Natural Products and Bioprospecting (2019) 9:357–392
https://doi.org/10.1007/s13659-019-00222-3

REVIEW

The Genus *Terminalia* (Combretaceae): An Ethnopharmacological, Phytochemical and Pharmacological Review

Xiao-Rui Zhang[1,2] · Joseph Sakah Kaunda[1,2] · Hong-Tao Zhu[1] · Dong Wang[1] · Chong-Ren Yang[1] · Ying-Jun Zhang[1,3]

Received: 31 July 2019 / Accepted: 15 October 2019 / Published online: 6 November 2019

Abstract

Terminalia Linn, a genus of mostly medium or large trees in the family Combretaceae with about 250 species in the world, is distributed mainly in southern Asia, Himalayas, Madagascar, Australia, and the tropical and subtropical regions of Africa. Many species are used widely in many traditional medicinal systems, e.g., traditional Chinese medicine, Tibetan medicine, and Indian Ayurvedic medicine practices. So far, about 39 species have been phytochemically studied, which led to the identification of 368 compounds, including terpenoids, tannins, flavonoids, phenylpropanoids, simple phenolics and so on. Some of the isolates showed various bioactivities, in vitro or in vivo, such as antitumor, anti HIV-1, antifungal, antimicrobial, antimalarial, antioxidant, diarrhea and analgesic. This review covers research articles from 1934 to 2018, retrieved from SciFinder, Wikipedia, Google Scholar, Chinese Knowledge Network and Baidu Scholar by using "*Terminalia*" as the search term ("all fields") with no specific time frame setting for the search. Thirty-nine important medicinal and edible *Terminalia* species were selected and summarized on their geographical distribution, traditional uses, phytochemistry and related pharmacological activities.

Keywords *Terminalia* · Combretaceae · Ethnomedicine · Traditional uses · Phytochemistry · Hydrolyzable tannins · Pharmacology

Abbreviations

A.	*Aspergillus*
BCG	*Bacillus Calmette Guerin*
BMM	Broth microdilution method
Ca.	*Candida*
Cr.	*Cryptococcus*
CC_{50}	Cytotoxic concentration of the extracts to cause death to 50% of host's viable cells
DPPH	2,2-Diphenyl-1-picrylhydrazyl
E.	*Escherichia*
EC_{50}	Half maximal effective concentration
FRAP	Ferric reducing/antioxidant power
GABA	Neurotransmitter gamma-aminobutyric acid
IC_{50}	Minimum inhibition concentration for inhibiting 50% of the pathogen
K.	*Klebsiella*
MIC	Minimum inhibitory concentration
MTT	3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyl tetrazolium bromide
Ps.	*Pseudomonas*
Sa.	*Salmonella*
Sta.	*Staphylococcus*
Str.	*Streptomyces*

✉ Ying-Jun Zhang
zhangyj@mail.kib.ac.cn

[1] State Key Laboratory of Phytochemistry and Plant Resources in West China. Kunming Institute of Botany, Chinese Academy of Sciences, Kunming 650204, People's Republic of China

[2] University of Chinese Academy of Sciences, Beijing 100049, People's Republic of China

[3] Yunnan Key Laboratory of Natural Medicinal Chemistry, Kunming Institute of Botany, Chinese Academy of Sciences, Kunming 650201, People's Republic of China

1 Introduction

Terminalia Linn, comprising about 250 species in the world mostly as medium or large trees, is the second largest genus in the family Combretaceae. The name "*Terminalia*" is derived from Latin word "terminus", which means the leaves are located at the tip of the branch. The bark of *Terminalia* plants usually has cracks and branches tucked into layers. Most of the *Terminalia* plants' leaves are large, leathery

with solitary or clustered small green white flowers. Their fruits are yellow, dark red or black; drupe, usually angular or winged. Some fruits are edible, highly nutritious and possess medicinal values.

Terminalia species are widely distributed in the southern Asia, Himalayas, Madagascar, Australia, and the tropical and subtropical regions of Africa. *Terminalia* plants in southern Asia have been intensively studied phytochemically due to their wide usage in Asian (India, Tibetan, and Chinese) traditional medicine systems [1]. For example, the fruits of *Terminalia bellirica* and *Terminalia chebula*, together with *Phyllanthus emblica* (Euphorbiaceae) which form the herbal remedy, Triphala, in Tibetan medicine, have received much attention because of its extensive and remarkable effectiveness in the treatment of anticancer, antifungal, antimicrobial, antimalarial, antioxidant.

So far, 39 *Terminalia* species have been investigated for their phytochemical constituents, which resulted in the identification of terpenes, tannins, flavonoids, lignans and simple phenols, amongst others. Pharmacological studies suggest that they have exhibited activity on liver and kidney protection, antibacterial, antiinflammatory, anticancer, and have displayed a positive effect on immune regulation, cardiovascular disease and diabetes, and acceleration of wound healing.

This paper features 39 important medicinal and edible *Terminalia* species and summarizes their traditional usage, geographical distribution, structures of isolated chemical constituents and pharmacological activities.

2 Species' Description, Distribution and Traditional Uses

So far, 50 *Terminalia* species have been documented, 39 of which have been reported to possess medicinal properties and/or being edible. Among them, eight species and four varieties including *T. argyrophylla*, *T. bellirica*, *T. catappa*, *T. chebula*, *T. franchetii*, *T. hainanensis*, *T. myriocarpa*, *T. intricate*, *T. chebula* var. *tomentella*, *T. franchetii* var. *membranifolia*, *T. franchetii* var. *glabra*, and *T. myriocarpa* var. *hirsuta* are distributed in China (Yunnan, southeast Tibet, Taiwan, Guangdong, south Guangxi and southwest Sichuan). Their distribution and traditional applications are shown in Table 1.

Terminalia species are broadly used in many aspects. Some are employed as drugs, while others can provide high quality wood, tannin or dyes. For example, fruits of *T. ferdinandiana*, a species largely distributed in Australia, are rich in vitamin C, and possess strong antioxidant activity [25]. *T. bellirica* and *T. chebula* are not only recorded in every version of Chinese pharmacopoeia, but are also the important and most commonly applied drugs in Han, Tibetan, Mongolian and many other folk medicinal systems in India, Burma, Thailand, Malaysia, Vietnam and other southeast asian countries. *T. catappa* is a commonly used medicinal plant for liver protection in China [20].

3 Chemical Composition

Since 1930s, the chemical compositions of the genus *Terminalia* have been vastly studied. *T. arjuna*, *T. bellirica*, *T. catappa* and *T. chebula*, having been frequently used in the Ayurvedic, Chinese and Tibetan medicines, attracted scholars' attention. To date, 368 compounds, largely terpenoids (**1–104**), tannins (**105–196**), flavonoids (**197–241**), lignans (**242–265**), phenols and glycosides (**268–318**) were reported from the genus (Tables 2, 3).

3.1 Terpenoids

So far, 104 terpenoids (Fig. 1) including 86 triterpenes (**1–86**), 14 monoterpenes (**87–100**), 4 sesquiterpenes (**101–104**) have been reported from the genus *Terminalia*. The triterpenoids are mainly oleanane, ursane and lupine types, and their glycosides. Particularly, Atta-ur-Rahman et al. isolated a new *seco*-triterpene terminalin A (**81**) possessing a novel rearranged *seco*-glutinane structure with a pyran ring-A and an isopropanol moiety from the stem barks of *T. glaucescens* [129]. Ponou et al. found two dimeric triterpenoid glucosides, ivorenosides A and B (**49–50**) possessing an unusual skeleton [131], and two new oleanane type triterpenes, 3-oxo-type ivorengenin A (**41**) and 3,24-dinor-2,4-secooleanane-type ivorengenin B (**53**) from the barks of *T. ivorensis* [132]. Compounds **41**, **49** and **53** showed significant anticancer activities. Wang et al. isolated five new 18,19-secooleanane type triterpene glycosyl esters, namely arjunasides A–E (**82–86**) from the MeOH extract of *T. arjuna*'*s* barks, TaBs [68]. Moreover, five ursane type triterpene glucosyl esters (**64–68**) were also obtained for the first time [76]. From the fruits of *T. chebula*, 23-*O*-neochebuloylarjungenin 28-*O*-β-D-glycosyl ester (**21**) and 23-*O*-4′-*epi*-neochebuloylarjungenin (**22**) with novel substituents at C-23 were reported, in addition to compounds **23–24**, **30–32** and **63**, whose C-23 substituents were gallate. Compounds **30** and **31** had strong hypoglycemic effect [146]. Furthermore, compound **40** was obtained from the barks of *T. arjuna* [85], while friedelin (**79**) with 3-oxo moiety was reported from the fruits of *T. arjuna* [83], the root barks of *T. avicennioides* [93], and the stem barks of *T. glaucescens* [130] and *T. mollis* [35].

Table 1 Local names, distributions and traditional uses of *Terminalia* plants

No.	Plants	Local names	Distributions	Traditional uses
T1	*T. alata*	Unknown	Southern Vietnam [2, 3]	Anti-diarrhea, ulcer, diuretics, supplements [3]
T2	*T. amazonia*	White olive	Southern Costa Rica [4]	Wood
T3	*T. arborea*	Jaha Kling	Indonesia	Cardiovascular disease, myocardial infarction, atherosclerosis, diabetes, cancer, stroke, cataract, shoulder stiffness, cold allergy, hypertension, senile dementia, inflammation, gum disease (e.g. gingivitis, pneumonia), Alzheimer's, skin conditions [5]
T4	*T. arjuna*	Arjuna, White Marudah, Koha	India, South Asia, Sri Lanka [6]	Cardiotonic, sores, bile infection, poison antidote [6] Coughs, dysentery, fractures, contusions, ulcers, hypertension ischaemic heart diseases [23]
T5	*T. argyrophylla*	Silver leaves Chebula, Xiao Chebula (Yunnan), Manna (Yunnan Dai language)	China (Yunnan) [7]	Autoimmune diseases [7]
T6	*T. australis*	Tanimbu, palo amarillo	Punta Lara, Argentina (Buenos Aires) [8]	Hemostasis
T7	*T. avicennioides*	kpayi, Kpace, baushe	Nigeria [9, 10]	Malaria, worms, gastric peptic ulcer [9], scorpion bites [10], tuberculosis, cough [90]
T8	*T. bellirica*	Beleric	China (southern Yunnan), Vietnam, Laos, Thailand, Cambodia, Myanmar, India (except West), Malaysia, Indonesia	Laxative, edible Edema, diarrhea, leprosy, bile congestion, indigestion, headache [11] Fever, diarrhea, cough, dysentery, skin diseases [12] Wine, palm sugar [23] Diarrhea [94]
T9	*T. bentzoe*	Unknown	Rodrigues [13]	Essential oil [13]
T10	*T. bialata*	Indian silver greywood	India, South Asia	Wood [14]
T11	*T. brachystemma*	Kalahari cluster leaf	Southern Africa	Shistosomiasis, gastrointestinal disorders [15]
T12	*T. brownii*	kuuku, muvuku (Kamba, Kenya), koloswa (northern region, Kenya), weba (Ethiopia), lbukoi (Samburu, Kenya), orbukoi (Maasai, Tanzania), and mbarao or mwalambe, in Kiswahili	Southern and central Africa	Diarrhea, stomach pain, gastric ulcer, colic, heartburn Genitourinary infection, urethral pain, endometritis, cystitis, leucorrhea, syphilis, gonorrhea, malaria, dysmenorrhea, nervousness, hysteria, epilepsy, athlete's foot, indigestion, stomach pain, gastric ulcer, colitis, cough, vomiting, hepatitis, jaundice, cirrhosis, yellow fever [16]
T13	*T. bursarina*	Yellow wood	Australia, South Asia [17]	Unknown
T14	*T. calamansanai*	Phillipine almond, Anarep	Philippines, Southeast Asia	Lithontriptic [18], horticultural plant [102]
T15	*T. calcicola*	Unknown	Madagascar Rain Forest [19]	Unknown
T16	*T. catappa*	Indian almond, umbrella tree, tropical almond	China (Guangdong, Taiwan, SE Yunnan), Australia and SE Asia, Africa, South America Tropical Coast	Blood stasis, liver injury [20] Diarrhea, dysentery, biliary inflammation [23], dermatitis, hepatitis [106]

Table 1 (continued)

No.	Plants	Local names	Distributions	Traditional uses
T17	*T. chebula*	Black Mytrobalan, Inknut, Chebulic Myrobalan	Nepal, northern India, Myanmar, Sri Lanka, Thailand, Bangladesh, China (Yunnan), Himalayan	Digestion appetizers, vomiting, infertility, asthma, sore throat, vomiting, urticaria, diarrhea, dysentery, bleeding, ulcers, gout, bladder disease [21]
T18	*T. chebula* var. *tomentella*	Weimaohezi (variant)	China (western Yunnan), Myanmar	Unknown
T19	*T. citrina*	Manahei, Yellow myrobalan	India, Bangladesh [22]	Dysmenorrhea, bleeding, heart disease, dysentery, constipation [22]
T20	*T. elliptica*	Indian laurel	SE Asia, India, Bangladesh, Laos, Myanmar, Nepal, Thailand, Cambodia, Vietnam	Wine, palm sugar Ulcers, fractures, bleeding, bronchitis, diarrhea [23]
T21	*T. franchetii*	Dianlanren	SW China [24]	Unknown
T22	*T. franchetii* var. *membranifolia*	Baoyedianlanren (variant)	China [western Guangxi (Longlin), central to SE Yunnan]	Unknown
T23	*T. franchetii* var. *glabra*	Guang yedianlanren (variant)	China (Sichuan and Yunnan Jinsha River Basin)	Unknown
T24	*T. ferdinandiana*	Gubinge, Bbillygoat plum, Kakadu plum, green plum, salty plum, murunga, mador	Australia [25]	Dietary supplements, skin care [25]
T25	*T. glaucescens*	Unknown	Nigeria [26]	Amenorrhea, vaginal infections, syphilis, sores, neurological disorders Anti-plasma, antiparasitic, antiviral, antimicrobial [26, 27]
T26	*T. hainanensis*	Ji zhenmu, Hainan lanren	China (Hainan)	Antioxidant [28]
T27	*T. intricate*	Cuozhilanren	China (NW Yunnan and SW Sichuan)	Unknown
T28	*T. ivorensis*	Idigbo, Black Afara, Shingle Wood, Brimstone Wood, Blackbark	Cameroon, West Africa, Ivory Coast, Liberia, Nigeria, Sierra Leone, Ghana	Rheumatism, gastroenteritis, psychotic analgesics [29] Syphilis, burns and bruises [30]
T29	*T. kaernbachii*	Okari Nut	Solomon Islands, Papua New Guinea	α-Glucosidase inhibitor activity [31]
T30	*T. kaiserana*	Unknown	Tanzania	Diarrhea, gonorrhea vomiting [44]
T31	*T. laxiflora*	Unknown	West Africa, Sudan Savannah	Malaria, cough [32] Fumigant, rheumatic pain, smoothen skin, body relaxation [33]
T32	*T. macroptera*	Bayankada	Tropical (West Africa)	Wound, hepatitis, malaria, fever, cough, diarrhea, tuberculosis, skin diseases [34]
T33	*T. mantaly*	Unknown	Africa, Madagascar	Dysentery
T34	*T. mollis*	Bush willow	Africa	Diarrhea, gonorrhea, malaria, AIDS adjuvant therapy [35]
T35	*T. muelleri*	Ketapang kencana	Indonesia, SE Asia, South Asia	Antibacterial [36], antioxidants [37]
T36	*T. myriocarpa*	Qianguolanren	China [Guangxi (Longjin), Yunnan (central to the south), and Tibet (Medog)], northern Vietnam, Thailand, Laos, northern Myanmar, Malaysia, NE India, Sikkim	Antioxidant, liver protection [38]
T37	*T. myriocarpa* var. *hirsuta*	Yingmaoqianguolanren (variant)	Yunnan, China; Thailand	Unknown

Table 1 (continued)

No.	Plants	Local names	Distributions	Traditional uses
T38	*T. oblongata*	Rose wood, yellow wood	Central Queensland [39]	Unknown [39]
T39	*T. paniculata*	Vellamaruth	India	Cholera, mumps, menstrual disorders, cough, bronchitis, heart failure, hepatitis, diabetes, obesity [40]
T40	*T. parviflora*	Tropical almond, umbrella tree, Indian almond	Sri Lanka and India [41]	Diarrhea [41]
T41	*T. prunioides*	Hareri, Sterkbos, Purple pod Terminalia, Mwangati	Southern Africa	Postnatal abdominal pain
T42	*T. sambesiaca*	Unknown	Southern Africa	Cancer, gastric ulcer, appendicitis Bloody diarrhea [45]
T43	*T. schimperiana*	Idi odan	Africa, Sierra Leone, Guinea, Uganda, Ethiopia	Local burns, bronchitis, dysentery [42]
T44	*T. sericea*	Monakanakane, Mososo, Mogonono, Amangwe, Vaalboom, Mangwe, Silver clutter-leaf	Northern South Africa, Botswana (except central Kalahari), southern Mozambique, Tanzania, Namibia, Zimbabwe, Northern Democratic Republic of Congo, tropical Africa [43]	Diarrhea, sexually transmitted infections, rash, tuberculosis [43] Fever, high blood pressure [44]
T45	*T. spinosa*	Musosahwai, spiny cluster leaf, Kasansa	Southern Africa	Malaria, fever [46] Epilepsy, poisoning [47]
T46	*T. stenostachya*	Rosette leaf Terminalia	Southern Africa	Epilepsy, poisoning [47]
T47	*T. stuhlmannii*	Unknown	Acacia [48]	Unknown
T48	*T. superba*	Limba	Tropical Western Africa	Gastroenteritis, diabetes, female infertility, abdominal pain, bacteria/fungi/viral infections [49], diabetes remedies, anesthetic, hepatitis [50]
T49	*T. triflora*	Lanza, lanza amarilla, amarillo derío, paloamarillo	Tropical (South America) Northern and Northwest Argentina [149]	Making posts, furniture, weapons, fuel [149]
T50	*T. tropophylla*	Unknown	Madagascan [51]	Unknown

SE southeastern, *NE* northeastern, *SW* southwestern, *NW* northwestern

Table 2 Chemical constituents isolated from the genus *Terminalia* and the studied plant organs

No.	Compounds	Plants	Organs	References
Triterpenes (86)				
1	2α,3β,19α-Trihydroxyolean-12-en-20-oic acid 3-*O*-β-D-galactosyl-(1 → 3)-β-D-glucoside	T1	R	[3]
2	2α,3β,19α-Trihydroxyolean-12-en-28-oic acid methylester 3β-*O*-rutinoside	T1	R	[53]
3	2α,3β,19β,23-Tetrahydroxyolean-12-en-28-oic acid 3β-*O*-β-D-galactosyl-(1 → 3)-β-D-glucoside-28-*O*-β-D-glucoside	T1	R	[52]
4	3-Acetylmaslinic acid	T1	RB	[54]
5	Arjunic acid	T1	B	[55, 74]
		T4	SB, F	[60, 79, 124]
		T17	F	[146]
		T25	SB	[130]
		T28	B	[132]
		T32	B	[145]
		T44	R	[133]
6	Arjunoside I	T4	SB	[61]
7	Arjunoside II	T4	SB	[61]
8	Arjunoside III	T4	R	[62, 63]
9	Arjunoside IV	T4	R	[62, 63]
10	Arjunetin	T1	B	[55, 74]
		T4	B, L, S, R, F	[23, 67]
		T8, T16, T17, T20, T39	B, L, S, R, F	[23]
11	Oleanolic acid	T1	H	[56]
		T9	L	[97]
		T4, T16, T20	B, L, S, R, F	[23]
		T8, T17	B, L, S, R	[23]
		T39	L, S, R, F	[23]
		T28	B	[132]
		T36	B	[140]
12	Ursolic Acid	T4, T16, T20	B, L, S, R, F	[23]
		T8, T17	L, S, R	[23]
		T39	B, L, S, F	[23]
13	Maslinic acid	T1	H	[56]
		T9	L	[97]
		T17	F	[21, 116]
		T36	B	[140]
14	2α,3α,24-Trihydroxyolean-11,13(18)-dien-28-oic acid	T33	SB	[158]
15	Terminoside A	T4	B	[58]
16	Arjungenin	T4	SB,L,R,F	[23, 60, 70, 74]
		T25	R	[60]
		T12	B	[99]
		T8, T16, T20, T39	B, L, S, R, F	[23]
		T17	B, L, S, R, F	[23, 146]
		T25	R, SB	[69, 130]
		T28	B	[132]
		T32	B	[145]
		T33	SB	[158]
		T44	RB	[133, 152]
17	Hypatic acid	T25	R	[69]
18	Arjunglucoside I	T4	B, R	[70, 74, 78]
		T17	F	[146]
		T50	R	[72]
		T32	B	[145]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
19	Sericoside	T4	B	[71]
		T25	SB	[130]
		T28	B	[76, 131]
		T44	R, L, SB	[43, 133, 149]
		T32	B	[145]
		T50	R	[72]
20	Crataegioside	T4	B	[75]
		T17	F	[146]
21	23-*O*-neochebuloylarjungenin 28-*O*-β-D-glycosyl ester	T17	F	[146]
22	23-*O*-4′-*epi*-neochebuloylarjungenin	T17	F	[146]
23	23-*O*-galloylarjunic acid	T39	B	[144]
		T32	B	[145]
		T17	F	[146]
24	Quercotriterpenoside I	T32	B	[145]
		T17	F	[146]
25	Sericic acid	T28	B	[132]
		T32	B	[145]
		T44	R	[150]
26	24-Deoxy-sericoside	T32	B	[138]
27	Arjunolic acid	T1	B, H	[55, 56, 74]
		T4	B, H, L, S, R, F	[23, 77, 78, 91]
		T7	RB	[97]
		T9	L	[23]
		T8	B, L, S, R	[23]
		T16, T17, T20, T39	B, L, S, R, F	[23, 144]
			L	[35]
		T34	B	[140]
		T36		
28	Terminolic acid	T1	H	[56]
		T17	F	[146]
		T7, T16, T31	H	[128]
		T25	H, Rl	[128]
		T32	H, B	[128, 145]
29	Arjunglucoside II	T4	B	[70, 74]
		T17	F	[146]
30	23-*O*-galloylarjunolic acid	T17	F	[146]
31	23-*O*-galloylarjunolic acid 28-*O*-β-D-glucosyl ester	T17	F	[146]
32	23-*O*-galloylterminolic acid 28-*O*-β-D-glucosyl ester	T17	F	[146]
33	Arjunolitin	T4	SB	[80]
34	Terminolitin	T4	F	[80]
35	Arjunglucoside III	T4	B	[74]
36	Methyl oleanate	T4	R, F	[80, 124]
37	Olean-3α,22β-diol-12 en-28-oic acid 3-*O*-β-D-glucosyl-(1 → 4)-β-D-glucoside	T4	B	[81, 84]
38	Arjunetoside	T4	R, SB	[82]
39	Olean 3β,6β,22α-triol-12en-28-oic acid-3-*O*-β-D-glucosyl-(1 → 4)-β-D-glucoside	T4	B	[84]
40	2α,19α,Dihydroxy-3-oxo-olean-12-en-28-oic acid-28-*O*-β-D-glucoside	T4	R	[85]
41	Ivorengenin A (2α,19α,24-trihydroxy-3-oxoolean-12-en-28-oic acid)	T28	B	[132]
42	Chebuloside I	T17	F	[115]
43	Chebuloside II	T17	F	[115]
		T32	B	[138]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
44	Arjunglucoside	T17	F	[115]
		T44	R, SB	[133]
		T33	SB	[158]
45	Glaucescic acid (2α,3α,6α,23-tetrahydroxyolean-2-en-28-oic acid)	T25	R	[69]
46	Glaucinoic acid (2α,3β,19α,24-tetrahydroxyolean-12-en-30-oic acid)	T25	SB	[130]
47	Termiarjunoside I (olean-1α,3β,9α,22α-tetraol-12-en-28-oic acid-3-β-D-glucoside)	T4	SB	[156]
48	Termiarjunoside II (olean-3α,5α,25-triol-12-en-23,28-dioic acid-3α-D-glucoside)	T4	SB	[156]
49	β-Amyrin	T25	SB	[129]
		T36	B	[140]
50	Ivorenoside A	T28	B	[131]
51	Ivorenoside B	T28	B	[131]
52	Ivorenoside C	T28	B	[131]
53	Ivorengenin B (4-oxo-19α-hydroxy-3,24-dinor-2,4-secoolean-12-ene-2,28-dioic acid)	T28	B	[132]
54	1α,3β-Hydroxyimberbic acid 23-*O*-α-L-4-acetylrhamnoside	T47	SB	[48]
55	1α,3β,3,23-Trihydroxy-olean-12-en-29-oate-23-*O*-α-[4-acetoxyrhamnosyl]-29-α-rhamnoside	T47	SB	[48]
56	2α,3β-Dihydroxyolean-12-en-28-oic acid 28-*O*-β-D-glucoside	T48	SB	[49]
57	2α,3β,21β-Trihydroxyolean-12-en-28-oic acid 28-*O*-β-D-glucoside	T48	SB	[49]
58	2α,3β,29-Trihydroxyolean-12-en-28-oic acid 28-*O*-β-D-glucoside	T48	SB	[49]
59	2α,3β,23,27-Tetrahydroxyolean-12-en-28-oic acid 28-*O*-β-D-glucoside	T48	SB	[49]
60	Terminaliaside A ((3β,21β,22α)-3-*O*-(3′-*O*-angeloylglucosyl)-21,22-dihydroxy-28-*O*-sophorosyl-16-oxoolean-12-ene)	T50	R	[72]
61	2, 3, 23-Trihydroxylolean-12-ene	T7	RB	[91]
62	2α,3β,23-Trihydroxylolean-12-en-28-oic acid	T48	SB	[49]
63	23-*O*-galloylpinfaenoic acid 28-*O*-β-D-glucosyl ester	T17	F	[146]
64	Pinfaenoic acid 28-*O*-β-D-glucosyl ester	T4	B	[76]
		T17	F	[146]
65	2α,3β-Dihydroxyurs-12,18-dien-28-oic acid 28-*O*-β-D-glucosyl ester	T4	B	[76]
66	Quadranoside VIII	T4	B	[76]
67	Kajiichigoside F1	T4	B	[76]
68	2α,3β,23Trihydroxyurs-12,19-dien-28-oic acid 28-*O*-β-D-glucosyl ester	T4	B	[76]
69	α-Amyrin	T7	RB	[91]
70	2α,3β,23-Trihydroxy-urs-12-en-28-oic acid	T34	L	[35]
71	2α-Hydroxyursolic acid	T34	L	[35]
		T17	F	[115, 116]
72	Ursolic acid	T11	L	[35]
73	2α-Hydroxymicromeric acid	T17	F	[115, 116]
74	Betulinic acid	T1	B	[55]
		T11	L	[35]
		T12	B	[99]
		T4, T16, T17, T20, T39	B, L, S, R, F	[23]
			B, L, S, R	[23]
		T8	SB	[129]
		T25	B	[132]
		T28	B	[140]
		T36		
75	Terminic acid	T4	R, H	[57, 62]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
76	Lupeol	T4	SB	[80]
		T25	SB	[129]
		T44	SB, R	[43]
77	Monogynol A	T12	B	[99]
78	Triterpenes	T25	SB	[129]
		T44	R, SB	[133]
79	Friedelin	T4	F	[83]
		T7	RB	[93]
		T25	SB	[129, 130]
		T34	SB	[35]
80	Maslinic lactone	T1	H	[56]
81	Terminalin A	T25	SB	[129]
82	Arjunaside A	T4	B	[68]
83	Arjunaside B	T4	B	[68]
84	Arjunaside C	T4	B	[68]
85	Arjunaside D	T4	B	[68]
86	Arjunaside E	T4	B	[68]
Mono- (14) and sesqui- (4) terpendoids				
87	α-Pinene	T9	L	[13]
88	Sabinene	T9	L	[13]
89	Myrcene	T9	L	[13]
90	β-Pinene	T9	L	[13]
91	1,8-Cineole	T9	L	[13]
92	Linalool	T9	L	[13]
93	Menthone	T9	L	[13]
94	γ-Terpineol	T9	L	[13]
95	α-Terpineol	T9	L	[13]
96	Limonene	T9	L	[13]
97	Neral	T9	L	[13]
98	Geraniol	T9	L	[13]
99	Thymol	T9	L	[13]
100	Isomenthone	T9	L	[13]
101	β-Copaene	T9	L	[13]
102	β-Caryophyllene	T9	L	[13]
103	Caryophyllene	T9	L	[13]
104	α-Humulene	T9	L	[13]
Hydrolysable (89) and condensed tannins (2)				
105	1,2,3,6-Tetra-*O*-galloyl-β-D-glucose	T17	F	[159]
106	Gallotannin (1,2,3,4,6 penta galloyl glucose)	T4	SB, L	[86]
		T17	F	[21, 118, 119]
		T19	F	[120]
		T30	R	[133]
		T45, T46	L	[133]
107	1,3,4,6-Tetra-*O*-galloyl-β-D-glucose	T17	F	[159]
108	2,3,4,6-Tetra-*O*-galloyl-D-glucose	T3	F	[154]
		T4	SB, L	[86]
109	1,2,6-Tri-*O*-galloyl-β-D-glucose	T31	R	[101]
110	Sanguiin H-1	T14	L	[102]
111	1,6-Di-*O*-galloyl-β-D-glucose	T3	F	[154]
		T17	F	[21, 119]
		T40	B	[41]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
112	1,3,6-Tri-*O*-galloyl-β-D-glucose	T3	F	[154]
		T40	B	[41]
		T19	F	[120]
		T17	F	[159]
113	Methyl 3,6-di-*O*-galloyl-β-D-glucoside	T40	B	[41]
114	4,6 Bis hexahydroxydiphenyl-1-galloyl-glucose	T4	SB, L	[86]
115	Sanguiin H-4	T14	L	[18, 102]
116	Corilagin	T3	F	[154]
		T31	R	[101]
		T16	L, B	[41, 106, 107]
		T17	F	[21, 118, 119, 159]
		T19	F	[120]
		T24	F	[126]
		T32	L	[135, 136]
117	Tercatain	T16	B, L	[41, 106, 107]
		T17	F	[159]
118	1,3-Di-*O*-galloyl-β-D-glucose	T17	F	[159]
119	2,3-*O*-(*S*)-HHDP-D-glucose	T3	F	[154]
		T14	L	[102]
		T4	B	[104]
		T16	B, L	[41, 107]
		T40	B	[41]
		T36	L	[38]
120	2,3-(*S*)-HHDP-6-*O*-galloyl-D-glucose	T3	F	[154]
		T4	B	[104]
		T40	B	[41]
		T32	B	[137]
121	3,6-Di-*O*-galloyl-D-glucose	T3	F	[154]
		T40	B	[41]
		T17	F	[159]
122	3,4-Di-*O*-galloyl-D-glucose	T3	F	[154]
123	6-*O*-galloyl-D-glucose	T17	F	[159]
124	3,4,6-Tri-*O*-galloyl-D-glucose	T17	F	[159]
125	Tellimagrandin I	T35	L	[139]
		T17	F	[159]
126	Gemin D	T17	F	[159]
127	Arjunin	T4	L	[65, 86]
		T17	F	[115]
128	Punicalin	T3	F	[154]
		T4	L, B	[65, 86, 104]
		T14	L	[102]
		T40	B	[41]
		T16	L	[106, 107]
		T17	L, F	[21, 155]
		T28	SB	[29]
		T49	L	[149]
129	Casuarinin	T4	L, B	[88, 104]
		T16	B	[41]
		T17	F	[21, 118, 119]
130	Casuariin	T4	B	[90, 104]
131	Terchebulin	T3	F	[154]
		T4	B	[90, 104]
		T7	SB	[92]
		T12	B	[100]
		T17	F	[21]
		T31	W	[134]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
132	Castalagin	T4	B	[90, 104]
		T16, T40	B	[41]
133	Grandinin	T16, T40	B	[41]
134	Castalin	T16, T40	B	[41]
135	α/β-Punicalagin	T3	F	[154]
		T7	SB	[92]
		T4	B	[104]
		T11	L	[35]
		T12	B	[100]
		T31	R	[101]
		T14	L	[18, 103]
		T16	B	[41]
		T17	L, F	[21, 106, 119, 155]
		T40	B	[41]
		T19	F	[120]
		T28	SB	[29]
		T32	B	[137]
		T35	L	[139]
		T36	L	[38]
		T38	L	[39]
136	1-α-*O*-galloylpunicalagin	T14	L	[18, 102, 103]
137	6′-*O*-methyl neochebulagate	T17	F	[159]
138	Dimethyl neochebulagate	T17	F	[159]
139	Neochebulagic acid	T17	F	[159]
140	Dimethyl 4′-epi-neochebulagate	T17	F	[159]
141	Methyl chebulagate	T17	F	[159]
142	Chebulagic acid	T3	F	[154]
		T4	B, L, S	[23]
		T8	F, B, L, S	[23]
		T17	F, B, L, S, R	[23, 96]
		T16	F, B, L, S, R	[3, 4, 9, 21, 110]
		T39	F, B, L, S, R	[23]
		T20	F, B, L, R	[23]
		T19	F	[120]
		T32	L	[135, 136]
		T35	L	[139]
143	Chebulinic acid	T3	F	[154]
		T4, T8, T16, T20, T39	F, B, L, S, R	[23]
		T17	F, B, L, S, R	[3, 4, 21, 110, 119, 155]
		T32	L	[23]
		T35		[110, 135, 139]
144	Chebulanin	T34, T11	L	[35]
		T17	F	[21, 119, 155, 159]
145	1,3-Di-*O*-galloyl-2,4-chebuloyl-β-D-glucose	T3	F	[154]
146	1,6-Di-*O*-galloyl-2,4-chebuloyl-β-D-glucose	T17	F	[155, 159]
147	2-*O*-galloylpunicalin	T14	L	[18]
		T40	B	[41]
		T32	B	[137]
		T49	L	[149]
148	1-Desgalloyleugeniin	T14	L	[102]
		T16	L	[107]
149	Eugeniin	T14	L	[102]
150	Rugosin A	T14	L	[102]
151	1(α)-*O*-galloylpedunculagin	T14	L	[102]
152	Praecoxin A	T14	L	[102]
153	Calamansanin	T14	L	[102]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
154	Calamanin A	T14	L	[102]
155	Calamanin B	T14	L	[102]
156	Calamanin C	T14	L	[102]
157	Terflavin C	T4	B	[104]
		T14	L	[103]
		T17	L	[21]
158	Terflavin A	T16	L	[106, 107]
		T17	F	[21]
		T32	B	[137]
159	Terflavin B	T16	L	[106, 107]
		T17	L, F	[21, 155]
		T32	B	[137]
160	3-Methoxy-4-hydroxyphenol-1-*O*-β-D-(6′-*O*-galloyl)-glucoside	T16	B	[41]
161	3,5-Di-methoxy-4-hydroxyphenol-1-*O*-β-D-(6′-*O*-galloyl)-glucoside	T16	B	[41]
162	Acutissimin A	T16	B	[41]
163	Eugenigrandin A	T16	B	[41]
164	Catappanin A	T16	B	[41]
165	Castamollinin	T40	B	[41]
166	Tergallagin	T16	L	[106, 107]
167	Geraniin	T16	L	[107]
168	Granatin B	T16	L	[107]
169	Gallotannic (tannic acid)	T17,T8	F	[113]
		T38	L	[141]
170	Chebulin	T17	F	[113, 114]
171	Terchebin	T17	F	[113, 119]
172	Neochebulinic acid	T3	F	[154]
		T17	F	[21, 119, 155]
173	Chebumeinin A	T17	F	[118]
174	Chebumeinin B	T17	F	[118]
175	Isoterchebulin	T32	B	[137]
176	Punicacortein C	T3	F	[154]
		T32	B	[137]
		T17	F	[159]
177	Punicacortein D	T17	F	[159]
178	4,6-*O*-Isoterchebuloyl-D-glucose	T32	B	[137]
179	Trigalloyl-β-D-glucose	T35	L	[139]
180	Tetragalloyl-β-D-glucose	T35	L	[139]
181	Pentagalloyl-β-D-glucose	T35	L	[139]
182	1,2,3-Tri-*O*-galloyl-6-*O*-cinnamoyl-β-D-glucose	T17	F	[159]
183	1,2,3,6-Tetra-*O*-galloyl-4-*O*-cinnamoyl-β-D-glucose	T17	F	[159]
184	1,6-Di-*O*-galloyl-2-*O*-cinnamoyl-β-D-glucose	T17	F	[159]
185	1,2-Di-*O*-galloyl-6-*O*-cinnamoyl-β-D-glucose	T17	F	[159]
186	4-*O*-(2″, 4″-di-*O*-galloyl-α-L-rhamnosyl) ellagic acid	T17	F	[159]
187	4-*O*-(4″-*O*-galloyl-α-L-rhamnosyl) ellagic acid	T17	F	[159]
188	4-*O*-(3″, 4″-di-*O*-galloyl-α-L-rhamnosyl) ellagic acid	T17	F	[159]
189	1′-*O*-methyl neochebulanin	T17	F	[159]
190	Dimethyl neochebulinate	T17	F	[159]
191	Phyllanemblinin E	T17	F	[159]
192	1′-*O*-methyl neochebulinate	T17	F	[159]
193	Phyllanemblinin F	T17	F	[159]
194	Procyanidin B-1	T16	B	[41]
195	3′-*O*-galloyl procyanidin B-2	T16	B	[41]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
Flavonoids (45)				
196	5,7,2′-Tri-*O*-methylflavanone4′-*O*-α-l-rhamnosyl-(1 → 4)-β-D-glucoside	T1	R	[52]
197	Arjunone	T4	B, F	[83, 89]
198	8-Methyl-5,7,2′,4′-tetramethoxy-flavanone	T1	R	[53]
		T39	B	[144]
199	Naringin	T4	L, S, F	[23]
		T8	B, F	[23]
		T17	L, R, F	[23]
		T39	R, F	[23]
		T20	B, L, S, R	[23]
200	Eriodictyol	T4, T8, T17, T20, T39	B, L, S, R, F	[23]
		T16	L, S, R, F	[23]
201	Hesperitin	T24	F	[122]
202	Flavanone	T24	F	[122]
203	Arjunolone (6,4-dihydroxy-7-methoxy flavone)	T4	SB	[64]
204	Bicalein (5,6,7-trihydroxy flavone)	T4	SB	[64]
205	Scutellarein	T4	B, R	[23]
		T8, T17, T20	B, L, S, R, F	[23]
		T16	L, F	[23]
		T39	B, L, R, F	[23]
206	Luteolin	T4	B, L	[23, 65]
		T8, T20	L, S	[23]
		T17	R, L	[23]
		T16	L	[23]
		T39	L, S, F	[23]
		T24	F	[122]
207	Apigenin	T4	B, L, S, R, F	[23, 66]
		T8, T16, T17, T20, T39	B, L, S, R, F	[23]
208	Isoorientin	T11	L	[35]
		T4, T8, T17, T16, T20, T39	B, L, S, R, F	[23]
			L	[139]
		T35	L	[38]
		T36		
209	Orientin	T11	L	[35]
		T4	L, F	[23]
		T8	B, S	[23]
		T17	B, L, S, R, F	[23]
		T16	L, R, F	[23]
		T39	B, S, F	[23]
		T20	L, S, F, R	[23]
		T35	L	[139]
		T36	L	[38]
210	Isovitexin	T11	L	[35]
		T4	L, F	[23]
		T17	L, R, F	[23]
		T16	L	[23, 105]
		T39	S, F	[23]
		T20	L, S, F	[23]
		T35	L	[139]
		T36	L	[38]
211	Apigenin-6-C-(2″-*O*-galloyl)-β-D-glucoside	T16	L	[105]
212	Apigenin-8-C-(2″-*O*-galloyl)-β-D-glucoside	T16	L	[105]
		T34	L	[35]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
213	Vitexin	T4, T17, T20	B, L, S, R, F	[23]
		T8	B, L, S, R	[23]
		T16	L, S, R, F	[23]
		T39	B, L, S, F	[23]
		T35	L	[139]
		T36	L	[38]
214	Amentoflavone	T8	L, S	[23]
		T17	L, R, F	[23]
		T20	L	[23]
215	Neosaponarin	T36	L	[38]
216	(−)-Epicatechin	T4	B	[76]
217	Epicatechin	T4, T8, T17, T20, T39	B, L, S, R, F	[23]
			L, S, R, F	[23]
		T16	SB	[35]
		T34		
218	Catechin	T34	SB	[35]
		T11	L	[35]
		T4, T8, T16, T17, T20, T39	B, L, S, R, F	[23]
			R	[133]
		T44		
219	Catechin–epicatechin	T44	R	[43]
220	Catechin–epigallocatechin	T44	R	[43]
221	Epigallocatechin	T34	SB	[35]
222	(−)-Epicatechin-3-*O*-gallate	T16	B	[41]
223	(−)-Epigallocatechin-3-*O*-gallate	T16	B	[41]
224	Flavanol	T24	F	[122]
225	Gallocatechin	T34	SB	[35]
		T24	F	[126]
226	Quercetin	T4	B, L, R	[23]
		T8	R	[23]
		T17	S, R, F	[23]
		T16	L, S, F	[23]
		T39	L, B	[23, 142]
		T20	F	[23]
		T24	F	[124]
		T49	L	[124]
227	Kaempferol	T4	B, L, S, R, F	[23, 66]
		T8	B, L, S, F	[23]
		T16, T17	B, L, S, R, F	[23]
		T20, T39	L, S, R, F	[23]
		T24	F	[122]
228	Kaempferol-3-*O*-β-D-rutinoside	T4, T8, T17	B, L, S, R, F	[23]
		T16	L, S, F	[23]
		T39	L, R, F	[23]
		T20	L, S, R	[23]
		T36	L	[38]
229	Afzelin (kaempferol 3-*O*-rhamnoside)	T49	L	[124]
230	Rutin	T4, T16	B, L, S, F	[23]
		T8	L, S	[23]
		T17, T39	B, L, S, R, F	[23]
		T20	L, S, F	[23]
		T32	L	[135, 136]
		T36	L	[38]
231	Narcissin	T32	L	[135, 136]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
232	Quercetin-3,4′-di-*O*-glucoside	T4	B, L, S, F	[23]
		T8	B, S, F	[23]
		T16, T17, T20, T39	B, L, S, R, F	[23]
233	Quercetin-7-*O*-rhamnoside	T4	F	[80]
234	2-*O*-β-glucosyloxy-4,6,2′,4′-tetramethoxychalcone	T1	R	[53]
235	Cerasidin	T4	F	[80]
236	Genistein	T4	B, L, S, R, F	[23, 80]
		T8, T16, T17, T20, T39	B, L, S, R, F	[23]
237	Cyaniding	T4	B	[66]
238	Pelargonidin	T4	B	[66]
239	Leucocyanidin	T4	B	[80]
240	7-Hydroxy-3′,4-(methylenedioxy)flavan	T8	FR	[12]
Lignan (27)				
241	Termilignan	T8	FR	[12]
		T39	B	[144]
242	Anolignan B	T8	FR	[12]
		T44	R	[43, 151]
243	Thannilignan	T8	FR	[12]
244	Termilignan B	T44	R	[133]
245	Ferulic acid dehydrodimer	T24	F	[125]
246	(7*S*,8*R*,7′*R*,8′*S*)-4′-hydroxy-4-methoxy-7,7′-epoxylignan	T48	SB	[50]
247	Meso-(rel7*S*,8*R*,7′*R*,8′*S*)-4,4′-dimethoxy-7,7′-epoxylignan	T48	SB	[50]
248	4′-*O*-cinnamoyl cleomiscosin A	T50	R	[72]
249	Diethylstilbestrol monosulphate	T24	F	[126]
250	Terminaloside A	T19	L	[22]
251	Terminaloside B	T19	L	[22]
252	Terminaloside C	T19	L	[22]
253	Terminaloside D	T19	L	[22]
254	Terminaloside E	T19	L	[22]
255	Terminaloside F	T19	L	[22]
256	Terminaloside G	T19	L	[22]
257	Terminaloside H	T19	L	[22]
258	Terminaloside I	T19	L	[22]
259	Terminaloside J	T19	L	[22]
260	Terminaloside K	T19	L	[22]
261	2-Epiterminaloside D	T19	L	[22]
262	6-Epiterminaloside K	T19	L	[22]
263	Terminaloside L	T19	L	[121]
264	Terminaloside M	T19	L	[121]
265	Terminaloside N	T19	L	[121]
266	Terminaloside O	T19	L	[121]
267	Terminaloside P	T19	L	[121]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
Phenols and glycosides (52)				
268	Ellagic acid	T1	B	[55]
		T7	SB	[92, 127]
		T10, TM, TT	SB	[14]
		T12	B	[100]
		T40	B	[41]
		T4, T8, T20	B, L, S, R, F	[23, 80, 83, 86]
		T17	L, SB, R F	[3, 9, 21, 23, 111,
		T16	SB, L, R, F	119]
		T39	B, L, S, R, F, H	[14, 23, 41, 108,
		T24	F	144]
		T25	B, R, Rl	[23, 142]
		T31	B	[123]
		T28, T32	H	[70, 127, 128]
		T35	L, F	[127, 134]
		T42	R, SB	[128]
		T30, T44	R	[37, 38]
		T36, T45, T46	L	[133]
		T48	SB	[133]
		T49	L	[133]
				[50]
				[124]
269	Methyl ellagic acid	T4	B	[90]
270	3-*O*-methylellagic acid	T33	SB	[158]
271	3,3′-Di-*O*-methylellagic acid	T28	SB	[29]
		T39	H,B	[8, 9, 143, 144]
		T48	SB	[50]
272	3,3′-Di-*O*-methylellagic acid 4-mono glucoside	T39	H	[147, 148]
273	Tetra-*O*-methyl ellagic acid	T39	H	[148]
274	3,3′-Di-*O*-methylellagic acid 4-*O*-β-D-glucosyl-(1 → 4)-β-D-glucosyl-(1 → 2)-α-L-arabinoside	T1	R	[52]
275	3,4,3′-Tri-*O*-methylflavellagic acid	T7	B	[126]
		T12	B	[100]
		T24	F	[126]
		T25	L, B, R, Rl	[26, 70, 127, 128]
		T31	B	[127]
		T28	SB, H	[29, 128]
		T32	H, B	[128, 138]
		T39	H	[143, 148]
276	3,3′,4-*O*-trimethyl-4′-*O*-β-D-glucosylellagic acid	T28	SB	[29]
277	3,3′-Di-*O*-methyl ellagic acid 4′-*O*-β-D-xyloside	T48	SB	[50]
278	3,4′-Di-*O*-methylellagic acid 3′-*O*-β-D-xyloside	T48	SB	[153]
279	4′-*O*-galloy-3,3′-di-*O*-methylellagic acid 4-*O*-β-D-xyloside	T48	SB	[153]
280	Flavogallonic acid	T7	SB	[92]
		T40	B	[41]
		T31	W	[134]
		T12	R	[101]
		T36	L	[38]
281	Methyl (*S*)-flavogallonate	T36	L	[38]
282	Vanillic acid 4-*O*-β-D-(6′-*O*-galloyl) glucoside	T32	B	[138]
283	3-*O*-methylellagic acid 4′-*O*-α-L-rhamnoside	T4	B	[76]
		T34	SB	[35]
		T33	SB	[158]
284	Eschweilenol C (ellagic acid 4-*O*-α-L-rhamnoside)	T12	B	[100]
		T17	F	[164]
285	3-*O*-methylellagic acid 4′-*O*-xyloside	T31	R	[101]
286	Brevifolincarboxylic acid	T35	L	[139]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
		T17	F	[159]
287	Terflavin D	T17	L	[21]
288	Gallic acid	T3	F	[154]
		T4, T8, T20, T39	B, L, S, R, F	[23, 80, 83, 86]
		T10, TM, TT	SB	[14]
		T17	SB, F, R, L	[14, 21, 23, 118, 119]
		T16	SB, F, R, L	
		T34	L	[14, 23, 41, 108]
		T12	B	[35]
		T31	R, W	[100]
		T40	B	[101, 134]
		T24	F	[41]
		T30	R	[123, 125]
		T35	L	[133]
		T36	L	[139]
		T38	L	[38]
		T42	R, SB	[141]
		T44	R	[133]
		T45, T46	L	[133]
		T48	SB	[133]
		T49	L	[50]
				[124]
289	Phyllemblin (ethyl gallate isomers1 progallin A)	T4	B	[86]
		T8	F	[96, 113]
		T24	F	[126]
		T28	SB	[29]
		T36	L	[38]
290	Monogalloyl glucose	T3	F	[154]
		T8	F	[113]
		T17	F	[21]
		T31	R	[101]
291	Methyl gallate	T14	L	[18]
		T8	F	[113]
		T32	L	[135, 136]
		T36	L	[38]
		T48	SB	[50]
		T49	L	[124]
292	Shikimic acid	T32	L	[135, 136]
293	5-*O*-galloyl-(−)-shikimic acid	T3	F	[118]
		T17	F	[154, 159]
294	4-*O*-galloyl-(−)-shikimic acid	T17	F	[159]
295	3,5-Di-*O*-galloyl-(−)-shikimic acid	T3	F	[154]
296	Digallic acid	T17	F	[159]
297	Ethyl gallate isomers2	T24	F	[126]
298	Ethyl gallate isomers3	T24	F	[126]
299	Dimethyl gallic acid	T35	L	[139]
300	Chebulic acid	T3	F	[154]
		T17	F	[4, 9, 112, 119, 159]
		T24	F	
		T35	L	[125, 126]
				[139]
301	6′-*O*-methyl chebulate	T17	F	[159]
302	7′-*O*-methyl chebulate	T17	F	[159]
303	Chebulic acid trimethyl ester	T32	L	[135, 136]
304	Terminalin	*T38*	L	[39]
305	Decarboxyellagic acid	T3	F	[154]
306	3-*O*-galloyl-D-glucose	T3	F	[154]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
307	6-*O*-galloyl-D-glucose	T3	F	[154]
		T17	F	[159]
308	Vanillic acid	T4, T8, T20, T39	B, L, S, R, F	[23]
		T17	B	[23, 117]
		T16	S, R, B, F	[23]
		T44	R	[43]
309	Benzoic acid	T44	R	[43]
		T24	F	[122]
310	Hydrocinnamic acid	T44	R	[43]
311	Gentisic acid	T16	L	[108]
312	Protocatechuic acid	T4, T8, T16, T17, T20, T39	B, L, S, R, F	[23]
313	2,3-Di-hydroxyphenyl β-D-glucosiduronic acid	T24	F	[125]
314	Quinic acid	T4, T8, T16, T17, T20, T39	B, L, S, R, F	[23]
		T24		[125]
315	*p*-Coumaric acid	T17	WP	[117]
		T44	R	[43]
316	Caffeic acid	T4, T8	L, S	[23]
		T17	L, S, R	[23]
		T16	L	[23]
		T39	B, L, S, R, F	[23]
		T20	B	[23]
		T44	R	[43]
317	Chlorogenic acid	T4	L, S	[23]
		T17	S, R, F, L	[23]
		T16, T39	L	[23]
		T20	B	[23]
318	Ferulic acid	T4	B, L, S, F	[23]
		T8, T17, T20, T39	B, L, S, R, F	[23]
		T16	L, S, R	[23]
319	Sinapic acid	T4, T16, T20, T39	B, L, S, R, F	[23]
		T8	S, R, F	[23]
		T17	B, S, R, F	[23]
Steroids (8), polyols (9) and esters (6)				
320	β-Sitosterol	T1	B, H	[55, 56]
		T4	S, F	[57, 83]
		T8	F	[96, 113]
		T12	F	[99]
		T16	B, SB	[128]
		T48	H	[128]
		T25	H	[129]
		T36	SB	[140]
		T39	B	[147, 148]
		T44	H, SB, R	[43, 133, 152]
321	β-Sitosterol-3-acetate	T44	SB, R	[43]
322	β-Sitosteryl palmitate	T16	SB, H	[128]
		T25, T31	L,F	[128]
323	Stigmasterol 3-*O*-β-D-glucoside	T4	F	[80]
		T33	SB	[158]
324	Stigmasterol	T12	B	[99]
		T25	SB	[129]
		T33	SB	[158]
		T44	RB	[133, 152]
325	Stigma-4-ene-3-one	T44	RB	[43]
326	16,17-Dihydroneridienone 3*O*-β-D-glucosyl-(1→6)-*O*-β-D-galactoside	T4	R	[59]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
327	Cannogenol 3-*O*-β-D-galactosyl-(1 → 4)-*O*-α-L-rhamno-side	T8	Se	[94]
328	2-Hexanol	T9	L	[13]
329	Octanol	T9	L	[13]
330	Methoxycarbonyloxymethyl methylcarbonate	T24	F	[125]
331	Ribonolactone	T24	F	[125]
332	Apionic acid	T24	F	[125]
333	Ascorbic acid	T24	F	[125]
334	Gluconolactone	T24	F	[125]
335	Glucohepatonic acid-1,4-lactone	T24	F	[125]
336	Galacturonic acid	T44	R	[43]
337	Geranyl formate	T9	L	[13]
338	Citronellyl acetate	T9	L	[13]
339	Geranyl acetate	T9	L	[13]
340	Geranyl tiglate	T9	L	[13]
341	Laxiflorin	T31	RB	[127]
342	(1*S*,5*R*)-4-oxo-6,8-dioxabicyclo[3.2.1]oct-2-ene-2-carboxylic acid	T24	F	[125]
Others (26)				
343	Glucuronic acid	T24	F	[125]
344	Coumarin	T45	L	[133]
345	Eujavonic acid	T24	F	[125]
346	Purine	T24	F	[125]
347	5-(4-Hydroxy-2,5-dimethylphenoxy)-2,2-dimethylpentanoic acid (gemfibrozil M1)	T24	F	[125]
348	*p*-Hydroxytiaprofenic acid	T24	F	[125]
349	*Cis*-polyisoprene	T32	L	[135]
350	Arachidic acid	T17	F	[113]
351	Behenic acid	T8, T17	F	[113]
352	Arjunaphthanoloside	T4	SB	[87]
353	Resveratrol (3′,4,5′-trihydroxystilbene)	T24 T44	F R	[126] [43]
354	Resveratrol glucoside (piceid)	T24 T44	F RB	[126] [152]
355	Resveratrol-β-D-glucoside	T44	RB	[152]
356	Combretastatin	T24	F	[126]
357	Combretastatin A1	T24	F	[126]
358	(*Z*)-Stilbene	T44	R	[133]
359	(*E*)-Stilbene	T44	R	[133]
360	3′5′-Dihydroxy-4-(2-hydroxyethoxy) resveratrol-3-*O*-β-rutinoside	T44	R, RB	[43, 152]
361	Resveratrol-3-β-rutinoside glycoside	T44	R, RB	[43, 152]
362	1,4-Cineole	T9	L	[13]
363	Terpinen-4-ol	T9	L	[13]
364	Terminalianone	T12	B	[98]
365	Termicalcicolanone A	T15	WP	[19]
366	Termicalcicolanone B	T15	WP	[19]

Table 2 (continued)

No.	Compounds	Plants	Organs	References
367	Mangiferin	T4	B, S, F	[23]
		T8	B, R, F	[23]
		T17	B, L, S, R, F	[23]
		T16	L, R, F	[23]
		T39	B, L, S, F	[23]
		T20	L, S, R	[23]
368	Benzoyl-β-D-(4′→10″geranilanoxy)-pyranoside	T8	F	[160]

R root, *SB* stem bark, *B* bark, *F* fruit, *S* stem, *H* heartwood, *RB* root bark, *Rl* rootlet, *Se* seed, *FR* fruit rind, *WP* whole plant, *T1–T50* plants from Table 1, *TM T. manii*, *TT T. tomentosa*

3.2 Tannins

As the main secondary metabolites, 91 tannins (**105–195**) were reported from the genus *Terminalia* (Fig. 2), including ellagitannins, gallotannins, dimeric, and trimeric tannins. Four cinnamoyl-containing gallotannins (**182–185**) were discovered firstly from the fruits of *T. chebula*, and 1,2,3,6-tetra-*O*-galloyl-4-*O*-cinnamoyl-β-D-glucose (**183**) and 4-*O*-(2″,4″-di-*O*-galloyl-α-L-rhamnosyl) ellagic acid (**186**) showed significant inhibitory activity on α-glucosidase with IC_{50} values of 2.9 and 6.4 μM, respectively [159].

Tannins possess not only liver and kidney protection properties, but also anti-diarrhea, anticancer, antibacterial and hypoglycemic activities [133]. However, a condensed tannin terminalin (**186**) from *T. oblongata* was reported to have severe hepatorenal toxicity and even caused renal necrosis [39].

3.3 Flavonoids

The *Terminalia* genus are rich in flavonoids (Fig. 3) comprising of flavanones (**196–202**), flavones (**203–215**), flavan-3-ols (**216–225**), and flavonols (**226–233**). Among them, cerasidin (**235**) of chalcone, genistein (**236**) of isoflavone, and leucocyanidin (**239**) of flavan-3,4-diol from *T. arjuna* [80] were described as rare structural types in the *Terminalia* genus. Moreover, a new chalcone glycoside 2-*O*-β-glucosyloxy-4,6,2′,4′-tetramethoxychalchone (**234**) was reported from the roots of *T. alata* [53]. In addition, anthocyanidin cyanidin (**237**) and pelargonidin (**238**), flavanoid 7-hydroxy-3′,4-(methylenedioxy)flavan (**240**) and other structure were reported [12, 23, 66]. Compounds **209–213**, **215** were *C*-glycosides at C-6 or C-8 of ring A.

3.4 Lignans

Twenty-seven lignans (**241–267**) were reported from the genus *Terminalia* (Fig. 4). A new lignan 4′-*O*-cinnamoyl cleomiscosin A (**248**) was reported from the ethanol extract of *T. tropophylla* roots [72]. Moreover, 13 new furofuran lignan glucosides, terminalosides A–K (**250–260**), 2-epiterminaloside D (**261**), 6-epiterminaloside K (**262**) and 5 new polyalkoxylated furofuranone lignan glucosides, terminalosides L–P (**263–267**) were obtained from the leaves of *T. citrina*. All of them were tested for their estrogenic and/or antiestrogenic activities using estrogen responsive breast cancer cell lines T47D and MCF-7, and showed varying degrees of inhibitory activity. Among them, terminalosides B (**251**), G (**256**), L (**263**) and M (**264**) inhibited cell growth by up to 90% at a minimum concentration of 10 nM [22, 121].

3.5 Phenols and Glycosides

There are 52 phenols and glycosides reported in the *Terminalia* genus (Fig. 5), in which ellagic acid (**268**) and gallic acid (**289**) are present in almost all species. Studies have shown that most of the simple phenolic compounds have antioxidant, antibacterial, hypoglycemic, liver and kidney protection [23].

3.6 Sterols and Cardiac Glycosides

Only 6 sterols (**320–325**) and 2 cardiac glycosides (**326-327**) were isolated from the genus *Terminalia* before 2001 (Fig. 6).

3.7 Polyols and Esters

Polyols and lipids were reported to be abundant in the genus *Terminalia* and concentrated mainly in fruits and leaves [125]. So far, 9 polyol (**328–336**) and 6 esters (**337–342**) have been documented (Fig. 7).

3.8 Other Compounds

Other compounds featured in the *Terminalia* genus are shown in Fig. 8 and are mostly styrenes. Cao et al. isolated two new cytotoxic xanthones - termicalcicolanone A (**365**),

Table 3 The numbers and main types of compounds reported from different *Terminalia* species

No.	Plant	Plant organs	Numbers	Main types
T1	*T. alata*	Roots, barks	18	Triterpenes
T3	*T. arborea*	Fruits	24	Hydrolysable tannin
T4	*T. arjuna*	Whole plants	93	Triterpenes, tannins, flavonoids
T7	*T. avicennioides*	Barks	10	Triterpenes, tannins
T8	*T. bellirica*	Fruits, barks	45	Triterpenes, flavonoids, lignin, simple phenols
T9	*T. bentzoe*	Leaves	29	Monoterpenoids, sesquiterpenoid
T11	*T. brachystemma*	Leaves	8	Flavonoids
T12	*T. brownii*	Leaves	13	Triterpenes
T14	*T. calamansanai*	Leaves	18	Hydrolysable tannin
T16	*T. catappa*	Whole plants	64	Triterpenes, tannins, flavonoids, simple phenols
T17	*T. chebula*	Whole plants	120	Triterpenes, tannins, flavonoids, simple phenols
T19	*T. citrina*	Fruits, leaves	23	Lignan
T20	*T. elliptica*	Whole plants	36	Flavonoids
T24	*T. ferdinandiana*	Fruits	35	Flavonoids, simple phenols, polyols
T25	*T. glaucescens*	Barks	19	Triterpenes
T28	*T. ivorensis*	Barks	18	Triterpenes
T31	*T. laxiflora*	Roots	13	Tannins
T32	*T. macroptera*	Whole plants	28	Triterpenes, tannins, simple phenols
T33	*T. mantaly*	Stem barks	7	Triterpenes, simple phenols
T34	*T. mollis*	Barks	12	Triterpenes, flavonoids
T35	*T. muelleri*	Leaves	16	Hydrolysable tannin, flavonoids, simple phenols
T36	*T. myriocarpa*	Leaves, barks	21	Triterpenes, flavonoids, simple phenols
T39	*T. paniculata*	Barks	43	Triterpenes, flavonoids, simple phenols
T40	*T. parviflora*	Barks	16	Tannins
T44	*T. sericea*	Roots	32	Triterpenes, simple phenols, other compounds
T48	*T. superba*	Barks	15	Triterpenes, simple phenols

Chemical components identified from the other 12 species, including *T. bialata* (T10), *T. calcicola* (T15), *T. kaiserana* (T30), *T. manii* (TM), *T. macroptera* (T32), *T. oblongata* (T38), *T. sambesiaca* (T42), *T. spinosa* (T45), *T. stenostachya* (T46), *T. stuhlmannii* (T47), *T. triflora* (T49), *T. tropophylla* (T50) were less than 6 compounds

termicalcicolanone B (**366**) in *T. calcicola*, and found an inhibitory effect on ovarian cancer [19]. Hiroko Negishi et al. obtained a new chromone derivative - terminalianone (**364**) from the barks of *Terminalia brownii* [98]. Ansari et al. isolated the novel compound, 4′-substituted benzoyl-β-D glycoside (**368**), from the fruits of *T. bellirica* and illustrated its potential for anticoagulation [160].

Moreover, chlorophyll and various vitamins were reported from the genus *Terminalia*.

4 Pharmacological Activities

The pharmacological activities of the genus *Terminalia*, mainly including antimicrobial, antioxidant, cytotoxicity, anti-inflammatory, hypoglycemic, cardiovascular, mosquitocidal and antiviral, have been extensively studied.

4.1 Antimicrobial

Extracts of several *Terminalia* species exhibit antimicrobial activity against various microbes. For example, methanol and aqueous extracts of *T. australis* were demonstrated antimicrobial activity against *Ca. albicans* (MIC = 180 and 250 µg/mL, resp.) and *Ca. kruzzei* (MIC = 250 and 300 µg/mL, resp.) [8]. Aqueous extracts of the stem barks, woods and whole roots of *T. brownii* showed antibacterial activity against standard strains of *Sta. aureus* (14.0 ± 1.1 µg/mL), *Escherichia coli*, *Ps. aeruginosa* (12.0 ± 1.1 µg/mL), *Klebsiella pneumonia* (6.0 ± 1.0 µg/mL), *Sa. typhi* and *Bacillus anthracis* (13.0 ± 1.0 µg/mL), as well as fungi *Ca. albicans* (12.3 ± 1.5 µg/mL) and *Cr. neoformans* (9.7 ± 1.1 µg/mL) [16]. Ethanol extracts of the root barks and leaves of *T. schimperiana* were against *Sta. aureus*, *Ps. aeruginosa* and *Sa. typhi* (MIC = 0.058–2.089 mg/mL), with inhibition

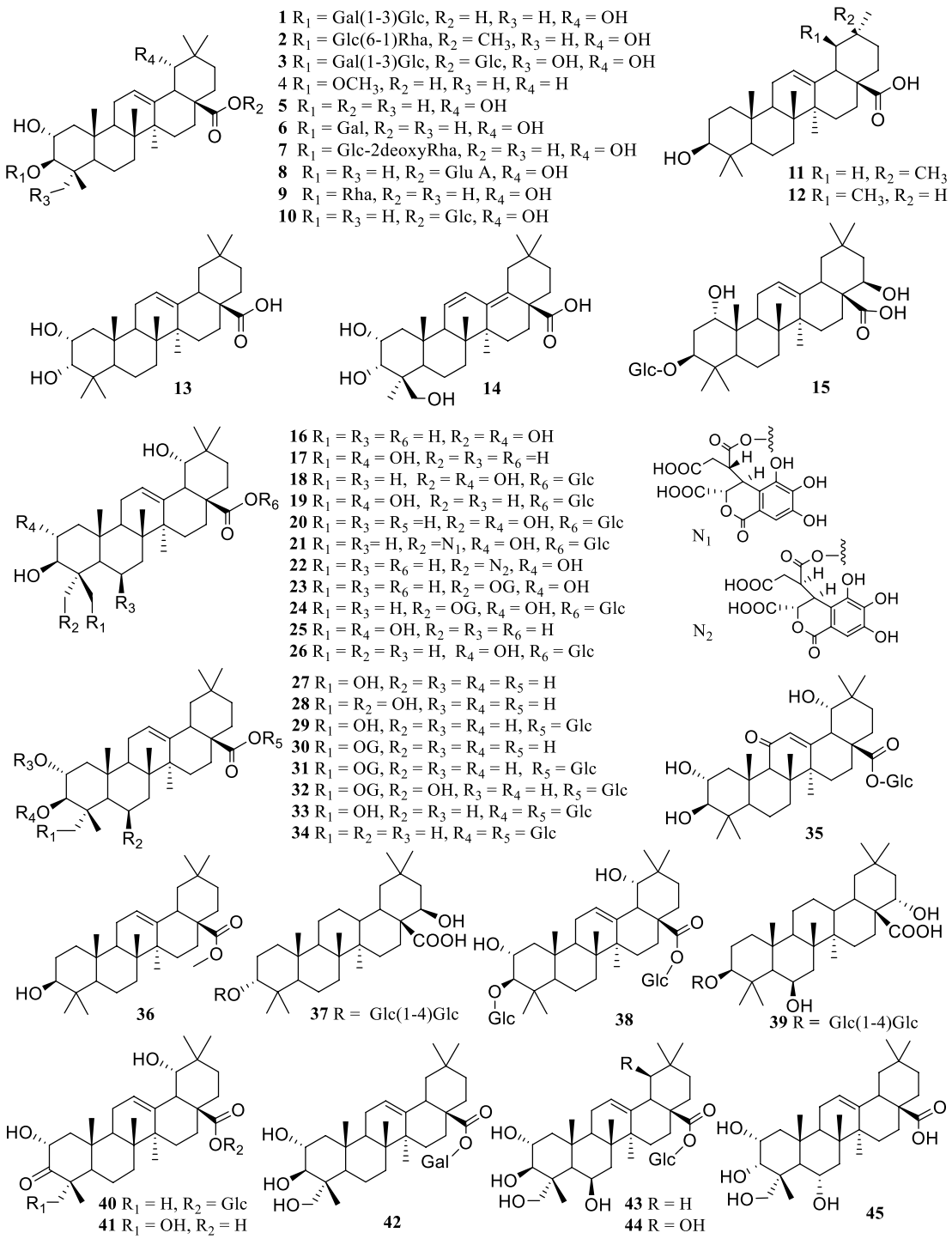

Fig. 1 The structures of terpenoids **1–104**

zone diameters (IZDs) of 17.2 to 10.0 mm, compared to gentamicin (IZD = 21.8–10 mm). The results supported the efficacy of the extracts in the folkloric treatment of burns wounds, bronchitis and dysentery, respectively [42]. Antibacterial tests on *Mycobacterium smegmatis* ATCC 14468 showed that methanol extract of *T. sambesiaca* roots and stem barks had promising effects (MIC = 1.25 mg/mL, both) [133].

Ellagitannin punicalagin (**133**) obtained from the stem barks of *T. mollis* demonstrated crucial activity against *Ca. parapsilosis* and *Ca. krusei* (MIC = 6.25 µg/mL), as well as *Ca. albicans* (MIC = 12.5 µg/mL) [35].

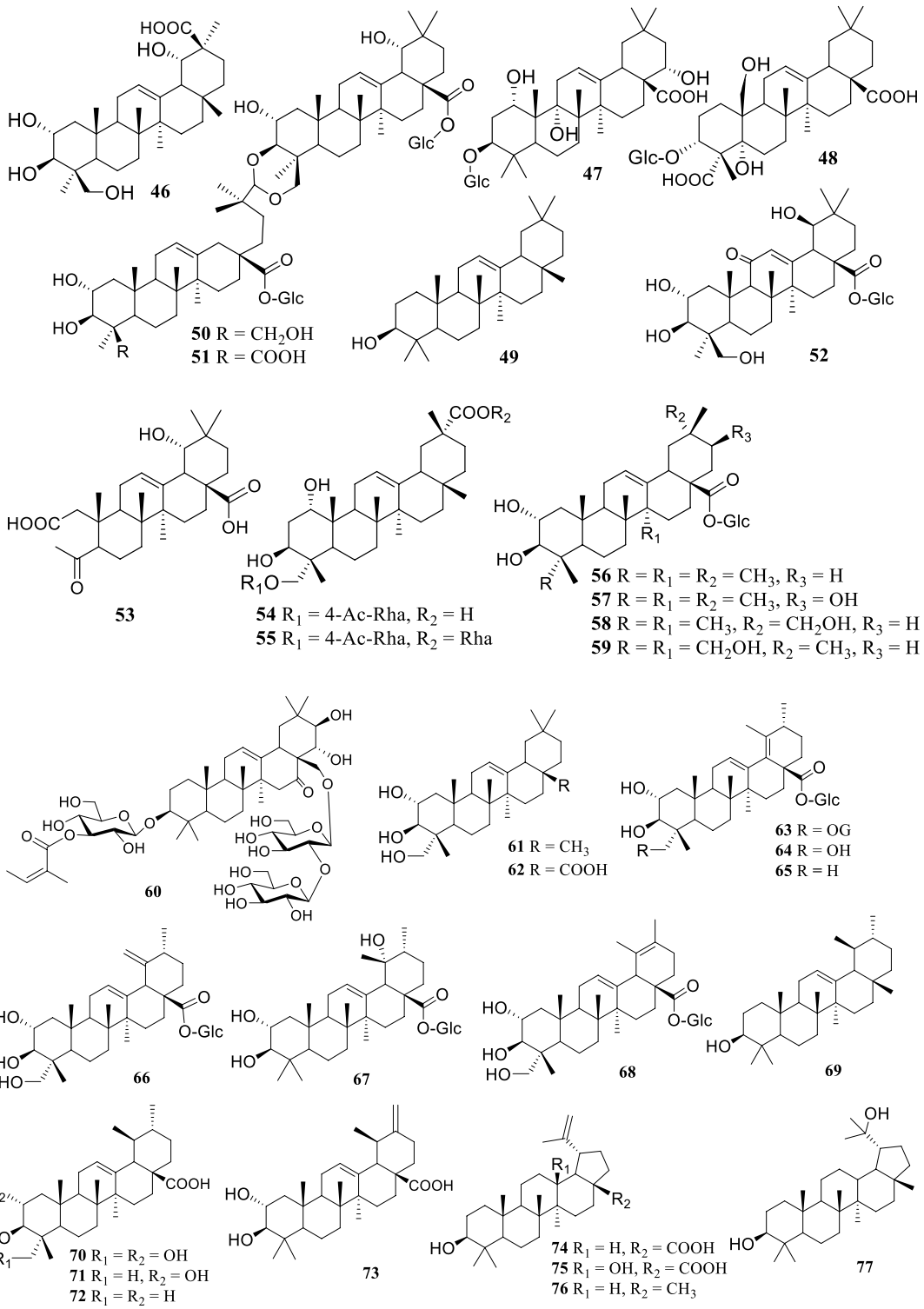

Fig. 1 (continued)

7-Hydroxy-3′,4′-(methylenedioxy) flavan (**240**), termilignan (**241**), anolignan B (**242**) and thannilignan (**243**) isolated from the fruit rinds of *T. bellirica* displayed significant antifungal activity against *Penicillium expansum* (MIC = 1.0, 2.0, 3.0 and 4.0 µg/mL, resp.), also with **240** and **241** against *Ca. albicans* at 10 and 6 µg/mL, resp. [12]. The antimycobacterial activity of friedelin (**79**) furnished from the root barks of *T. avicennioides* was 4.9 µg/mL in terms of MIC

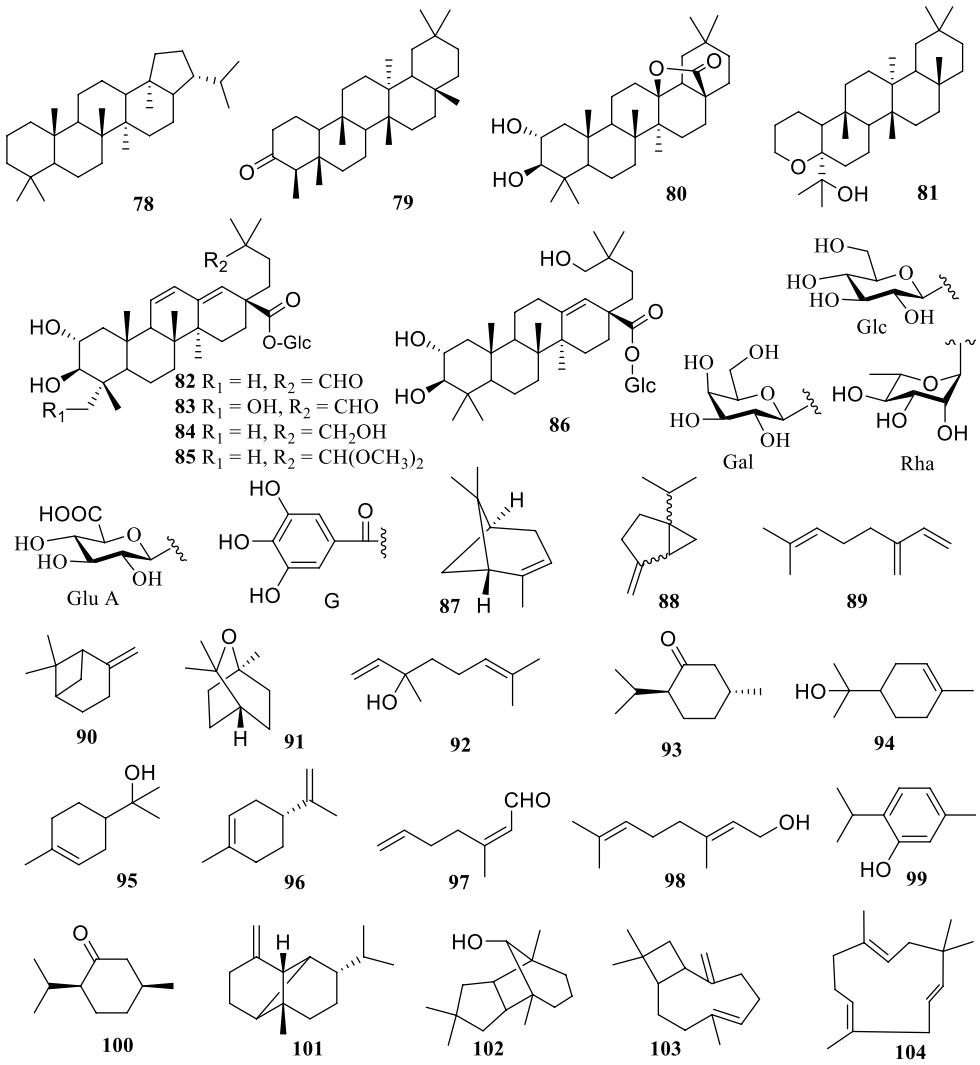

Fig. 1 (continued)

value [93]. *β*-Arjungenin (**16**), betulinic acid (**74**), sitosterol (**319**) and stigmasterol (**323**) from *T. brownii* were proved to possess antibacterial activity, with **74** the most active against *A. niger* and *S. ipomoea* (MIC = 50 µg/ml) [99].

4.2 Antioxidant

Terminalia species have also illustrated some interesting antioxidant properties [161]. By a 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay, relatively high antioxidant activities of the methanol extracts of *T. alata*, *T. bellirica* and *T. corticosa* trunk-barks were found (IC_{50} = 0.24, 1.02 and 0.25 mg/mL, resp.), compared to the positive control, L-ascorbic acid (IC_{50} = 0.24 mg/mL) [2].

Flavonoid glycosides, apigenin-6-*C*- (**211**) and apigenin-8-*C*- (**212**) (2″-*O*-galloy1)-*β*-D-glucoside, isolated from dried fallen leaves of *T. catappa*, showed significant antioxidative effects (IC_{50} = 2.1 and 4.5 µM, resp.) on $Cu^{2+}/0^2$-induced low density lipoprotein lipid peroxidation, with probucol (IC_{50} = 4.0 µM) as positive control [105].

Arjunaphthanoloside (**351**), isolated from the stem barks of *T. arjuna* showed potent antioxidant activity and inhibited nitric oxide (NO) production in lipopolysaccharide (LPS)-stimulated rat peritoneal macrophages [87], while ivorenosides B (**51**) and C (**52**), two triterpenoid saponins from *T. ivorensis*, exhibited scavenging activities against DPPH and $ABTS^+$ radicals [131].

The antioxidant potential of *T. paniculata* (TPW) was investigated by DPPH, $ABTS^{2-}$, NO, superoxide (O^{2-}), Fe^{2+} chelating and ferric reducing/antioxidant power (FRAP) assays. TPW showed maximum superoxide, $ABTS^{2-}$, NO, DPPH inhibition, and Fe^{2+}-chelating property at 400 µg/mL, resp. FRAP value was 4.5 ± 0.25 µg Fe(II)/g, which

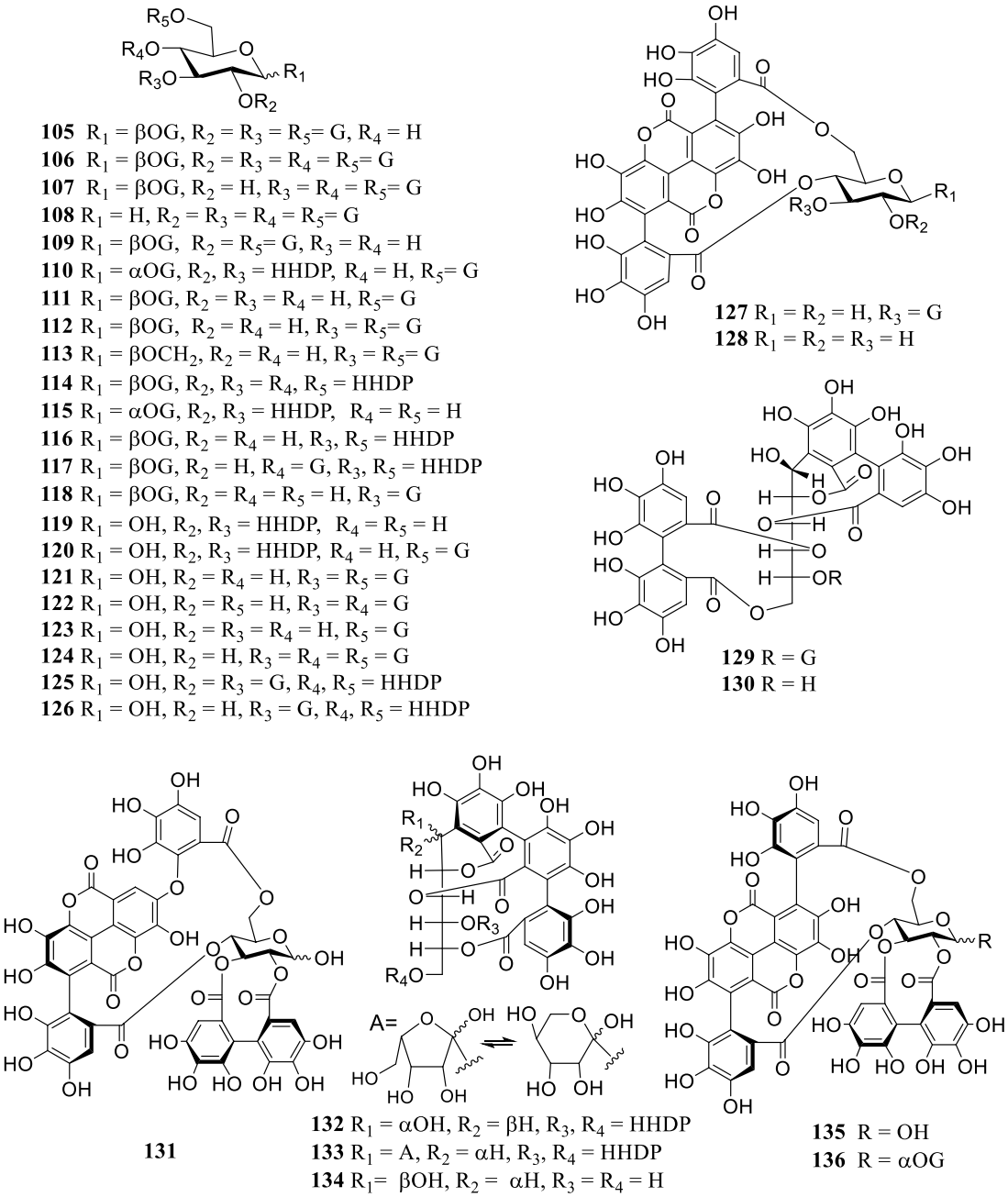

Fig. 2 The structures of tannins **105–195**

demonstrated the efficacy of aqueous barks extract of *T. paniculata* as a potential antioxidant and analgesic agent [142].

TaB contains various natural antioxidants and has been used to protect animal cells against oxidative stress. The alleviating effect of TaB aqueous extract against Ni toxicity in rice (*Oryza sativa* L.) suggested that TaB extract considerably alleviated Ni toxicity in rice seedlings by preventing Ni uptake and reducing oxidative stress in the seedlings [162]. Behavioral paradigms and PCR studies of TaB extract against picrotoxin-induced anxiety showed that TaB supplementation increased locomotion towards open arm (EPM), illuminated area (light–dark box test), and increased rearing frequency (open field test) in a dose dependent manner, compared to picrotoxin ($P < 0.05$). Furthermore, alcoholic extract of TaB showed protective activity against picrotoxin in mice by modulation of genes related to synaptic plasticity, neurotransmitters, and antioxidant enzymes [174].

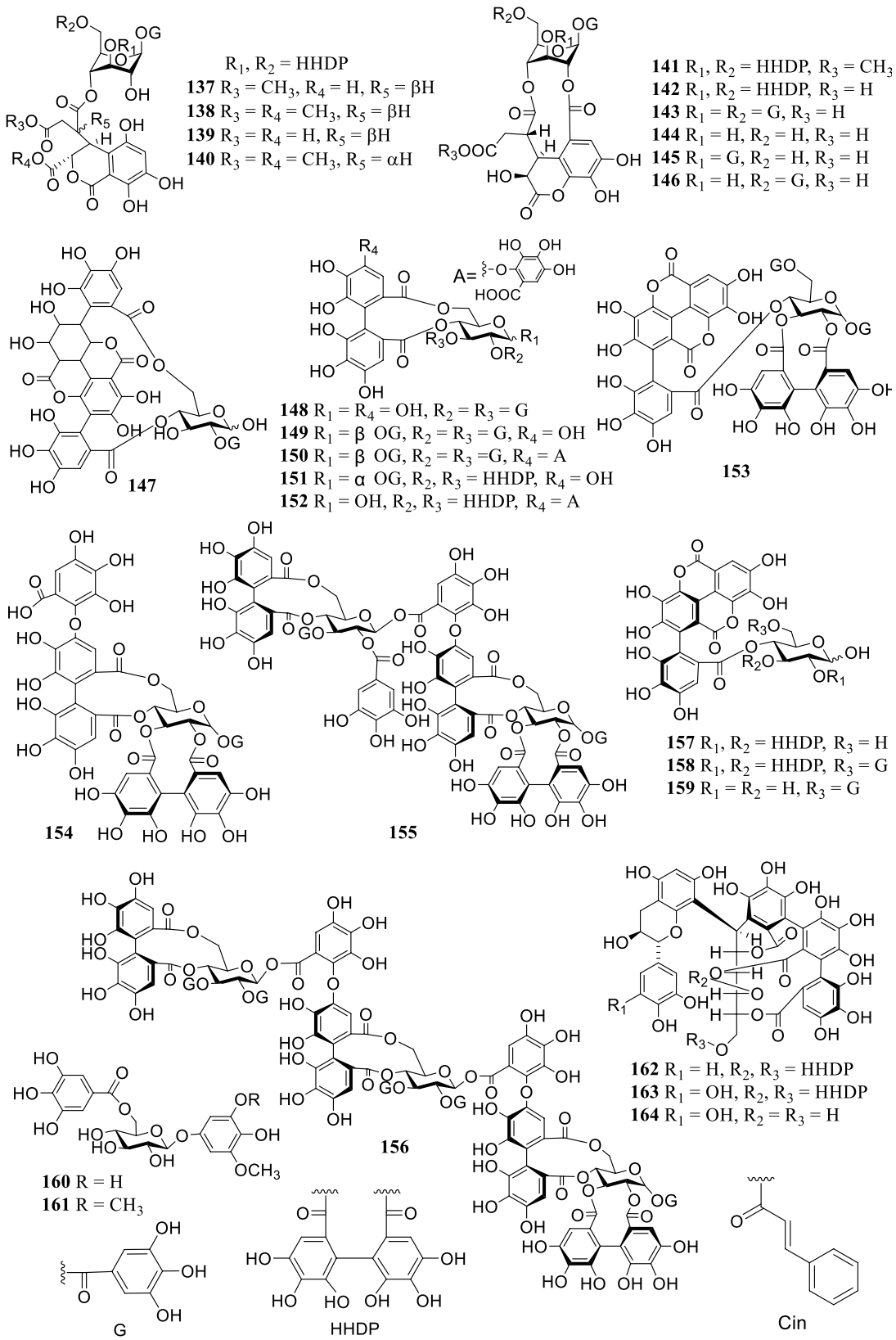

Fig. 2 (continued)

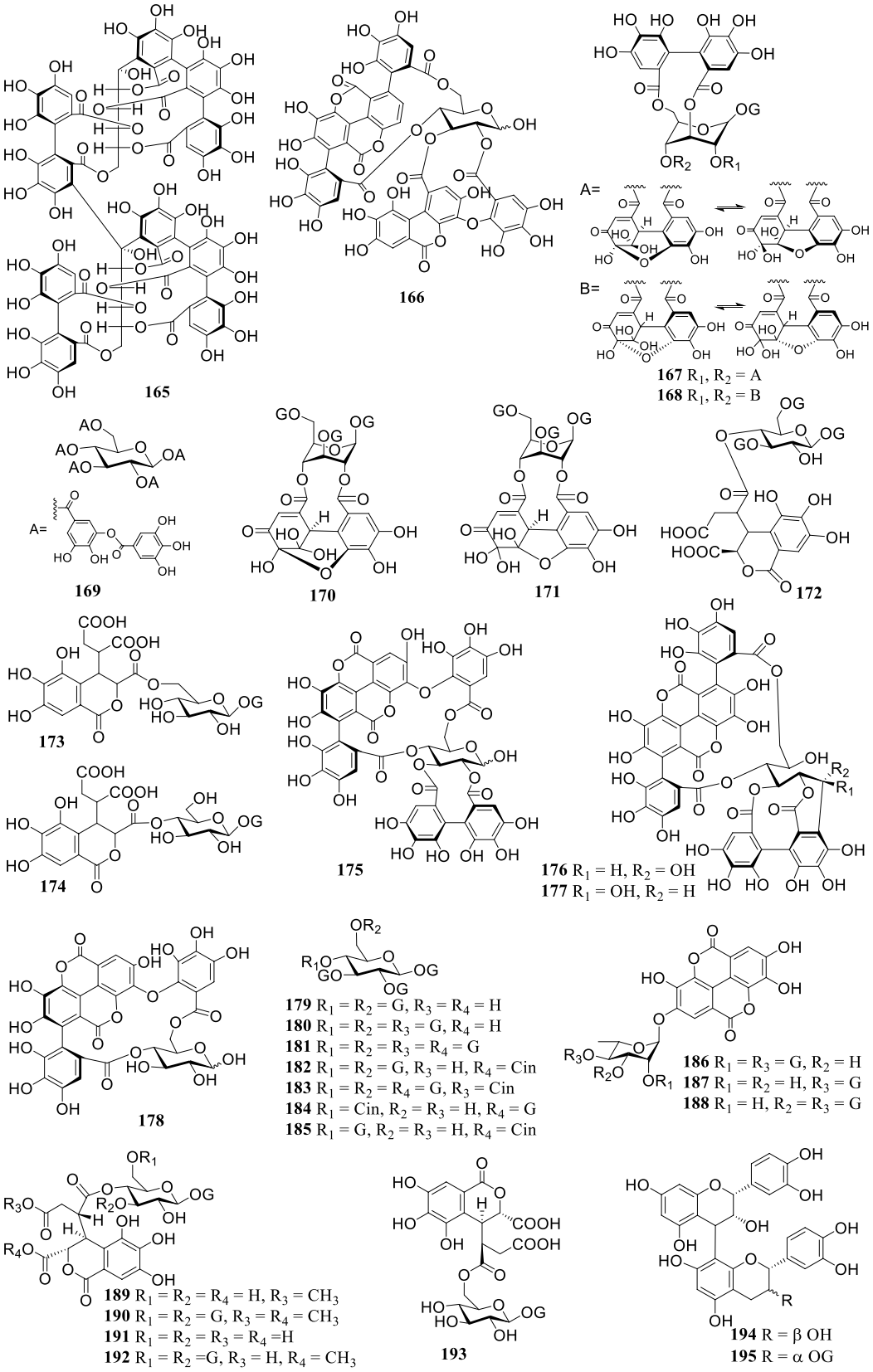

Fig. 2 (continued)

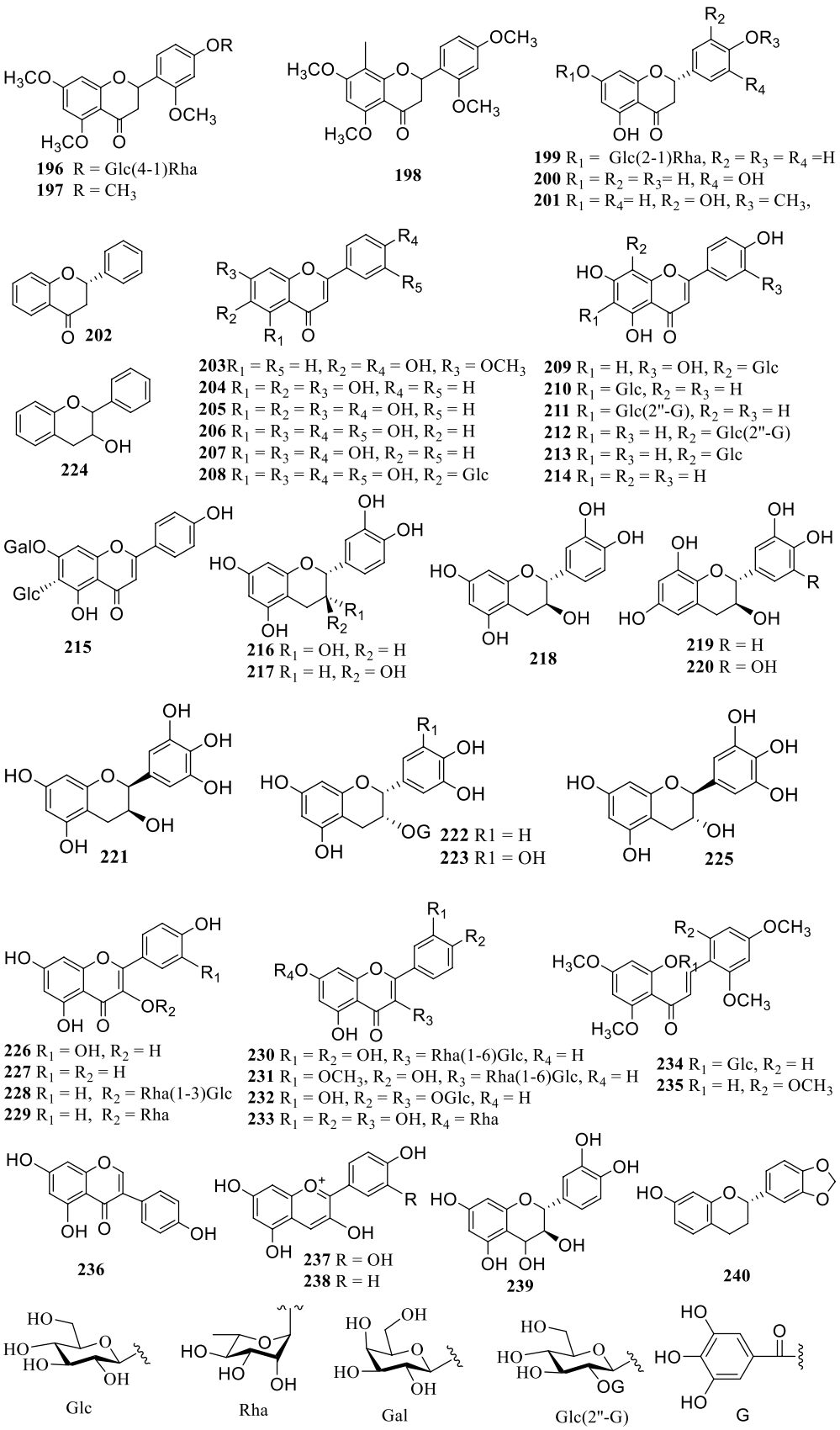

Fig. 3 The structures of flavonoids **197–240**

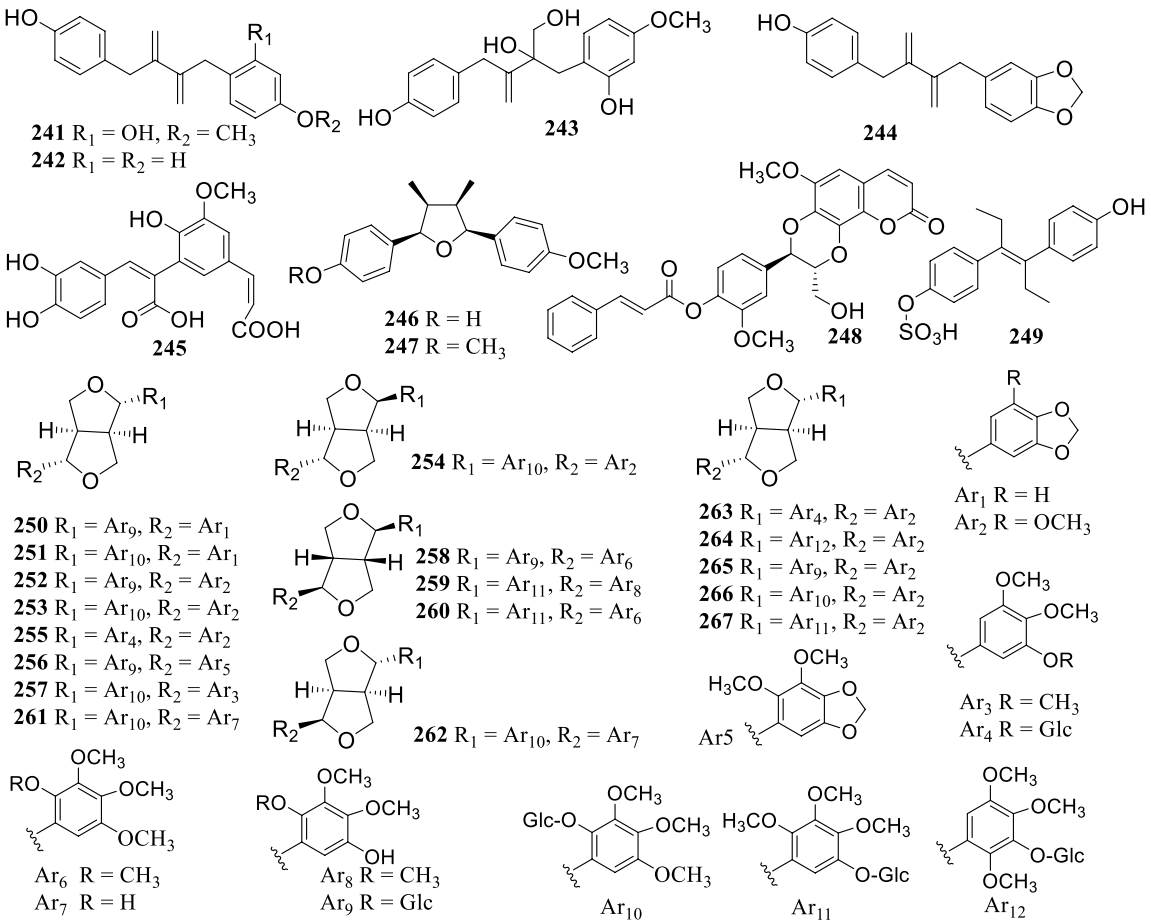

Fig. 4 The structures of lignans **241–267**

4.3 Cytotoxicity

70% Acetone extracts of *T. calamansanai* leaves inhibited the viability of human promyelocytic leukemia HL-60 cells. Sanguiin H-4 (**115**), 1-*α*-*O*-galloylpunicalagin (**136**), punicalagin (**135**), 2-*O*-galloylpunicalin (**147**) and methyl gallate (**290**) were the main components isolated from *T. calamansanai* with the IC_{50} values of 65.2, 74.8, 42.2, 38.0 and > 100 µM, respectively, for HL-60 cells. Apoptosis of HL-60 cells treated with 1-*α*-*O*-galloylpunicalagin, **115**, **135**, and **147** was noted by the appearance of a sub-G1 peak in flow cytometric analysis and DNA fragmentation by gel electrophoresis. **115** and **147** induced a decrease of the human poly (ADP-ribose) polymerase (PARP) cleavage-related procaspase-3 and elevated activity of caspase-3 in HL-60 cells, but not normal human peripheral blood mononuclear cells, PBMCs [18].

Terminaliaside A (**60**), an oleanane-type triterpenoid saponin isolated from the roots of *T. tropophylla* showed antiproliferative activity against the A2780 human ovarian cancer cell line with an IC_{50} value of 1.2 µM [72]. The 70% methanolic extract of *T. chebula* fruits was found to decrease cell viability, inhibit cell proliferation, and induce cell death of human (MCF-7) and mouse (S115) breast cancer, human osteosarcoma (HOS-1), human prostate cancer (PC-3) and a non-tumorigenic, immortalized human prostate (PNT1A) cell lines. Flow cytometry and other analyses showed that some apoptosis was induced by the extract at lower concentrations, but at higher concentrations, necrosis was the major mechanism of cell death. Chebulinic acid (**143**) and ellagic acid (**186**) were tested by ATP assay on HOS-1 cell line in comparison with three known anti-growth phenolics of *Terminalia*, gallic acid (**287**), methyl gallate (**290**), luteolin (**206**), and tannic acid (**169**). Results showed that the most growth inhibitory phenolics in *T. chebula* fruits were chebulinic acid (IC_{50} = 53.2 µM ±/0.16) >/ tannic acid (IC_{50} = 59.0 mg/mL ±/0.19) > ellagic acid (IC_{50} = 78.5 µM ±/0.24) [111].

Aqueous and ethanolic extracts of *T. citrina* fruits were revealed to exhibit significant mutagenicity in tested strains of baby hamster kidney cell line (BHK-21). Ethanolic extract showed higher mutagenicity in TA 100 strain, whereas aqueous extract exhibited higher mutagenicity in TA 102 strain than TA 100. Both extracts showed dose-dependent

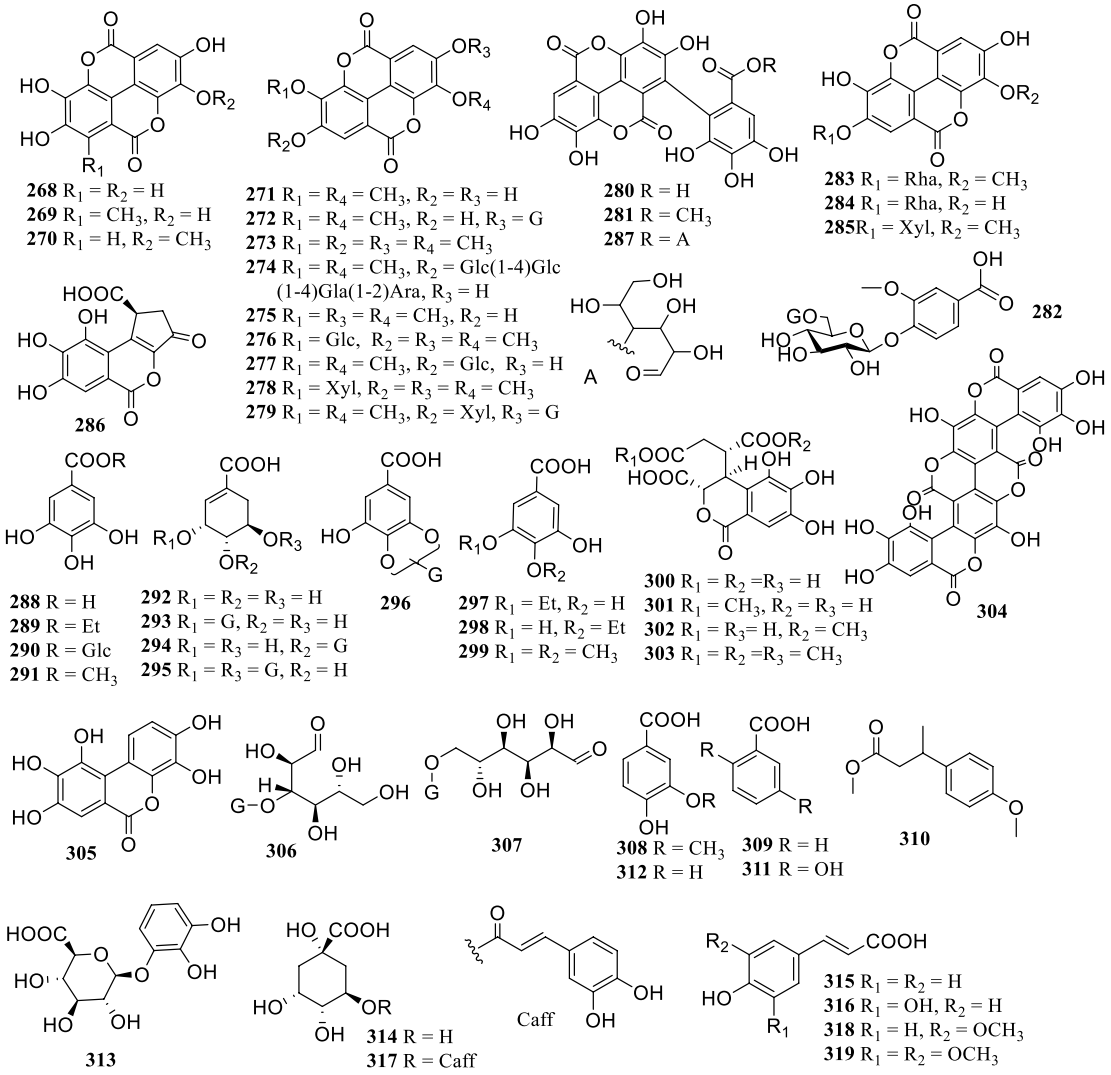

Fig. 5 The structures of phenols and glycosides (**268–319**)

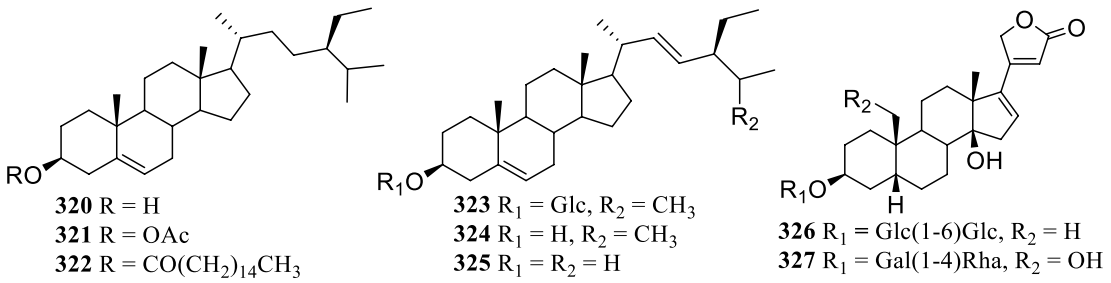

Fig. 6 The structures of steroids (**320–325**) and cardiac glycosides (**326–327**)

mutagenicity. Fifty percent cell viability was exhibited by 260 and 545 µg/mL of ethanolic and aqueous extracts respectively [169]. Moreover, ivorenoside A (**50**) showed antiproliferative activity against MDA-MB-231 and HCT116 human cancer cell lines with IC_{50} values of 3.96 and 3.43 µM, respectively [131].

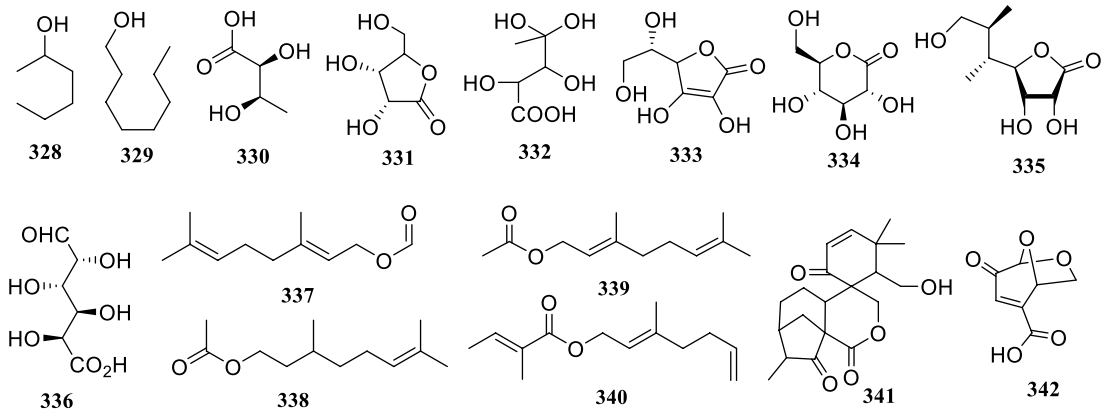

Fig. 7 The structures of polyols and esters (**328–342**)

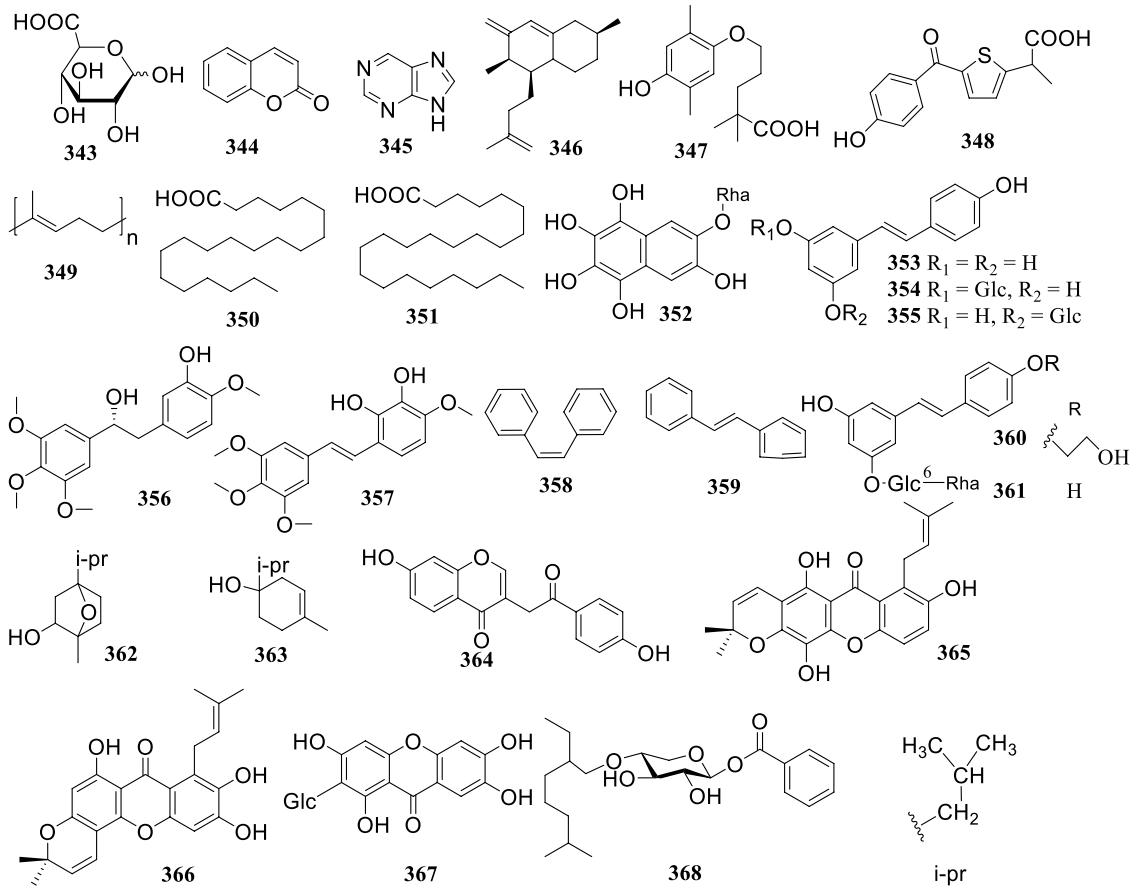

Fig. 8 The structures of other compounds (**343–368**)

4.4 Anti-inflammatory

Inflammation has been considered as a major risk factor for various kinds of human diseases. Macrophages play substantial roles in host defense against infection. It can be activated by LPS, the major component of the outer membrane of Gram-negative bacteria. An investigation was carried out to determine anti-inflammatory potential of ethyl acetate fraction isolated from *T. bellirica* (EFTB) in LPS stimulated RAW 264.7 macrophage cell lines. EFTB (100 µg/mL) inhibited all inflammatory markers in dose dependent manner. Moreover, EFTB down regulated the mRNA expression of TNF-α, IL-6, COX-2 and NF-κB against LPS stimulation. These results demonstrated that EFTB is able to attenuate

inflammatory response possibly via suppression of ROS and NO species, inhibiting the production of arachidonic acid metabolites, proinflammatory mediators and cytokines release [165].

Anolignan B (**242**) isolated from roots of *T. sericea* was tested for anti-inflammatory activity using the cyclooxygenase enzyme assays (COX-1 and COX-2) It showed activity against both COX-1 (IC_{50} = 1.5 mM) and COX-2 (IC_{50} = 7.5 mM) enzymes [151]. Termiarjunosides I (**47**) and II (**48**) isolated from stem barks of *T. arjuna* inhibited aggregation of platelets and suppressed the release of NO and superoxide from macrophages [156].

The anti-inflammatory activities of a polyphenol-rich fraction (TMEF) obtained from *T. muelleri* was assessed using carrageenan-induced paw edema model by measuring PGE2, TNF-α, IL-1b, and IL-6 plasma levels as well as the paw thickness. The group treated with 400 mg/kg of TMEF showed a greater inhibition in the number of writhes (by 63%) than the standard treated group (61%). TMEF pretreatment reduced the edema thickness by 48, 53, and 62% at the tested doses, respectively. TMEF administration inhibited the carrageenan-induced elevations in PGE2 (by 34, 43, and 47%), TNF-α (18, 28, and 41%), IL-1β (14, 22, and 29%), and IL-6 (26, 31, and 46%) [166].

4.5 Hypoglycemic

Some species and isolates from *Terminalia* have indicated possession of α-glucosidase inhibitory capabilities. Gallic acid (**287**) and methyl gallate (**290**), from stem barks of *T. superba*, showed significant activity (IC_{50} = 5.2 ± 0.2 and 11.5 ± 0.1 µM, resp.). Arjunic acid (**5**) and glaucinoic acid (**46**) from stem barks of *T. glaucescens* showed significant *β*-glucuronidase inhibitory activity with IC_{50} value 80.1 and 500 µM, resp., against *β*-glucuronidase [130].

In a study to investigate *α*-glucosidase inhibition of extracts and isolated compounds from *T. macroptera* leaves, chebulagic acid (**142**) showed an IC_{50} value of 0.05 µM towards *α*-glucosidase and 24.9 ± 0.4 µM towards 15-lipoxygenase (15-LO), in contrast to positive controls (acarbose: IC_{50} = 201 ± 28 µM towards *α*-glucosidase, quercetin: IC_{50} = 93 ± 3 µM towards 15-LO). Corilagin (**116**) and narcissin (**231**) were good 15-LO and *α*-glucosidase inhibitors. Rutin (**230**) was a good *α*-glucosidase inhibitor (IC_{50} ca. 3 µM), but less active towards 15-LO [136].

From the fruits of *T. chebula*, 23-*O*-galloylarjunolic acid (**30**) and 23-*O*-galloylarjunolic acid 28-*O*-*β*-D-glucosyl ester (**31**) were afforded and showed potent inhibitory activities with IC_{50} values of 21.7 (**30**) and 64.2 (**31**) µM, resp., against Baker's yeast *α*-glucosidase, compared to the positive control, acarbose (IC_{50} 174.0 µM) [146].

Hydrolyzable tannins, 1,2,3,6-tetra-*O*-galloyl-4-*O*-cinnamoyl-*β*-D-glucose (**183**) and 4-*O*-(2″,4″-di-*O*-galloyl-α-L-rhamnosyl) ellagic acid (**186**) from the fruits of *T. chebula*, showed significant *α*-glucosidase inhibitory activities with IC_{50} values of 2.9 and 6.4 µM, resp. In addition, inhibition kinetic studies showed that both compounds have mixed-type inhibitory activities with the inhibition constants (Ki) of 1.9 and 4.0 µM, respectively [159].

4.6 Cardiovascular

A few species of *Terminalia* have demonstrated cardiovascular activities. It was reported that the barks of *T. arjuna* possessed significant inotropic and hypotensive effect, mild diuretic, antithrombotic, prostaglandin E2 enhancing and hypolipidaemic activities [66].

Ethanolic extract of *T. pallida* fruits (TpFE) were studied to determine their cardioprotection against isoproterenol (ISO)-administered rats. The supplementation of TpFE dose-dependently exerts notable protection on myocardium by virtue of its strong antioxidant activity. It could be used as a medicinal food for the treatment of cardiovascular ailments [163].

4.7 Mosquitocidal

Insect-borne diseases remain to this day a major source of illness and can cause death worldwide. The resistance to chemical insecticides among mosquito species has been a major problem in vector control. The larvicidal and ovicidal activities of crude benzene, hexane, ethyl acetate, chloroform and methanol extracts of *T. chebula* were tested for their toxicity against three important vector mosquitoes, viz., *Anopheles stephensi*, *Aedes aegypti* and *Culex quinquefasciatus*. All extracts showed moderate larvicidal effects, the highest larval mortality was found in the methanol extract of *T. chebula* against the larvae of *A. stephensi*, *A. aegypti*, and *C. quinquefasciatus* with the LC_{50} values of 87.13, 93.24 and 111.98 ppm, respectively. Mean percent hatchability of the ovicidal activity was observed 48 h post treatment. All the five solvent extracts showed moderate ovicidal activity. The maximum egg mortality (zero hatchability) was observed in the methanol extract of *T. chebula* at 200 and 250 ppm against *A. stephensi*, while *A. aegypti* and *C. quinquefasciatus* showed 100% mortality at 300 ppm. No mortality was observed in the control group. The finding of the investigation revealed that the leaf extract of *T. chebula* possesses remarkable larvicidal and ovicidal activity against medically important vector mosquitoes [167, 168].

4.8 Antiviral

Termilignan (**241**) and anolignan B (**242**), obtained from *T. bellirica* exhibited antimalarial activity against the

chloroquine-susceptible strain 3D7 of *Plasmodium falciparum* (IC_{50} = 9.6 ± 1.2 μM)[12]. Casuarinin (**129**), chebulagic acid (**142**) from the fruits of *T. chebula* possessed hepatitis C virus inhibition activities (IC_{50} = 9.6 and 5.2 μM, resp.) [118]. Punicalin (**128**) and 2-*O*-galloylpunicalin (**147**), isolated from aqueous extract of *T. triflora* leaves, showed inhibitory activity on HIV-1 reverse transcriptase with IC_{50} of 0.11 μg/mL (0.14 μM) and 0.10 μg/mL (0.11 μM), resp. [149].

In vitro anti-HIV-1 activity of acetone and methanol extracts of *T. paniculata* fruits was studied by Durge A. et al. Cytotoxicity tests were conducted on TZM-bl cells and PBMCs, the CC_{50} values of both extracts were ≥ 260 μg/mL. By using TZM-bl cells, the extracts were tested for their ability to inhibit replication of two primary isolates HIV-1 (X4, Subtype D) and HIV-1 (R5, Subtype C). The activity against HIV-1 primary isolate (R5, Subtype C) was confirmed by using activated PBMC and quantification of HIV-1 p24 antigen. Both the extracts showed anti-HIV-1 activity in a dose-dependent manner. The EC_{50} values of the acetone and methanol extracts of *T. paniculata* were ≤ 10.3 μg/mL. Furthermore, the enzymatic assays were performed to determine the mechanism of action which indicated that the anti-HIV-1 activity might be due to inhibition of reverse transcriptase (≥ 77.7% inhibition) and protease (≥ 69.9% inhibition) enzymes [172].

Kesharwani A. et al. investigated anti-HSV-2 activity of *T. chebula* extract and its constituents, chebulagic acid (**142**) and chebulinic acid (**143**). Cytotoxicity assay using Vero cells revealed CC_{50} = 409.71 ± 47.70 μg/mL for the extract whereas **142** and **143** showed more than 95% cell viability up to 200 μg/mL. The extract from *T. chebula* (IC_{50} = 0.01 ± 0.0002 μg/mL), chebulagic (IC_{50} = 1.41 ± 0.51 μg/mL) and chebulinic acids (IC_{50} = 0.06 ± 0.002 μg/mL) showed dose dependent in vitro anti-viral activity against HSV-2, which can also effectively prevent the attachment and penetration of the HSV-2 to Vero cells. In comparison, acyclovir showed poor direct anti-viral activity and failed to significantly ($p > 0.05$) prevent the attachment as well as penetration of HSV-2 to Vero cells when tested up to 50 μg/mL. Besides, in post-infection plaque reduction assay, *T. chebula* extract, chebulagic and chebulinic acids showed IC_{50} values of 50.06 ± 6.12, 31.84 ± 2.64, and 8.69 ± 2.09 μg/mL, resp., which were much lower than acyclovir (71.80 ± 19.95 μg/mL) [173].

4.9 Others

Terminalia species were also reported to be used in the treatment of diarrhea [95], Alzheimer's disease [112], psoriasis [164], liver disease [170], kidney disease [171], etc. Terminalosides A–K (**249–259**) from the leaves of the Bangladeshi medicinal plant *T. citrina* possess estrogen-inhibitory properties. Among them, Terminaloside E (**253**) showed inhibitory activity against the T47D cell line, such terminalosides C (**252**), F (**255**), and I (**258**). Besides, 6-epiterminaloside K (**262**) displayed antiestrogenic activity against MCF-7 cells [22].

5 Conclusion and Future Prospects

The genus *Terminalia* contains not only a large number of tannins, simple phenolics, but also a lot of terpenoids, flavonoids, lignans and other compounds. Most tannins, simple phenolics and flavonoids have antioxidation, antibacterial, antiinflammatory and anticancer activities. The plants of the genus *Terminalia* have exhibited positive effect on immune regulation, cardiovascular disease and diabetes, and can accelerate wound healing [157]. Therefore, the *Terminalia* genus has great medicinal potential. However, most of the chemical composition of species is still unknown, we should use modern advanced technology such as LC–MS to continue to isolate its compounds, and determine their pharmacological activities and mechanism of action, to explore other possible greater medicinal value.

Acknowledgements This work was supported by the Key Projects of Yunnan Science and Technology, and Yunnan Key Laboratory of Natural Medicinal Chemistry (S2017-ZZ14).

Conflict of interest All authors declare no conflict of interest.

References

1. L.J. McGaw, T. Rabe, S.G. Sparg, A.K. Jäger, J.N. Eloff, J. van Staden, J. Ethnopharmacol. **75**, 45–50 (2001)
2. Q. Nguyen, V.B. Nguyen, J. Eun, S. Wang, D.H. Nguyen, T.N. Tran, A.D. Ngugen, Res. Chem. Intermed. **42**, 5859–5871 (2016)
3. S.K. Srivastava, B.K. Chouksey, S.D. Srivastava, Fitoterapia **72**, 191–193 (2001)
4. D. Arias, J. Calvo-Alvarado, D.B. de Richter, A. Dohrenbusch, Biomass Bioenergy **35**, 1779–1788 (2011)
5. Y. Noboru, I. Ayako, K. Chika, S. Keisuke, JP2001098264 A 20010410 (2001)
6. R.N. Yadav, K. Rathore, Phytochem. Commun. **72**, 459–461 (2001)
7. S. Fangwen, P. Raoji, CN105232959 A 20160113 (2016)
8. S.M. Carpano, E.D. Spegazzini, J.S. Rossi, M.T. Castro, S.L. Debenedetti, Fitoterapia **74**, 294–297 (2003)
9. A.A. Omonkhua, M.C. Cyril-Olutayo, O.M. Akanbi, O.A. Adebayo, Parasitol. Res. **112**, 3497–3503 (2013)
10. H. Zanna, S. Ahmad, B. Abdulmalik, Tasi'u M, Abel GO, Musa HM. Adv. Biochem. **2**, 55–59 (2014)

11. R.N. Chopra, S.L. Nayar, I.C. Chopra, *Glossary of Indian Medicinal Plants* (CSIR, New Delhi, 1956), p. 241
12. R. Valsaraj, P. Pushpangadan, U.W. Smitt, A. Adsersen, S.B. Christensen, A. Sittie, U. Nyman, C. Nielsen, C.E. Olsen, J. Nat. Prod. **60**, 739–742 (1997)
13. A. Gurib-Fakim, J. Essent. Oil Res. **6**, 533–534 (1994)
14. S. Khatoon, N. Singh, N. Srivastava, A. Rawat, S. Mehrotra, J. Planar Chromatogr. **21**, 167–171 (2008)
15. M. Gelfand, *The Traditional Medical Practitioner in Zimbabwe, His Principles of Practice and Pharmacopoeia* (Mambo Press, Gweru, 1985), pp. 58–61
16. Z.H. Mbwambo, M.J. Moshi, P.J. Masimba, M.C. Kapingu, R.S. Nondo, BMC Complement. Altern. Med. **7**, 9 (2007)
17. K.S. McIntosh, Qld Agric. J. **42**, 727–729 (1934)
18. L.G. Chen, W.T. Huang, L.T. Lee, C.C. Wang, Toxicol. Vitro **23**, 603–609 (2009)
19. S. Cao, P.J. Brodie, J.S. Miller, R. Randrianaivo, F. Ratovoson, C. Birkinshaw, R. Andriantsiferana, V.E. Rasamison, D.G.I. Kingston, J. Nat. Prod. **70**, 679–681 (2007)
20. Y. Lin, Y. Kuo, M. Shiao, C. Chen, J. Ou, J. Chin. Chem. Soc. **47**, 253–256 (2000)
21. A. Bag, S.K. Bhattacharyya, R.R. Chattopadhyay, Asian Pac. J. Trop. Biomed. **3**, 244–252 (2013)
22. M.A. Muhit, K. Umehara, K. Moriyasumoto, H. Noguchi, J. Nat. Prod. **79**, 1298–1307 (2016)
23. A. Singh, V. Bajpai, S. Kumar, B. Kumar, M. Srivastava, K.B. Rameshkumar, Ind. Crop Prod. **87**, 236–246 (2016)
24. T. Zhang, H. Sun, J. Plant. Res. **124**, 63–73 (2011)
25. I. Konczak, F. Maillot, A. Dalar, Food Chem. **151**, 248–256 (2014)
26. J. Koudou, G. Roblot, R. Wylde, Planta Med. **61**, 490–491 (1995)
27. T. Okpekon, S. Yolou, C. Gleye, F. Roblot, P. Loiseau, C. Bories, P. Grellier, F. Frappier, A. Laurens, R. Hocquemiller, J. Ethnopharmcol. **90**, 91–97 (2004)
28. O. Nobuhiko, S. Shizu, C. Nuan, JP2007099733 A 20070419 (2007)
29. V.A. Adiko, B.K. Attioua, F.Z. Tonzibo, K.M. Assi, C. Siomenan, L.A. Djakouré, Afr. J. Biotechnol. **12**, 4393–4398 (2013)
30. J. Hutchinson, J.M. Dalziel, *Appendix to the Flora of West Tropical Africa* (Published on behalf of the Governments of Nigeria, Ghana, Sierra Leone and the Gambia by the Crown Agents for Oversea Governments and Administrations, London, 1936), p. 81
31. K. Anam, R.M. Widharna, D. Kusrini, Int. J. Pharmacol. **5**, 277–280 (2009)
32. M.S. Musa, F.E. Abdelrasool, E.A. Elsheikh, L.A. Ahmed, A.L.E. Mahmoud, S.M. Yagi, J. Med. Plants Res. **5**, 4287–4297 (2011)
33. W. Ogbazghi, E. Bein, Drylands Coord. Group Rep. **40**, 26–27 (2006)
34. Y. Zou, G.T.T. Ho, K.E. Malterud, N.H.T. Le, K.T. Inngjerdingen, H. Barsett, D. Diallo, T.E. Michaelsen, B.S. Paulsen, J. Ethnopharmacol. **155**, 1219–1226 (2014)
35. M. Liu, D.R. Katerere, A.I. Gray, V. Seidel, Fitoterapia **80**, 369–373 (2009)
36. K. Anam, A.G. Suganda, E.Y. Sukandar, L.B.S. Kardono, Res. J. Med. Plant **4**, 197–205 (2010)
37. M. Bajpai, A. Pande, S.K. Tewari, D. Prakash, Int. J. Food Sci. Nutr. **56**, 287–291 (2005)
38. M.S.A. Marzouk, S.A.A. El-Toumy, F.A. Moharram, Planta Med. **68**, 523–527 (2002)
39. P.B. Oelrichs, C.M. Pearce, J. Zhu, L.J. Filippich, Nat. Toxins **2**, 144–150 (1994)
40. F. Malekzadeh, H. Ehsanifar, M. Shahamat, Int. J. Antimicrob. Agents **18**, 85–88 (2001)
41. T.C. Lin, F.L. Hsu, J. Chin. Chem. Soc. **46**, 613–618 (1999)
42. E.E. Nmema, E.N. Anaele, J. Appl. Sci. Environ. Manag. **17**, 595 (2013)
43. N.I. Mongalo, L.J. McGaw, T.V. Segapelo, J.F. Finnie, J. Van Staden, J. Ethnopharmacol. **194**, 789–802 (2016)
44. P. Fyhrquist, L. Mwasumbi, C.A. Haeggstrom, H. Vuorela, R. Hiltunen, P. Vuorela, J. Ethnopharmacol. **79**, 169–177 (2002)
45. S.C. Chhabra, R.L.A. Mahunnah, E.N. Mshiu, J. Ethnopharmacol. **25**, 339–359 (1989)
46. B. Heine, M. Brenzinger, *Plants of the Borana (Ethiopia and Kenya), Plant Concepts and Plant Use: An Ethno-botanical Survey of the Semi-arid and Arid Lands of East Africa: Part 4* (Verlag Brentenbach, 1988), p. 23
47. J. Ndamba, E. Lemmich, P. Mølgaard, Phytochemistry **35**, 95–98 (1994)
48. D.R. Katerere, A.I. Gray, R.J. Nash, R.D. Waigh, Phytochemistry **63**, 81–88 (2003)
49. T.K. Tabopda, J. Ngoupayo, S.A.K. Tanoli, A.C. Mitaine-Offer, B.T. Ngadjui, M.S. Ali, B. Luu, M.A. Lacaille-Dubois, Planta Med. **75**, 522–527 (2009)
50. J.D. Wansi, M.C. Lallemand, D.D. Chiozem, F.A.A. Toze, L.M.A. Mbaze, S. Naharkhan, M.C. Iqbal, Z.T. Fomum, Phytochemistry **68**, 2096–2100 (2007)
51. T. Jono, Curr. Herpetol. **34**, 85–88 (2015)
52. S.K. Srivastava, S.D. Srivastava, B.K. Chouksey, Fitoterapia **72**, 106–112 (2001)
53. S.K. Srivastava, S.D. Srivastava, B.K. Chouksey, Fitoterapia **70**, 390–394 (1999)
54. A.S.R. Anjaneyulu, A.V.R. Reddy, R.G. Mallavarapu, R.S. Chandrasekhara, Phytochemistry **25**, 2670–2671 (1986)
55. G.R. Mallavarapu, S.B. Rao, K.V. Syamasundar, J. Nat. Prod. **49**, 549–550 (1986)
56. G.R. Mallavarapu, E. Muralikrishna, J. Nat. Prod. **46**, 930–931 (1983)
57. A.S.R. Anjaneyulu, A.V.R. Prasad, Phytochemistry **22**, 993–998 (1983)
58. A. Ali, G. Kaur, H. Hamid, T. Abdullah, M. Ali, M. Niwa, M.S. Alam, J. Asian Nat. Prod. Res. **5**, 137–142 (2003)
59. R.N. Yadav, K. Rathore, Fitoterapia **72**, 459–461 (2001)
60. T. Honda, T. Murae, T. Tsuyuki, Chem. Pharm. Bull. **24**, 178–180 (1976)
61. T. Honda, T. Murae, T. Tsuyuki, T. Takahashi, M. Sawai, Bull. Chem. Soc. Jpn **49**, 3213–3218 (1976)
62. A.S.R. Anjaneyulu, A.S.R. Prasad, J. Chem. **21B**, 530–533 (1982)
63. A.S.R. Anjaneyulu, A.V.R. Prasad, Phytochemistry **21**, 2057–2060 (1982)
64. P.N. Sharma, P.N. Shoeb, R.S. Kapil, Indian J. Chem. **21**, 263–264 (1982)
65. G.R. Pettit, M.S. Hoard, D.L. Doubek, J.M. Schmidt, R.K. Pettit, L.P. Tackett, J.C. Chapuis, J. Ethnopharmacol. **53**, 57–63 (1996)
66. S. Dwivedi, J. Ethnopharmacol. **114**, 114–129 (2007)
67. L.R. Row, P.S. Murty, G.S. Rao, C.P. Sastry, K.V.J. Rao, Indian J. Chem. **8**, 772–775 (1970)
68. W. Wang, Z. Ali, X.C. Li, Y. Shen, I.A. Khan, Planta Med. **76**, 903–908 (2010)
69. O. Aiyelaagbe, O. Olaoluwa, I. Oladosu, S. Gibbons, Rec. Nat. Prod. **8**, 7–11 (2014)
70. J. Kalola, M. Rajani, Chromatographia **63**, 475–481 (2006)
71. E. Bombardelli, E.M. Martinelli, G. Mustich, Phytochemistry **13**, 2559–2562 (1974)
72. S. Cao, P.J. Brodie, M. Callmander, R. Randrianaivo, E. Rakotobe, V.E. Rasamison, D.G. Kingston, Phytochemistry **71**, 95–99 (2010)
73. A.K. Nandy, G. Podder, N.P. Sahu, S.B. Mahato, Phytochemistry **28**, 2769–2772 (1989)

74. T. Tsuyuki, Y. Hamada, T. Honda, T. Takahashi, K. Matsushita, Bull. Chem. Soc. Jpn **52**, 3127–3128 (1979)
75. S.W. Jung, M.H. Shin, J.H. Jung, N.D. Kim, K.S. Im, Arch. Pharmacal Res. **24**, 412–415 (2001)
76. W. Wang, Z. Ali, Y. Shen, X.C. Li, I.A. Khan, Fitoterapia **81**, 480–484 (2010)
77. F.E. King, T.J. King, J.M. Ross, J. Chem. Soc. **85**, 3995 (1954)
78. L.R. Row, P.S. Murty, G.S.R.S. Rao, C.S.P. Sastry, K.V.J. Rao, Indian J. Chem. **8**, 716–721 (1970)
79. R.R. Aggarwal, S. Dutt, Proc. Natl. Acad. Sci. U.S.A. **6**, 305 (1936)
80. V.K. Tripathi, B. Singh, R.C. Tripathi, R.K. Upadhyay, V.B. Pandey, Orient. J. Chem. **12**, 1–16 (1996)
81. R.K. Upadhyay, M.B. Pandey, R.N. Jha, V.P. Singh, V.B. Pandey, J. Asian Nat. Prod. Res. **3**, 207–212 (2001)
82. R.S. Pawar, K.K. Bhutani, Phytomedicine **12**, 391–393 (2005)
83. A. Nagar, V.K. Gujral, S.R. Gupta, Planta Med. **37**, 183–185 (1979)
84. A. Ali, S.T. Abdullah, H. Hamid, M. Ali, M.S. Alam, Indian J. Chem. **42**, 2905–2909 (2003)
85. B.K. Chouksey, S.K. Srivastava, Indian J. Chem. **40**, 354–356 (2001)
86. F.E. Kandil, N.I. Narsar, Phytochemistry **47**, 1567–1568 (1998)
87. A. Ali, G. Kaur, K. Hayat, M. Ali, M. Ather, Pharmazie **58**, 932–934 (2003)
88. H.Y. Link, L. Chang, Planta Med. **71**, 237–243 (2005)
89. S. Nair, R. Nagar, South Asian J. Prev. Cardiol. **1**, 33–35 (1997)
90. T.C. Lin, S.C. Chien, H.F. Chen, F.L. Hsu, Chin. Pharm. J. **52**, 1–26 (2000)
91. A. Mann, K. Ibrahim, A.O. Oyewale, J.O. Amupitan, M.O. Fatope, J.I. Okogun, Am. J. Org. Chem. **2**, 14–20 (2012)
92. M.N. Shuaibu, P.T. Wuyep, T. Yanagi, K. Hirayama, A. Ichinose, T. Tanaka, I. Kouno, Parasitol. Res. **102**, 697–703 (2008)
93. A. Mann, K. Ibrahim, A.O. Oyewale, J.O. Amupitan, M.O. Fatope, J.I. Okogun, Am. J. Chem. **1**, 52–55 (2011)
94. R.N. Yadava, K. Rathore, Fitoterapia **72**, 310–312 (2001)
95. G. Pandey, S.S. Gupta, A. Bhatia, O.P. Sidhu, A.K.S. Rawat, C.V. Rao, J. Ethnopharmacol. **202**, 63–66 (2017)
96. J.R. Row, P.S. Murty, Indian J. Chem. **8**, 1047–1048 (1970)
97. H.E. Elsayed, M.R. Akl, H.Y. Ebrahim, A.A. Sallam, E.G. Haggag, A.M. Kamal, K.A. El Sayed, Chem. Biol. Drug Des. **85**, 231–243 (2015)
98. H. Negishi, T. Maoka, M. Njelekela, N. Yasui, S. Juman, J. Mtabaji, T. Miki, Y. Nara, Y. Yamori, K. Ikeda, J. Asian Nat. Prod. Res. **13**, 281–283 (2011)
99. S.A. Opiyo, L.O.A. Manguro, P.O. Owuor, C.O. Ochieng, E.M. Ateka, P. Lemmen, Nat. Prod. J. **1**, 116–120 (2011)
100. K. Yamauchi, T. Mitsunaga, A.M. Muddathir, J. Wood Sci. **62**, 285–293 (2016)
101. E.Y.A. Salih, M. Kanninen, M. Sipi, O. Luukkanen, R. Hiltunen, H. Vuorela, R. Julkunen-Tiitto, P. Fyhrquist, S. Afr. J. Bot. **108**, 370–386 (2017)
102. T. Tanaka, A. Morita, G.I. Nonaka, T.C. Lin, I. Nishioka, F.C. Ho, Chem. Pharm. Bull. **39**, 60–63 (1991)
103. L.G. Chen, C.C. Wang, L.L. Yang, Abstr. Pap. Am. Chem. Soc. **228**, 61 (2004)
104. T.C. Lin, Y.T. Ma, F.L. Hsu, Chin. Pharm. J. (Taipei) **48**, 25–35 (1996)
105. P.S. Chen, J.H. Li, T.Y. Liu, T.C. Lin, Cancer Lett. **152**, 115–122 (2000)
106. Y. Chandrasekhar, E.M. Ramya, K. Navya, G.P. Kumar, K.R. Anilakumar, Biomed. Pharmacother. **86**, 414–425 (2017)
107. T. Tanaka, G.I. Nonaka, I. Nishioka, Chem. Pharm. Bull. **34**, 1039–1049 (1986)
108. *Dukes Phytochemical and Ethnobotanical Database* (2008), p. 11
109. S. Mandloi, R. Mishra, R. Varma, B. Varughese, J. Tripathi, Int. J. Pharm. Bio Sci. **4**, 1385–1393 (2013)
110. Q. Han, J. Song, C. Qiao, L. Wong, H. Xu, J. Sep. Sci. **29**, 1653–1657 (2006)
111. A. Saleem, M. Husheem, P. Härkönen, K. Pihlaja, J. Ethnopharmacol. **81**, 327–336 (2002)
112. A.R. Afshari, H.R. Sadeghnia, H. Mollazadeh, Adv. Pharmacol. Sci. (2016). https://doi.org/10.1155/2016/8964849
113. M.S. Baliga, J. Altern. Complement. Med. **16**, 1301–1308 (2010)
114. T. Sornwatana, K. Bangphoomi, S. Roytrakul, N. Wetprasit, K. Choowongkomon, S. Ratanapo, Biotechnol. Appl. Biochem. **62**, 746–753 (2015)
115. D. Mammen, S. Bapat, R. Sane, Int. J. Pharm. Bio Sci. **3**, 416–419 (2012)
116. S. Chandan, Phytochemistry **29**, 2348–2350 (1990)
117. C.P. Khare, *Botany, Indian Herbal Remedies: Rational Western Therapy, Ayurvedic, and Other Traditional Usage* (Springer, New York, 2004), pp. 451–452
118. O.S. Ajala, A. Jukov, C.M. Ma, Fitoterapia **99**, 117–123 (2014)
119. L.J. Juang, S.J. Sheu, T.C. Lin, J. Sep. Sci. **27**, 718–724 (2004)
120. S. Burapadaja, A. Bunchoo, Planta Med. **61**, 365–366 (1995)
121. M.A. Muhit, K. Umehara, H. Noguchi, Fitoterapia **113**, 74–79 (2016)
122. I. Konczak, D. Zabaras, M. Dunstan, P. Aguas, Food Chem. **123**, 1048–1054 (2010)
123. A.B. Cunningham, S. Garnett, J. Gorman, K. Courtenay, D. Boehme, Econ. Bot. **63**, 16–28 (2009)
124. V.S. Martino, M.N. Graziano, O. Hnatyszyn, J.D. Coussio, Planta Med. **27**, 226–230 (1975)
125. P. Rayan, B. Matthews, P.A. McDonnell, I.E. Cock, Parasitol. Res. **114**, 2611–2620 (2015)
126. J. Sirdaarta, B. Matthews, I.E. Cock, J. Funct. Food **17**, 610–620 (2015)
127. D.E.U. Ekong, O.G. Idemudia, J. Chem. Soc. C (1967). https://doi.org/10.1039/J39670000863
128. O.G. Idemudia, Phytochemistry **9**, 2401–2402 (1970)
129. S. Zareen, M.I. Choudhary, F.N. Ngounou, A. Yasin, M. Parvez, Tetrahedron Lett. **43**, 6233–6236 (2002)
130. A.U. Rahman, S. Zareen, M.I. Choudhary, M.N. Akhtar, F.N. Ngounou, Z. Nat. B **60**, 347–350 (2005)
131. B.K. Ponou, R.B. Teponno, M. Ricciutelli, L. Quassinti, M. Bramucci, G. Lupidi, L. Barboni, L.A. Tapondjou, Phytochemistry **71**, 2108–2115 (2010)
132. B.K. Ponou, R.B. Teponno, M. Ricciutelli, T.B. Nguelefack, L. Quassinti, M. Bramucci, G. Lupidi, L. Barboni, L.A. Tapondjou, Chem. Biodivers. **8**, 1301–1309 (2011)
133. P. Fyhrquist, I. Laakso, S.G. Marco, R. Julkunen-Tiitto, R. Hiltunen, S. Afr. J. Bot. **90**, 1–16 (2014)
134. A.M. Muddathir, K. Yamauchi, T. Mitsunaga, J. Wood Sci. **59**, 426–431 (2013)
135. A.T. Pham, K.E. Malterud, B.S. Paulsen, D. Diallo, H. Wangensteen, Nat. Prod. Commun. **6**, 1125–1128 (2011)
136. A.T. Pham, K.E. Malterud, B.S. Paulsen, D. Diallo, H. Wangensteen, Pharm. Biol. **52**, 1166–1169 (2014)
137. J. Conrad, B. Vogler, S. Reeb, I. Klaiber, S. Papajewski, G. Roos, E. Vasquez, M.C. Setzer, W. Kraus, J. Nat. Prod. **64**, 294–299 (2001)
138. J. Conrad, B. Vogler, I. Klaiber, S. Reeb, J.H. Guse, G. Roos, W. Kraus, Nat. Prod. Lett. **15**, 35–42 (2001)
139. N.M. Fahmy, E. Al-Sayed, M.M. Abdel-Daim, M. Karonen, A.N. Ingab, Pharm. Biol. **54**, 303–313 (2016)
140. K. Majumdar, M.B. Sinha, U.K. Som, S. Das, J. Indian Chem. Soc. **82**, 673–674 (2005)
141. T.B. Murdiati, C.S. McSweeney, J.B. Lowry, Aust. J. Agric. Res. **43**, 1307–1319 (1992)

142. S. Talwar, P.G. Nayak, J. Mudgal, P. Paul, P. Bansal, K. Nandakumar, J. Med. Food **16**, 1153–1161 (2013)
143. L.R. Row, R.R. Raju, Tetrahedron **23**, 879–884 (1967)
144. R. Mopuri, M. Ganjayi, K.S. Banavathy, B.N. Parim, B. Meriga, BMC Complement. Altern. Med. **15**, 76 (2015)
145. J. Conrad, B. Vogler, I. Klaiber, G. Roos, U. Walter, W. Kraus, Phytochemistry **48**, 647–650 (1998)
146. D.Y. Lee, K.H. Woo, H.J. Yang, S.S. Hyun, Bioorg. Med. Chem. Lett. **27**, 34–39 (2017)
147. R.L. Ramachandra, R.R. Ramkrishnam, Curr. Sci. **34**, 177 (1965)
148. L.R. Row, G.S. Rao, Tetrahedron **18**, 357–360 (1962)
149. V. Martino, J. Morales, J.J. Martínez-Irujo, M. Font, A. Monge, J. Coussio, Phytother. Res. **18**, 667–669 (2004)
150. M.J. Moshi, Z.H. Mbwambo, J. Ethnopharmacol. **97**, 43–47 (2005)
151. I.M. Eldeen, E.E. Elgorashi, D.A. Mulholland, J. van Staden, J. Ethnopharmacol. **103**, 135–138 (2006)
152. C.C. Joseph, M.J. Moshi, E. Innocent, M.H.H. Nkunya, Afr. J. Tradit. Complement. Altern. Med. **4**, 383–386 (2007)
153. V. Kuete, T.K. Tabopda, B. Ngameni, F. Nana, T.E. Tshikalange, B.T. Ngadjui, S. Afr. J. Bot. **76**, 125–131 (2010)
154. T.C. Li, F.L. Hsu, Chin. Pharm. J. **48**, 167–175 (1996)
155. L.F. Wu, Y.B. Yuan, K.F. Wang, S.Q. Li, J. Liu, L.Z. Zhang, G.M. She, Chin. Tradit. Herb. Drugs **45**, 290–299 (2014)
156. M.S. Alam, G. Kaur, A. Ali, H. Hamid, M. Ali, M. Athar, Nat. Prod. Res. **22**, 1279–1288 (2008)
157. I.E. Cock, Inflammopharmacology **23**, 203–229 (2015)
158. M.T. Tchuenmogne, T. Kammalac, S. Gohlke, R. Kouipou, A. Aslan, M. Kuzu, N. Sewald, Medicines (Basel) **4**, 6 (2017)
159. D.Y. Lee, H.W. Kim, H. Yang, S.H. Sung, Phytochemistry **137**, 109–116 (2017)
160. V.A. Ansari, M. Arif, M.S. Hussain, H.H. Siddiqui, R.K. Dixit, Integr. Med. Res. **5**, 317–323 (2016)
161. C. Rice-Evans, N. Miller, G. Paganga, Trends Plant Sci. **2**, 152–159 (1997)
162. R. Rajpoot, A. Rani, R.K. Srivastava, P. Pandey, R.S. Dubey, Protoplasma **253**, 1449–1462 (2016)
163. S.A. Hussain, M.A. Kareem, S.N. Rasoo, S.Y. Al Omar, A. Saleh, M.A. Al-Fwuaires, K.L. Devi, Biol. Trace Elem. Res. **181**, 112–121 (2018)
164. J. An, T. Li, Y. Dong, Z. Li, J. Huo, Cell. Physiol. Biochem. **39**, 531–543 (2017)
165. K. Jayesh, L.R. Helen, A. Vysakh, E. Binil, M.S. Latha, Biomed. Pharmacother. **95**, 1654–1660 (2017)
166. N.M. Fahmy, E. Al-Sayed, M.M. Abdel-Daim, A.N. Singab, Drug Dev. Res. **78**, 146–154 (2017)
167. T. Veni, T. Pushpanathan, J. Mohanraj, J. Parasit. Dis. **41**, 693–702 (2017)
168. A. Thanigaivel, P. Vasantha-Srinivasan, S. Senthil-Nathan, E.S. Edwin, A. Ponsankar, M. Chellappandian, K. Kalaivani, Ecotoxicol. Environ. Saf. **137**, 210–217 (2017)
169. M.F. Akhtar, A. Saleem, A. Sharif, B. Akhtar, M.B. Nasim, S. Peerzada, S. Ali, EXCLI J. **15**, 589 (2016)
170. J. Kuriakose, H.L. Raisa, A. Vysakh, B. Eldhose, M.S. Latha, Biomed. Pharmacother. **93**, 327–333 (2017)
171. A. Mittal, S. Tandon, S.K. Singla, C. Tandon, Cytotechnology **69**, 349–358 (2017)
172. A. Durge, P. Jadaun, A. Wadhwani, A.A. Chinchansure, M. Said, H.V. Thulasiram, S.S. Kulkarni, Nat. Prod. Res. **31**, 1468–1471 (2017)
173. A. Kesharwani, S.K. Polachira, R. Nair, A. Agarwal, N.N. Mishra, S.K. Gupta, BMC Complement. Altern. Med. **17**, 110 (2017)
174. Y.C. Sekhar, G.P. Kumar, K.R. Anilakumar, Chin. J. Nat. Med. **15**, 584–596 (2017)