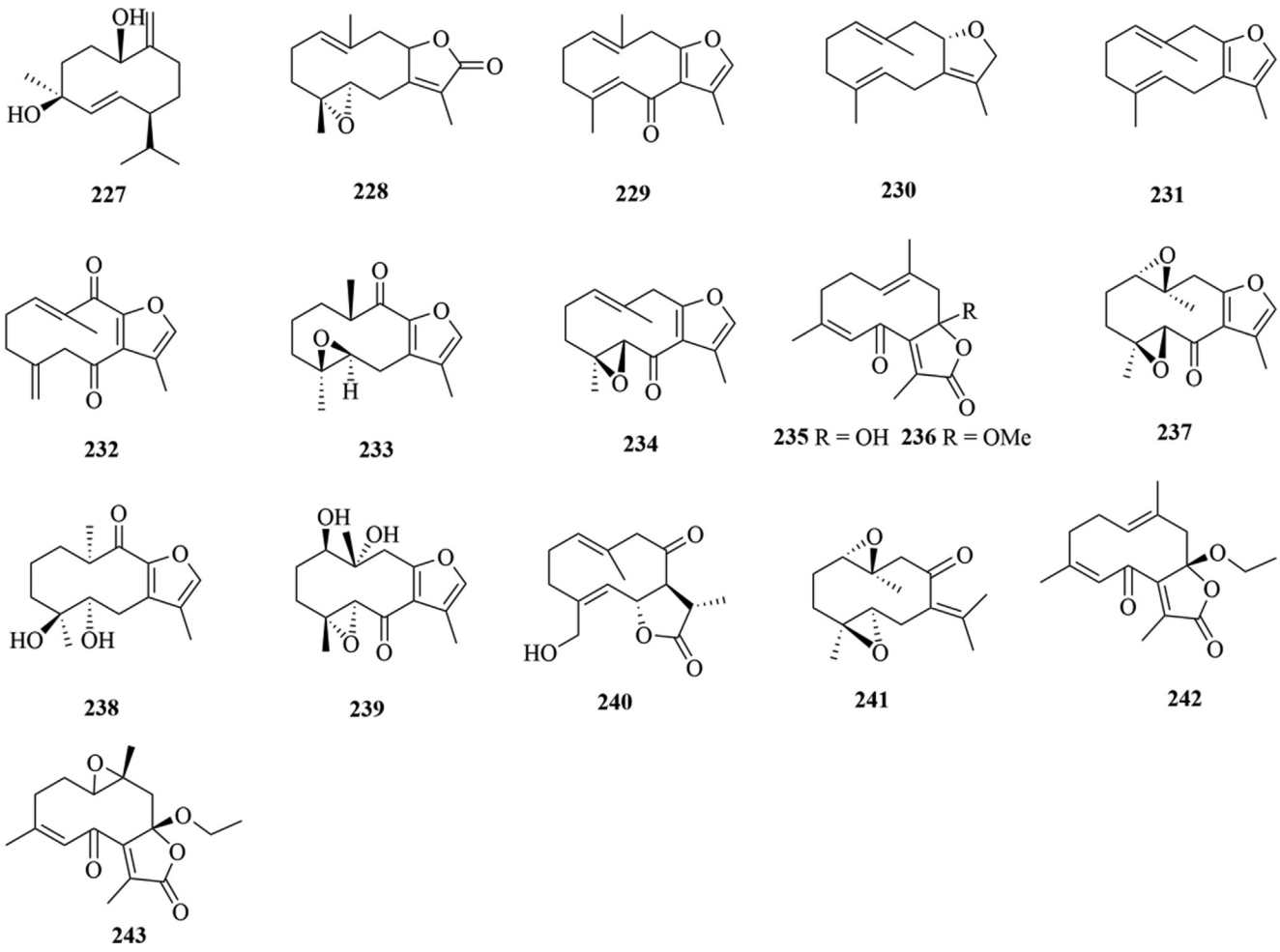


Fig. 3 Structures of germacrane sesquiterpenes in genus *Chloranthus*.

nistic effects on HepG-2, OV420 and MCF-7 cells (Kuang et al., 2008).

5.15. Antiinflammatory activity

The genus *Chloranthus* showed strong effect in anti-inflammatory activity, which are used to treat arthritis and bruises. Pan *et al*. demonstrated that the sesquiterpene dimer shizukaol B (**65**) exerted stronger anti-inflammatory activity in LPS-induced BV2 microglia model by modulating the JNK-AP-1 signaling pathway (Pan et al., 2017). Similarly, Wang lijun's group (Wang et al., 2014b) found that the compounds zederone epoxide (**237**), chloramultilide A (**43**), shizukaol B (**65**) and spicachlorantin B (**72**) isolated from *C. henryi* also showed significant anti-inflammatory effects through inhibiting the release of NO. Zhuo et al. (2017) reported that chlorajaponol B (**10**) identified from *C. japonicus* significantly inhibited lipopolysaccharide-induced NO release by RAW 264.7 cells. Furthermore, fortunilides K (**116**) isolated from *C. multistachys* whole herb showed the most significant anti-inflammatory activity in LPS-induced RAW 264.7 cell model. By comparison, the sesquiterpene lactones were significantly more active than the other sesquiterpenes (Huang et al., 2020). Besides, chlojaponilactones B (**10**) from *C. japonicus* exerted anti-inflammatory activity by inhibiting inflammatory mediators such as iNOS, TNF-α and IL-6, whose mechanism is related to the inhibition of NF-κB signaling pathway (Zhao et al., 2016). Zhang et al. (2012b) found active components shizukaol B (**65**) and D (**69**) isolated from *C. serratus* exhibited significant anti-inflammatory activity in LPS-induced RAW 264.7 inflammation model with IC_{50} values of 0.22 and 0.15 μM, respectively. Similarly, shizukaol G (**67**), M (**102**), and O (**125**) isolated from *C. fortu*nei also showed strong anti-inflammatory activity with IC_{50} values of 1.90, 3.68, 1.95, 7.01 and 1.95 μM, respectively (Zhang et al., 2012c). Moreover, the compounds chololactones A-H (**137**–**144**) from *C. holostegius* roots showed moderate anti-inflammatory activity by inhibiting NO production against LPS-induced RAW 264.7 (Shen et al., 2017). Sun *et al*. found that the ethanolic extract of the roots of *C. serratus* showed the strongest anti-arthritic activity (Sun et al., 2020). In addition, TNF-α and PDE4 were also important signaling molecules involved in the inflammatory response. It was reported that sesquiterpene dimer chlojapolactone B (**10**) identifed from *C. japonicus* could exert anti-inflammatory effects by inhibiting the release of TNF-α (IC_{50} of 76.16 μM) (Li et al., 2019).

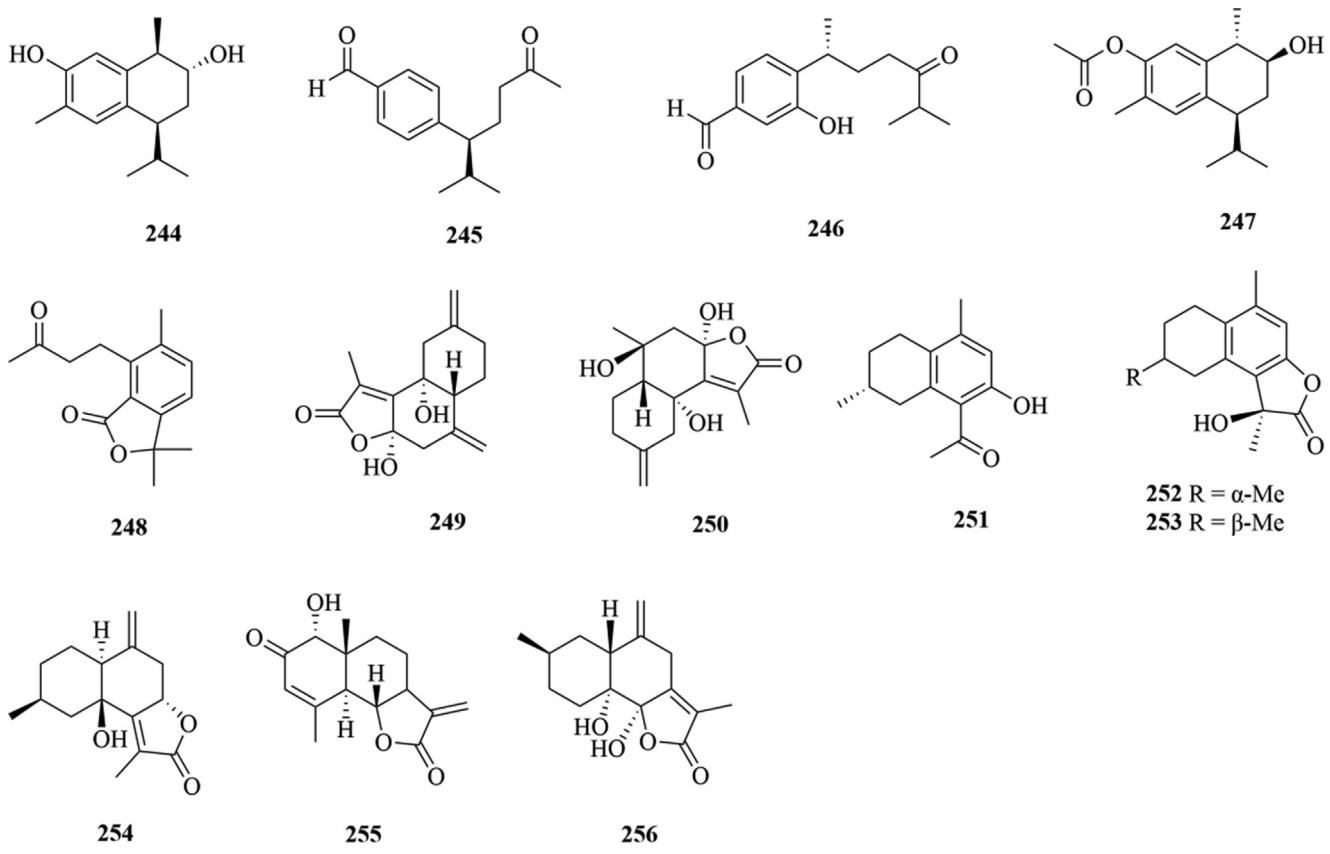


Fig. 4 Structures of cadinane sesquiterpenes in genus *Chloranthus*.

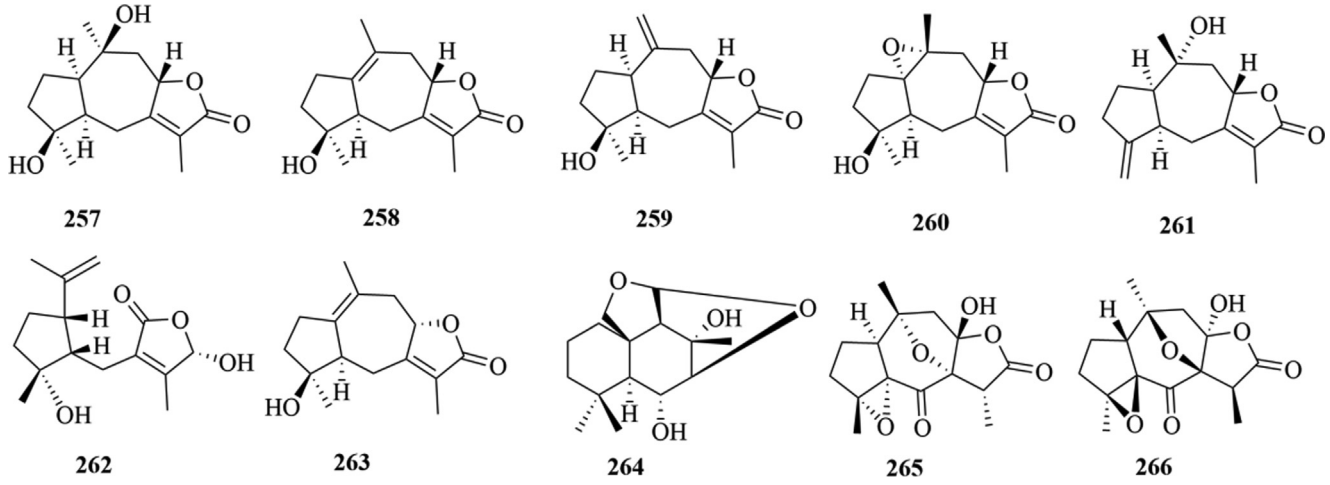


Fig. 5 Structures of guaiane sesquiterpenes in genus *Chloranthus*.

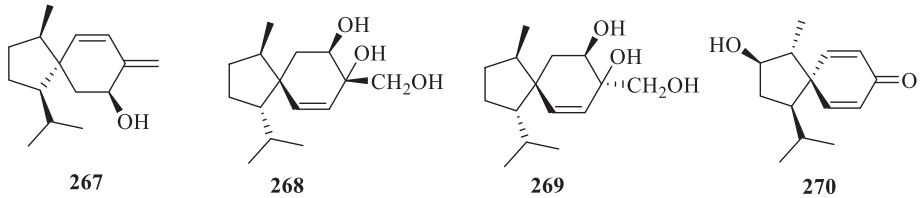


Fig. 6 Structures of acorane sesquiterpenes in genus *Chloranthus*.

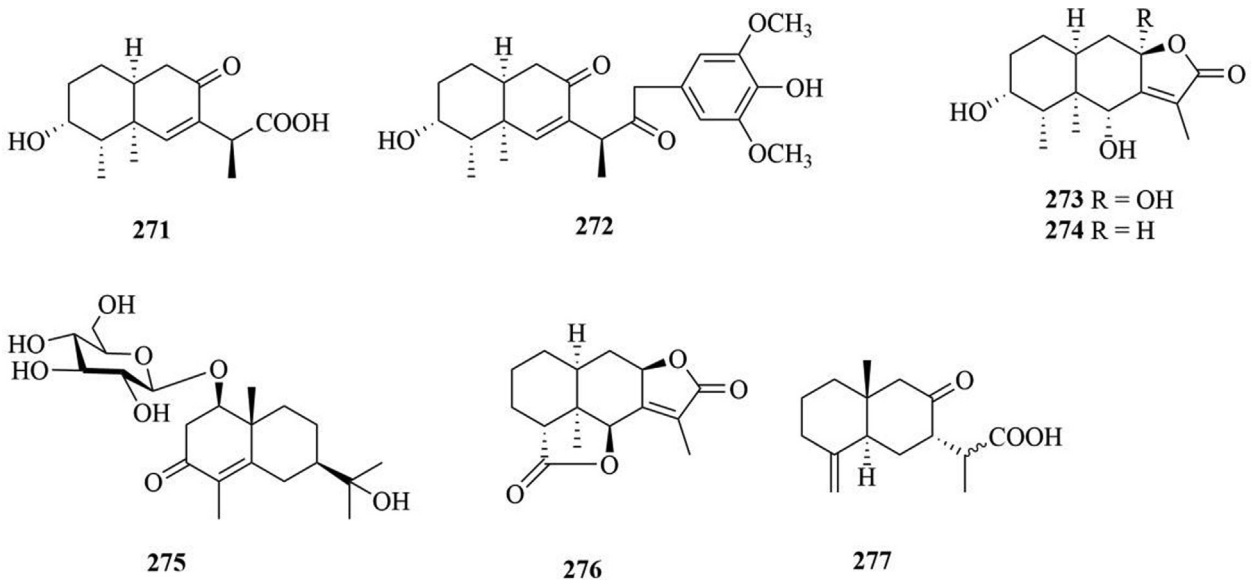


Fig. 7 Structures of eremophilane sesquiterpenes in genus *Chloranthus*.

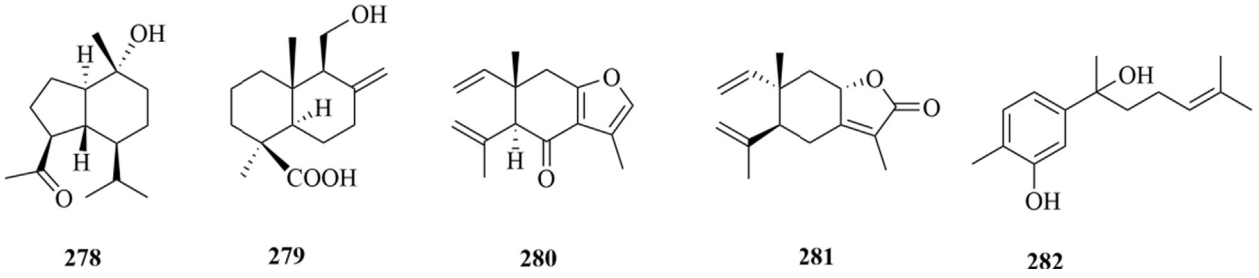


Fig. 8 Structures of oplopanone sesquiterpenes, drimane sesquiterpene, elemene sesquiterpene and brasilane sesquiterpene in genus *Chloranthus*.

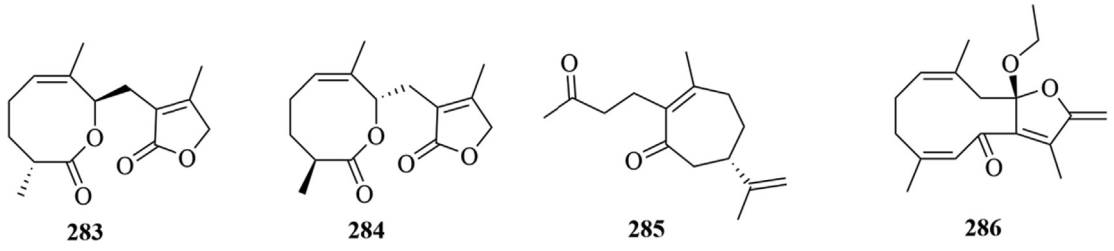


Fig. 9 Structures of others sesquiterpene in genus *Chloranthus*.

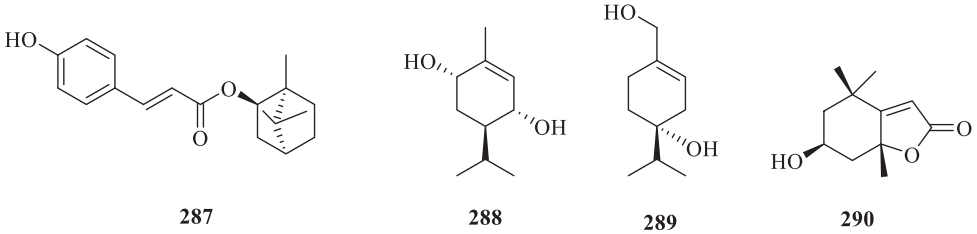


Fig. 10 Structures of monoterpenes in genus *Chloranthus*.

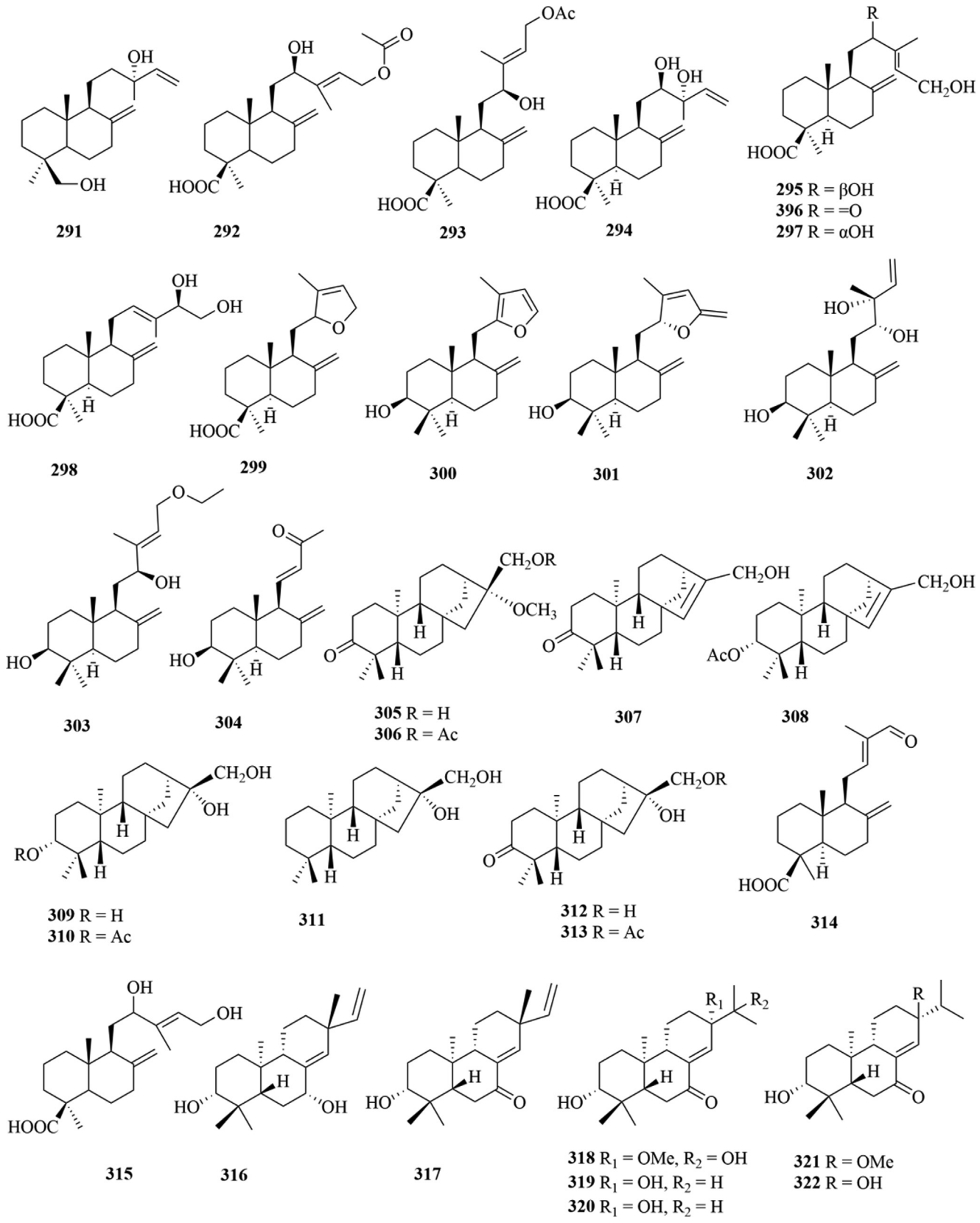


Fig. 11 Structures of diterpenoids in genus *Chloranthus*.

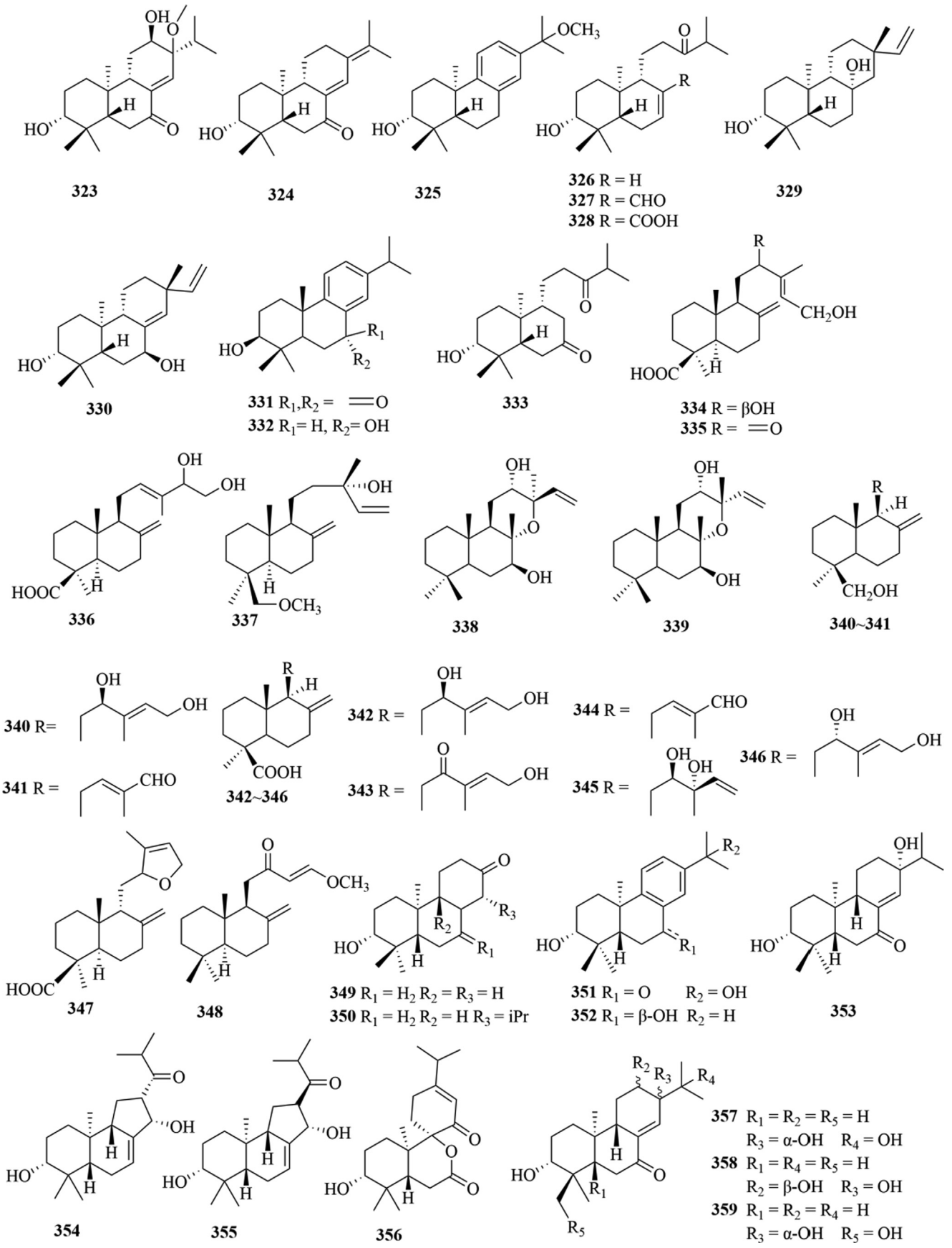


Fig. 11 (*continued*)

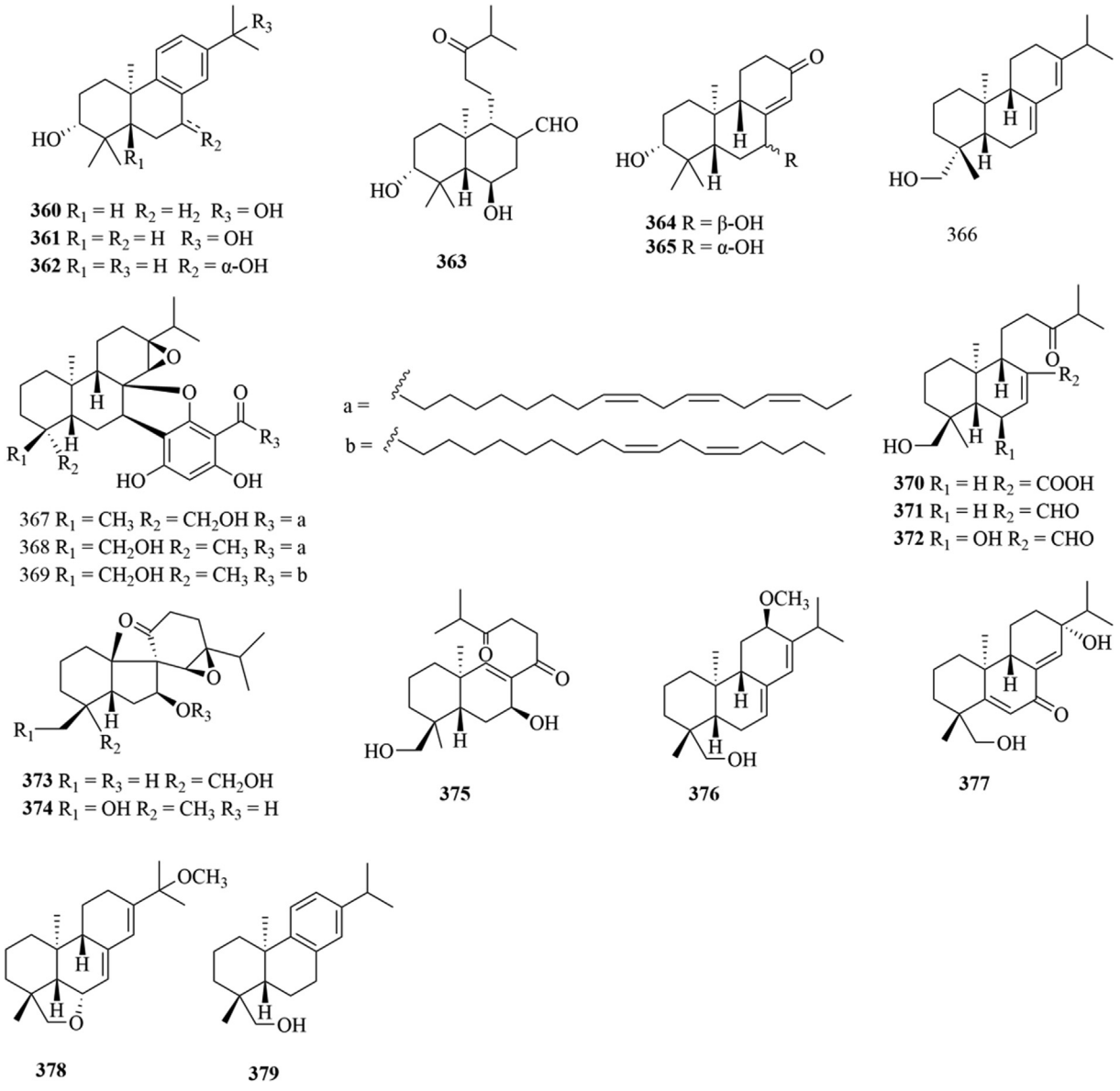


Fig. 11 (*continued*)

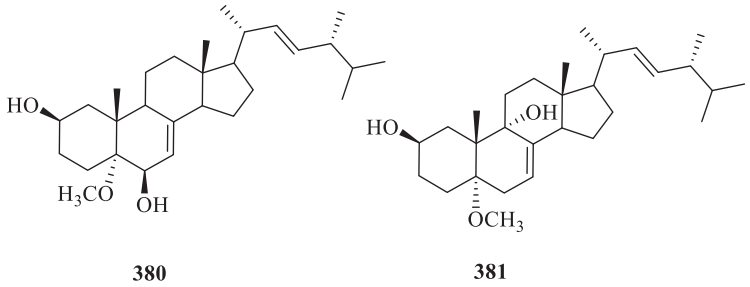


Fig. 12 Structures of triterpenoids in genus *Chloranthus*.

5.16. Antibacterial activity

In recent years, it has been confirmed that *Chloranthus* has antibacterial effects. Li (2011). found that ethyl acetate extracts of *C. japonicus* and *C. multistachys* showed a better antibacterial activity against Garcinia octococci. Furthermore, Xu et al. (2007) reported that chloramultilide B (**71**) isolated from *C. spicatus* showed inhibitory activity against both Can-

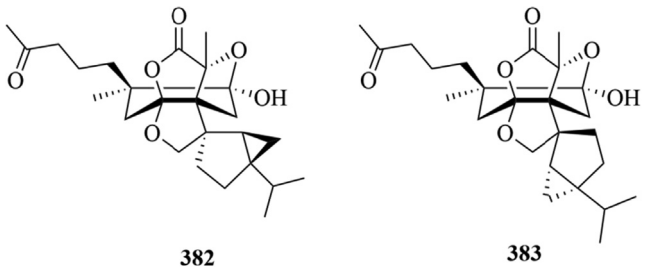


Fig. 13 Structures of C_{25} terpenoids in genus *Chloranthus*.

dida albicans and Clostridium parvum with an MIC value of 0.068 μM through antifungal assays. Additionally, the monomeric shizukaol C (**68**) and F (**66**) obtained from *C. japonicus* showed more than 85 % inhibitory activity against Puccinia recondita (wheat leaf rust) and Phytophthora infestans (tomato late blight) (Kang et al., 2017). At the same time, the sesquiterpene dimers shizukaol C and F reported from *C. japonicus* whole herb showed good inhibitory activity against phytopathogenic fungi (MICs of 4 to 16 μM).

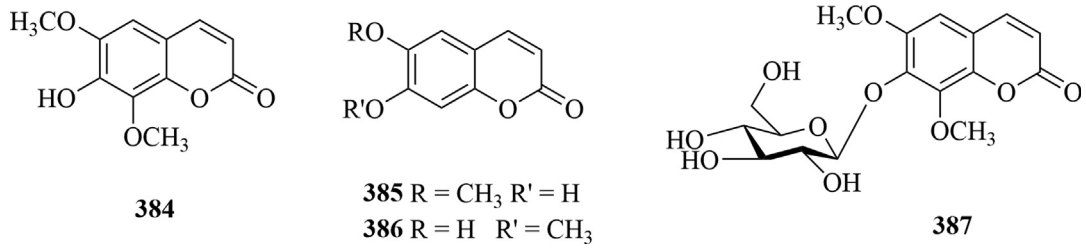
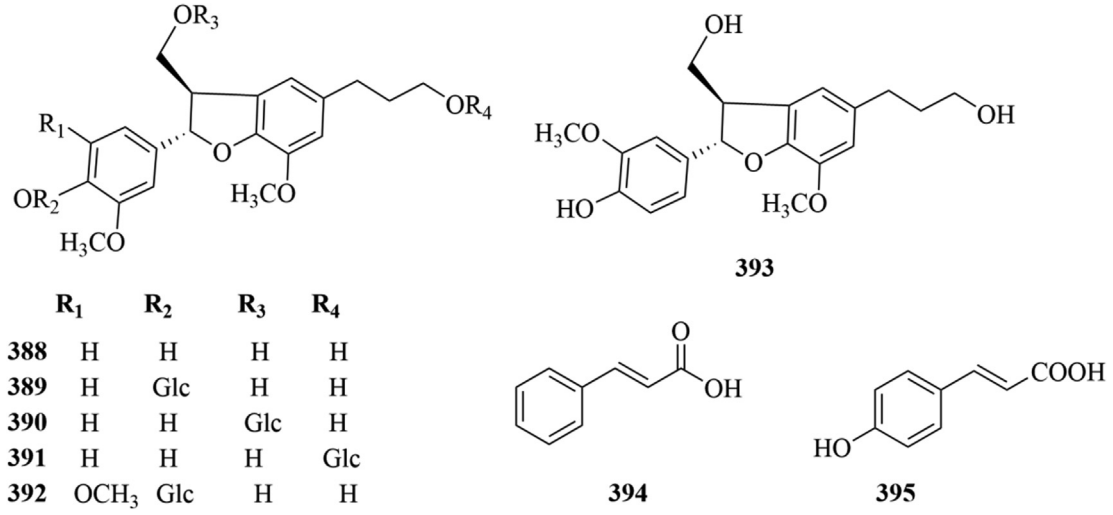


Fig. 14 Structures of coumarins in genus *Chloranthus*.



	R_1	R_2	R_3	R_4
388	H	H	H	H
389	H	Glc	H	H
390	H	H	Glc	H
391	H	H	H	Glc
392	OCH_3	Glc	H	H

Fig. 15 Structures of lignans and simple phenylpropanoids in genus *Chloranthu*.

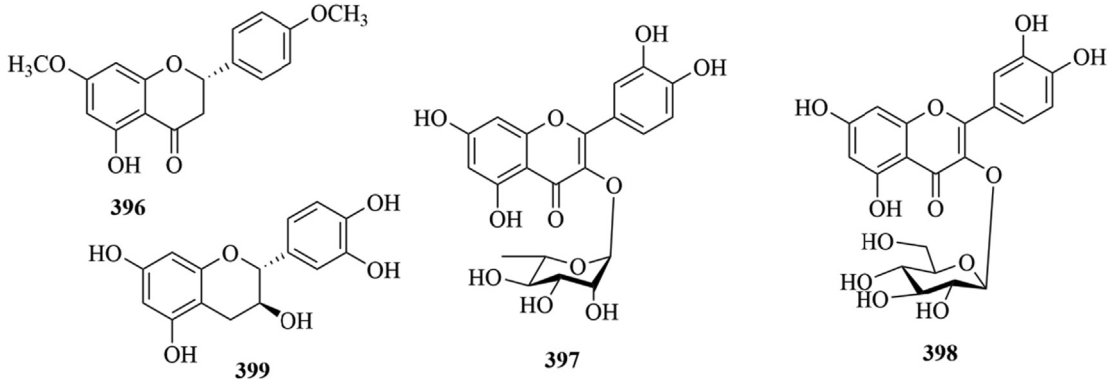


Fig. 16 Structures of flavonoids in genus *Chloranthus*.

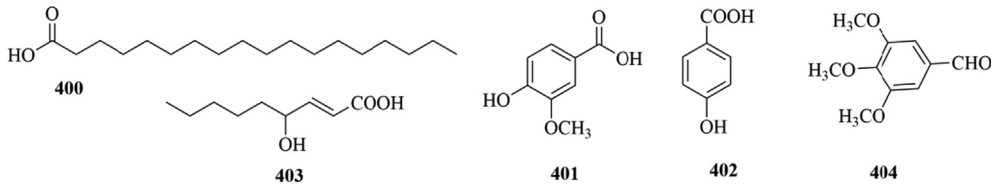


Fig. 17 Structures of Organic acids in genus *Chloranthus*.

5.17. Neuroprotective activity

Alzheimer's disease (AD) is one of the most common chronic diseases in old age, which has become a major threat to human life and health. The search for natural active drugs from Chinese medicine to treat AD has attracted a lot of attention from researchers. Chen *et al* (Chen et al., 2021c). demonstrated that chlohenriol A-C (**264**–**266**) isolated from *C. henryi* showed significant neuroprotective activity against H_2O_2-induced PC12 cell injury model. Furthermore, shizukanolide H (**30**) isolated from *C. anhuiensis* exhibited significant neuroprotective activity against glutamate-induced apoptosis in PC12 cells. The active ingredients could reduce PC12 apoptosis by suppressing caspase-3 activity (Xu et al., 2018).

5.18. Antimalarial activity

In recent years, the antimalarial activity of the gens *Chloranthus* has also been widely studied. Zhou et al. (2017b) demonstrated that 16 lindenane-type sesquiterpenoids dimers isolated from *C. fortunei* showed antimalarial activity. Among which, fortunilide A (**96**), sarglabolide J (**100**) and chloraholide D (**103**) showed the strongest antimalarial activity, which was comparable to the potency and selectivity index values of artemisinin. Meanwhile, fortunoid A (**118**) and B (**119**) isolated from *C. fortunei* also showed moderate antimalarial activity (Zhou et al., 2017a).

5.19. Anti-viral activity

It was reported that shizukaol B (**65**), shizukaol C (**68**), shizukaol F (**66**) and shizukaol H (**70**) isolated from *C. japonilides* exhibited anti-HIV activity. However, Fang et al. (2011). found that the compound shizukaol B showed more stronger inhibition.

5.20. Hypoglycemic activity

Few studies have been reported on the hypoglycemic activity of the genus *Chloranthus*. Hu et al. (2017) discovered that shi-

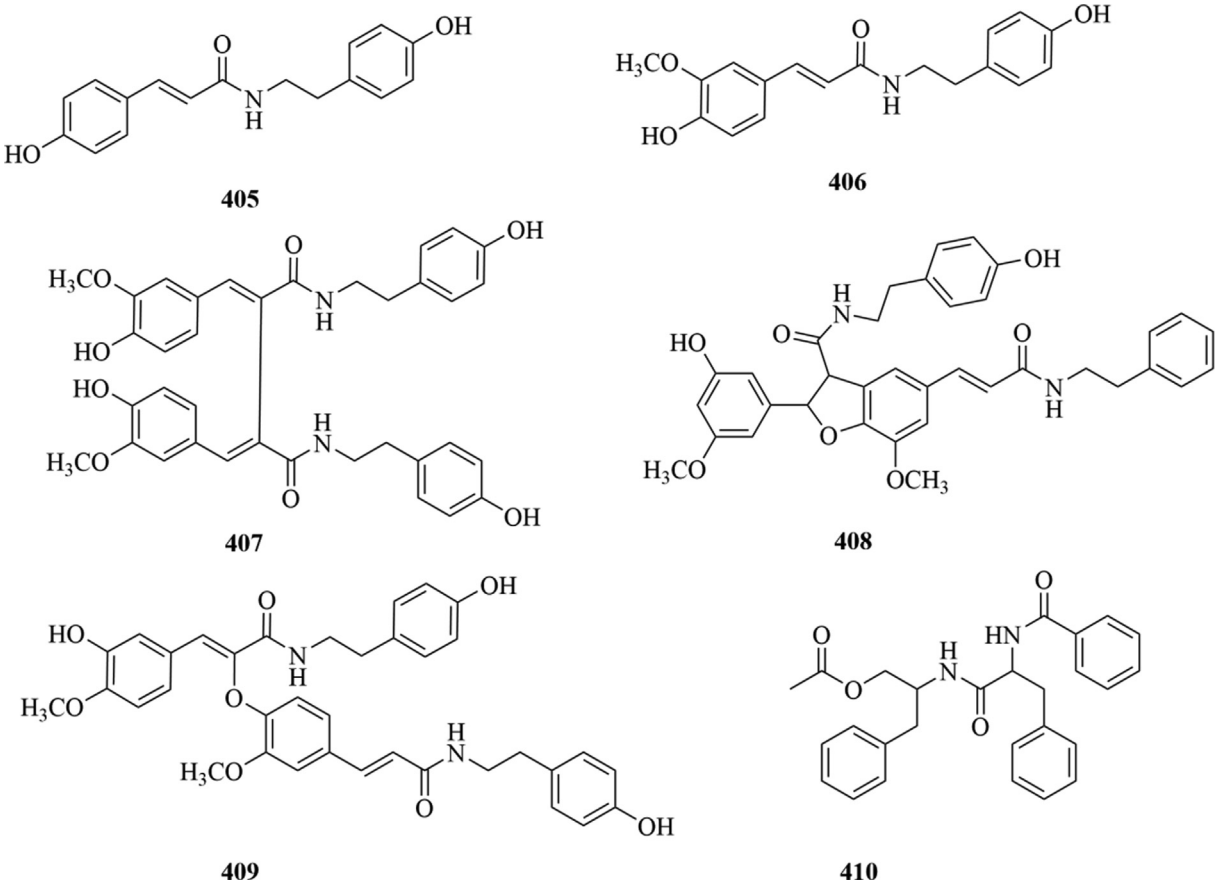


Fig. 18 Structures of amides in genus *Chloranthus*.

zukaol D (**69**) isolated from *C. japonicus* could activate AMP-activated protein kinase and regulate glucose metabolism. In addition, chlorabietols A-C (**366**–**368**) isolated from the roots of *C.oldhamii* plants exhibited some complexinase inhibitory effects (Xiong et al., 2015).

5.21. Other activities

In addition, the genus *Chloranthus* also exert other pharmacological effects. Li et al. (2008) found that henriol A (**75**) and henrilabdanes A-C (**334**–**336**) isolated from *C. henryi* exhibited moderate hepatoprotective activity with IC_{50} values of 0.19, 0.66, 0.09 and 0.18 μM. Besides, the researchers reported that hexane extract of *C. japonicus* play a significant role in promoting adipogenesis. The extract activated the Wnt/β-catenin signaling pathway by promoting adipocyte differentiation (Yun et al., 2021). Moreover, three sesquiterpenoids shizukaol B (**65**), cycloshizukaol A (**123**) and shizukaol F (**66**), isolated from *C. japonicus* whole herb, also prevented monocyte adhesion to HUVEC by inhibiting TNF-α-stimulated cell adhesion molecule expression (Kwon et al., 2006). And it was reported that chloraholide A (**148**) and B (**130**) identified from *C. holostegius* were two stronger potassium channel blockers (Yang et al., 2007b). In addition, Sun *et al*. conducted toxicity experiments on rat hearts by taking alcoholic extracts of *C. serratus* roots, stems and leaves, the results showed that the extracts of the alcoholic parts of *C. serratus* stems were the most cardiotoxic, followed by the alcoholic extracts of the leaves (Sun et al., 2019).

6. Development and utilization

6.1. Indoleamine 2, 3-dioxygenase 1(IDO1)

IDO1 inhibitors, as drugs with new targets and mechanisms, can be applied to the treatment of tumors, Alzheimer's disease, depression and other diseases, and are potential targets for tumor immunotherapy. It has been found that chloranthalactone A (**2**), chloranthalactones C-E (**6**–**8**) can be effective inhibitors of IDO1, and their inhibition rate has reached about 80 % (5 μM), so inhibition of IDO1 is expected to be a novel tumor treatment strategy (Tan, 2018a; Tan, 2018b; Tan, 2018c; Tan, 2018d; Tan, 2018e).

6.2. Antitumor drugs

In recent years, several components with antitumor activity have been reported from the genus *Chloranthus*. Researchers found that the application of shizukaol D (**69**) in the preparation of anti-liver cancer drugs, the addition of shizukaol D to cultures of liver cancer cells can significantly slow down the scratch healing and migration of liver cancer cells (Yu and Tang, 2016), and the component also has the effect of increasing the sensitivity of tumor multidrug-resistant cells to anti-tumor drugs, which can be used as a

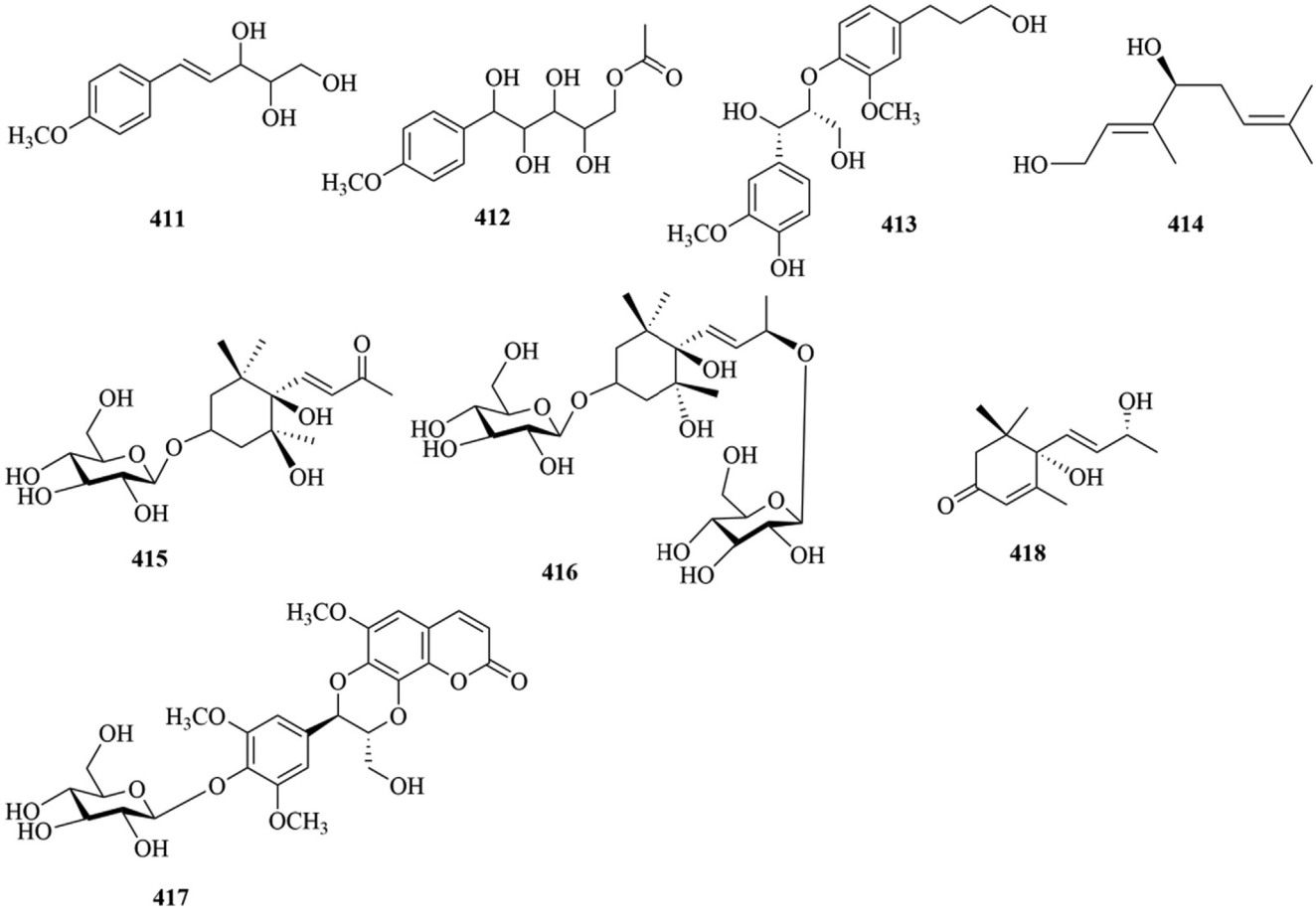


Fig. 19 Structures of others compounds in genus *Chloranthus*.

Table 2 Pharmacological Activities of *Chloranthus*.

Pharmacological Action	Effective Fraction/ Compounds	Model	Responses along with Critical Assessment	Target or Possible Mechanism	References
Anti-inflammatory activity	shizukaol B	In vitro / BV-2 microglial cells	At the concentrations $\geq$ 25 μM Excellent activity	TNF-a and IL-1b	(Pan et al., 2017)
	chlorabietin B chlorabietin C chlorabietin F chlorabietin G	BV-2 microglial cells	IC_{50} = 16.4 ~ 33.8 μM Excellent activity	Inhibiting NO	(Xiong et al., 2016)
	sessilifol F sessilifol I	BV-2 microglial cells	IC_{50} = 8.3, 7.4 μM, respectively Moderate *activity*	Inhibiting NO	(Wang et al., 2015b)
	3α,7β-dihydroxyabieta-8,11,13-triene	In vitro /BV-2 microglial cells	IC_{50} = 4.3 μM Significant activityCell viability (%) : 94.6 ± 7.9	Inhibiting NO	(Wang et al., 2015c)
	shizukaolA fortunilide I shizukanolide G	RAW 264.7 cells	IC_{50} = 7.22 μM, 3.68 μM, 0.15 μM, respectively Overall good activity	Inhibiting NO	(Gong et al., 2021)
	chloramultilide A spicachlorantin G shizukaol B spicachlorantin B	BV-2 microglial cells	IC_{50} = 31.1 ~ 79.4 μ*M* Significant activity	Inhibiting NO	(Wang et al., 2014b)
	chlorajaponol B	RAW 264.7 cells	IC_{50} = 9.56 ± 0.71 μMpositive control amino guanidine (IC_{50} = 8.50 ± 0.35 μM) Good activity	Inhibiting NO	(Zhuo et al., 2017)
	fortunilide K	RAW 264.7 cells	Not mentioned	Inhibiting NO	(Huang et al., 2020)
	chlojaponilactone B	(TPA)-stimulated mice	Not mentioned	iNOS, TNF-α, IL-6, NF-κB	(Sun et al., 2020)
	shizukaol D	RAW 264.7 cells	IC_{50} = 3.7 μM (cell activity (%) at an initial concentration of 50 μM) positive control L-NIL (IC_{50} = 7.0 μM) Good activity	Inhibiting NO	(Bai et al., 2019)
	henriol D shizukaol E shizukaol G shizukaol M shizukaol O	RAW 264.7 cells	IC_{50} = 1.90, 3.68, 1.95, 7.01, 1.95 μM, respectively Significant activity	Inhibiting NO	(Zhang et al., 2012c)
	chololactone A chololactone B chololactone E chololactone F chololactone G chololactone H	RAW 264.7 cells	IC_{50} = 4.4 ~ 35.4 μM dexamethasone as a positive control (IC_{50} = 0.45 ± 0.5 μM) Moderate activity	Inhibiting NO	(Shen et al., 2017)
	serralabdanes A serralabdanes B serralabdanes C serralabdanes D serralabdanes E	RAW 264.7 cells	IC_{50} = 38.45 ± 1.02, 29.78 ± 0.92, 44.37 ± 0.58, 53.68 ± 1.52, 47.31 ± 1.26 μM, respectivelypositive control dexamethasone (IC_{50} = 1.08 ± 0.15 μM) Overall good activity	Inhibiting NO	(Zhang et al., 2013)
Anti-tumor activity	shizukaol D	liver cancer cells	At the concentrations $\geq$ 6.25 μM Excellent activity	Wnt, β-catenin	(Tang et al., 2016)
	serralactone A	breast cancer cells	Against MDA-MB-23, MDA-MB-468 cells IC_{50} = 3.14 μM, 4.64 μM Excellent activity	LIM kinase 1	(Fu et al., 2018)
	codonolactone	breast cancer cells	Not mentioned	Runx2	(Wang et al., 2014b)
	yinxiancaoside A yinxiancaoside B yinxiancaoside C chloranoside A pisumionoside	Hepg-2, OV420 and MCF-7 cells	Against Hepg-2, OV420, MCF-7 cell lines Marginal *activity*	Not mentioned	(Kuang et al., 2009) (Kuang et al., 2008)

(*continued on next page*)

Table 2 (*continued*)

Pharmacological Action	Effective Fraction/ Compounds	Model	Responses along with Critical Assessment	Target or Possible Mechanism	References
	sarcaglaboside A chlotrichenes B	U2 OS	Synergetic cytotoxicity with DOX on U2 OS cells (CI: 0.94 ± 0.03)	Not mentioned	(Chi et al., 2019)
	henriols C	BEL7402, BGC-823, HCT-8 cells	Against BEL-7402, BGC823 cells IC_{50} = 1.4, 3.2 μM Good *activity*	Not mentioned	(Li et al., 2008)
	henrilabdanes A		Against BEL-7402, HCT-8, BGC-823 cells IC_{50} = 1.7, 0.54, 5.76 μM Moderate *activity*		
	chlorahupetones A chlorahupetones G chlorahupetones H chlorahupetones I	A549, U87, SMMC-7721 cells	Against A549 cells, U87 cells, SMMC-7721 cells IC_{50} = 9.82 ± 1.21, 0.43 ± 0.12, 0.94 ± 0.28, 3.15 ± 1.25 μMPaclitaxel (IC_{50} = 1.62 ± 0.13 μM) Excellent activity	Not mentioned	(Zhang et al., 2021)
	1α-hydroxy-8,12-epoxyeudesma-4,7,11-triene-6,9-dione	Hela, K562 human tumor cells	Against Hela, K562 human cells IC_{50} = 22.2, 21.8 μM Moderate *activity*	Not mentioned	(Wu et al., 2006)
	14-methoxy-15,16-dinor-5αH,9αH-labda-13(*E*),8(17)-dien-12-one		Against Hela, K562 human cells IC_{50} = 5.6, 5.9 μM Strong *activity*		
	shizukaol B shizukaol C shizukaol F shizukaol H	C8166 cells	Against C8166 cells IC_{50} = 0.020, 0.089, 0.047, 0.022 μM, respectively Significant *activity*	Not mentioned	(Fang et al., 2011)
	chloranthalactone A chloranthalactone B	MDA- MB-231, MDA-MB- 468 cells	ID_{50} = 2.5 μM, 1 ~ 2.5 μM, respectively Moderate activity	Snail、Slug and p53 protein	(Gong et al., 2021)
	chlohenriol A chlohenriol B chlohenriol C	PC12 cells	Increased cell viability from 55.4 ± 3.1 % to 66.2 ± 9.8, 58.2 ± 2.8, 78.5 ± 4.8 % at 10 μM, respectively, Moderate activity	Not mentioned	(Chen et al., 2021c)
	shizukanolide H	PC12 cells	EC_{50} = 3.3 ± 0.9 μM Strong activity	caspase-3, Akt	(Xu et al., 2018)
	chlogermacrone C zederone epoxide	PC12 cells	Increased cell viability from 43.4 ± 1.3 % to 99.6 ± 8.7, 68.1 ± 4.8 at 10 μM, respectively Excellent activity	Not mentioned	(Chen et al., 2020)
Neuroprotective activity	curzerenone zederone curcodione chlorantene C (1*E*,4*Z*)-8-hydroxy-6-oxogermacra-1(10),4,7(11)-trieno-12,8-lactone zederone epoxide	PC12 cells	Increased cell viability from 43.41 % ± 1.59 % to 62.61 % ± 5.23 %, 64.87 % ± 8.42 %, 56.06 % ± 6.65 %, 65.87 % ± 5.34 %, 60.54 % ± 3.32 %, 68.11 % ± 4.76 % at 10 μM, respectively Moderate activity	Not mentioned	(Chen et al., 2021a)
Regulation of glucose metabolism	shizukaol D	C3H10T1/2 cells	Not mentioned	Wnt3a, β-catenin, AMP-activated protein kinase	(Hu et al., 2017) (Yun et al., 2021)
Antimalarial activity	fortunoid A fortunoid B	P. falciparum strain Dd2	IC_{50} = 10.2 ± 0.37 μM, 0.5 ± 0.01 μM, respectively Moderate activity	Not mentioned	(Zhou et al., 2017b)
	fortunilide A sarglabolide J	P. falciparum strain Dd2	IC_{50} = 5.2 ± 0.6, 7.2 ± 1.3, 1.1 ± 0.2 μM, respectively	Not mentioned	(Zhou et al., 2017b)

Table 2 (*continued*)

Pharmacological Action	Effective Fraction/ Compounds	Model	Responses along with Critical Assessment	Target or Possible Mechanism	References
	chlorajaponilide C trichloranoids A trichloranoids D analogue	P. falciparum strain Dd2	Excellent activity IC_{50} = 2.50 ~ 5.00, 10.0 ~ 15.0, 1.25 ~ 2.50 μM, respectively Moderate activity	Not mentioned	(Zhou et al., 2021)
Potassium channel blocker	chloraholides A chloraholides B	rat dissociated hippocampal neurons	IC_{50} = 10.9, 18.6 μM, respectively tetraethylammonium chloride as the positive control Strong activity	Potassium (K +) channels	(Yang et al., 2007b)
	chloraholide C chloraholide D chloraholide E chloraholide F	rat hippocampal neurons	IC_{50} = 3.6 ± 10.1, 2.7 ± 0.3, 27.5 ± 5.1,57.5 ± 6.1 μM, respectively tetraethylammonium chloride as the positive control Strong activity	delayed rectifier Kñ current (IK)	(Yang et al., 2008)
Hepatoprotective activity	henriols A henrilabdanes A henrilabdanes B henrilabdanes C	WB-F344 rat cells	IC_{50} = 0.19, 0.66, 0.09, 0.18 μM, respectively Moderate activity	Not mentioned	(Li et al., 2008)
	sarcaglaboside A sarcaglaboside B sarcaglaboside C sarcaglaboside D sarcaglaboside E	WB-F344 rat hepatic epithelial stem-like cells	Against d-galactosamine-induced toxicity Cell survival rate = 47.5 ± 5.4, 74.9 ± 9.8, 53.0 ± 7.3, 46.3 ± 4.1, 45.5 ± 1.6, 42.4 ± 4.2, 54.5 ± 3.4 μM, respectively bicyclol = 46.6 (Positive control substance) Pronounced activity	D-Galactosamine	(Li et al., 2006)
Cell adhesion inhibitors	shizukaol B cycloshizukaol A shizukaol F	THP-1 cells	MIC = 34.1 *n*M, 0.9 *n*M, 27.3 *n*M, respectively IC_{50} = 54.6, 1.2, 34.1 μM Overall good activity	TNF-alpha	(Kwon et al., 2006)
Antiviral activity	shizukaol B shizukaol C shizukaol F shizukaol H	HIV_{wt}, $HIV_{RT\text{-}K103N}$, $HIV_{RT\text{-}K103N}$	Against HIV_{wt}, $HIV_{RT\text{-}K103N}$, $HIV_{RT\text{-}K103N}$ EC_{50} = 0.22, 0.47, 0.50 μM EC_{50} = 0.98, 1.36, 1.00 μM EC_{50} = 0.11, 3.39, 4.05 μM EC_{50} = 0.83, 2.35, 0.86 μM respectively, Best activity	Not mentioned	(Fang et al., 2011)

Table 3 Traditional uses of the genus *Chloranthus*.

Species	Local name	Parts	Distribution	Dosage forms	Traditioanal uses
Chloranthus multistachys	Siyexixin Dasiyedui Dasikuaiwa Sidatianwang Sidajingang Siyexixin	Whole herb Roots	China (Shaanxi, Jiangxi, Chongqing, Hubei, Hunan, Guangdong, Guangxi and Guizhou)	Decoction, vinum, pill, powder (taken orally); External application	Itchy skin, bruises and injuries, whole body pain, snakebite, nameless swelling poison and fracture
Chloranthus serratus	Siyedui Sidatianwang Sikuaiwa Zhangerxixin Siyexixin	Whole herb Roots Stems and Leaves	China (Jiangsu, Hubei, Hunan, Guangdong, Guangxi, Anhui, Zhejiang, Jiangxi, Sichuan and Fujian), Japan	Liniment; External application	Bruises and injuries, rheumatism, back and leg pain, furuncle and swelling poison, poisonous snake bite, dysmenorrhea, head sores and white baldness
Chloranthus spicatus	Zhulan Yuzilan Chalan Zhenzhulan Jizhualan	Whole herb Roots Leaves	China (Yunnan, Sichuan, Guizhou, Fujian and Guangdong), Japan	Decoction, vinum(orally); External application	Rheumatic pain, bruises and injuries, dermatitis and moss, strain and back pain epilepsy, insecticide, indigestion

(*continued on next page*)

Table 3 (*continued*)

Species	Local name	Parts	Distribution	Dosage forms	Traditioanal uses
	Mizilan				
Chloranthus henryi	Dayejiji Sidatianwang Siyedui Siyexixin Sidatianwang	Whole herb Roots	China (Zhangjiang, Jiangxi, Guangdong, Chongqing, Sichuan, Guizhou, Fujian, Hubei and Shaanxi)	Decoction, vinum(orally) ; External application	Snakebite, boils and sores, psoriasis wind-cold cough and asthma bone fracture, bruises and injuries
Chloranthus holostegius	Sikuaiwa Siyejin Heixixin Tuxixin	Whole herb Roots	China (Sichuan, Guangxi, Guizhou and Yunnan)	Decoction, vinum, pill (orally) ; External application	Paralysis, bone bruises and injuries, functional uterine bleeding, moss, rubella, furuncle, poisonous snake bite, liver wind headache, toothache
Chloranthus fortunei	Shuijinghua Foshijiinsulan Yinxianjinsulan Sizilian Sidajingang	Whole herb	China (Guangxi, Shandong, Jiangsu, Anhui, Zhejiang, Taiwan, Jiangxi, Hubei, Hunan, Guangdong and Sichuan)	Decoction (orally); External application	Rheumatism and cold paralysis, rheumatism and numbness, menstrual disorders, urticaria, bruises and injuries, wind-cold cough, canker sore and swelling poison
Chloranthus sessilifolius	Sikuaiwa Hongmaoqi Sidatianwang	Whole herb Roots	China (Guangxi, Guizhou, Sichuan and Hunan)	External application	Dispersing cold and relieving cough, promoting blood circulation and relieving pain
Chloranthus oldhamii	Dongnanjinsulan Luanbaojinsulan	Whole herb	China (Fujian, Taiwan and Guangdong)	Decoction, vinum(orally) ; External application	Stomach pain, poisonous snake bite, painful traumatic bruising to the chest, oral ulceration, dysmenorrhea, bruises and injuries
Chloranthus angustifolius	Siyexixin	Whole herb	China (Hubei, Chonhqing and Sichuan)	Decoction (taken orally)	Dispel wind-dampness, promoting menstruation
Chloranthus japonicus	Siyecao Sikuaiwa Siyeqi Sidatianwang Baimaoqi Jingangqi Maweiqi Guiduyou Duyaocao	Whole herb Roots Stems Leaves	China (Jilin, Liaoning, Hebei, Shaanxi, Shanxi, Gansu, Shandong and Hunan), Korea and Japan	Decoction, vinum(orally) ; External application	Traumatic bruises, sores and boils, breast Knot, itchy skin, menorrhagia, snake bite
Chloranthus elatior	Zhulan Yezhilan Xiaogeda Jiujiefeng Jiejiecha Shijiefeng	Whole herb Leaves Branches Flowers	China (Yunnan, Guangxi, Sichuan and Guizhou), Malaysia, Indonesia, Philippines and India	Decoction, pill, powder (orally) ; External application	Cold and flu, epilepsy, rheumatic soup bucket, bruises and injuries, postpartum bleeding

chemotherapy sensitizer (Yu and Jie, 2017). In addition, chloranthalactone C (**6**) can significantly inhibit the proliferation of tumor cells, such as blood, cervical, breast or pancreatic cancers. It can be developed as a new anti-tumor drug or its adjuvant component with significant tumor suppression effect (Yu et al., 2013). Yinxiancaoside A (**3**), yinxiancaoside B (**416**), and yinxiancaoside C (**417**) were shown to have significant anti-tumor activity in vitro, which can be used to develop into new, low-toxicity antitumor drugs from natural Chinese medicine (Kuang et al., 2010).

6.3. Others

The whole herb of *C. fortunei* and Chinese patent medicine snakebite detoxification tablet powder or Liushenwan can be mixed to make a kind of detoxification powder which has the function of local detoxification, dispersing blood stasis and reducing swelling. This product provides an effective treatment medicine for people working in the field after preventing poisonous insect bites, and several inventions have disclosed its

preparation method (Zhang et al., 2018a; Zhang et al., 2018b). C. spicatus combined with other herbs can be made into a medicinal wine with health effects and treatment of migraine (Cheng & Cheng, 2015; Liang, 2015). In addition, *C. japonicus* herb of the genus *Chloranthus* has a very broad development prospect in the treatment of psoriasis (Mao, 2017).

7. Conclusions and discussion

Many species of the genus *Chloranthus* have been used in TCM or folk medicines to treat various diseases. Among which the most widely studies are *C. japonicus*, *C. serratus*, *C. multistachys* and *C. henryi* (Fig. 20.). This article updates the references of this genus for the last three decades and summarized all the compounds of genus *Chloranthus*. To date, **418** compounds have been reported from the genus *Chloranthus*, which include **383** terpenoids, **4** coumarins, **6** lignans, **2** simple phenylpropanoids, **4** flavonoids, **5** organic acids, **6** amides, and **8** other compounds. Among them, sesquiterpenes were generally considered as major bioactive ingredients in *Chloranthus* which exhibited various qualities. Furthermore, pharmacological studies showed that *Chloranthus* plants possessed a wide range of pharmacological activities, such as anti-cancer, antibacterial, antiviral, hypoglycemic anti-inflammatory and antimalarial. Regardless, there are still several aspects that need to be concerned about the further development of genus *Chloranthus*.

In terms of chemical composition, sesquiterpenes are the most important active components of the genus *Chloranthus* (Fig. 21), which mainly distributed in *C. japonicus* and *C. fortunei* (Fig. 22). For further in-depth phytochemical scanning, Fig. 23 is performed to illustrate the type and the relative percentage of each chemical class isolated from *Chloranthus* species. These notifications are as the following: (1) Terpenoids are its main chemical components, mostly in the form of rings, with great structural variation. Some compounds open part of the ring

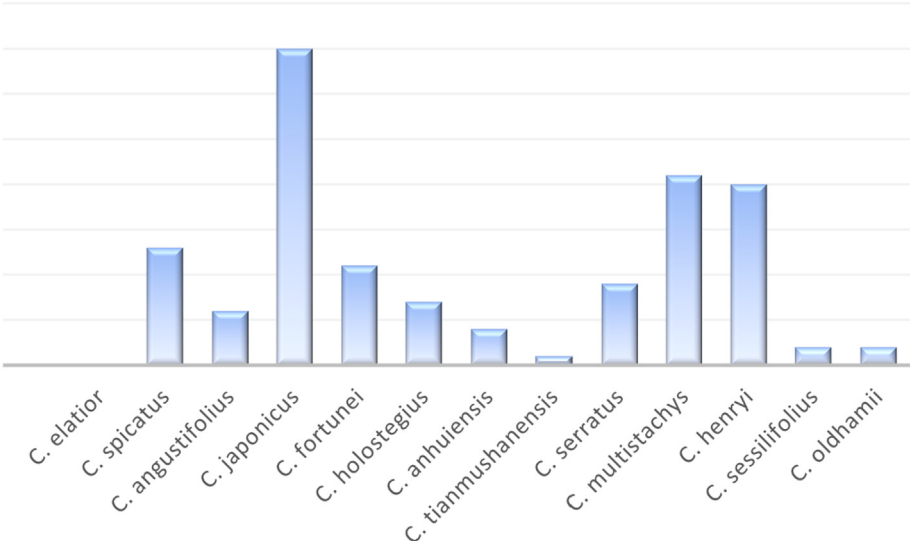


Fig. 20 The relative percentage of all published chemical and biological reports regarding *Genus Chloranthus* species.

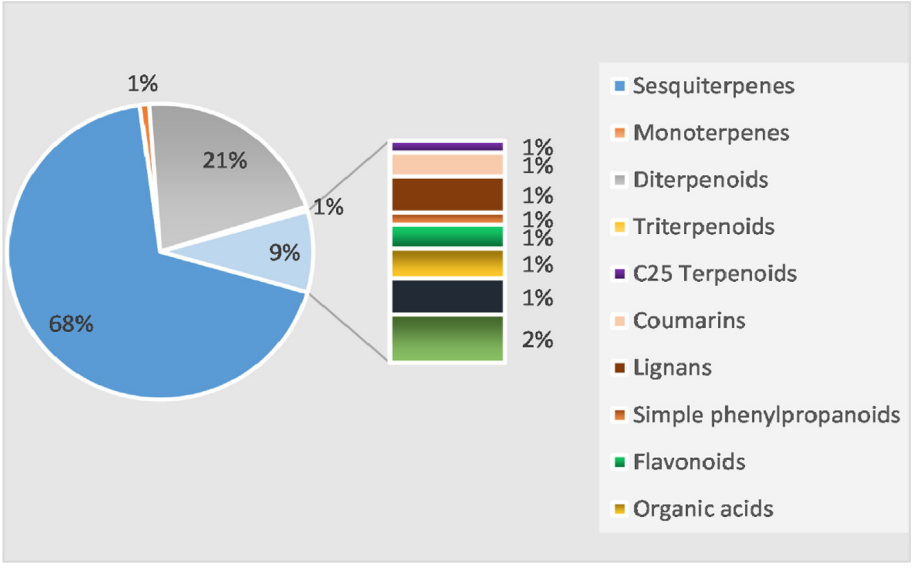


Fig. 21 The distribution of the secondary metabolites among *Genus Chloranthus* species.

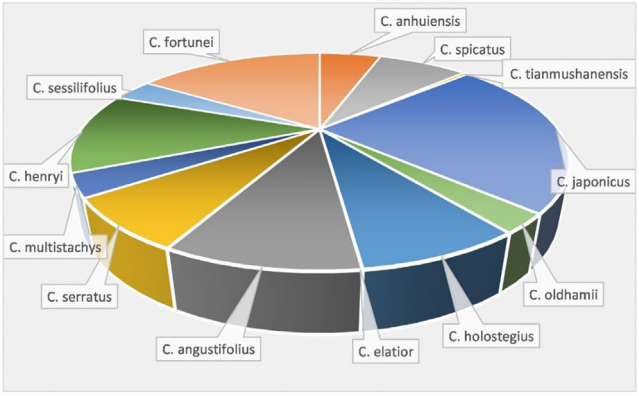


Fig. 22 The relative percentage of secondary metabolites isolated from *Genus Chloranthus* species.

structure on the original basis or form new rings on the original basis to form new compounds. In addition, the current research hot spot is the large ring structure of sesquiterpene dimer class, especially compounds shizukaol B (**65**), shizukaol F (**66**), shizukaol C (**68**) and chloramultilide B (**71**) were the most widely distributed and most frequently reported in the literature. (2): Diterpenes are the second major active constituents of the genus, in which more new bioactive monomers are continuously found. And they are mainly discovered in the *C. henryi*, *C. oldhamii*, *C. sessilifolius* and *C. serratus*, which are also the focus studying of the genus *Chloranthus*. (3): Fig. 23 is performed to illustrate that the chemical composition of *C. japonicus* is the most abundant, such as sesquiterpenes, monoterpenes, diterpenoids, C_{25} terpenoids, coumarins and lignans.

As a group of plants possess multiple biological activities, the genus *Chloranthus* is particularly well studied in terms of pharmacological mechanisms of action (Fig. 24), which include antitumor, anti-inflammatory, hypoglycemic and antimalarial. Among them, shizukanolide C (**29**) and chloranthalactone A-E (**2, 5, 6–8**) are the main active compounds, which have varieties of pharmacology activities. Meanwhile, chlorahupetones G, isolated from *C. henryi*, exhibited the most potent cytotoxicity against A549 cells, even about 4 times than paclitaxel (Zhang et al., 2021). Of course, it cannot be ignored that monomeric compounds with outstanding pharmacological activities can be considered the source of new drugs with excellent therapeutic effects. Furthermore, the characteristic components of aconite-type sesquiterpenes and their dimers in the genus *Chloranthus* are novel, complex and variable in structure and rich in pharmacological activities, which deserve attention in the subsequent research and development.

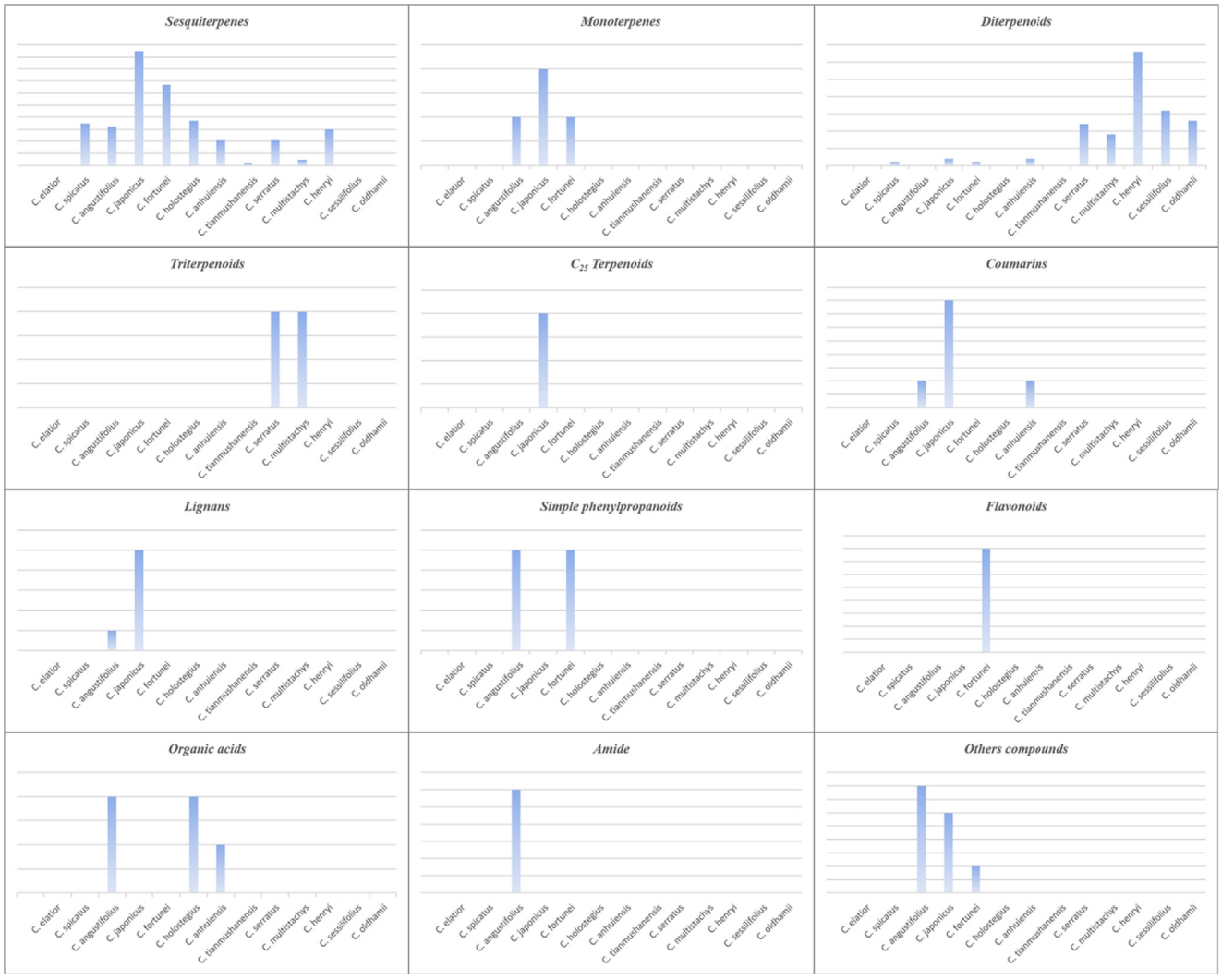


Fig. 23 The relative percentage of each chemical classes among different *Genus Chloranthus*.

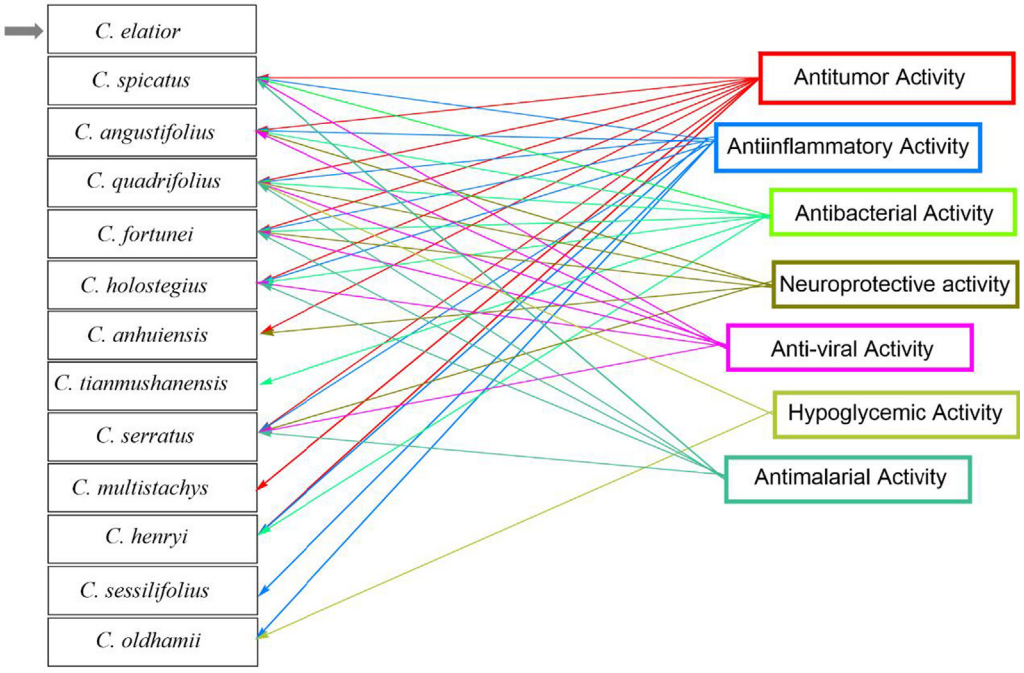


Fig. 24 The pharmacological activities of different *Genus Chloranthus* species.

As a genus with a complete distribution and the presence of endemic species in China, the research and development were still incomplete. Only a bit species has been studied so far, therefore, a systematic and in-depth study and development of the genus *Chloranthus* is critical.

Author contributions

All the authors have accepted responsibility for the entire content of this submitted manuscript and approved submission.

Funding

his work is supported by program project for Shaanxi Province (grant No 2019ZDLSF04-03-02); Subject Innovation Team of Shaanxi University of Chinese Medicine (grant number 2019-YL12) and the Natural Science Basic Research Project of Department of science and technology of Shaanxi Province (grant number: 2021JQ-744).

References

Bai, B., Ye, S.X., Yang, D.P., Zhu, L.P., Tang, G.H., Chen, Y.Y., Li, G.Q., Zhao, Z.M., 2019. Chloraserrtone A, a sesquiterpenoid dimer from *Chloranthus serratus*. J. Nat. Prod. 82, 407–411.

Cao, C.M., Peng, Y., Xiao, P.G., 2008. Advances in study on chemical constituents and pharmacological effects of *Chloranthus* plants. China J. Chin. Materia Medica 13, 1509–1515.

Chen, F.Y., Li, H.T., Chen, J., Lou, Y.M., 2019. Characteristic lindenane sesquiterpenoid dimers and labdane diterpenoids from *Chloranthus serratus*. J. Biochem. Syst. Ecol. 86, 103394.

Chen, F.Y., Li, H.T., Li, C.J., Chen, J., Huang, J.W., Li, C., Luo, Y. M., 2020. Neuroprotective racemic germacranolides from the roots of *Chloranthus henryi*. J. Fitoterapia 141, 104472.

Chen, F.Y., Chen, Z.C., Huang, W.M., Bian, Y.T., Shuang, P.C., Li, H.S., Luo, Y.M., 2021b. Chemical constituents from *Chloranthus fortunei* and their neuroprotective effects. Natl. Prod. Res. Develop. 33 (8), 1333–1338.

Chen, F.Y., Bian, Y.T., Huang, W.M., Chen, Z.C., Shuang, P.C., Feng, Z.G., 2021c. Research progress on chemical constituents from *Chloranthus* plants and their biological activities. China J. Chin. Materia Medica 46 (15), 3789–3796.

Chen, F., Yu, W.W., Lin, F.X., Huang, J.W., Huang, W.M., Shuang, P.C., Bian, Y.T., Luo, Y.M., 2021a. Sesquiterpenoids with neuroprotective activities from the Chloranthaceae plant Chloranthus henryi. J. Fitoterapia 151 (prepublish).

Cheng, X.G., Cheng, J.Q., 2015. A kind of external multifunctional health drink. CN104983963A.

Chi, J., Xu, W.J., Wei, S.S., Wang, X.B., Li, J.X., Gang, H.L., Kong, L.Y., Lou, J., 2019. Chlotrichenes A and B, Two lindenane sesquiterpene dimers with highly fused carbon skeletons from *Chloranthus holostegius*. Org. Lett. 21 (3), 789–792.

Chloranthaceae plant in Flora of China @ efloras.org., 2020. Chloranthaceae plant in Flora of *Chloranthus* 2020.

Chloranthus Swartz in Flora of China @ efloras.org" eFlora. Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA., 2002. Web. Accessed February 2018.

Du, X.Y., Wang, L.F., Li, Y.Z., 2017. Study on the chemical composition of the above-ground parts of *Chloranthus angustifolius* Oliv. Chin. Tradit. Herbal Drugs 48, 42–46.

Fang, P.L., 2011. Studies on chemical constituents and biological activities of Chloranthaceae. Qingdao University of Science and Technology, Qingdao.

Fang, P.L., Cao, Y.L., Yan, H., Pan, L.L., Liu, S.C., Gong, N.B., Lü, Y., Chen, C.X., Zhong, H.M., Guo, Y., Liu, H.Y., 2011. Lindenane disesquiterpenoids with anti-HIV-1 activity from *Chloranthus japonicus*. J. Nat. Prod. 74, 1408–1413.

Fu, J.J., Yu, J.J., Chen, J., Xu, H.J., Luo, Y.M., Lu, H., 2018. In vitro inhibitory properties of sesquiterpenes from *Chloranthus serratus* on cell motility via down-regulation of LIMK1 activation in human breast cancer. Phytomedicine 49, 23–31.

Gan, X.W., Ma, L., Chen, Q.G., Chen, Q.Q., Yu, Q., Hu, L.H., 2009. Terpenoids from roots of *Chloranthus henryi*. Planta Med. 75, 1344–1348.

Gong, X.M., Ou, C.L., Zhang, W.Y., Mo, D.D., Tang, B.L., Zhou, X.L., Wang, S., 2021. Research progress of yao medicine Chloranthus fortunei. Chin. Ethnic Folk Med. 30.

Guo, Y.Q., Tang, G.H., Li, Z.Z., Lin, S.L., Yin, S., 2015. Chlojapolactone A, an unprecedented 1,3-dioxolane linked-lindenane sesquiterpenoid dimer from *Chloranthus japonicus*. RSC Adv. 5 (125), 103047–103051.

Guo, Y.Q., Zhao, J.J., Li, Z.Z., Tang, G.H., Zhao, Z.M., Yin, S., 2016. Natural nitric oxide (NO) inhibitors from *Chloranthus japonicus*. Bioorg. Med. Chem. Lett. 26 (13), 3163–3166.

Heo, J.E., Jin, J.L., Lee, Y.Y., 2005. Chemical constituents of the aerial parts of *Chloranthus japonicus* Sieb. Nat. Prod. Sci. 11, 41–44.

Hu, R., Yan, H., Fei, X., Liu, H.Y., Wu, J.R., 2017. Modulation of glucose metabolism by a natural compound from *Chloranthus japonicus* via activation of AMP-activated protein kinase. Sci. Rep. 7, 778.

Huang, W.M., Chen, F.Y., Bian, Y.T., Ning, T.J., Chen, Z.C., Shuang, P.C., Luo, Y.M., 2021. Three pairs of sesquiterpene enantiomers from *Chloranthus multistachys* Pei. Nat. Prod. Res. 27, 1–8.

Huang, W.M., Chen, F.Y., Bian, Y.T., 2020. Study on the chemical composition and anti-inflammatory activity of *Chloranthus multistachys* Pei., vol. 32, pp. 1688–1697.

Kang, T.H., Lee, Y.M., Lee, W.J., Hwang, E.I., Park, K.D., Choi, G. J., Moon, J.S., Park, H.Y., Kim, S.U., 2017. Antifungal activities of dimeric sesquiterpenes, shizukaols C and F, isolated from *Chloranthus japonicus* Sieb. J. Microbiol. Biotechn. 27, 1272–1275.

Kawabata, J., Tahara, S., Mizutani, J., 1981. Isolation and structural elucidation of four sesquiterpenes from *Chloranthus japonicus* (Chloranthaceae). Agr. Biol. Chem. 45 (6), 1447–1453.

Kawabata, J., Fukushi, Y., Tahara, S., Mizutani, J., 1984. Structures of novel sesquiterpene alcohols from *Chloranthus japonicus*. Agric. Biol. Chem. 48, 713–717.

Kawabata, J., Fukushi, Y., Tahara, S., Mizutani, J., 1990. a sesquiterpene dimer from *Chloranthus japonicus*. Phytochemistry 29 (7), 2332–2334.

Kim, S.Y., Kashiwada, Y., Kawazoe, K., Murakami, K., Sun, H.D., Li, S.L., Takaishi, Y., 2011. Spicachlorantins G-J, new lindenane sesquiterpenoid dimers from the roots of *Chloranthus spicatus*. Chem. Pharm. Bull. 59 (10), 1281–1284.

Kim, S.Y., Nagashima, H., Tanaka, N., Kashiwada, Y., Kobayashi, J., Kojoma, M., 2016. Hitorins A and B, hexacyclic C_{25} terpenoids from *Chloranthus japonicus*. Org. Lett.. 18 (20), 5420–5423.

Kuang, H.X., Yang, B.Y., Xia, Y.G., Wang, Q.H., Lü, S.W., Sun, G. R., Gu, W.Q., Compounds with antitumor activity isolated from *Chloranthus* and their uses. CN101824014A. 2010.09.08.

Kuang, H.X., Xia, Y.G., Yang, B.Y., Wang, Q.H., Lü, S.W., 2008. Sesquiterpene glucosides from *Chloranthus japonicus* Sieb. Chem. Biodivers. 5 (9), 1736–1742.

Kuang, H.X., Xia, Y.G., Yang, B.Y., Wang, Q.H., Lü, S.W., 2009. Lignan constituents from *Chloranthus japonicus*. Sieb. Arch. Pharm. Res. 32 (3), 329–334.

Kwon, O.E., Lee, H.S., Lee, S.W., Bae, K., Kim, K., Hayashi, M., Rho, M.C., Kim, Y.K., 2006. Dimeric sesquiterpenoids isolated from *Chloranthus japonicus* inhibited the expression of cell adhesion molecules. J. Ethnopharmacol. 104, 270–277.

Li, Q., Wang, Y., Wen, S., Wu, Y., Sun, Z., 2019. A new dimeric sesquiterpenoid from *Chloranthus japonicus* Sieb. Rec. Nat. Prod. 13, 483–490.

Li, X.H., Yan, H., Ni, W., Qin, X.J., Liu, H.Y., 2016. Antifungal sesquiterpenoids from *Chloranthus japonicus*. Phytochem. Lett. 15, 199–203.

Li, Y., Zhang, D.M., Li, J.B., Yu, S.S., Li, Y., Luo, Y.M., 2006. Hepatoprotective sesquiterpene glycosides from sarcandra glabra. J. Nat. Prod. 69, 616–620.

Li, C.J., Zhang, D.M., Luo, Y.M., Yu, S.S., Li, Y., Lu, Y., 2008. Bissesquiterpenes and diterpenes from *Chloranthus henryi*. Phytochemistry 69, 2867–2874.

Li, L.X., 2011. Analysis of the antibacterial activity of the extracts of *Chloranthus japonicus* Sieb and *Chloranthus multistachys* Pei. Shaanxi University of Normal Studies.

Liang, D., A kind of medicinal wine for migraine. CN104758643A. 2015.07.08.

Liu, C.J., Li, G.H., Huang, R., Li, Y.Z., Ding, W.B., 2015. Chemotaxonomic significance of sesquiterpenes and amide derivatives from *Chloranthus angustzfolius* oliv. Biochem. Syst. Ecol.. 58, 30–33.

Liu, H.Y., Ran, X.H., Gong, N.B., Ni, W., Qin, X.J., Hou, Y.Y., Lü, Y., Chen, C.X., 2013. Sesquiterpenoids from *Chloranthus multistachys*. Phytochemistry 88, 112–118.

Lu, Y.B., Jiang, Y.L., Tan, X.M., 2020. Morphological diversity and geographical distribution of the genus *Chloranthus* in China. Guihaia 40 (1), 31–43.

Lu, Q.Q., Shi, X.W., Yang, X.K., 2015. Crystal structure of 4α-hydroxy-5α,8β(H)-eudesm-7(11)-en-8,1-2-olide monohydrate. Acta. Crystallogr. Sect. E. 71, 0518.

Lu, Q.Q., Shi, X.W., Zheng, S.J., Zhou, J.H., Cui, X.A., Gao, J.M., 2016. Two new sesquiterpenes from *Chloranthus japonicus* Sieb. Nat. Prod. Res. 30 (21), 2476–2482.

Luo, Y.M., Li, S.Y., Yin, X.Y., 2009. Study on the chemical composition of the family of Chloranthaceae. In: Proceedings of the 2009 National Symposium on Traditional Chinese Medicine, pp. 262–265.

Luo, Y.M., Luo, Y.D., Chen, F.Y., Fu, J.J., Liu, H., 2014. Terpenoids from *Chloranthus multistachys*. Adv. Mater. Res. 3514, 1033–1034.

Ma, L.F., Chen, Y.L., Shan, W.G., Zhang, Z.J., 2020. Natural disesquiterpenoids: an update. Nat. Prod. Rep. 37 (7), 999–1030.

Mao, Y., A kind of Chinese medicine for the treatment of parapsoriasis. CN106692625A. 2017.05.24.

Pan, L.L., Xu, P., Luo, X.L., Wang, L.J., Liu, S.Y., Zhu, Y.Z., Hu, J. F., Liu, X.H., 2017. Shizukaol B, an active sesquiterpene from *Chloranthus henryi*, attenuates LPS-induced inflammatory responses in BV2 microglial cells. Biomed. Pharmacother. 88, 878–884.

Shen, W.Y., Bai, R., Wang, A.R., He, J.Y., Wang, H., Zhang, Y., Zhao, X.F., Dong, J.Y., 2016. Two new polyhydroxysterols produced by fusarium solani, an endophytic fungus from *Chloranthus multistachys*. Nat. Prod. Res. 30 (19), 2173–2182.

Shen, C.P., Luo, J.G., Yang, M.H., Kong, L.Y., 2017. Sesquiterpene dimers from the roots of *Chloranthus holostegius* with moderate anti-inflammatory activity. Phytochemistry 137, 117–122.

Shi, X.W., Lu, Q.Q., Gennaro, P., Ivšić, T., Zhou, J.H., Gao, J.M., 2015. Three sesquiterpenoid dimers from *Chloranthus japonicus*: Absolute configuration of chloraholide A and related compounds. J. Chirality 28 (2), 158–163.

Sun, S.P., Li, H.X., Zhang, X.P., Ma, Y.F., Yang, M., 2019. Mechanisms of Toxicity and Cardiotoxicity of Alcohol Extract from root, stem and leaf of *Chloranthus Serratus*. J. Forensic Med. 35, 224–229.

Sun, S., Li, S., Du, Y., Wu, C., Zhang, M., Li, J., Zhang, X., 2020. Anti-inflammatory effects of the root, stem and leaf extracts of *Chloranthus serratus* on adjuvant-induced arthritis in rats. Pharm. Biol. 58, 528–537.

Tan, M.J., 2018. Biomedical use of chloranthalactone A as an indoleamine 2,3-dioxygenase 1 inhibitor. CN108379250A. 2018a.08.10.

Tan, M.J., 2018. Biomedical use of chloranthalactone D as an indoleamine 2,3-dioxygenase 1 inhibitor. CN108558903A. 2018b.09.21.

Tan, M.J., 2018. Biomedical use of chloranthalactone F as an indoleamine 2,3-dioxygenase 1 inhibitor. CN108578401A. 2018c.09.28.

Tan, MJ., 2018. Biomedical use of chloranthalactone C as an indoleamine 2,3-dioxygenase 1 inhibitor. CN108478565A. 2018d.09.04.

Tan, MJ., 2018. Biomedical use of chloranthalactone E as an indoleamine 2,3-dioxygenase 1 inhibitor. CN108392477A. 2018e.08.14.

Tang, L.S., Zhu, H.R., Yang, X.M., Xie, F., Peng, J., Jiang, D., Xie, J., Qi, M., Yu, L., 2016. Shizukaol D, a dimeric sesquiterpene isolated from *Chloranthus serratus*, represses the growth of human liver cancer cells by modulating wnt signalling pathway. PLoS ONE 11, 0152012.

Teng, F., Zhong, H.M., Chen, C.X., Liu, H.Y., 2010. Four new eudesmane sesquiterpenoid lactones from *Chloranthus serratus*. Helv. Chim. Acta 92, 1298–1303.

Uchida, M., Koike, Y., Kusano, G., Kondo, Y., Nozoe, S., Kabuto, C., Takemoto, T., 1980. Studies on the constituents of *Chloranthus* spp. III. Six sesquiterpenes from *Chloranthus japonicus*. Chem. Pharm. Bull. 28 (1), 92–102.

Wang, C., 2014. Study on the Chemical Constituents of Four Medicinal Plants. South-Central Minzu University, Wuhan.

Wang, W., Chen, B., Zou, R., Tu, X., Tan, S., Lu, H., Liu, Z., Fu, J., 2014b. Codonolactone, a sesquiterpene lactone isolated from *Chloranthus henryi* hemsl, inhibits breast cancer cell invasion, migration and metastasis by downregulating the transcriptional activity of Runx2. Int. J. Oncol. 45 (5), 1891–1900.

Wang, Q.H., Kuang, H.X., Yang, B.Y., Xia, Y.G., Wang, J.S., Kong, L.Y., 2011. Sesquiterpenes from *Chloranthus japonicus*. J. Nat. Prod. 74 (1), 16–20.

Wang, A.R., Song, H.C., An, H.M., Huang, Q., Luo, X., Dong, J.Y., 2015a. Secondary metabolites of plants from the genus *Chloranthus*: chemistry and biological activities. Chem. Biodivers. 12 (4), 451–473.

Wang, X.C., Wu, W.Q., Ma, S.P., Liu, J.H., Hu, L.H., 2008. A New Sesquiterpenoid from the roots of *Chloranthus fortunei*. Chin. J. Nat. Med. 6 (6), 404–407.

Wang, X.C., Wang, L.L., Ouyang, X.W., Liu, J.H., Hu, L.H., 2009. Sesquiterpenes and dimers thereof from *Chloranthus fortunei*. Helv. Chim. Acta. 92 (2), 313–320.

Wang, L.J., Xiong, J., Liu, S.T., Liu, X.H., Hu, J.F., 2014a. Sesquiterpenoids from *Chloranthus henryi* and their anti-neuroinflammatory activities. Chem. Biodivers. 11, 919–928.

Wang, L.J., Xiong, J., Lau, C., Pan, L.L., Hu, J.F., 2015b. Sesquiterpenoids and further diterpenoids from the rare Chloranthaceae plant *Chloranthus sessilifolius*. J. Asian. Nat. Prod. Res. 17 (12), 1220–1230.

Wang, L.J., Xiong, J., Liu, S.T., Pan, L.L., Yang, G.X., Hu, J.F., 2015c. Ent-abietane-type and related Seco-/Nor-diterpenoids from the rare Chloranthaceae plant *Chloranthus sessilifolius* and their antineuroinflammatory activities. J. Nat. Prod.. 78 (7), 1635–1646.

Wu, B., He, S., Wu, X.D., Pan, Y.J., 2006. Bioactive terpenes from the roots of *Chloranthus henryi*. Planta Med. 72 (14), 1334–1338.

Wu, B., He, S., Wu, X.D., 2007. Cadinane and eudesmane sesquiterpenoids from *Chloranthas henryi*. Helv. Chim. Acta 90, 1586–1592.

Wu, B., He, S., Wu, X.D., Pan, Y.J., 2008. New tyrosinase inhibitory sesquiterpenes from *Chloranthus henryi*. Chem. Biodivers.. 5 (7), 1298–1303.

Wu, B., Gan, L.S., Qu, H.B., 2010. An unusual stress metabolite induced by CuCl(2) and other constituents from the leaves of *Chloranthus anhuiensis*. J. Nat. Prod. 73 (6), 1069–1074.

Xie, C.F., Sun, L.M., Liao, K.S., Liu, S., Wang, M., Xu, J., Bartlam, M., Guo, Y., 2015. Bioactive ent-pimarane and ent-abietane diterpenoids from the whole plants of *Chloranthus henryi*. J. Nat. Prod. 78 (11), 2800–2807.

Xiong, J., Hong, Z.L., Gao, L.X., Shen, J., Liu, S.T., Yang, G.X., Li, J., Zeng, H., Hu, J.F., 2015. Chlorabietols A-C, phloroglucinol-diterpene adducts from the Chloranthaceae plant *Chloranthus oldhamii*. J. Org. Chem. 80, 11080–11085.

Xiong, J., Hong, Z.L., Xu, P., Zou, Y., Yu, S.B., Yang, G.X., Hu, J. F., 2016. Ent-Abietane diterpenoids with anti-neuroinflammatory activity from the rare Chloranthaceae plant *Chloranthus oldhamii*. Org. Biomol. Chem. 14, 1–15.

Xu, Y.J., 2013. Phytochemical and biological studies of *Chloranthus* medicinal plants. Chem. Biodivers. 10 (10), 1754–1773.

Xu, L.L., 2016. Chemical Composition Study of *Chloranthus Holostegius* and *Sarcandra glabra*. Yunnan University of Traditional Chinese Medicine, Kunming.

Xu, Y.J., Tang, C.P., Ke, C.Q., Zhang, J.B., Weiss, H.C., Gesing, E. R., Ye, Y., 2007. Mono- and di-sesquiterpenoids from *Chloranthus spicatus*. J. Nat. Prod. 70 (12), 1987–1990.

Xu, Y.J., Tang, C.P., Tan, M.J., Ke, C.Q., Wu, T., Ye, Y., 2010. Sesquiterpenoids and diterpenoids from *Chloranthus anhuiensis*. Chem. Biodivers. 7, 151–157.

Xu, J., Zhu, H.L., Zhang, J., Du, T., Guo, E.Y., Liu, W.Y., Luo, J. G., Ye, F., Feng, F., Qu, W., 2018. Sesquiterpenoids from *Chloranthus anhuiensis* with neuroprotective effects in PC12 Cells. J. Nat. Prod. 81 (6), 1391–1398.

Yan, H., Li, X.H., Zheng, X.F., Sun, C.L., Liu, H.Y., 2013. Chlojaponilactones B - E, four new lindenane sesquiterpenoid lactones from *Chloranthus japonicus*. Helv. Chim. Acta. 96 (7), 1386–1391.

Yan, H., Qin, X.J., Li, X.H., Yu, Q., Ni, W., Li, H.e., Liu, H.Y., 2019. Japonicones A-C: Three lindenane sesquiterpenoid dimers with a 12-membered ring core from *Chloranthus japonicus*. Tetrahedron Lett. https://doi.org/10.1016/j.tetlet.

Yang, S.P., Zhang, C.R., Chen, H.D., Liao, S.G., Yue, J.M., 2007a. Sesquiterpenoids from *Chloranthus spicatus* (Thunb.) Makino. Chin. J. Chem. 25 (12), 1892–1895.

Yang, S.P., Gao, Z.B., Wang, F.D., Liao, S.G., Chen, H.D., Zhang, C.R., Hu, G.Y., Yue, J.M., 2007b. Chlorahololides A and B, two potent and selective blockers of the potassium channel isolated from *Chloranthus holostegius*. Org. Lett. 9, 903–906.

Yang, S.P., Gao, Z.B., Yan, W., Hu, G.Y., Yue, J.M., 2008. Chloraholides C-F: a new class of potent and selective potassium channel blockers from *Chloranthus holostegius*. Tetrahedron 64 (9), 2027–2034.

Yang, S.P., Chen, H.D., Yue, J.M., 2012. Sesquiterpenoids from *Chloranthus spicatus*. Chin. J. Chem. 30, 1243–1248.

Yang, X.Z., Wang, C., Yang, J., Wan, D., Lin, Q., Yang, G., Mei, Z., Feng, Y., 2014. Antimicrobial sesquiterpenes from the Chinese medicinal plant, *Chloranthus angustifolius*. Tetrahedron Lett. 55, 5632–5634.

Yim, N.H., Hwang, EII., Yun, B.S., Park, K.D., Moon, J.S., Lee, S. H., Sung, N.D., Kim, S.U., 2008. Sesquiterpene furan compound CJ-01, a novel chitin synthase 2 inhibitor from *Chloranthus japonicus* sibe. Biol. Pharm. Bull. 31 (5), 1041–1044.

Yu, L., Jie, F., 2017. Application of shizukaol D in the preparation of antitumor drug sensitizer. CN106902109A. 2017.06.30.

Yu, L., Tang, L.S., 2016. Application of shizukaol D in preparation of drugs for hepatocellular carcinoma. CN105213369A. 2016.01.06.

Yu, L., Tang, L.S., Liu, Z.L., 2013. Application of chloranthalactone C in the preparation of antitumor drugs. CN103054851A. 2013.

Yuan, T., Zhang, C.R., Yang, S.P., Yin, S., Wu, W.B., Dong, L., Yue, J.M., 2008. Sesquiterpenoids and phenylpropanoids from *Chloranthus serratus*. J. Nat. Prod. 71, 2021–2025.

Yun, U.J., Nho, C.W., Park, K.W., Yang, D.K., 2021. Hexane Extract of *Chloranthus japonicus* increases adipocyte differentiation by acting on Wnt/β-Catenin signaling pathway. Life-Basel. 11, 241.

Zhan, Z.C., Wu, Z.N., Tang, Q., Li, C.J., Wang, W.Z., Zhang, J.H., Zhuo, X.F., Zhang, Y.B., Wang, G.C., Li, Y.L., 2021. Sesquiterpenoids from the whole plants of *Chloranthus holostegius* and their anti-inflammatory activities. Chin. J. Chem. 39. https://doi.org/10.1002/cjoc.202000625.

Zhang, H., 2016. Progress in the study of medicinal plants of the genus *Chloranthus*. Inner Mongolia Tradit. Chin. Med. 35 (2), 155–156.

Zhang, K.C., Zhang, Y., Zhang, L., 2018. The invention relates to a preparation method of compound *Chloranthus fortunei*. CN108904680A 2018a.11.30.

Zhang, K.C., Zhang, Y., Zhang, L., 2018. An antidote to the poison of *Chloranthus fortunei*. CN109010393A 2018b.12.18.

Zhang, M., Wang, J.S., Wang, P.R., Oyama, M., Luo, J., Ito, T., Iinuma, M., Kong, L.Y., 2012a. Sesquiterpenes from the aerial part of *Chloranthus japonicus* and their cytotoxicities. Fitoterapia 83 (8), 1604–1609.

Zhang, M., Iinuma, M., Wang, J.S., Oyama, M., Ito, T., Kong, L.Y., 2012b. Terpenoids from *Chloranthus serratus* and their anti-inflammatory activities. J. Nat. Prod. 75 (4), 694–698.

Zhang, M., Wang, J.S., Oyama, M., Luo, J., Guo, C., Ito, T., Iinuma, M., Kong, L.Y., 2012c. Anti-inflammatory sesquiterpenes and sesquiterpene dimers from *Chloranthus fortunei*. J. Asian Nat. Prod. Res. 14, 708–712.

Zhang, M., Wang, J.S., Luo, J., Wang, P.R., Guo, C., Kong, L.Y., 2013. Labdane diterpenes from *Chloranthus serratus*. Fitoterapia 91, 95–99.

Zhang, D.Y., Wang, X.X., Wang, Y.N., Wang, M., Zhuang, P.Y., Yang, J., Liu, H., 2021. Nine sesquiterpenoid dimers with four unprecedented types of carbon skeleton from *Chloranthus henryi* var. hupehensis. J. Org. Chem. Front. 8.

Zhang, S., Yang, S.P., Yuan, T., Li, B.D., Wu, Y., Yue, J.M., 2010. Multistalides A and B, two novel sesquiterpenoid dimers from *Chloranthus multistachys*. Tetrahedron Lett. 51, 764–766.

Zhao, J.J., Guo, Y.Q., Yang, D.P., Xue, X., Liu, Q., Zhu, L.P., Yin, S., Zhao, Z.M., 2016. Chlojaponilactone B from *Chloranthus japonicus*: Suppression of inflammatory responses via inhibition of the NF-κB Signaling Pathway. J. Nat. Prod. 79, 2257–2263.

Zhou, B., Liu, Q.F., Dalal, S., Cassera, M.B., Yue, J.M., 2017a. Fortunoids A-C, three sesquiterpenoid dimers with different carbon skeletons from *Chloranthus fortunei*. Org. Lett. 19, 734–737.

Zhou, J.S., Liu, Q.F., Zimbres, F.M., Butler, J.H., Yue, J.M., 2021. Trichloranoids A-D, antimalarial sesquiterpenoid trimers from *Chloranthus spicatus*. Org. Chem. Front. 8 (8), 1795–1801.

Zhou, B., Wu, Y., Dalal, S., Merino, E.F., Liu, Q.F., Xu, C.H., Yuan, T., Ding, J., Kingston, D.G., Cassera, M.B., Yue, J.M., 2017b. Nanomolar antimalarial agents against chloroquine-resistant plasmodium falciparum from medicinal plants and their structure-activity relationships. J. Nat. Prod. 80 (1), 96–107.

Zhu, H.L., Qu, W., Zhang, J., Guo, E.Y., Du, T., Liu, W.Y., Cao, W. Y., Feng, F., Xu, J., 2018. Chemical constituents from *Chloranthus anhuiensis* and their cytotoxic activities. Chem. Biodivers. 15, (10) e1800249.

Zhuo, Z.G., Wu, G.Z., Fang, X., Tian, X.H., Dong, H.Y., Xu, X.K., Li, H.L., Xie, N., Zhang, W.D., Shen, Y.H., 2017. Chlorajaponols A-F, sesquiterpenoids from *Chloranthus japonicus* and their in vitro anti-inflammatory and anti-tumor activities. Fitoterapia 119, 90–99.