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Review

Naturally Occurring Chromone Glycosides: Sources, Bioactivities, and Spectroscopic Features

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Abstract: Chromone glycosides comprise an important group of secondary metabolites. They are widely distributed in plants and, to a lesser extent, in fungi and bacteria. Significant biological activities, including antiviral, anti-inflammatory, antitumor, antimicrobial, etc., have been discovered for chromone glycosides, suggesting their potential as drug leads. This review compiles 192 naturally occurring chromone glycosides along with their sources, classification, biological activities, and spectroscopic features. Detailed biosynthetic pathways and chemotaxonomic studies are also described. Extensive spectroscopic features for this class of compounds have been thoroughly discussed, and detailed ^{13}C-NMR data of compounds **1**–**192**, have been added, except for those that have no reported ^{13}C-NMR data.

Keywords: chromone glycosides; chemical structure; activity; benzo-γ-pyrone; ^{13}C-NMR data

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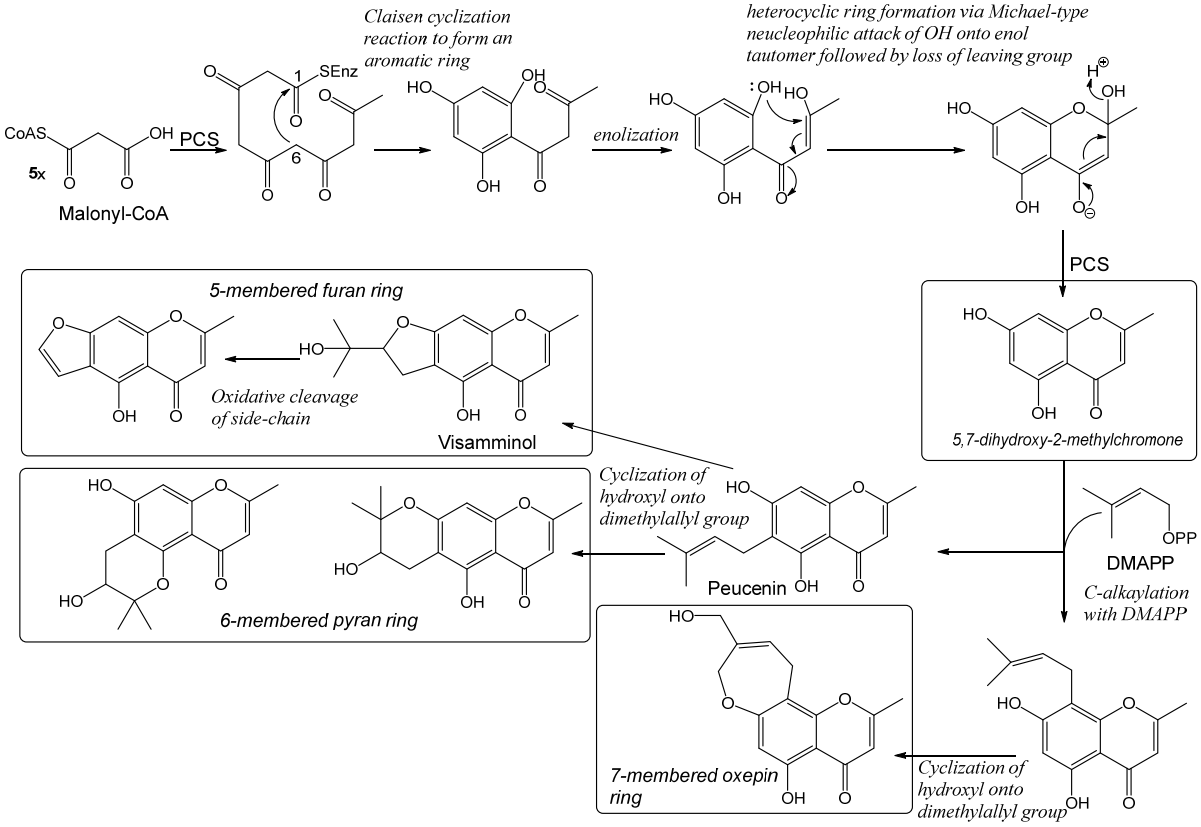
1. Introduction

Chromone glycosides are a class of secondary metabolites with various medicinal properties. They are widely distributed in many plant genera and, to a lesser extent, in some fungal species and other sources [1]. Several biological activities have been reported for various chromone glycosides. For example, aloesin and its analogues, from Aloe, are used in cosmetic preparations to treat hyperpigmentation induced by UV radiation, owing to their role in inhibition of tyrosinase enzyme [2,3]. Additionally, 8-[C-β-D-[2-*O*-(*E*)-cinnamoyl]glucopyranosyl]-2-[(*R*)-2-hydroxypropyl]-7-methoxy-5-methylchromone), isolated from certain Aloe species, was reported to have potent topical anti-inflammatory activity comparable to the effect of hydrocortisone without affecting thymus weight [3]. Macrolobin, from *Macrolobium latifolium*, has a remarkable acetylcholinesterase inhibitory activity with an IC_{50} value of 0.8 μM. Uncinosides A and B, isolated from the Chinese herbal medicine *Selaginella uncinata*, showed potent anti-RSV (respiratory syncytial virus) activity with IC_{50} values of 6.9 and 1.3 μg/mL. Taking into consideration the broad biological activities of chromone glycosides, this review summarizes the naturally occurring chromone glycosides and categorizes these compounds on their structural basis, in addition to their sources, bioactivities and spectroscopic features. Importantly, this review will shed more light toward the NMR features of chromone glycosides to help natural product researchers in the identification of various chemical structures. Scientific databases as SciFinder, PubMed, and Google Scholar were used to collect the relevant literature data.

2. Biosynthesis

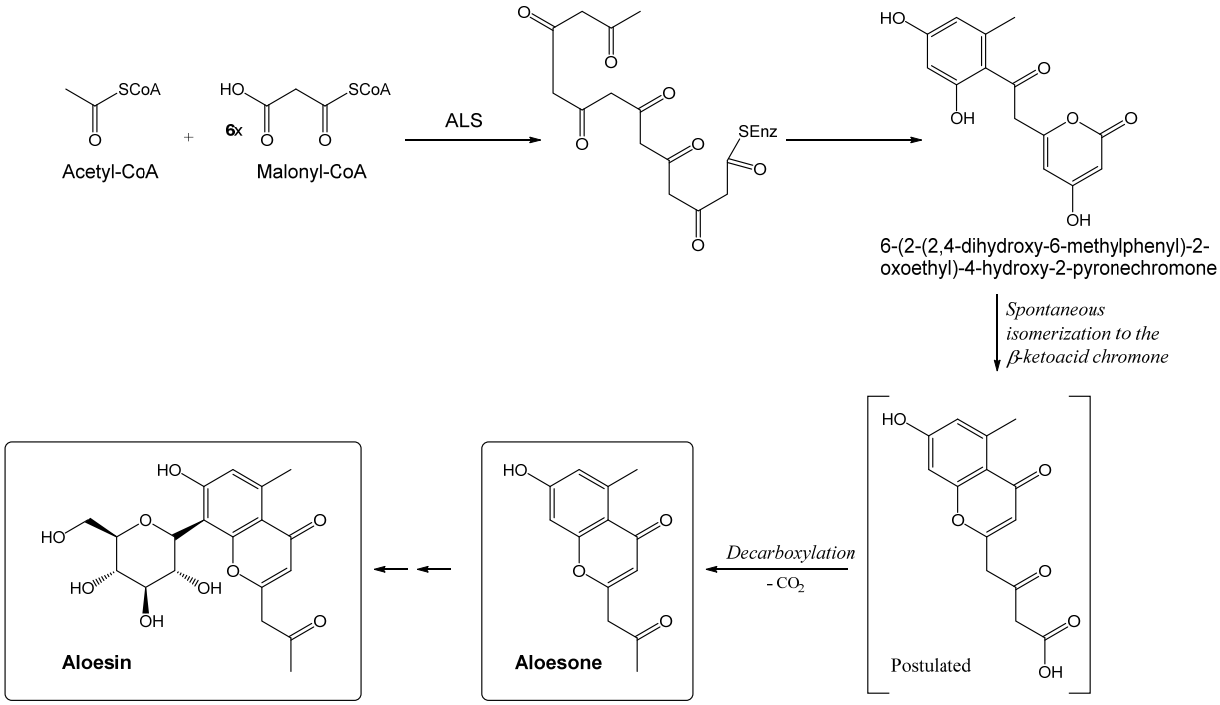
Chromones are biosynthesized through the acetic acid pathway by the condensation of five acetate molecules. These compounds, generally, have a methyl group at C-2 and are oxygenated at C-5 and C-7 [4]. Pentaketide Chromone Synthase (PCS) is a key enzyme in the biosynthesis process that catalyzes the formation of a pentaketide chromone (5,7-dihydroxy-2-methylchrome) from five-step decarboxylative condensations of malonyl-CoA, followed by the Claisen cyclization reaction to form an aromatic ring. However, it is unclear whether the heterocyclic ring closure of the pentaketide chromone is enzymatic or not, because the ring closure can take place due to spontaneous Michael-like ring closure, as in the case of flavanone formation from chalcone in vitro. PCS also accepts acetyl-CoA, resulting from decarboxylation of malonyl-CoA, as a starter substrate, but it is a poor substrate for PCS [5].The pentaketide chromone has been isolated from several plants and is known to be the biosynthetic precursor of the chromone derivatives with additional heterocyclic rings (e.g., furano-, pyrano- and oxepino-chromone glycosides). Scheme 1 ([6] with modifications) shows the sequence of steps utilized in the biosynthesis of these compounds, fully consistent with the biosynthetic rationale developed above. The key intermediate is 5,7-dihydroxy-2-methylchromone [5,6]. For many years, the cyclization had been postulated to involve an intermediate epoxide, such that nucleophilic attack of the phenol onto the epoxide group might lead to formation of either five-membered furan, six-membered pyran or the seven-membered oxepin heterocycles, as commonly encountered in natural products [6].



Scheme 1. Proposed mechanisms for the enzymatic formation of 5,7-dihydroxy-2-methylchromone and its derivatives.

Aloesone Synthase (ALS) (Scheme 2, [5] with modifications) is a key enzyme in the biosynthesis of heptaketide chromone aloesone derivatives, such as aloesone 7-*O*-β-D-glucopyranoside (**53**) in rhubarb and anti-inflammatory aloesone 8-C-β-D-glucopyranoside (aloesin, **98**) in Aloe (*A. arborescens*). ALS efficiently catalyzes the formation of a heptaketide aromatic pyrone 6-(2-(2,4-dihydroxy-6-methylphenyl)-2-oxoethyl)-4-hydroxy-2-

pyronechromone from acetyl-CoA and six molecules of malonyl-CoA through an aldol cyclization. The unstable heptaketide pyrone (or acid form) would then undergo subsequent spontaneous isomerization to the β-ketoacid chromone, which is followed by decarboxylation to produce the heptaketide aloesone [5].



Scheme 2. Proposed mechanisms for the enzymatic formation of aloesone and its derivatives.

3. Taxonomy

We have reviewed the literature concerning the occurrence of chromone glycosides, and we have found that 192 different chromone glycosides have been isolated from different natural sources, including angiosperms, ferns, lichens, fungi and actinobacteria (Table 1). The occurrence of chromone glycosides is mostly confined to botanical families: Apiaceae, Fabaceae, Myrtaceae, Asphodelaceae, Ranunculaceae, Rubiaceae, Hypericaceae, Ericaceae, Amaryllidaceae, Polygonaceae and Araceae. However, few chromone glycosides are also present in Asteraceae, Eucryphiaceae, Saxifragaceae, Smilacaceae, Pentaphylaceae, Salicaceae, Meliaceae, Euphorbiaceae, Staphyleaceae, Amaranthaceae, Aquifoliaceae, Rosaceae, Bignoniaceae, Olacaceae, Pinaceae, Selaginellaceae, Gentianaceae, Cannabaceae, Euphorbiaceae, Cucurbitaceae, Thymelaeaceae and Poaceae. Many of the naturally occurring chromone-8-C-glycosides such as the well-known chromone glycoside aloesin (**98**) were reported from genus *Aloe*. Until now, chromone glycosides with additional heterocyclic moieties such as pyrano-, oxepino- and pyrido-chromone glycosides were only isolated from *Saposhnikovia divaricate*, *Eranthis* species and *Schumanniophyton magnificum*, respectively. Another interesting category comprises hybrids of furano-chromones with cycloartane triterpenes, which were reported from *Cimicifuga foetida*. Actinobacteria also constitute an important source of the chromone alkaloid aminoglycosides, which are isolated from *Streptomyces*, *Saccharothrix* and *Actinomycete* species.

Table 1. The distribution of chromone glycosides reported through this review.

		Family	Genus	Species	Compounds
Plants (Angiosperms)	1	Ericaceae	*Rhododendron*	*ovatum*	**2**
				spinuliferum	**3**
				collettianum	**55**
			Calluna	*vulgaris*	**13**
	2	Rubiaceae	*Schumanniophyton*	*magnificum*	**7**, **25**, **156**
			Knoxia	*corymbosa*	**20**, **24**, **35**, **36**
			Adina	*rubescens*	**20**
			Neonauclea	*sessilifolia*	**26**, **166**
	3	Amaryllidaceae	*Gethyllis*	*ciliaris*	**10**
			Pancratium	*biflorum*	**20**, **66**
				maritimum	**20**, **47**
	4	Polygonaceae	*Polygonum*	*capitatum*	**15**
			Rheum	*austral*	**50**
				sp.	**52**, **53**
	5	Apiaceae	*Ammi*	*visnaga*	**20**, **140**, **146**
			Peucedanum	*austriacum*	**20**
				japonicum	**149**
			Cnidium	*monnieri*	**57**, **58**, **123–130**
				juponicum	**123**, **124**
			Bupleurum	*chinense*	**58**
			Angelica	*archangelica*	**125**
				genuflexa	**146**, **149**
				japonica	**146**, **149**
			Archangelica	*litoralis*	**125**
			Saposhnikovia	*divaricata*	**143–146**, **149**, **150**
			Ledebouriella	*seseloides*	**144**
			Diplolophium	*buchananii*	**144**, **146**, **151**
			Sphallerocarpus	*gracilis*	**144**
			Glehnia	*littoralis*	**149**
	6	Hypericaceae	*Hypericum*	*henryi*	**22**, **23**
				erectum	**22**, **38**
				sikokumontanum	**38**, **39**, **60**, **61**
				japonicum	**82**, **83**
	7	Ranunculaceae	*Delphinium*	*hybridum*	**28**
			Cimicifuga	*heracleifolia*	**141**
				foetida	**146**, **147**, **157–165**
			Eranthis	*hyemalis*	**131**, **132**, **152**, **153**, **154**
				cilicica	**133**, **134**, **153**, **155**

Table 1. *Cont.*

		Family	Genus	Species	Compounds
Plants (Angiosperms)	8	Myrtaceae	*Myrtus*	*communis*	**34**
			Syzygium	*aromaticum*	**66**, **71**, **80**, **86**
			Baeckea	*frutescens*	**66**, **67**, **70**, **72**, **85**, **87**
			Kunzea	*ambigua*	**67**, **70**, **72–74**, **80**, **85**, **88**, **89**
			Eucalyptus	*globulus*	**80**
				maidenii	**82**, **83**
				grandis	**83**
				urograndi	**83**
	9	Fabaceae	*Cassia*	*multijuga*	**51**, **77**
				siamea	**59**
				obtusifolia	**68**, **69**
				spectablis	**78**
				obtusifolia	**84**
			Macrolobium	*latifolium*	**64**
			Aspalathus	*linearis*	**65**
			Abrus	*mollis*	**80**
			Ononis	*vaginalis*	**135**
	10	Asphodelaceae	*Aloe*	*vera*	**75**, **76**, **90–98**, **103**, **104–110**, **112–117**, **120–122**
				barbadensis	**97**, **98**, **103**, **107**, **108**
				rupestris	**99**
				cremnophila	**101**
				nobilis	**111**, **118**, **119**
	11	Araceae	*Scindapsus*	*officinalis*	**18–20**, **29**, **31**, **32**, **56**, **57**
	12	Asteraceae	*Mutisia*	*acuminate*	**1**
	13	Eucryphiaceae	*Eucryphia*	*cordifolia*	**4**
	14	Saxifragaceae	*Astilbe*	*thunbergii*	**4**
	15	Smilacaceae	*Smilax*	*glabra*	**4**
	16	Pentaphylaceae	*Eurya*	*japonica*	**5**
	17	Salicaceae	*Salix*	*matsudana*	**6**
	18	Meliaceae	*Dysoxylum*	*binectariferum*	**7**
	19	Euphorbiaceae	*Acalypha*	*fruticose*	**7**
	20	Staphyleaceae	*Staphylea*	*bumalda*	**7**
	21	Amaranthaceae	*Salicornia*	*europaea*	**12**
	22	Aquifoliaceae	*Ilex*	*hainanensis*	**13**
	23	Rosaceae	*Dasiphora*	*parvifolia*	**16**, **17**
	24	Bignoniaceae	*Tecomella*	*undulata*	**20**, **27**
	25	Olacaceae	*Scorodocarpus*	*borneensis*	**26**
	26	Pinaceae	*Pseudotsuga*	*sinensis*	**37**
	27	Selaginellaceae	*Selaginella*	*uncinata*	**46**, **48**
	28	Gentianaceae	*Swertia*	*punicea*	**54**

Table 1. *Cont.*

		Family	Genus	Species	Compounds
Plants (Angiosperms)	29	Cannabaceae	*Humulus*	*lupulus*	**62**
	30	Euphorbiaceae	*Chrozophora*	*prostrata*	**79**
	31	Cucurbitaceae	*Cucumis*	*melo*	**136**
	32	Thymelaeaceae	*Aquilaria*	*sinensis*	**137**, **139**
	33	Poaceae	*Imperata*	*cylindrical*	**138**
Ferns	1	Polypodiaceae	*Drynaria*	*fortunei*	**7**, **28**, **30**, **32**, **33**, **57**
	2	Dryopteridaceae	*Dryopteris*	*fragrans*	**20**, **21**
	3	Onocleaceae	*Matteuccia*	*intermedia*	**49**
Lichens			*Roccellaria*	*mollis*	**41**, **42**, **45**
			Schismatomma	*accedens*	**41**, **42**, **45**
			Roccella	*galapagoensis*	**41**, **42**, **45**
			Lobodirina	*cerebriformis*	**44**
Fungi			*Armillaria*	*tabescens*	**11**
			Orbiocrella	sp.	**40**, **43**
			Stemphylium	*botryosum*	**63**
Actinobacteria			*Streptomyces*	*phaeoverticillatus* var. *takatsukiensis*	**168**
				pluricolorescens	**169**–**171**
				sp.	**172**–**178**, **180**
				griseoruber	**179**
			Saccharothrix	sp.	**181**–**183**
			Actinomycete		**184**–**192**

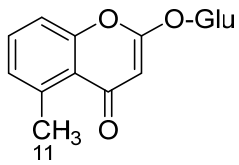
4. Chromone Glycosides

Chromone glycosides belong to a group of oxygen-containing heterocyclic compounds with a benzo-γ-pyrone skeleton. Naturally occurring chromone glycosides can be either *O*-glycosides or C-glycosides. For *O*-glycosides, the most frequently encountered group is the 7-*O*-glycosides; however, 2-, 3-, 5-, 8-, 11- and 13-*O*-glycosides also exist but to a lower extent. For an example, only one 6-*O*-glycoside **11** has been reported from nature, and from fungi, not higher plants [1]. Glycosylation can also be detected at side chains for chromones, at C-11 and C-12 as in compounds **56**–**59**, at the hydroxyprenyl and hydroxyisoprenyl side chains as in **123** and **128**, respectively, or at the phenyl ethyl moiety as **139**. The most abundant among chromone glycosides is the glucoside from. However, other sugar moieties such as xylose, arabinose and rhamnose were also detected in 3-, 7- and 11-*O*-glycosides.

4.1. Chromone O-glycosides

4.1.1. 2-*O*-Glycosides

This category includes compound **1** (Figure 1), 2-hydroxy-5-methylchromone-*β*-D-glucopyranoside, isolated from the aerial parts of *Mutisia acuminata* var. *hirsuta*, a member of family Asteraceae [7]. The authors did not report biological activity for this compound.

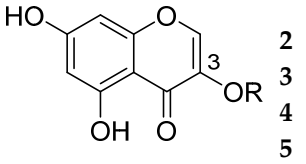


1

Figure 1. Structure of compound **1**.

4.1.2. 3-*O*-Glycosides

This category includes compounds **2**–**5**. They share the same aglycone nucleus but with different sugar moieties at C-3. Eucryphin **4** was reported as a new compound in 1979 [8]; however, it was reported again in 1996 as a new compound under the name smiglanin [9]. In addition, 3,5,7-trihydroxychromone 3-*O*-*β*-D-xylopyranoside **2** was first reported in 2005 from *Rhodadendron ovatum* [10], but it was reported again as a new compound in 2013 [11]. Compounds **2**–**5** are shown in Figure 2. The sources and the reported biological activities are summarized in Table 2.



	R
2	**Xyl**
3	**Ara**
4	**Rha**
5	**Glu**

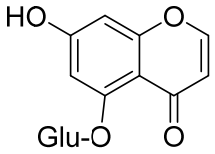
Figure 2. Structures of compounds **2**–**5**.

Table 2. 3-*O*-Chromone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
2	3,5,7-trihydroxychromone-3-*O*-*β*-D-xylopyranoside	*Rhododendron ovatum* roots [10] *Eurya japonica* stems [11]	Inhibitory effects on LPS (Lipopolysaccharide)-induced NO (Nitric Oxide) production with inhibition rate 36.24 ± 1.29% at 20 μg/mL [11]
3	3,5,7-trihydroxylchromone-3-*O*-*α*-L-arabinopyranoside	*Rhododendron spinuliferum* aerial parts [12]	Inhibition of NO production in LPS-stimulated RAW 264.7 cells with an IC_{50} value more than 100 mM [12]
4	Eucryphin (5,7-dihydroxy-3-(*α*-*O*-L-rhamnopyranosyl)-4H-L-benzopyran-4-one)	*Eucryphia cordifolia* bark [8] *Astilbe thunbergii* rhizomes [13]	Norepinephrine-enhancing lipolytic effect 6.432 ± 0.014 FFA μmol/mL at 1000 μg [13] Enhancing effect on burn wound repair at 100 mg ointment per mouse [14]
	Smiglanin (3,5,7-trihydroxychromone-3-*O*-*α*-L-rhamnopyranoside)	*Smilax glabra* roots [9]	No reported biological activity
5	5,7-Dihydroxy-4H-chromen-4-one-3-*O*-*β*-D-glucopyranoside	*Eurya japonica* stems [11]	Inhibitory effects on LPS-induced NO production with inhibition rate 53.79 ± 1.78% at 20 μg/mL [11]

4.1.3. 5-*O*-Glycosides

Among the naturally occurring 5-*O*-glycosides, Staphylosides A and B (**8**–**9**), isolated from *Staphylea bumalda*, are characterized by a presence of a disaccharide moiety attached to C-5. The disaccharide chain in **8** is *β*-D-glucopyranosyl-(1→6)-*β*-D-glucopyranoside while in **9**, is *α*-D-glucopyranosyl-(1→6)-*β*-D-glucopyranoside. Compounds **6**–**10** are shown in Figure 3. The sources and the reported biological activities (if any) are summarized in Table 3.



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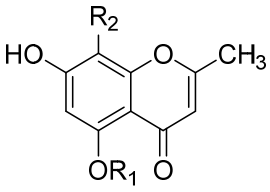


	R_1	R_2
7	Glu	H
8	Glu (6'→1'') β-Glu	H
9	Glu (6'→1'') α-Glu	H
10	Glu	CH_3

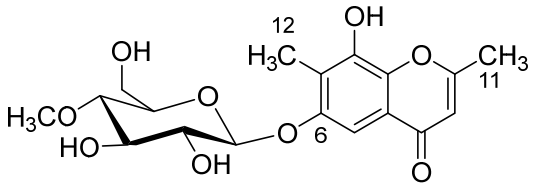
Figure 3. Structures of compounds **6**–**10**.

Table 3. 5-*O*-Chromone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
6	Matsudoside A (5-β-D-glucosyloxy-7-hydroxychromone)	*Salix matsudana* leaves [15]	No reported biological activity
7	Schumaniofioside A (2-methyl-5,7-dihydroxychromone 5-*O*-β-D-glucopyranoside)	*Schumanniophyton magnificum* root bark [16] *Dysoxylum binectariferum* fruits [17]. *Acalypha fruticose* aerial parts [18,19] *Drynaria fortune* rhizomes [13]	Inhibition of proinflammatory cytokines TNF-α (39.51 ± 1.21%) and IL-6 (22.21 ± 0.58%) at 5 μM [17] Inhibition of NF-kB transcriptional activity and iNOS with IC_{50} value of 29.5 ± 6.5 μg/mL [19]
8	Staphyloside A	*Staphylea bumalda* leaves [20]	No reported biological activity
9	Staphyloside B		
10	Isoeugenitol glucoside	*Gethyllis ciliaris* underground parts [21]	No reported biological activity

4.1.4. 6-*O*-Glycosides

Compound **11** (Figure 4) has a unique structure for bearing 4-*O*-methylglucopyranosyl unit. Chemically, it is 6-*O*-(4-*O*-methyl-β-D-glucopyranosyl)-8-hydroxy-2,7-dimethyl-4H-benzopyran-4-one, isolated from the rice culture of the fungus *Armillaria tabescens* [1]. Although such compounds are not common in higher plants, several of them have previously been isolated from fungi [1].

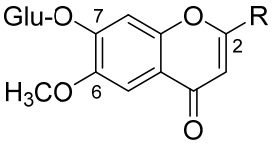


11

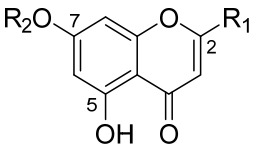
Figure 4. Structure of compound **11**.

4.1.5. 7-*O*-Glycosides

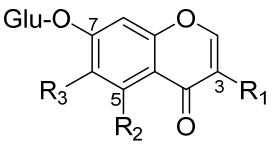
This subclass is characterized by the presence of sugar at C-7. Hyperimone A is the same as Urachromone A (**22**), reported at nearly the same time from different co-authors from the genus Hypericum. Takanechromone A (**38**) is the same as Hyperimone B, isolated from the same genus by different co-authors. They were reported each time as new compounds. We preferred to add only ^{13}C-NMR data of one set of these compounds (Table 23). Several biological activities have been reported to some members of this subclass. Compounds **12**–**53** are shown in Figure 5. The sources and the reported biological activities (if any) are summarized in Table 4.



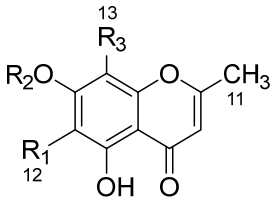
	R
12	H



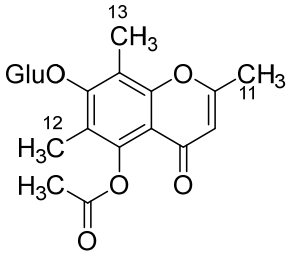
	R_1	R_2
13	H	Glu
14	H	Glucuronide methy ester
15	H	Glu-6'-Gall
16	H	Glu-6'-*cis* Cou
17	H	Glu-6'-*trans* Cou
18	CH_3	Xyl
19	CH_3	Rha
20	CH_3	Glu
21	CH_2CH_3	Glu
22	$CH(CH_3)_2$	Glu
23	$CH(CH_3)CH_2CH_3$	Glu
24	CH_3	Glu-6'-acetyl
25	CH_3	Api (1''→2') Glu
26	CH_3	Api (1''→6') Glu
28	CH_3	Rha (1''→6') Glu
29	CH_3	Glu (1''→2') Rha
30	CH_3	Glu (1'→3'') Rha
31	CH_3	Glu-6''-acetyl (1''→3') Rha
32	CH_3	Glu (1''→4') Rha
33	CH_3	Rha (4'→1'') Glu (2''→1''') Arab
34	CH_3	Glu-6'-Gall
35	CH_3	Glu-6'-Caf-4''→1'''All
36	CH_3	Glu-6'-Fer-4''→1'''All



	R_1	R_2
37	H	OH
38	CH_3	OH
39	CH_2CH_3	OH



	R_1	R_2	R_3
40	CH_3	Glu 4'-methyl	H
41	CH_3	Glu-2'-acetyl	H
42	CH_3	Glu-2',6'-di-acetyl	H
43	H	Glu-4'-methyl	CH_3
44	CH_3	Glu-2',3,6'-tri-acetyl	CH_3
45	CH_3	Glu-6'-acetyl	CH_3
46	CH_3	Glu	CH_3
47	OCH_3	Glu	H



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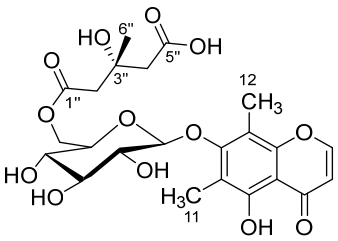
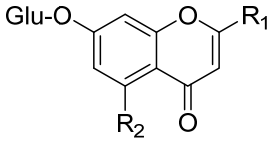


49



	R_1	R_2
50	CH_3	CH_3
51	CH_3	CH_2COCH_3
52	CH_3	$CH_2COCH_2CH(OH)CH_3$
53	CH_2COCH_3	CH_3

Figure 5. Structures of compounds **12**–**53**.

Table 4. 7-*O*-Chromone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
12	7-*O*-*β*-D-glucopyranosyl-6-methoxychromone	*Salicornia europaea* leaves and stems [25]	No reported biological activity
13	5,7-dihydroxychromone 7-*O*-*β*-D-glucopyranoside	*Ilex hainanensis* leaves [26] *Calluna vulgaris* flowers [27]	No reported biological activity
14	5,7-dihydroxychromone 7-*O*-*β*-D-glucuronide methyl ester	*Davallia mariesii* rhizomes [28]	No reported biological activity
15	7-*O*-(6′-galloyl)-*β*-D-glucopyranosyl-5-hydroxychromone	*Polygonum capitatum* aerial parts [29]	No reported biological activity
16	5-hydroxy-7-*O*-(6-*O*-*p*-*cis*-coumaroyl-*β*-D-glucopyranosyl)-chromone	*Dasiphora parvifolia* aerial parts [30]	No reported biological activity
17	5-hydroxy-7-*O*-(6-*O*-*p*-*trans*-coumaroyl-*β*-D-glucopyranosyl)-chromone	*Dasiphora parvifolia* aerial parts [30]	No reported biological activity
18	Officinaliside A	*Scindapsus officinalis* stems [31]	No reported biological activity
19	7-*O*-*α*-L-rhamnosyl-nereugenin	*Scindapsus officinalis* stems [31]	No reported biological activity
20	Undulatoside A (2-methyl-5,7-dihydroxychromone 7-*O*-*β*-D-glucopyranoside)	*Scindapsus officinalis* stems [31] *Ammi visnaga* fruits [32] *Knoxia corymbosa* [33] *Pancratium biflorum* roots [34] *Panacratium biflorum* flowering bulbs [35] *Pancratium maritimum* L. fresh bulbs [36] *Peucedanum austriacum* [37] *Tecomella undulata* bark [38] *Adina rubescens* leaves [39] *Dryopteris fragrans* [40] *Staphylea bumalda* leaves [20]	Immunomodulatory activity inhibited the proliferation of murine B lymphocytes in vitro at 10^{-5} M [33] Inhibition of nitric oxide production in lipopolysaccharide induced RAW 264.7 macrophages with an IC_{50} value of 49.8 μM [40] Weak antimigratory activity against human metastatic prostate cancer cells (PC-3M) at 50 μM [36]
21	Frachromone C (5-hydroxy-2-ethylchromone-7-*O*-*β*-D-glucopyranoside)	*Dryopteris fragrans* whole plant [40]	Inhibition of nitric oxide production in lipopolysaccharide induced RAW 264.7 macrophages with an IC_{50} value of 45.8 μM [40]
22	Urachromone A (5-hydroxy-2-isopropylchromone-7-*O*-*β*-D-glucopyranoside)	*Hypericum henryi* aerial parts [41] *Hypericum erectum* [42]	No reported biological activity
	Hyperimone A		
23	Urachromone B	*Hypericum henryi* aerial parts [41]	No reported biological activity
24	Corymbosin K_2 (7-*O*-*β*-D-6-acetylglucopyranosyl-5-hydroxy-2-methylchromone)	*Knoxia corymbosa* [33]	Immunomodulatory activity inhibited the proliferation of murine B lymphocytes in vitro at 10^{-5} M [33]
25	Schumanniofioside B	*Schumanniophyton magnificum* root bark [16]	No reported biological activity
26	5-hydroxy-2-methylchromone-7-*O*-*β*-D-apiofuranosyl-(1→6)-*β*-D-glucopyranoside	*Neonauclea sessilifolia* roots [43] *Scorodocarpus borneensis* leaves [44] *Staphylea bumalda* leaves [20]	No reported biological activity

Table 4. *Cont.*

No.	Compound	Source	Biological Activity
27	Undulatoside B	*Tecomella undulata* [45]	No reported biological activity
28	2-methyl-chromone-5,7-diol 7-*O*-*α*-L-rhamnopyranosyl-(1-6)-*β*-D-glucopyranoside	*Delphinium hybridum* aerial parts [46] *Drynaria fortunei* rhizomes [22]	No reported biological activity
29	Officinaliside C (7-*O*-[*β*-D-glucopyranosyl-(1-2)-*α*-L-rhamnopyranosyl]-5-hydroxy-2-methyl-4H-1-benzopyran-4-one)	*Scindapsus officinalis* stems [31]	No reported biological activity
30	Drynachromoside C (5-hydroxy-2-methyl chromone-7-*O*-*β*-D-glucopyranosyl (1-3)-*α*-L-rhamnopyranoside)	*Drynaria fortunei* rhizomes [22]	Inhibitory activity on triglyceride accumulation at 10 μM [22]
31	Officinaliside B (7-*O*-[6-acetyl-*β*-D-glucopyranosyl-(1-3)-*α*-L-rhamnopyranosyl]-5-hydroxy-2-methyl-4H-1-benzopyran-4-one)	*Scindapsus officinalis* stems [31]	Inhibition of NO production in LPS-stimulated RAW 264.7 cells with an IC_{50} value of 16.1 μM [31]
32	Drynachromoside A (5-hydroxy-2-methyl-4H-benzopyran-4-one-7-*O*-*β*-D-glucopyranosyl-(1-4)-*α*-L-rhamnopyranoside)	*Scindapsus officinalis* stems [31] *Drynaria fortunei* rhizomes [47]	Proliferative activity 10.1% on MC3T3-E1 (Mouse osteoblast) cells at 25 μg/mL [47]
33	Drynachromoside D (5-hydroxy-2-methyl chromone-7-*O*-*α*-L-arabinopyranosyl(1-2)-*β*-D-glucopyranosyl(1-4)-*α*-L-rhamnopyranoside)	*Drynaria fortunei* rhizomes [22]	Inhibitory activity on triglyceride accumulation (inhibited PPARγ, C/EBPα and aP2 expression by 50%, 43% and 37% at 10 mM) [22]
34	Undulatoside A 6′-*O*-gallate	*Myrtus communis* leaves [48]	
35	Corymbosin K3 (7-*O*-[6-*O*-(4-*O*-*trans*-caffeoyl-*β*-D-allopyranosyl)]-*β*-D-glucopyranosyl-5-hydroxy-2-methylchromone)	*Knoxia corymbosa* [33]	Immunomodulatory activity inhibited the proliferation of murine B lymphocytes *in vitro* at 10^{-5} M [33]
36	7-*O*-[6-*O*-(4-*O*-*trans*-feruloyl-*β*-D-allopyranosyl)]-*β*-D-glucopyranosyl-5-hydroxy-2-methylchromone	*Knoxia corymbosa* [33]	No reported biological activity
37	5-hydroxy-6-methylchromone-7-*O*-*β*-D-glucopyranoside	*Pseudotsuga sinensis* [49]	No reported biological activity
38	Takanechromone A (5,7-dihydroxy-3-methylchromone-7-*O*-*β*-D-glucopyranoside) Hyperimone B	*Hypericum sikokumontanum* aerial parts [50] *Hypericum erectum* [42]	No reported biological activity
39	Takanechromone B (5,7-dihydroxy-3-ethylchromone-7-*O*-*β*-D-glucopyranoside)	*Hypericum sikokumontanum* aerial parts [50]	No reported biological activity

Table 4. *Cont.*

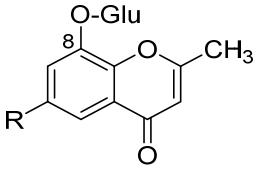
No.	Compound	Source	Biological Activity
40	7-*O*-(4-*O*-Methyl-*β*-D-glucopyranosyl)eugenitol	The scale-insect pathogenic fungus *Orbiocrella* sp. [23]	No reported biological activity
41	Mollin	Lichens (*Roccellaria mollis*, *Schismatomma accedens*, *Roccella galapagoensis*) [51]	No reported biological activity
42	Roccellin	Lichens (*Roccellaria mollis*, *Schismatomma accedens*, *Roccella galapagoensis*) [51]	No reported biological activity
43	7-*O*-(4-*O*-Methyl-*β*-D-glucopyranosyl)isoeugenitol	The scale-insect pathogenic fungus *Orbiocrella* sp. [23]	No reported biological activity
44	Lobodirin	*Lobodirina cerebriformis* lichen [51]	No reported biological activity
45	Galapagin	Lichens (*Roccellaria mollis*, *Schismatomma accedens*, *Roccella galapagoensis*) [51]	No reported biological activity
46	Uncinoside A (5-hydroxy-2,6,8-trimethylchromone 7-*O*-*β*-D-glucopyranoside)	*Selaginella uncinate* Herb [24]	Antiviral activity against respiratory syncytial virus (RSV) with an IC_{50} value of 6.9 μg/mL, against parainfluenza type 3 virus (PIV 3) with an IC_{50} value of 13.8 μg/mL [24]
47	Pancrichromone	*Pancratium maritimum* L. fresh bulbs [36]	No reported biological activity
48	Uncinoside B (5-acetyoxyl-2,6,8-trimethylchromone 7-*O*-*β*-D-glucopyranoside)	*Selaginella uncinate* herb [24]	Antiviral activity against respiratory syncytial virus (RSV) with an IC_{50} value of 1.3 μg/mL, against parainfluenza type 3 virus (PIV 3) with an IC_{50} value of 20.8 μg/mL [24]
49	Matteuinterin B	*Matteuccia intermedia* rhizomes [52]	
50	2,5-dimethylchromone-7-*O*-*β*-D-glucopyranoside	*Rheum austral* D. Don underground parts [53] *Rumex gmelini* Turcz. roots [54]	Anti-oxidant activity (DPPH radical scavenging capacity with an IC_{50} value of 66.9 ± 1.3 μM) [53]
51	5-acetonyl-7-*β*-D-glucopyranosyl-2-methylchromone	*Cassia multijuga* leaves [55,56]	No reported biological activity
52	2-methyl-5-(2′-oxo-4′-hydroxyphenyl)-7-hydroxychromone 7-*O*-*β*-D-glucopyranoside	Chinese rhubarb (Rhei Rhizoma) [57]	No reported biological activity
53	Aloesone 7-*O*-*β*-D-glucopyranoside	Chinese rhubarb (Rhei Rhizoma) [57]	No reported biological activity

Drynachromosides C (**30**) and D (**33**) exhibited inhibitory activity on triglyceride accumulation [22]. The effects of these compounds on mRNA expression of the three adipogenesis-related marker genes, PPARγ, C/EBPα and Ap2, in 3T3-L1 were investigated. The mRNA expression levels of PPARγ, C/EBPα and Ap2 were found to be dramatically downregulated. Compounds **40** and **43**, having a unique sugar unit of 4-*O*-methyl-*β*-D-glucopyranose, were isolated from the scale-insect pathogenic fungus *Orbiocrella* sp. BCC 33248 [23]. Uncinosides A (**46**) and B (**48**) [24], isolated from the Chinese herbal medicine *Selaginella uncinata*, showed potent anti-RSV (respiratory syncytial virus) activity with IC_{50} values of 6.9 and 1.3 μg/mL, respectively. Uncinoside B (**48**) was found to have a TI value of 64.0, a large therapeutic index comparable to that of ribavirin with a TI value of 24.0, which is an approved drug for the treatment of RSV infection in humans. They also showed

moderate antiviral activities against PIV 3 (parainfluenza type 3 virus) with IC_{50} values of 13.8 and 20.8 μg/mL and TI values of 6.0 and 4.0, respectively.

4.1.6. 8-*O*-Glycosides

Only two compounds **54**–**55** were reported in nature. They are shown in Figure 6. The sources and the reported biological activities (if any) are summarized in Table 5.



	R
54	**H**
55	**OH**

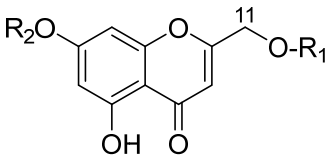
Figure 6. Structures of compounds **54**–**55**.

Table 5. 8-*O*-Chromone glycosides with their sources and biological activities.

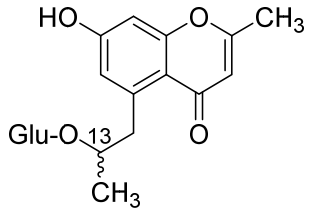
No.	Compound	Source	Biological Activity
54	8-*O*-*β*-D-Glucopyranosyl-2-methylchromone	*Swertia punicea* whole herb [58]	No reported biological activity
55	8-*O*-*β*-D-Glucopyranosyl-6-hydroxy-2-methyl-4H-1-benzopyrane-4-one	*Rhododendron collettianum* aerial parts [59]	Inhibitory activity against tyrosinase enzyme with an IC_{50} value of 256.97 μM [59]

4.1.7. 11- and 13-*O*-Glycosides

Compound **57** was reported in 2012 as Monnieriside A [60] and was then reported as Drynachromoside B [22,31,47]. Compounds **56**–**59** are shown in Figure 7. The sources and the reported biological activities (if any) are summarized in Table 6.



	R_1	R_2
56	Ara	H
57	Glu	H
58	Glu	CH_3



59

Figure 7. Structures of compounds **56**–**59**.

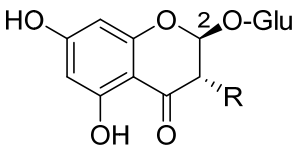
Table 6. 11, 13-*O*-chromone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
56	Officinaliside D (2-hydroxymethyl-5,7-dihydroxy-4H-benzopyran-4-one-1′-*O*-α-L-arabinopyranoside)	*Scindapsus officinalis* stems [31]	Inhibition of NO production in LPS-stimulated RAW 264.7 cells with an IC_{50} value of 19.1 μM [31]
57	Drynachromoside B	*Drynaria fortune* rhizomes [22,47] *Scindapsus officinalis* stems [31]	Mild inhibitory activity against MC3T3-E1 (mouse osteoblast) cells at 3.125 to 100 μg/ml [47] Triglyceride accumulation inhibitory effect at 0.1 to 10 μM [22]
	Monnieriside A	*Cnidium monnieri* fruits [60]	No reported biological activity
58	Saikochromoside A	*Bupleurum chinense* [61] *Cnidium monnieri* fruits [60]	No reported biological activity
59	2-Methyl-5-propyl-7,12-dihydroxychromone-12-*O*-*β*-D-glucopyranoside	*Cassia siamea* stem [62]	No reported biological activity

4.1.8. Chromanone Glycosides

Chromanone glycosides or 2,3-dihydrochromone glycosides are not abundant in nature. Reviewing the literature, we encountered only four examples **60**, **61**, **62** and **63**. Their structures are shown in Figure 8. The sources and biological activities (if any) of these compounds are summarized in Table 7.

2-*O*-glycosides

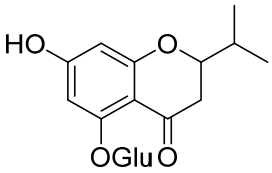


R

60 CH_3

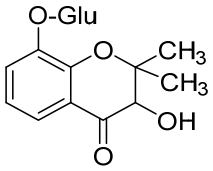
61 CH_2CH_3

5-*O*-glycoside



62

8-*O*-glycoside



63

Figure 8. Structures of compounds **60**–**63**.

Table 7. Chromanone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
60	Takanechromanone A	*Hypericum sikokumontanum* aerial parts [50]	Anti-*Helicobacter pylori* at 100 μg/disc [50]
61	Takanechromanone B		
62	5-*β*-D-glucopyranosyloxy-7-hydroxy-2-isopropyl-chromanone	*Humulus lupulus* L. bracts [63]	No reported biological activity
63	Stemphylin (3-hydroxy-2, 2-dimethyl-5-α-D-glucopyranoside-2, 3-dihydrochromone)	The liquid culture of the fungus *Stemphylium botryosum* [64]	Phytotoxic activity [64]

4.2. Chromone C-Glycosides

In contrast to chromone *O*-glycosides, which are widely distributed and of common occurrence, C-glycoside derivatives are rarely found out.

4.2.1. 3-C-Glycosides

This subclass includes the unusual 5,7-dihydroxychromone-3α-D-C-glucoside, named macrolobin, isolated from the aerial parts of *Macrolobium latifolium* [65]. Its structure is shown in Figure 9. Its source and biological activities are summarized in Table 8.

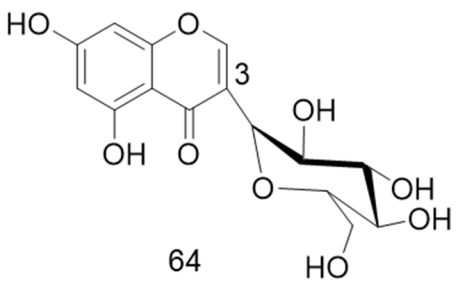


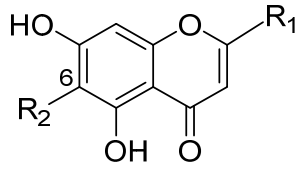
Figure 9. Structure of compound **64**.

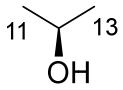
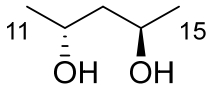
Table 8. 3-C-Chromone glycoside with its source and biological activities.

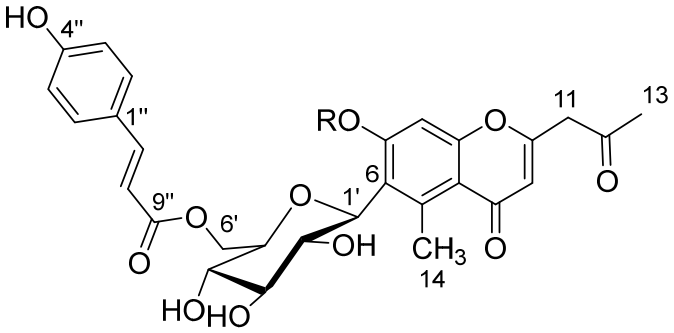
No.	Compound	Source	Biological Activity
64	Macrolobin (5,7-dihydroxychromone-3α-D-C-glucoside)	*Macrolobium latifolium* aerial parts [65]	Inhibition of acetylcholinesterase enzyme with an IC_{50} value of 0.8 μM Antimicrobial activity against *P. aeruginosa* and *Salmonella* at 0.73 and 0.44 μM, respectively [65]

4.2.2. 6-C-Glycosides

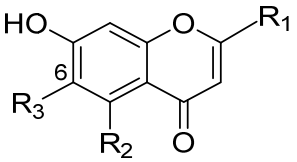
Compounds **65–79** are shown in Figure 10. The sources and the reported biological activities (if any) are summarized in Table 9.



	R_1	R_2
65	H	Glu
66	CH_3	Glu
67	$CH(CH_3)_2$	Glu
68		Glu
69		Glu
70	CH_3	Glu-2'-Gall
71	CH_3	Glu-6'-Gall
72	$CH(CH_3)_2$	Glu-2'-Gall
73	CH_3	Glu-2',3'-di-Gall
74	$CH(CH_3)_2$	Glu-2',3'-di-Gall



	R
75	H
76	CH_3



	R_1	R_2	R_3
77	CH_3	CH_2COCH_3	Glu
78	CH_3	CH_2COCH_3	Glu (2'→1'') Glu
79	CH_2COCH_3	CH_3	Glu (2'→1'') Glu

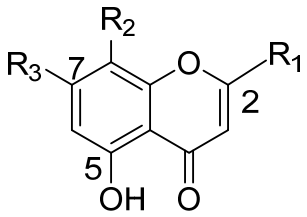
Figure 10. Structures of compounds **65–79**.

Table 9. 6-C-Chromone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
65	5,7-dihydroxy-6-C-glucosyl-chromone	*Aspalathus linearis* fermented rooibos (red-brownish dry leaves) [66]	No reported biological activity
66	Biflorin (6-*β*-C-glucopyranosyl-5,7-dihydroxy-2-methylchromone)	*Pancratium Biflorum* roots [34] *Syzygium aromaticum* L. flower buds [67,68] *Baeckea frutescens* leaves [69,70]	Inhibitory activity to phosphodiesterase and spared cyclic nucleotides at 10^{-9} M [34] Inhibition of LPS-induced production of nitric oxide (NO) and prostaglandin E_2 (PGE2) in RAW 264.7 macrophages with IC_{50} values of 51.7 and 37.1 μM, respectively [67]
67	6-*β*-C-glucopyranosyl-5,7-dihydroxy-2-isopropylchromone	*Baeckea frutescens* leaves [69,70] *Kunzea ambigua* leaves [71]	Inhibitory activity 70.4% against EBV-EA (Epstein–Barr virus early antigen) activation induced by 12-*O*-tetradecanoylphorbol 13-acetate (TPA) at 500 mol ratio/TPA [71]
68	Obtusichromoneside C	*Cassia obtusifolia* seeds [72]	Weak inhibitory activity against human organic anion/cation transporters (OATs/OCTs) and organic anion transporting polypeptides (OATPs) at 50 μM [72]
69	Obtusichromoneside A		
70	Kunzeachromone C	*Kunzea ambigua* leaves [71] *Baeckea frutescens* leaves [70]	Inhibition of copper-induced LDL oxidation with an IC_{50} value of 3.35 ± 0.36 μM [70]
71	6-C-*β*-D-(6′-*O*-galloyl)glucosylnoreugenin	*Syzygium aromaticum* flower buds [68,73]	Cytotoxicity against human ovarian cancer cells (A2780) with an IC_{50} value of 66.78 ± 5.49 μM [68] Prolyl endopeptidase inhibitory effects with an IC_{50} value of 1.74 ± 0.03 μM [73]
72	6-*β*-C-(2′-*O*-galloylglucopyranosyl)-5,7-dihydroxy-2-isopropylchromone	*Baeckea frutescens* leaves [69,70] *Kunzea ambigua* leaves [71]	Inhibitory activity 68.4% against EBV-EA activation induced by TPA at 500 mol ratio/TPA [71] Inhibition of copper-induced LDL oxidation with an IC_{50} value of 3.90 ± 0.24 μM [70]
73	Kunzeachromone D	*Kunzea ambigua* leaves [71]	No reported biological activity
74	Kunzeachromone A		
75	Aloeveraside B	*Aloe vera* resin [74–76]	Inhibition of urease enzyme (55% and 62%, respectively) at 1 mg/mL concentration, significant growth inhibition (70.5 and 76.4%) of the breast cancer cell line MDA-MB-231 at 100 μM, and antioxidant (80% and 60%) at 1 mg/mL [74] Anti-lipid peroxidation activity with IC_{50} values of 432.1 ± 0.6 and 469.5 ± 0.4 μmol/L, respectively [75]
76	Aloeveraside A		
77	Acetonyl-6-glycosyl -7-hydroxy -2-methylchromone	*Cassia multijuga* leaves [55,56]	No reported biological activity
78	5-acetonyl-7-hydroxy-6-C-glucopyranosyl-2-methyl chromone 2″-*O*-glucopyranoside	*Cassia spectablis* seeds [77]	No reported biological activity
79	2-acetonyl-5-methyl-7-hydroxy-6-C-glucopyranosyl chromone 2″-*O*-glucopyranoside	*Chrozophora prostrata* roots [78]	No reported biological activity

4.2.3. 8-C-Glycosides

Many of the naturally occurring chromone-8-C-glycosieds can be found in genus *Aloe*. Approximately 26 chromone-8-C-glycosides were reported in the perennial plant *Aloe vera*, which is a well-known pharmaceutical herb used in traditional Chinese medicine [76]. Some significant bioactive chromone-8-C-glycosides were isolated and identified in *Aloe vera*, including Aloesin (**98**), aloeresin E (**109**), isoaloeresin D (**110**), aloeresin A (**114**) and other derivatives. For instance, aloeresin A (**114**) exhibited a promising therapeutic activity toward α-glucosidase enzyme [79], while the compound isobiflorin (**80**), isolated from the flower buds of *Syzygium aromaticum*, had the capacity to inhibit LPS-induced production of nitric oxide (NO) and prostaglandin E_2 (PGE2) in RAW 264.7 macrophages [67]. A chromone-8-C-glycoside, 5,7-dihydroxy-2-isopropylchromone-8-*β*-D-glucoside, reported in *Hypericum japonicum*, showed an activity against Epstein–Barr virus [71]. Additionally, BACE1 (*β*-secretase), which is a possible potential target in the treatment of Alzheimer's disease, was inhibited by some compounds as aloesin (**98**) [80], 7-*O*-methyl-aloeresin A (**115**) [81] and 2′-feruloyl-7-*O*-methylaloesin (**119**) [80]. Furthermore, tyrosinase, which is the key enzyme for controlling the production of melanin, was inhibited by aloeresin E (**109)** and isoaloeresin D (**110**) [82]. The compounds **80**–**122** are shown in Figures 11–13. The sources and the reported biological activities (if any) are summarized in Table 10.



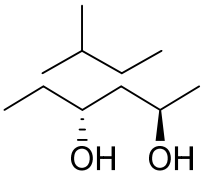
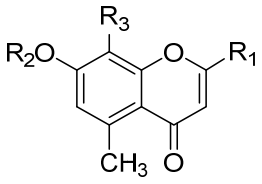
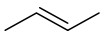
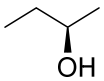
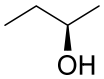
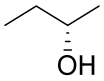
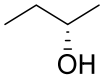
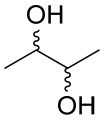
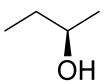
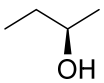
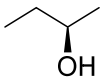
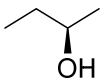
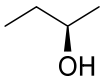
	R_1	R_2	R_3
80	CH_3	Glu	OH
81	CH_3	Glu	OCH_3
82	$CH(CH_3)_2$	Glu	OH
83		Glu	OH
84		Glu	OH
85	CH_3	Glu-2'-Gall	OH
86	CH_3	Glu-6'-Gall	OH
87	$CH(CH_3)_2$	Glu-2'-Gall	OH
88	CH_3	Glu-2',3'-di-Gall	OH
89	$CH(CH_3)_2$	Glu-2',3'-di-Gall	OH

Figure 11. Structures of compounds **80**–**89**.



	R_1	R_2	R_3
90	CH_3	CH_3	Glu
91		CH_3	Glu
92		H	Glu
93		CH_3	Glu
94		H	Glu
95		CH_3	Glu
96		CH_3	Glu
97	CH_2COCH_3	H	Glucofuranose
98	CH_2COCH_3	H	Glu
99	CH_2COCH_3	CH_3	Glu
100	CH_2COCH_3	H	Glu-2',3',4',6'-tetra-acetate
101	CH_2COCH_3	H	Glu-2'-tigloyl
102	COOH	H	Glu
103		CH_3	Glu-2'-cin
104		CH_3	Glu-2'-*p*-Cou
105		CH_3	Glu-2'-Caf
106		CH_3	Glu-2'-(*Z*)-Cou
107		CH_3	Glu-2'-Cou-6'-acetyl

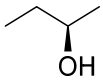
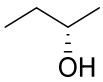
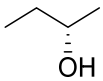
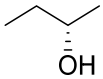
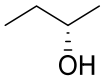
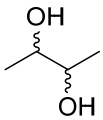
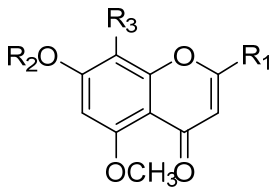
	R_1	R_2	R_3
108		CH_3	Glu-2'-*p*-methoxy-Cin
109		CH_3	Glu-2'-Cin
110		CH_3	Glu -2'-*p*-Cou
111		H	Glu-2'-*p*-methoxy-Cinn
112		CH_3	Glu-2'-Caf
113		CH_3	Glu-2'-Cin
114	CH_2COCH_3	H	Glu-2'-*p*-Cou
115	CH_2COCH_3	CH_3	Glu-2'-*p*-Cou

Figure 12. Structures of compounds **90**–**115**.



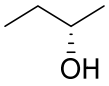
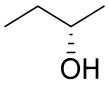
	R_1	R_2	R_3
116	CH_2COCH_3	H	Glu-6'-*p*-Cou
117	CH_2COCH_3	CH_3	Glu-6'-*p*-Cou
118	CH_2COCH_3	H	Glu-2'-Fer
119	CH_2COCH_3	CH_3	Glu-2'-Fer
120	$C(OH)_2COCH_3$	CH_3	Glu-2'-Cin
121		CH_3	Glu-2'-*p*-Cou-4'-Glu
122		CH_3	Glu-2'-(*Z*)-Cou-4'-Glu

Figure 13. Structures of compounds **116**–**122**.

Table 10. 8-C-Chromone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
80	Isobiflorin	*Abrus mollis* Hance. aerial parts [83] *Syzygium aromaticum* L. flower buds [67] *Kunzea ambigua* (SM.) Druce. leaves [71] *Eucalyptus globulus* leaves [84,85] *Eugenia caryophyllata* flower buds [86]	Inhibition of LPS-induced production of nitric oxide (NO) with an IC_{50} > 60 μM and prostaglandin E2 (PGE2)) with an IC_{50} value of 46.0 μM [67]
81	7-methoxy-isobiflorin	Zhuyeqing Liquor; a famous traditional Chinese functional health liquor [87]	No reported biological activity
82	5,7-Dihydroxy-2-isopropylchromone-8-*β*-D-glucoside	*Hypericum japonicum* aerial parts [71,88,89] *Eucalyptus maidenii* bark [84]	Inhibit Epstein–Barr virus early antigen induced by 12-*O*-tetradecanoylphorbol 13-acetate (TPA) in Raji cells (70.4%) at 500 mol ratio/TPA [71]
83	5,7-Dihydroxy-2-(1-methylpropyl) chromone-8-*β*-D-glucoside	*Hypericum japonicum* aerial parts [71,88] *Eucalyptus grandis*, *Eucalyptus urograndi*, and *Eucalyptus maidenii* bark [90]	No reported biological activity
84	Obtusichromoneside B	*Cassia obtusifolia* seeds [72]	Inhibitory activity against human organic anion/cation transporters (OATs/OCTs) and organic anion transporting polypeptides (OATPs) at 50 μM [72]
85	Kunzeachromone E [8-*β*-C-(2′-galloylglucopyranosyl)-5,7-dihydroxy-2-methylchromone]	*Kunzea ambigua* leaves [71] *Baeckea frutescens* leaves [70]	Inhibition activity toward copper-induced LDL oxidation with IC_{50} value of 3.98 ± 0.24 μM [70]

Table 10. *Cont.*

No.	Compound	Source	Biological Activity
86	8-C-β-D-(6′-*O*-galloyl)glucosylnoreugenin [2-Methyl-5,7-dihydroxy-chromone-8-β-D-(6′-*O*-galloyl)-glucopyranoside]	*Syzygium aromaticum* L. leaves [91] *Syzygium aromaticum* L. flower buds [68,73]	Cytotoxicity against human ovarian cancer cells (A2780) with an IC_{50} value of 87.50 ± 1.56 μM [68] Significant inhibition capacity against Prolyl Endopeptidase with IC_{50} value of 1.48 ± 0.02 μM [73]
87	8-β-C-(2′-galloylglucopyranosyl)-5,7-dihydroxy-2-isopropylchromone	*Baeckea frutescens* leaves [70]	Active against copper-induced LDL oxidation with an IC_{50} value of 3.91 ± 0.18 μM [70]
88	Kunzeachromone F [2-Methyl-5,7-dihydroxy-chromone-8-β-D-(2′,3′-di-*O*-galloyl)-glucopyranoside]	*Kunzea ambigua* leaves [71]	No reported biological activity
89	Kunzeachromone B [2-Isopropyl-5,7-dihydroxy-chromone-8-β-D-(2′,3′-di-*O*-galloyl)-glucopyranoside]	*Kunzea ambigua* leaves [71]	No reported biological activity
90	2,5-dimethyl-8-C-β-D-glucopyranosyl-7-hydroxy-chromone	*Aloe vera* [92]	No reported biological activity
91	2-(*E*)-propenyl-7-methoxy-8-C-β-D-glucopyranosyl-5-methylchromone	*Aloe vera* [76,80]	BACE1 (β-secretase) inhibitory activity with an IC_{50} value of 20.5 μM [80]
92	8-C-β-D-glucosyl-(*R*)-aloesol	*Aloe vera* [76,80]	BACE1 (β-secretase) inhibitory activity (39.2%) at 100 μM [80]
93	8-C-β-D-glucosyl-7-*O*-methyl-(*R*)-aloesol	*Aloe vera* [76,80] and anerobic incubation of aloesin with bacterial mixture [93]	BACE1 (β-secretase) inhibitory activity (26.8%) at 100 μM [80]
94	8-C-β-D-glucosyl-(*S*)-aloesol	*Aloe vera* [76] and anerobic incubation of aloesin with bacterial mixture [93]	No reported biological activity
95	8-C-β-D-glucosyl-7-*O*-methyl-(*S*)-aloesol	*Aloe vera* [76] and anerobic incubation of aloesin with bacterial mixture [93]	No reported biological activity
96	8-C-β-D-glucosyl-7-*O*-methylaloediol	*Aloe vera* [76,80]	No reported biological activity
97	Neoaloesin A	*Aloe vera* [76] *Aloe barbadensis* leaves [94]	No reported biological activity
98	Aloesin	*Aloe vera* [76,80] *Aloe barbadensis* leaves [95]	Antioxidant activity (50 ± 1 μM trolox equivalent) at 100 mg of soluble solid/L solution [95] BACE1 inhibitory activity (37.5%) at 100 μM [80] Suppresses hyperpigmentation (40%) at 100 mg/g polyethylene glycol [2]
99	7-*O*-methylaloesin	*Aloe rupestris* leaves exudate [96]	No reported biological activity
100	Aloesin-2″,3″,4″,6″-tetra-*O*-acetate	Anerobic incubation of aloesin with bacterial mixture [93]	No reported biological activity

Table 10. *Cont.*

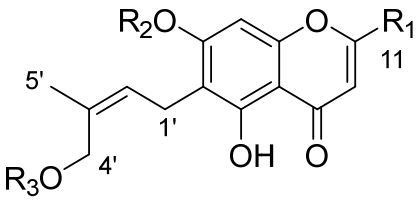
No.	Compound	Source	Biological Activity
101	2″-*O*-tigloylaloesin	*Aloe cremnophila* leaves exudate [97]	No reported biological activity
102	8-*C*-*β*-D-glucopyranosyl-7-hydroxy-5-methylchromone-2-carboxylic acid	Herbal tea "*muti*" [98]	No reported biological activity
103	8-[C-*β*-D-[2-*O*-(*E*)-cinnamoyl]glucopyranosyl]-2-[(*R*)-2-hydroxypropyl]-7-methoxy-5-methylchromone	*Aloe vera* [76] *Aloe barbadensis* leaves [99]	Topical anti-inflammatory activity at 200 µg/ear [99]
104	Aloeresin D	*Aloe vera* [76]	No reported biological activity
105	Rabaichromone	*Aloe vera* [76]	No reported biological activity
106	Allo-aloeresin D	*Aloe vera* [76]	No reported biological activity
107	Aloeresin K	*Aloe vera* [76] *Aloe barbadensis* leaf skin [100]	No reported biological activity
108	Aloeresin J	*Aloe vera* [76] *Aloe barbadensis* leaf skin [100]	No reported biological activity
109	Aloeresin E	*Aloe vera* leaves [76,82]	Inhibition of tyrosinase enzyme (40% and 80% at 50 and 100 ppm, respectively) [82]
110	Isoaloeresin D	*Aloe vera* leaves [76,82]	Inhibition of tyrosinase enzyme (20% and 40% at 50 and 100 ppm, respectively) [82] Antiviral activity against Pepper mild mottle virus; PMMoV (37.5 ± 6.5% at 1.5 mg/mL) [81]
111	2′-*O*-[*p*-methoxy-(*E*)-cinnamoyl]-(*S*)-aloesinol	*Aloe nobilis* leaves [12]	BACE1 inhibitory activity (34.1%) at 100 µM [80]
112	Iso-rabaichromone	*Aloe vera* [76,82]	No reported biological activity
113	8-C-glucosyl-(2′-*O*-cinnamoyl)-7-*O*-methylaloediol B	*Aloe vera* leaves [76]	No reported biological activity
114	Aloeresin A	*Aloe vera* [76]	Antioxidant activity [101] *α*-glucosidase inhibitory activities, with IC_{50} values of 11.94 and 2.16 mM against rat intestinal sucrase and maltase [79]
115	7-*O*-methyl-aloeresin A	*Aloe vera* [76]	Tyrosinase inhibitory activity with an IC_{50} value of 9.8 µM [81]
116	6′-*O*-coumaroyl-aloesin	*Aloe vera* [76]	Anti-lipid peroxidation activity with an IC_{50} value of 476.4 ± 0.9 µM [75]
117	7-Methoxy-6′-*O*-coumaroyl-aloesin	*Aloe vera* [76]	Weak anticancer activity against breast cancer cell line, MDA-MB-231 (induce 30% decline in cell survival at 25 µM) [102]
118	2′-Feruloylaloesin	*Aloe nobilis* leaves [80]	Inhibition activity against *β*-secretase (36.4%) at 100 µM [80] Inhibition effect against mushroom tyrosinase (27 ± 0.57%) at 0.4 µM [103]
119	2′-Feruloyl-7-*O*-methylaloesin	*Aloe nobilis* leaves [80]	Inhibition activity against BACE1 (*β*-secretase) (48.7%) at 100 µM [80]

Table 10. *Cont.*

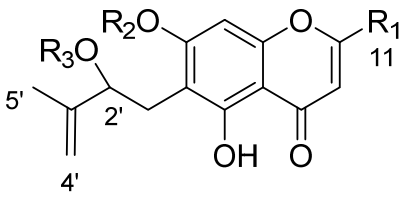
No.	Compound	Source	Biological Activity
120	9-Dihydroxyl-2′-*O*-(*Z*)-cinnamoyl-7-methoxy-aloesin	*Aloe vera* [76]	Inhibition of tyrosinase enzyme (9.5 ± 9.0%) at 100 μM Antiviral against Pepper mild mottle virus; PMMoV (31.5 ± 4.2% inhibition at 1.5 mg/mL) [81]
121	4′-*O*-*β*-D-glucosyl-isoaloeresin DI	*Aloe vera* [76]	No reported biological activity
122	4′-*O*-*β*-D-glucosyl-isoaloeresin DII	*Aloe vera* [76]	No reported biological activity

4.3. Phenyl and Isoprenyl Chromone Glycosides

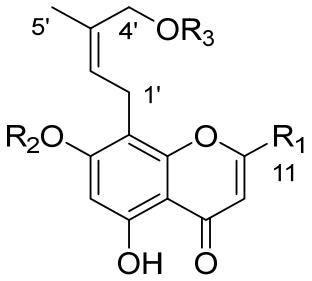
This category is characterized by a hydroxyl prenyl moiety at C-6 or C-8, or a hydroxyl isoprenyl moiety at C-6 only. The sugar moiety can be either situated at C-7 hydroxyl of the chromone nucleus or C-4′ of the hydroxyl prenyl or C-2′ of the hydroxyl isoprenyl moiety. Most of the compounds in this category were reported from the genus Cnidium, belonging to family Apiaceae. The reported biological activity associated with several compounds in this category is their significant inhibition of fat accumulation in differentiated adipocytes employing 3T3-L1 preadipocyte cells as an assay system [60]. The compounds **123**–**134** are shown in Figure 14. The sources and the reported biological activities (if any) are summarized in Table 11.



	R_1	R_2	R_3
123	CH_3	H	Glu
124	CH_3	CH_3	Glu
125	CH_3	Glu	H
126	CH_2OH	H	Glu
127	CH_2OH	Glu	H



	R_1	R_2	R_3
128	CH_3	H	Glu
129	CH_2OH	H	Glu
130	CH_2OH	Glu	H



	R_1	R_2	R_3
131	CH_3	H	Glu
132	CH_2OH	H	Glu
133	CH_3	Glu	H
134	CH_2OH	Glu	H

Figure 14. Structures of compounds **123**–**134**.

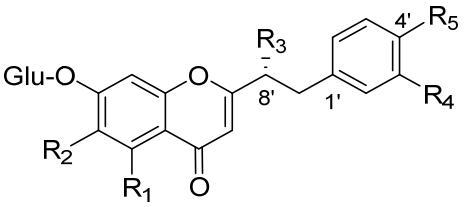
Table 11. Prenyl and isoprenyl chromone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
123	Cnidimoside A	*Cnidium Juponicum* whole plant [104,105] *Cnidium monnieri* fruits [60,106]	Significant inhibition of fat accumulation at 300 μM in differentiated adipocytes [60] Antitumor and antimetastatic actions at 0.1–100 μM (in vitro) and 20, 50 mg/kg, twice daily (in vivo) [105]
124	Cnidimoside B	*Cnidium Juponicum* whole plant [104] *Cnidium monnieri* fruits [60]	Significant ihibition of fat accumulation at 300 μM in differentiated adipocytes [60]
125	2-methyl-5-hydroxy-6-(2-butenyl-3-hydroxymethyl)-7-(*β*-D-glucopyranosyloxy)-4H-1-benzopyran-4-one	*Cnidium monnieri* fruits [60] *Angelica archangelica* [107] *Archangelica litoralis* [107]	No reported biological activity
126	Hydroxycnidimoside A	*Cnidium monnieri* fruits [60,106]	Significant inhibition of fat accumulation at 300 μM in differentiated adipocytes [60]
127	Monnieriside B	*Cnidium monnieri* fruits [60,106]	
128	Monnieriside C	*Cnidium monnieri* fruits [60]	No reported biological activity
129	Monnieriside D		
130	Monnieriside E		
131	7,8-Secoeranthin-*β*-D-glucopyranoside (8-{(2*E*)-4-[*β*-D-glucopyranosyl)oxy]-3-methylbut-2-enyl}-5,7-dihydroxy-2-methyl-4H-L-benzopyran-4-one)	*Eranthis hyemalis* tubers [108]	No reported biological activity
132	2-C-Hydroxy-7,8-seroeranthipn-*β*-D-glucopyranoside (8-{(2*E*)-4-[*β*-D-glucopyranosyl)oxy]-3-methylbut-2-enyl}-5,7-dihydroxy-2-(hydroxymethyl)-4H-1-benzopyran-4-on2)		
133	7-[(*β*-D-glucopyranosyl)oxy]-5-hydroxy-8-[(2*E*)-4-hydroxy-3-methylbut-2-enyl]-2-methyl-4H-1-benzopyran-4-one	*Eranthis cilicica* tubers [109]	No reported biological activity
134	7-[(*β*-D-glucopyranosyl)oxy]-5-hydroxy-2-hydroxymethyl-8-[(2*E*)-4-hydroxy-3-methylbut-2-enyl]-4H-1-benzopyran-4-one		

4.4. Phenyl Ethyl Chromone Glycosides

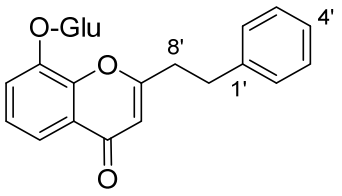
Reviewing the literature, we encountered five phenyl ethyl chromone glycosides. The phenyl ethyl moiety is usually located at C-2 of the chromone nucleus. The sugar moiety is attached to C-7 of the chromone skeleton in compounds **135**–**137**, while in compound **138**, the sugar is attached to C-8. In compound **139**, the sugar is not attached directly to the basic chromone skeleton. Compounds **135**–**139** are shown in Figure 15. Their sources are summarized in Table 12. There are no reported biological activities of these compounds.

7-*O*-glycosides

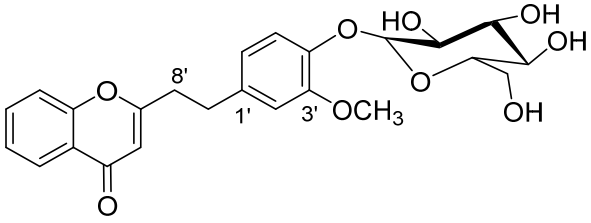


	R_1	R_2	R_3	R_4	R_5
135	H	H	OH	H	OH
136	HO	H	H	H	OH
137	OH	OCH_3	H	OH	OCH_3

8-*O*-glycoside



138



139

Figure 15. Structures of compounds **135**–**139**.

Table 12. Phenyl ethyl chromone glycosides with their sources.

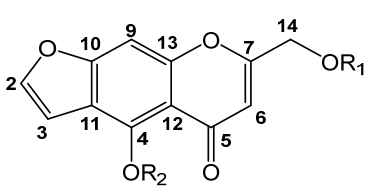
No.	Compound	Source
135	Ononin glucoside	*Ononis vaginalis* whole plant [110]
136	7-Glucosyloxy-5-hydroxy-2-[2-(4-hydroxyphenyl)ethyl]chromone	*Cucumis melo* seeds [111]
137	Aquilarinoside C (6,4′-dimethoxy-3′-hydroxy-2-(2-phenylethyl)chromone 7-*O*-*β*-D-glucopyranoside)	*Aquilaria sinensis* stems [112]
138	2-(2-phenylethyl) chromone-8-*O*-*β*-D-glucopyranoside	*Imperata cylindrical* rhizomes [113]
139	2-[2-(4-glucosyloxy-3-methoxyphenyl)ethyl]chromone	*Aquilaria sinensis* resinous heartwood [114]

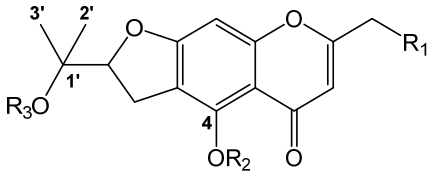
4.5. Chromone Glycosides with Additional Heterocyclic Moieties

This category of chromone glycosides is further classified based on the additional heterocyclic moiety into furano-chromone glycosides, pyrano-chromone glycosides, oxepino-chromone glycosides and pyrido-chromone glycosides.

4.5.1. Furano-Chromone Glycosides

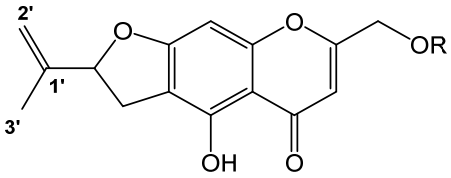
This subclass of compounds is characterized by presence of an additional furan, or a tetrahydrofuran ring fused with the benzo-δ-pyrone. Khellol glucoside (**140**), isolated from *Ammi visnaga*, is one of the important members in this subclass. It possess potent coronary vasodilator and bronchodilator activities [115]. It was reported to have a significant hypocholesterolemic effect. It lowered low-density lipoprotein cholesterol (LDL-C) by 73%, high-density lipoprotein cholesterol (HDL-C) by 23%, and total-C by 44%, after a single oral dose of 20 mg/kg per day after two weeks [116]. Compounds **140**–**148** are shown in Figure 16. The sources and the reported biological activities (if any) are summarized in Table 13.





	R_1	R_2
140	Glu	CH_3
141	Api (1''→6') Glu	H
142	Glu (1''→6') Glu	H

	R_1	R_2	R_3
143	H	H	Glu
144	H	CH_3	Glu
145	H	H	Api (1'''→6'') Glu
146	Glu	CH_3	H
147	Glu-6'-Fer	CH_3	H



	R
148	Glu

Figure 16. Structures of compounds **140**–**148**.

Table 13. Furano-chromone glycosides with their sources and biological activities.

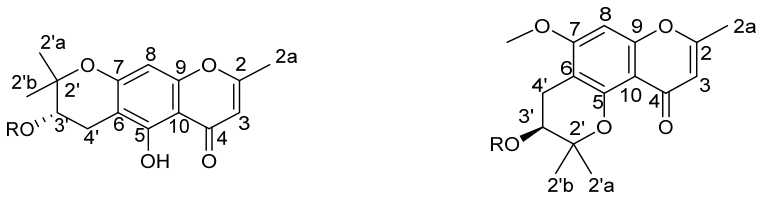
No.	Compound	Source	Biological Activity
140	Khellol glucoside (Khellinin; Khelloside)	*Ammi visnaga* fruits [117] *Eranthhis hyernalis* tubers [108]	Potent coronary vasodilator and bronchodilator [115] Hypocholesterolemic effect at 20 mg/kg per day [116]
141	Norkhelloside	*Cimicifuga heracleifolia* rhizomes [118]	No reported biological activity
142	7-[(*O*-*β*-D-glucopyranosyl-(1→6)-*β*-D-glucopyranosyl)oxy]methyl-4-hydroxy-5*H*-furo[3,2-g][1]benzopyran-5-one	*Eranthis cilicica* tubers [109]	No reported biological activity
143	4′-*O*-*β*-D-glucopyranosylvisamminol (Monnieriside G)	*Cnidium monnieri* fruits [60] *Saposhnikovia divaricata* roots [119]	Antitumor activity against SK-OV-3 with an IC_{50} value of 93.91 μM [120]
144	4′-*O*-*β*-D-glucopyranosyl-5-*O*-methylvisamminol	*Ledebouriella seseloides* roots and rhizomes [121] *Saposhnikovia divaricata* roots [119,122] *Diplolophium buchananii* aerial parts [123] *Sphallerocarpus gracilis* roots [124]	Analgesic, antipyretic, anti-inflammatory, and anti-platelet aggregation activities [125,126] Antitumor activity with against H-460 cell line with an IC_{50} value of 86.91 μM [120]
145	(2′*S*)-4′-*O*-*β*-D-apiofuranosyl-(1→6)-*β*-D-glucopyranosylvisamminol	*Saposhnikovia divaricata* roots [119]	Antitumor activities against PC-3 and SK-OV-3 cell lines with IC_{50} values of 48.5, 81.91 μM, respectively [120]

Table 13. *Cont.*

No.	Compound	Source	Biological Activity
146	*prim*-*O*-glucosylcimifugin	*Ammi visnaga* fruits [127] *Angelica genuflexa* roots [128] *Eranthis hyernalis* tubers [108] *Angelica japonica* roots [129] *Cimicifuga foetida* rhizomes [130] *Diplolophium buchananii* aerial parts [123] *Saposhnikovia divaricata* roots [131]	Analgesic, antipyretic, anti-inflammatory, anti-platelet aggregation and antitumor activities [125,126,131]
147	Cimifugin-4′-*O*-[6″-feruloyl]-*β*-D-glucopyranoside	*Cimicifuga foetida* rhizomes [132]	No reported biological activity
148	Monnieriside F	*Cnidium monnieri* fruits [60]	No reported biological activity

4.5.2. Pyrano-Chromone Glycosides

This subclass of compounds is characterized by the presence of an additional pyran ring fused with the benzo-δ-pyrone. Only three compounds were reported from nature until now. Of them, 3′-*O*-glucopyranosylhamaudol (*Sec*-*O*-glucopyranosylhamaudol) (**149**) and (3′*S*)-3′-*O*-*β*-D-apiofuranosyl-(1→6)-*β*-D-glucopyranosylhamaudol (**150**), isolated from the *Saposhnikovia divaricata*, showed weak anti-cancer activity. Both compounds were screened against three cancer cell lines, namely human prostatic cancer cell (PC-3), human ovarian carcinoma cell (SK-OV-3), and human lung cancer cell (H460) using the conventional MTT assay. Compound **149** showed a weak activity against H460, with an IC_{50} value of 94.25 ± 1.45 μM while compound **150**, showed an activity against SK-OV-3 with an IC_{50} value of 86.21 ± 1.03 μM [119]. Compounds **149**–**151** are shown in Figure 17. The sources and the reported biological activities (if any) are summarized in Table 14.



	R
149	Glu
150	Api(1‴→6″)Glu

	R
151	Glu

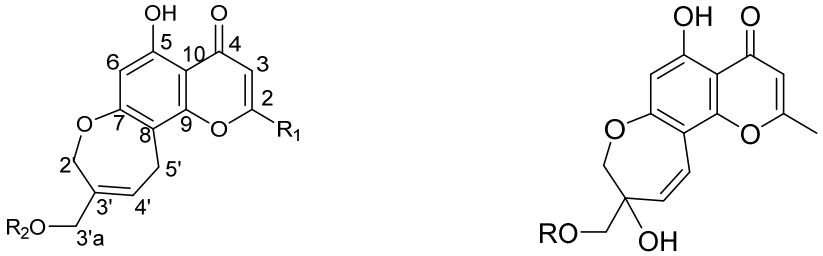
Figure 17. Structures of compounds **149**–**151**.

Table 14. Pyrano-chromone glycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
149	3′-*O*-glucopyranosylhamaudol (*Sec*-*O*-glucopyranosylhamaudol)	*Angelica genuflexa* roots [128] *Angelica japonica* roots [129] *Glehnia littoralis* roots [133] *Peucedanum japonicum* roots [134] *Saposhnikovia divaricata* roots [119,122]	Antitumor activity against H-460 cell line with an IC_{50} value of 94.25 ± 1.45 μM [119]
150	(3′*S*)-3′-*O*-*β*-D-apiofuranosyl-(1→6)-*β*-D-glucopyranosylhamaudol	*Saposhnikovia divaricata* roots [119]	Antitumor activity against SK-OV-3 with an IC_{50} value of 86.21 ± 1.03 μM [119]
151	(2′S)-2′-hydroxy-7-*O*-methylallopeucenin 2′-*O*-*β*-D-glucopyranoside	*Diplolophium buchananii* aerial parts [123]	No reported biological activity

4.5.3. Oxepino-Chromone Glycosides

This subclass of compounds is characterized by the presence of an additional oxepin fused with the benzo-δ-pyrone. Only four compounds were reported from nature until now, and all of them were reported from *Eranthis* species. The compounds **152–155** are shown in Figure 18. The sources are summarized in Table 15. There are no reported biological activities for these compounds.



	R_1	R_2		R
152	CH_3	Glu	**155**	Glu(1'''→6'')Glu
153	CH_3	Glu(1'''→6'')Glu		
154	CH_2OH	Glu		

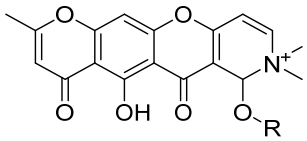
Figure 18. Structures of compounds **152–155**.

Table 15. Oxepino-chromone glycosides with their sources.

No.	Compound	Source
152	Eranthin β-D-glucopyranoside	*Eranthis hyemalis* tubers [108]
153	Eranthin β-D-gentiobioside	*Eranthis cilicica* tubers [109] *Eranthis hyemalis* tubers [108]
154	2-C-Hydroxyeranthin β-D-glucopyranoside	*Eranthis hyemalis* tubers [108]
155	9-[(*O*-β-D-glucopyranosyl-(1→6)-β-D-glucopyranosyl)oxy]methyl-8,11-dihydro-5,9-dihydroxy-2-methyl-4*H*pyrano[2,3-g][1]benzoxepin-4-one	*Eranthis cilicica* tubers [109]

4.5.4. Pyrido-Chromone Glycosides

This subclass includes only the chromone alkaloidal glycoside; Schumanniofoside. This compound was found to reduce the lethal effect of black cobra (*Naja melanoleuca*) venom in mice [135]. The authors proved that this effect is greatest when the venom is mixed and incubated with the extract or schumanniofoside. They concluded that the mode of action is by oxidative inactivation of the venom. *Schumanniophyton magnificum* is used extensively in African ethno-medicine for the treatment of various diseases and, most commonly, the treatment of snake bites [135]. Its structure is shown in Figure 19. Its source and biological activity are summarized in Table 16.



	R
156	Rha(1''→2')Glu

Figure 19. Structure of compound **156**.

Table 16. Pyrido-chromone glycosides with its source and biological activity.

No.	Compound	Source	Biological Activity
156	Schumanniofoside	*Schumanniophyton magnificum* stem bark [135]	Anti-snake venom activity at 0.01–0.16 g/kg [135]

4.6. Hybrids of Chromones with Other Classes of Secondary Metabolites

This is an interesting category, as the chromone skeleton is conjugated to another high molecular weight compound, as shown in the following subclasses.

4.6.1. Hybrids of Furano-Chromones with Cycloartane Triterpenes

This subclass of compounds is a hybrid of cycloartane triterpene and chromone. The reported compounds were isolated from the rhizomes of *Cimicifuga foetida*. The compounds **157–165** are shown in Figure 20. The sources and the reported biological activities (if any) are summarized in Table 17.

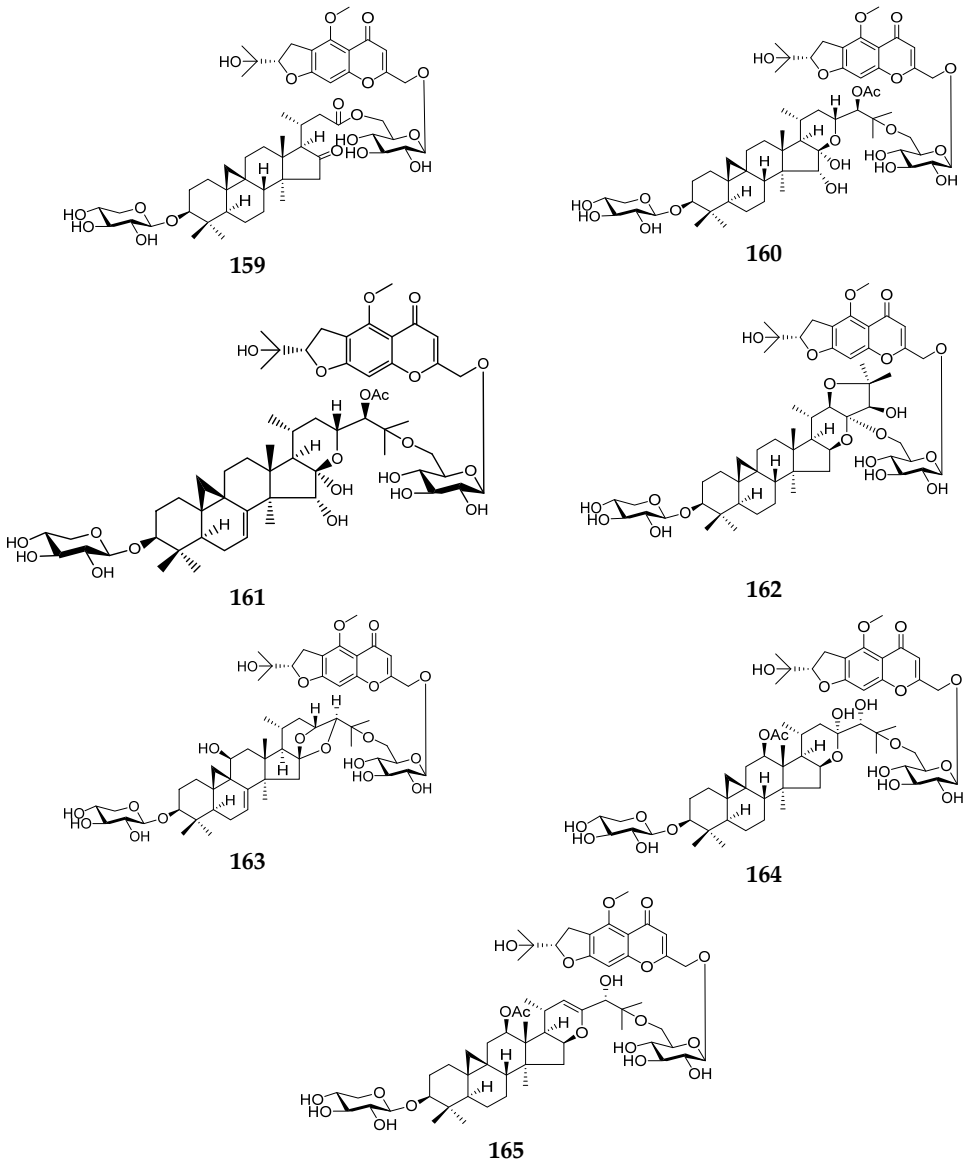


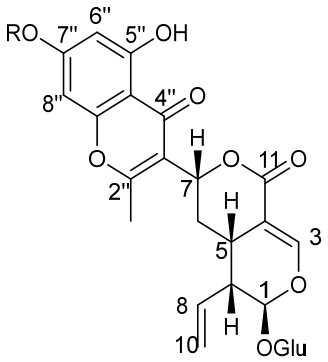
Figure 20. Structures of compounds **157–165**.

Table 17. Hybrids of furanochromones with cycloartane triterpenes with their sources and biological activities.

No.	Compound	Source	Biological Activity
157	Cimitriteromone A	*Cimicifuga foetida* rhizomes [130]	No reported biological activity
158	Cimitriteromone B	*Cimicifuga foetida* rhizomes [130]	Anti-proliferative activity with an IC_{50} value of 15.73 ± 0.59 μM [130]
159	Cimitriteromone C	*Cimicifuga foetida* rhizomes [130]	No reported biological activity
160	Cimitriteromone D	*Cimicifuga foetida* rhizomes [130]	Anti-proliferative activity with an IC_{50} value of 24.21 ± 0.61 μM [130]
161	Cimitriteromone E	*Cimicifuga foetida* rhizomes [130]	No reported biological activity
162	Cimitriteromone F	*Cimicifuga foetida* rhizomes [130]	No reported biological activity
163	Cimitriteromone G	*Cimicifuga foetida* rhizomes [130]	No reported biological activity
164	Cimitriteromone H	*Cimicifuga foetida* rhizomes [136]	No reported biological activity
165	Cimitriteromone I	*Cimicifuga foetida* rhizomes [136]	Anti-proliferative activity with an IC_{50} value of 27.14 ± 1.38 μM [136]

4.6.2. Hybrids of Chromones with Secoiridoids

There are only two compounds (Figure 21) belonging to this class, sessilifoside (**166**) and 7″-*O*-*β*-D-glucopyranosylsessilifoside (**167**). Both compounds were isolated from the roots of *Neonauclea sessilifolia* roots [41]. The authors did not report biological activities for these compounds.

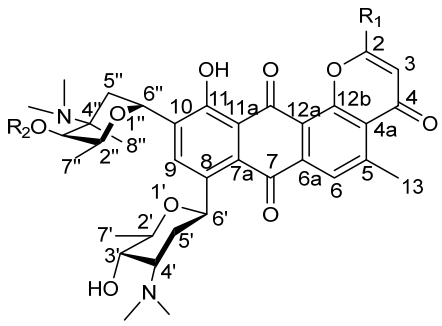


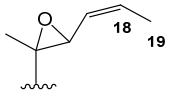
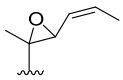
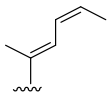
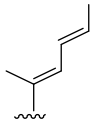
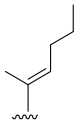
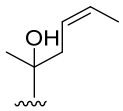
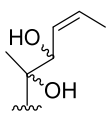
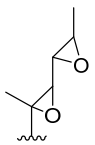
	R
166	H
167	Glu

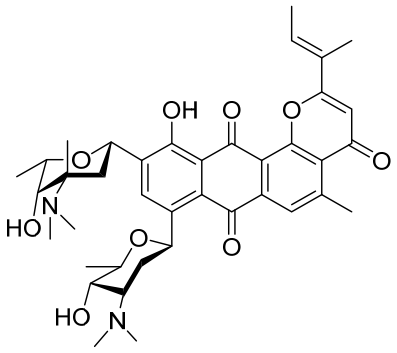
Figure 21. Structures of compounds **166**–**167**.

4.6.3. Chromone Alkaloids Aminoglycosides

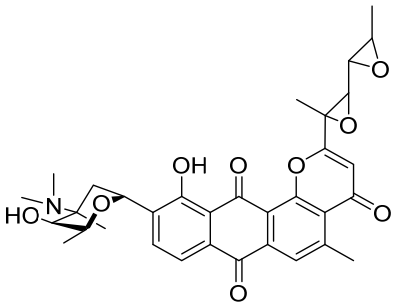
This category includes compounds **168**–**192**. Compounds **168**–**180** were reported from a strain of Streptomyces, isolated from a soil sample. These compounds showed antimicrobial activity against Gram-positive bacteria, as well as a potent antitumor activity. Conversely, compounds **181**–**183** were isolated from *Saccharothrix* species, while compounds **184**–**192** were reported from *Actinomycete* and exhibited antitumor and antimicrobial activities [137]. Compounds **168**–**192** are shown in Figures 22 and 23. The sources and the reported biological activities (if any) are summarized in Table 18.



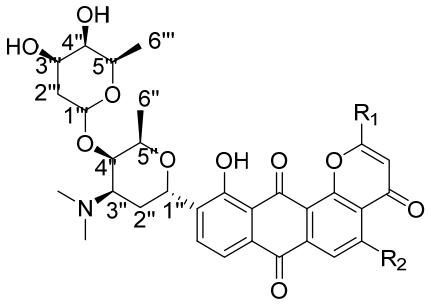
	R_1	R_2
168		H
169		$COCH_3$
170		H
171		$COCH_3$
172		H
173		H
174		H
175		H
176		H
178		H
179		H



177



180



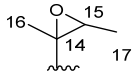
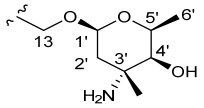
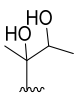
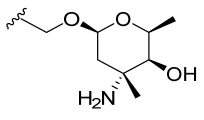
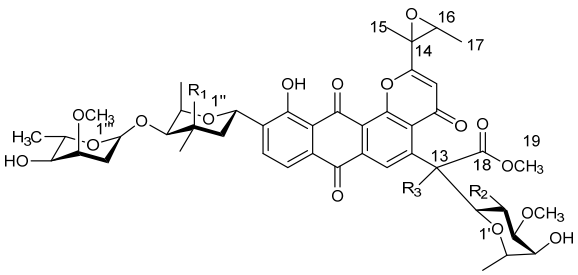
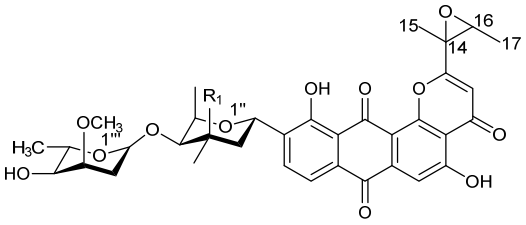
	R_1	R_2
181		
182		
183		

Figure 22. Structures of compounds **168**–**183**.



	R_1	R_2	R_3
184	$NHCH_3$	OH	OH
185	$NH(CH_3)_2$	OH	OH
186	$NHCH_3$	H	OH
187	$NH(CH_3)_2$	H	OH
188	$NHCH_3$	OH	H
189	$NH(CH_3)_2$	OH	H
190	NH_2	OH	OH



	R_1
191	$NHCH_3$
192	$NH(CH_3)_2$

Figure 23. Structures of compounds **184**–**192**.

Table 18. Chromone alkaloids aminoglycosides with their sources and biological activities.

No.	Compound	Source	Biological Activity
168	Kidamycin (rubiflavin B)	*Streptomyces phaeoverticillatus* var. *takatsukiensis* [138]	Antibiotic with MIC (minimum inhibitory concentration) ranges from 0.19–1.56 µg/mL and potent antitumor activity [138]
169	Neopluramycin	*Streptomyces pluricolorescens* [139,140]	Antibiotics and potent antitumor activity [140]
170	14, 16-Epoxykidamycin	*Streptomyces pluricolorescens* [141]	Antibiotic against Gram-positive bacteria with MIC ranges from 0.5 to 10 µg/mL and antitumor activity [141]
171	Pluramycin A	*Streptomyces pluricolorescens* [139,140]	Antibiotic and antitumor activity [140]
172	Rubiflavin A	*Streptomyces* species [142]	Antibiotic and antitumor activity [142]
173	Rubiflavin C-1		
174	Rubiflavin C-2		
175	Rubiflavin D		
176	Rubiflavin E		
177	Rubiflavin F (isokidamycin)		
178	PD 121,222	*Streptomyces* species [143]	Antibiotic and potent antitumor activity [143]
179	Hedamycin	*Streptomyces griseoruber* [144,145]	Antibiotic and potent antitumor activity against HeLa cells [144]
180	Ankinomycin (dean-golosaminylhedamycin)	*Streptomyces* species [146]	Antibiotic against Gram-positive bacteria with MICs ranges from 0.39–1.56 µg/mL and potent antitumor activity [146]
181	Pluraflavin A	*Saccharothrix* species [147]	Antibiotic and potent antitumor activity [147]
182	Pluraflavin B		
183	Pluraflavin E		

Table 18. *Cont.*

No.	Compound	Source	Biological Activity
184	Altromycin A	*Actinomycete*, AB 1246E-26 [148,149]	Antibiotic against Gram-positive bacteria and potent antitumor activity [137]
185	Altromycin B		
186	Altromycin C		
187	Altromycin D		
188	Altromycin E	*Actinomycete*, AB 1246E-26 [137]	
189	Altromycin F		
190	Altromycin G		
191	Altromycin H		
192	Altromycin I		

5. Spectroscopic Features

5.1. UV Features

Most of the published work on chromones show several strong bands in the range of 200–320 nm [150,151]. In contrast to chromone, the pyrone ring of 4-chromanone contains no double bond. The ultraviolet absorption spectra of chromones and chromanones are summarized in Table 19 [150].

Table 19. UV Band maxima of chromones and chromanone in 3-methylpentane at 25 °C.

Chromones		Chromanones
Band system	λ_{max}	λ_{max}
A	360, 352, 345, 337, 324	363, 347
B	301, 290, 283	322(sh), 312
C	225, 246, 239, 227, 223, 216, 202	252, 246 219(sh), 213

The UV spectrum of chromones in alcohol shows two strong bands at λ_{max} 245 and 299 nm [152–154]. Some data reported three bands at λ_{max} 245, 303 and 297 nm [150]. 2-methyl-5,7-dihydroxy chromone shows bands at λ_{max} 250, 255, 295 and 325 nm, meanwhile 2-methyl-5-hydroxy-7-*O*-glycosyl chromone shows bands at λ_{max} 248, 255 and 290 nm [154]. The presence of an electron attracting group at C-2 resulted in a bathochromic shift in all bands [151]. The information gained from applying spectral shift reagents with flavonoids can be also applied to chromones. In the case of $AlCl_3$, a bathochromic shift of 20–70 nm, which is non-reversible with acids, indicates a free hydroxyl group at position 5. Meanwhile, a bathochromic shift with NaOAc can be diagnostic for the presence of a free 7-hydroxyl group [154,155].

5.2. IR Features

Carbonyl region: The IR carbonyl stretching frequency for a chromone is observed at 1640~1660 cm^{-1}, which is slightly higher than that of δ-pyrone (1650 cm^{-1}) but is much lower than that of coumarins (1720–1740 cm^{-1}) [25,153]. Despite that the OH group attached to C-5 of the chromone nucleus chelates strongly with the CO group, this intramolecular H-bonding has only a slight bathochromic effect on the CO stretching frequency [156]. All 5-hydroxychromones possess three significant maxima in the 1580–1700 cm^{-1} region. The two higher frequencies are intense at 1660 and 1630 cm^{-1}, with a constant wavenumber separation of 34 ($\pm$ 5) cm^{-1} in both carbon tetrachloride and chloroform.

Hydroxyl region: The IR hydroxyl stretching vibration for a chromone was observed at 2500–3650 cm^{-1}. A strong chelation in 5-hydroxychromones does not produce a considerable bathochromic shifts in both the OH and CO stretching bands [156].

Chelated 5-hydroxychromones produce no absorption maxima in the 3300–3600 cm^{-1} region, but a weak absorption envelope extends from 2400 to 3300 cm^{-1}. The entire envelope is associated with various stretching modes of the chelated 5-OH group [156]. For 7-hydroxychromones, a steric buttressing effect is observed when the 7-OH group is flanked by a bulky substituent in the ortho-position (6 or 8). The free OH band appears as a doublet centered at 3615 cm^{-1}, the separation of the components being ~26 cm^{-1}. When a prenyl moiety is located in the ortho-position to the 7-OH group, an intramolecular OH interaction occurs, resulting in two OH stretching frequencies. When a 7-OH group is flanked by an OMe group, intense intramolecularly bonded OH stretching frequencies are found at ~3513 and 3517 cm^{-1}, respectively [156]. The 2-hydroxymethyl group exhibits a free stretching frequency at ≈3615 cm^{-1}. At concentrations higher than 0.15 M, a broad-bonded OH frequency at 3400 cm^{-1} occurs due to intermolecular H-bonding, and it consequently disappears on dilution [156].

5.3. ^{1}H-NMR Features

In the following text, we try to give insight about the most characteristic ^{1}H-NMR features of the benzo-δ-pyrone skeleton (Figure 24) and its glycosides. The δ-pyrone ring has two olefinic protons assigned as H-2 and H-3. In 2, 3 unsubstituted chromones, for example compound **12,** the ^{1}H-NMR spectrum shows two ortho-coupled doublets (J = 6.0 Hz), located downfield at δ_H 8.19 (H-2) and upfield at δ_H 6.26 (H-3) [25]. For 2-alkyl and 2-*O*-glycosyl chromones (compounds **21** and **1**, respectively), they are characterized by an upfield singlet proton (H-3) at δ_H 6.11 and 5.98, respectively [7,40]. Meanwhile, 3-alkyl and 3-*O*-glycosyl chromones (compounds **39** and **2**, respectively) are characterized by a downfield singlet proton (H-2) at δ_H 7.93 and 8.07, respectively [10,50].

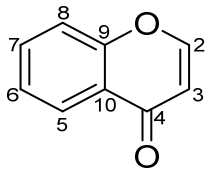


Figure 24. Basic skeleton of Chromone.

Chromanone glycosides or 2,3-dihydrochromone glycosides are characterized by an oxygenated proton (H-2) at δ_H 4.12 and 5.44 as in compounds **62** [63] and **60** [**50**], respectively. The splitting pattern of H-2 can be either d, dd or ddd, depending on the number of neighboring protons. A small coupling constant between H-2 and H-3 (J= 2.8 Hz) can determine that they are located in the equatorial–equatorial position [50]. Further information on the detailed configuration can be clarified from observing NOESY correlations. Unsubstituted chromanones at C-3, as in **62,** show two geminal protons at δ_H 2.50 and 2.70. Their splitting pattern shows geminal ($J_{3a\text{-}3b}$ = 16.2 Hz) and vicinal ($J_{ax\text{-}eq}$ = 2.7 Hz or $J_{ax\text{-}ax}$ = 12.6 Hz) couplings [63]. In 3-alkyl substituted chromanones, as in **60** and **61**, H-3 is also detected at δ_H 2.79 [50].

Naturally occurring chromones often bear a hydroxyl or methoxy group at C-5 and/or C-7 and a methyl group at C-2 and/or C-5 [153]. The C-5 methyl is usually observed in 6-C and 8-C glycosides. In aprotic solvents such as DMSO-d_6, the chelated 5-OH is detected as a singlet at δ_H 12.57; meanwhile, the 7-OH is detected at δ_H 10.00, as in compound **56** [**31**]. The C-2 methyl in Schumaniofioside A **7** can be detected at δ_H 2.33 (3H, s) [17]. Meanwhile, those located at C-5, can be detected more downfield at δ_H 2.64 (3H, s) as in **79** [**78**].

For the phenyl part of the benzo-δ-pyrone skeleton, the protons show chemical shift and coupling constant values similar to those observed for protons in substituted benzenes.

Sugar moiety: Xylosyl, arabinosyl and glucosyl chromones show an anomeric proton signal at δ_H ~4.73 (d, J = 7–7.6 Hz) [10–12]. The former moieties can be differentiated by the number of the oxygenated protons at the δ_H 3-5 region, in addition to the difference in ^{13}C-NMR values. Rhamnosyl chromones show a distinct signal at δ_H ~1.25 (3H, d,

J = 6.0 Hz) corresponding to CH_3-6′ of α-L-rhamnose [8]. The most abundant chromone of C-glycosides is the 8-C-glycoside form, followed by 6-C-glycosides. However, we encountered a unique 3-C-glycoside named macrolobin **64** [65]. The anomeric proton in macrolobin is detected at δ_H 5.32 (d, *J* = 1.5 Hz), the small coupling constant being indicative of the α-anomer [65]. Biflorin **66** and isobiflorin **80**, as representative for 6-C and 8-C-glycosides, respectively, show the anomeric proton signal at δ_H 4.55 (d, *J* = 9.8 Hz), and 4.63 (d, *J* = 9.8 Hz), respectively [69]. The former coupling constant value is higher than that observed in case of O-glycosides (*J* = 7–7.6 Hz) [11,12]. In 5-*O*, 7-*O*, 6-C, furano-, pyrano-, oxepino-chromone glycosides, the sugar moiety can be further substituted with another sugar, as in **8**–**9, 25**–**32**, **78**–**79**, **141**–**142**, **150** and **153,** respectively. In 6-C, 8-C and, to a lesser extent, 7-*O*-glycosides, the sugar moiety can be mono- or disubstituted with a phenolic acid moiety, commonly at C-2′ or C-6′ or C-2′ and C-3′. The most commonly occurring phenolic moiety is gallic acid, but other phenyl propanoids such as cinnamoyl, coumaroyl, feruloyl and coniferoyl moieties also exist. The galloyl moiety is characterized by a singlet aromatic signal integrated for two protons at δ_H 6.75 [27]. The cinnamoyl moiety is confirmed by two trans-coupled olefinic protons at δ_H 7.43 (d, *J* = 15.8 Hz) and 6.25 (d, *J* = 15.8 Hz), in addition to the aromatic signals of the benzene ring [30]. The presence of coumaroyl substitution is characterized by AA′ BB′ system for two pairs of ortho-coupled aromatic protons at δ_H 7.31 (2H, d, *J* = 8.6 Hz) and δ_H 6.74 (2H, d, *J* = 8.6 Hz), a trans-olefinic proton signals at δ_H 7.35 (1H, d, *J* = 16.1 Hz) and δ_H 6.03 (1H, d, *J* = 15.9 Hz) [29].

Prenyl and Isoprenyl chromone glycosides: In the case of 7-*O*-glycoside **127**, hydroxyl prenyl moiety can be easily characterized by the allylic methylene protons at δ_H 3.53 (2H, m, H-1′), an olefinic proton at δ_H 5.39 (t, *J* = 6.4, H-2′), oxygenated methylene protons δ_H 4.20 and 4.46 (1H each, d, *J* = 12.0 Hz, H-4′), and an olefinic methyl at δ_H 1.75 (3H, d, *J* = 1.2, H-5″) [60]. Its isomeric 4′-*O*-glycoside **126** showed similar signals; however, the hydroxyl methylene protons (H-4′) were slightly downfield at δ_H 4.34 and 4.65 due to *O*-glycosidation [106]. Meanwhile, the hydroxyl isoprenyl group in the 7-*O*-glycoside **130** is characterized by the methylene protons at δ_H 2.96 (2H, m, H-1′), an oxygenated methine proton at δ_H 4.35 (H-2′, m), exomethylene protons at δ_H 4.74 and 4.91 (H-4′) and an olefinic methyl at δ_H 1.87 (3H, s, H-5′). Its isomeric 2′-*O*-glycoside **129** showed similar signals, but the oxygenated methine proton (H-2′) is shifted downfield at δ_H 4.74 due to *O*-glycosidation [60].

Phenyl ethyl chromone glycosides: The presence of the phenyl ethyl moiety in compound **136** can be detected by the methylene proton signals at δ_H 2.75 (2H each, dd, *J* = 14.8, 6.4 Hz, H-7′) and 3.19 (2H each, *J* = 14.8, 3.1 Hz, H-8′), in addition to the aromatic protons of the phenyl ring. The 8′-hydroxy phenyl ethyl moiety in **135** shows an oxygenated proton signal δ_H 5.85 (dd, *J* = 3.5, 5.9 Hz, H-8′) [110].

5.4. ^{13}C-NMR Features

For better understanding of the differences in chemical shifts related to the substituents on the chromone moiety, we preferred to add the ^{13}C-NMR data in Tables 20–40. For the numbering of the skeleton, the following figure (Figure 25) gives few examples for the numbering system of the skeleton with multiple substituents. Briefly, the basic chromone nucleus was assigned numbers 1–10. In the case of a substitution at C-2, numbers 11, 12 … etc. were given to the substituents, followed by substitution at C-3 and so on. Sugar moiety, and substituents attached to it, were assigned numbers 1′, 2′, … and then 1″, 2″, … etc. For better understanding, the following figure shows representative examples for the numbering system. Some complicated structures have their own numbering system, shown on them within the review.

Table 20. The ^{13}C-NMR spectral data of compounds **1–14** except those which have no reported ^{13}C-NMR data.

C	1	2	3	4	5	7	11	13	14
2	161.2	147.4	147.7	147.8	147.4	167.2	167.8	158.6	159.5
3	93.1	141.2	141.0	138.1	141.5	111.7	109.1	112.0	112.8
4	166.6	178.4	178.5	177.0	178.4	180.3	183.2	183.6	184.4
5	137.1	163.4	163.3	161.5	163.4	160.2	93.9	163.4	163.9
6	132.0	100.1	100.2	98.8	100.2	104.6	162.0	101.3	101.9
7	127.8	166.4	166.3	164.3	166.5	164.7	110.2	164.9	165.2
8	114.9	95.0	95.0	93.8	95.0	99.1	159.6	96.2	96.9
9	154.3	159.3	159.3	157.2	159.4	161.1	156.6	159.5	160.2
10	114.5	106.2	106.2	104.8	106.1	109.2	106.1	108.4	109.3
11	23.2	-	-	-	-	19.9	20.3	-	-
12	-	-	-	-	-	-	8.2	-	-
1′	100.1	104.6	104.4	100.6	104.2	105.0	101.7	101.6	102.1
2′	73.2	74.6	72.0	69.9	74.8	74.6	75.1	74.7	75.1
3′	77.5	77.1	73.6	70.2	77.4	77.3	78.4	77.9	77.8
4′	69.6	70.8	69.2	71.5	71.3	71.3	80.5	71.2	73.9
5′	76.7	67.1	67.1	69.7	78.5	78.7	78.1	78.4	77.5
6′	60.7	-	-	17.7	62.6	62.5	60.9	62.4	171.5
OCH_3	-	-	-	-	-	-	-	-	53.8
Solvent	DMSO-d_6	CD_3OD	CD_3OD	DMSO-d_6	CD_3OD	CD_3OD	C_5D_5N	CD_3OD	CD_3OD
References	[7]	[10]	[12]	[9]	[11]	[17]	[1]	[27]	[28]

Table 21. The ^{13}C-NMR spectral data of compounds **15–23** except which has no reported ^{13}C-NMR data.

C	15	16	17	18	20	21	22	23
2	158.1	158.4	158.5	168.9	161.6	174.3	175.5	174.6
3	110.8	111.9	112.0	108.8	108.8	107.8	106.2	106.6
4	181.8	183.6	183.6	182.5	182.5	184.3	183.3	183.1
5	161.3	163.1	163.2	161.2	157.9	163.0	162.2	162.7
6	99.8	101.2	101.2	99.8	100.3	101.0	100.6	100.7
7	162.9	164.6	164.8	163.1	168.9	164.8	164.2	164.2
8	94.6	96.2	96.2	94.9	95.0	95.9	95.3	95.3
9	157.7	159.4	159.4	157.9	163.4	159.5	158.4	158.4
10	106.8	108.5	108.5	105.5	105.5	107.0	106.5	107.4

Table 21. *Cont.*

C	15	16	17	18	20	21	22	23
11	-	-	-	20.5	20.5	28.3	33.3	40.4
12	-	-	-	-	-	11.2	19.9	27.6
13	-	-	-	-	-	-	19.9	17.7
14	-	-	-	-	-	-	-	11.7
1′	99.7	101.5	101.5	100.6	99.9	101.6	101.7	101.7
2′	73.1	74.7	74.7	73.3	73.5	74.7	74.8	74.8
3′	76.2	77.9	77.9	76.6	77.6	77.8	78.5	78.5
4′	69.7	71.9	72.0	69.6	70.7	71.2	71.2	71.1
5′	74.1	75.8	76.0	66.2	76.8	78.4	79.3	79.2
6′	63.4	64.2	64.7	-	61.1	62.4	62.4	62.3
1″	119.5	127.4	127.3	-	-	-	-	-
2″	108.8	133.7	131.2	-	-	-	-	-
3″	145.6	115.8	117.0	-	-	-	-	-
4″	138.6	160.0	161.4	-	-	-	-	-
5″	145.6	115.8	117.0	-	-	-	-	-
6″	108.8	133.7	131.2	-	-	-	-	-
7″	165.9	145.1	146.9	-	-	-	-	-
8″	-	116.0	115.1	-	-	-	-	-
9″	-	168.1	168.9	-	-	-	-	-
Solvent	DMSO-d_6	CD_3OD	CD_3OD	DMSO-d_6	DMSO-d_6	CD_3OD	C_5D_5N	C_5D_5N
References	[29]	[30]	[30]	[31]	[157]	[40]	[41]	[41]

Table 22. The ^{13}C-NMR spectral data of compounds **24**–**32** except which has no reported ^{13}C-NMR data.

C	24	25	26	28	29	30	31	32
2	168.7	157.3	167.9	168.2	168.9	169.2	168.9	168.5
3	108.7	108.3	108.8	108.8	108.8	109.3	108.8	108.4
4	182.4	181.9	182.7	182.8	182.5	184.2	182.5	182.1
5	161.5	161.1	162.4	162.4	161.7	163.1	161.7	161.3
6	99.9 *	108.7	100.6	100.7	100.2	100.8	100.0	99.6
7	162.9	162.6	163.9	163.9	161.9	163.4	161.9	161.6
8	94.9	108.2	95.3	95.1	95.2	95.7	95.1	94.7
9	157.7	168.2	158.3	158.3	157.9	159.5	157.9	157.5

Table 22. *Cont.*

C	24	25	26	28	29	30	31	32
10	105.5	105.0	106.3	106.3	105.7	106.8	105.6	105.2
11	20.3	19.9	19.9	20.1	20.5	20.4	20.5	20.1
1′	99.8 *	99.3	101.9	102.0	98.8	99.6	98.5	98.1
2′	73.3	77.0	74.6	74.6	81.2	71.0	69.8	69.5
3′	76.5	75.8	78.5	78.5	70.4	82.5	82.1	70.3
4′	70.2	68.9	71.5	71.6	70.9	72.4	70.7	81.4
5′	74.1	76.0	77.4	77.5	69.4	70.9	68.7	68.5
6′	63.7	60.5	69.0	68.0	18.3	18.1	18.0	17.9
1″	-	108.7	111.2	102.7	105.0	105.9	104.8	104.4
2″	-	76.7	77.9	72.0	74.5	75.4	74.1	74.5
3″	-	79.2	80.3	72.8	77.2	77.8	76.8	77.1
4″	-	73.9	75.1	74.1	70.0	71.1	70.6	70.1
5″	-	64.1	65.8	69.8	76.7	77.7	74.8	76.7
6″	-	-	-	18.6	61.5	62.2	64.1	61.2
CH_3CO	20.9, 170.5	-	-	-	-	-	21.1, 170.6	-
Solvent	DMSO-d_6	$CDCl_3$, DMSO-d_6	C_5D_5N	C_5D_5N	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6
References	[33]	[16]	[44]	[46]	[31]	[22]	[31]	[47]

* Data interchangeable.

Table 23. The ^{13}C-NMR spectral data of compounds **33**–**41**.

C	33	34	35	36	37	38	39	40	41
2	168.3	168.2	168.3	168.3	157.8	154.8	154.7	168.6	168.4
3	108.2	108.7	108.3	108.2	110.6	120.3	125.8	108.7	108.4
4	181.4	182.7	181.9	181.9	181.5	183.8	183.5	182.5	182.3
5	161.1	162.3	161.1	161.2	157.7	163.0	163.1	158.4	185.1
6	99.5	100.6	99.8	99.5	108.9	100.9	100.8	109.1	108.5
7	161.4	163.7	162.6	162.6	160.9	164.6	164.6	161.1	155.56
8	94.5	94.6	94.3	94.5	93.3	95.8	95.8	93.3	97.7 *
9	157.3	158.3	157.4	157.4	155.4	159.4	159.5	155.9	160.3
10	105.0	106.3	105.1	105.1	106.0	107.4	107.6	105.1	105.0
11	19.9	19.9	19.8	19.8	7.4	10.2	19.3	20.5	19.9
12	-	-	-	-	-	-	13.4	7.9	6.9

Table 23. *Cont.*

C	33	34	35	36	37	38	39	40	41
1′	98.0	101.6	99.5	98.1	100.1	101.6	101.6	100.2	93.1 *
2′	69.5	74.4	72.9	73.0	73.1	74.7	74.7	73.8	77.3
3′	69.8	78.1	76.1	76.2	76.4	77.8	77.8	76.5	74.5
4′	80.9	71.3	69.9	69.9	69.6	71.2	71.2	79.4	69.7
5′	68.4	75.8	73.9	73.9	77.1	78.4	78.4	76.1	73.3
6′	17.9	64.5	63.4	63.4	60.6	62.4	62.4	60.7	60.5
1″	102.3	121.0	128.5	127.9	-	-	-	-	-
2″	81.4	110.4	114.8	114.9	-	-	-	-	-
3″	76.6	147.4	146.9	148.9	-	-	-	-	-
4″	69.8	140.8	147.7	149.3	-	-	-	-	-
5″	77.6	147.4	120.7	122.5	-	-	-	-	-
6″	61.0	110.4	115.9	115.8	-	-	-	-	-
7″	-	167.1	144.6	144.7	-	-	-	-	-
8″	-	-	115.7	115.8	-	-	-	-	-
9″	-	-	166.1	166.2	-	-	-	-	-
1‴	103.5	-	99.5	99.5	-	-	-	-	-
2‴	71.2	-	70.3	71.2	-	-	-	-	-
3‴	71.7	-	71.0	71.6	-	-	-	-	-
4‴	66.4	-	67.1	67.1	-	-	-	-	-
5‴	64.2	-	75.0	74.8	-	-	-	-	-
6‴	-	-	61.0	61.0	-	-	-	-	-
OCH_3	-	-	-	55.8	-	-	-	60.1	-
CH_3CO	-	-	-	-	-	-	-	-	20.7, 169.6
Solvent	DMSO-d_6	C_5D_5N	DMSO-d_6	DMSO-d_6	DMSO-d_6	CD_3OD	CD_3OD	DMSO-d_6	DMSO-d_6
References	[47]	[48]	[33]	[33]	[49]	[50]	[50]	[23]	[51]

* Data interchangeable.

Table 24. The ^{13}C-NMR spectral data of compounds **43**–**52** except those which have no reported ^{13}C-NMR data.

C	43	45	46	47	48	49	50	52
2	168.7	168.4	168.4	169.5	170.0	160.0	164.9	164.9
3	108.4	108.0	108.0	108.4	109.1	112.5	101.9	118.6
4	182.9	182.7	182.7	182.4	185.0	185.0	178.8	177.6
5	159.5	152.6	155.9	152.5	157.8	158.8	141.8	137.9
6	98.3	109.7	114.3	135.2	116.3	117.3	116.6	110.5
7	160.9	158.5	158.8	157.8	160.2	161.2	160.4	159.8
8	104.6	114.3	109.8	94.7	111.6	112.9	111.5	99.6
9	155.0	155.9	152.6	155.6	154.6	155.5	159.3	158.5
10	105.2	106.5	106.5	106.2	108.2	110.6	117.1	115.7
11	20.5	20.0	20.1	20.2	20.5	10.3	22.8	19.4
12	8.1	8.8	9.0	-	8.9	10.5	19.9	48.7
13	-	8.9	9.1	-	9.5	-	-	205.3
14	-	-	-	-	-	-	-	52.0
15	-	-	-	-	-	-	-	62.7
16	-	-	-	-	-	-	-	23.6
1′	100.3	104.3	104.4	100.8	105.7	106.5	100.3	102.1
2′	73.9	76.0	74.1	74.1	75.3	76.5	77.6	73.0
3′	76.5	73.9	76.3	78.0	75.6	78.5	73.6	76.3
4′	79.4	70.0	69.9	69.9	71.7	72.5	70.1	69.4
5′	76.1	73.4	77.0	77.0	77.7	76.4	76.9	77.0
6′	60.7	63.0	61.0	61.2	64.3	65.3	61.0	60.5
1″	-	-	-	-	-	173.1	-	-
2″	-	-	-	-	-	47.3	-	-
3″	-	-	-	-	-	71.4	-	-
4″	-	-	-	-	-	46.9	-	-
5″	-	-	-	-	-	176.6	-	-
6″	-	-	-	-	-	28.4	-	-
OCH_3	60.1	-	-	56.7	-	-	-	-
CH_3CO	-	20.4, 170.1	-	-	20.4, 172.5	-	-	-
Solvent	DMSO-d_6	DMSO-d_6	*	DMSO-d_6	*	CD_3OD	$CDCl_3$	DMSO-d_6
References	[23]	[51]	[24]	[36]	[24]	[52]	[53]	[57]

* The authors did not report the NMR solvent.

Table 25. The ^{13}C-NMR spectral data of compounds **53**–**64** except those which have no reported ^{13}C-NMR data.

C	53	54	55	56	57	60	61	62	64
2	161.0	166.3	169.9	166.6	166.5	105.9	104.7	83.5	148.0
3	117.2	110.7	109.3	107.6	106.9	46.2	52.9	42.2	140.5
4	178.1	177.4	184.0	182.2	182.5	199.2	198.9	193.7	178.9
5	141.3	117.8	96.0	162.0	162.0	165.3	165.2	161.5	163.6
6	113.0	125.0	162.9	99.5	98.8	97.5	97.5	100.0	100.2
7	159.9	119.2	101.0	165.1	164.8	168.4	168.4	166.6	166.2
8	99.7	147.4	164.7	94.5	93.6	97.0	97.0	99.1	95.3
9	158.8	147.3	159.3	158.1	158.2	160.4	160.2	166.2	159.3
10	116.1	125.4	119.0	104.3	104.2	102.0	102.4	106.7	106.6
11	47.3	20.1	20.3	66.1	66.0	13.8	23.7	33.2	-
12	202.5	-	-	-	-	-	11.8	18.2 *	-
13	29.8	-	-	-	-	-	-	-	-
14	22.3	-	-	-	-	-	-	-	-
1′	101.3	102.4	101.6	102.8	102.7	104.1	104.1	104.0	102.1
2′	73.1	74.8	74.7	73.9	73.6	75.0	75.0	74.6	72.0
3′	76.3	78.6	78.3	76.4	76.6	77.9	77.9	77.4	74.0
4′	69.5	71.2	71.4	67.7	70.1	71.0	71.0	71.2	71.5
5′	77.0	79.2	77.8	63.6	76.8	78.0	78.0	78.5	72.4
6′	60.9	62.4	62.4	-	61.3	62.5	62.5	62.5	62.5
Solvent	DMSO-d_6	C_5D_5N	CD_3OD	DMSO-d_6	CD_3OD	CD_3OD	CD_3OD	CD_3OD	CD_3OD
References	[57]	[58]	[59]	[31]	[60]	[54]	[50]	[63]	[65]

* Data interchangeable.

Table 26. The ^{13}C-NMR spectral data of compounds **66**–**72**.

C	66	67	68	69	70	71	72
2	167.3	174.7	168.3	168.4	167.8	169.4	174.4
3	107.8	105.1	108.6	108.8	107.0	109.2	105.3
4	181.8	182.2	181.8	181.8	182.0	184.3	182.2
5	160.6	160.6	160.6	160.6	160.4	162.3	160.4
6	108.7	108.7	108.6	108.8	108.1	108.9	107.0
7	163.2	163.3	163.1	163.1	162.4	165.0	163.4
8	93.3	93.4	93.3	93.3	93.9	95.2	93.7
9	156.6	156.7	156.6	156.6	157.0	159.4	156.9
10	103.0	103.3	103.2	103.2	102.9	105.1	103.1

Table 26. *Cont.*

C	66	67	68	69	70	71	72
11	19.8	32.3	43.1	66.2	20.0	20.4	32.4
12	-	19.8	64.1	46.0	-	-	19.8
13	-	19.8	23.3	63.8	-	-	19.8
14	-	-	-	43.8	-	-	-
15	-	-	-	23.5	-	-	-
1′	73.0	73.0	72.9	72.9	70.8	75.6	70.7
2′	70.1	70.2	70.0	70.0	72.0	72.6	72.0
3′	78.9	78.9	78.8	78.8	76.7	80.1	76.6
4′	70.6	70.6	70.5	70.5	70.8	71.9	70.7
5′	81.4	81.6	81.4	81.4	82.0	80.2	81.8
6′	61.4	61.5	61.4	61.4	61.6	65.2	61.5
1″	-	-	-	-	119.9	121.6	119.9
2″	-	-	-	-	108.9	110.4	108.7
3″	-	-	-	-	145.4	146.6	145.4
4″	-	-	-	-	138.2	140.0	138.1
5″	-	-	-	-	145.4	146.6	145.4
6″	-	-	-	-	108.9	110.4	108.9
7″	-	-	-	-	164.8	168.6	164.7
Solvent	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6	CD_3OD	DMSO-d_6
References	[69]	[69]	[72]	[72]	[71]	[73]	[69]

Table 27. The ^{13}C-NMR spectral data of compounds **73**–**79** except those which have no reported ^{13}C-NMR data.

C	73	74	75	76	79
2	167.7	174.9	162.3	163.1	160.6
3	106.3	105.3	113.2	111.0	112.4
4	182.0	182.2	181.9	181.8	178.5
5	161.1	160.9	143.1	146.1	*
6	108.1	106.4	127.0	128.3	126.5
7	163.1	163.2	160.1	161.1	160.8
8	93.4	93.4	119.4	121.1	100.6
9	157.1	157.0	161.3	157.9	159.0
10	103.0	103.1	115.8	114.3	114.6
11	19.9	32.4	48.7	48.5	47.8

Table 27. *Cont.*

C	73	74	75	76	79
12	-	19.78	204.4	204.6	202.4
13	-	19.75	29.8	30.7	29.8
14	-	-	23.3	23.3	22.5
CH_3O	-	-	-	55.8	-
1′	70.7	70.7	75.5	75.6	71.4
2′	69.7	69.7	71.9	72.3	81.7
3′	77.6	77.6	80.0	79.9	78.2
4′	68.7	68.7	72.9	72.1	70.1
5′	81.8	81.7	79.8	78.5	81.1
6′	61.2	61.2	65.2	65.4	60.9
1″	119.7	119.7	133.6	128.3	105.1
2″	108.9	108.9	131.2	131.0	74.3
3″	145.5	145.4	116.8	115.3	76.1
4″	138.5	138.4	161.3	160.4	69.3
5″	145.5	145.4	116.8	115.3	76.1
6″	108.9	108.9	131.2	131.0	60.3
7″	165.3	165.4	146.2	146.2	-
8″	-	-	114.9	116.0	-
9″	-	-	169.2	169.1	-
1‴	119.1	119.0	-	-	-
2‴	108.7	108.7	-	-	-
3‴	145.3	145.3	-	-	-
4‴	138.4	138.3	-	-	-
5‴	145.3	145.3	-	-	-
6‴	108.7	108.7	-	-	-
7‴	164.6	164.4	-	-	-
Solvent	DMSO-d_6	DMSO-d_6	CD_3OD	CD_3OD	DMSO-d_6
References	[71]	[71]	[74]	[74]	[78]

* The authors missed assigning this position.

Table 28. The ^{13}C-NMR spectral data of compounds **80**–**89**.

C	80	81	82	83	84	85	86	87	88	89
2	167.0	169.3	174.4	173.0	168.2	167.6	167.2	174.8	167.7	174.5
3	107.4	108.7	105.0	106.2	108.3	107.8	107.5	105.4	108.0	105.6
4	181.9	184.3	182.2	181.9	181.9	182.2	181.9	182.4	182.2	182.4
5	160.4	149.4	160.4	160.4	160.3	160.8	160.5	160.7	161.0	161.0
6	98.4	94.5	98.5	98.7	98.3	97.6	98.3	97.8	98.0	97.9
7	162.5	162.8	162.8	164.2	162.7	162.2	162.6	162.3	162.4	162.6
8	104.3	105.2	104.1	104.7	108.4	103.9	104.0	102.8	103.9	102.1
9	156.1	164.6	156.5	156.6	158.9	157.1	156.3	157.2	157.1	157.2
10	103.5	106.3	102.0	103.3	103.8	102.8	103.5	104.0	102.0	104.0
11	19.6	20.3	32.7	39.1	42.1	11.0	19.7	33.1	20.1	33.1
12	-	-	20.0	27.0	66.5	-	-	19.8	-	20.3
13	-	-	19.5	11.4	45.8	-	-	20.3	-	20.1
14	-	-	-	17.4	64.1	-	-	-	-	-
15	-	-	-	-	23.6	-	-	-	-	-
1′	73.1	74.9	73.1	73.3	73.2	70.6	73.3	70.7	70.7	70.8
2′	71.0	72.8	71.2	71.2	70.3	72.5	70.0	72.5	70.1	70.2
3′	78.5	80.0	78.5	78.7	78.6	76.1	78.1	76.0	77.0	77.0
4′	70.3	71.7	70.8	70.9	71.0	70.8	70.7	71.2	68.5	68.9
5′	81.1	82.4	81.5	81.5	81.4	81.7	78.3	82.0	81.5	81.9
6′	61.3	62.9	61.8	61.7	61.5	61.5	63.8	61.8	61.0	61.3
1″	-	-	-	-	-	119.7	119.4	119.6	119.6	119.6
2″, 6″	-	-	-	-	-	108.8	108.5	108.7	108.9	108.9
3″, 5″	-	-	-	-	-	145.5	145.5	145.4	145.6	145.5
4″	-	-	-	-	-	138.8	138.3	138.3	138.7	138.7
7″	-	-	-	-	-	165.0	165.8	165.0	165.5	165.4
1‴	-	-	-	-	-	-	-	-	118.7	118.7
2‴, 6‴	-	-	-	-	-	-	-	-	108.7	108.7
3‴, 5‴	-	-	-	-	-	-	-	-	145.5	145.4
4‴	-	-	-	-	-	-	-	-	138.5	138.6
7‴	-	-	-	-	-	-	-	-	164.8	164.8
OCH_3	-	56.8	-	-	-	-	-	-	-	-
Solvent	DMSO-d_6	CD_3OD	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6
References	[86]	[87]	[158]	[158]	[72]	[71]	[91]	[69]	[71]	[71]

Table 29. The ^{13}C-NMR spectral data of compounds **91**–**100** except which has no reported ^{13}C-NMR data.

C	91	93	94	95	96	97	98	99	100
2	162.7	164.9	167.1	167.0	169.2	160.2	160.2	160.8	159.6
3	109.8	111.2	112.2	111.9	110.8	112.6	112.4	113.0	113.7
4	182.7	178.7	182.3	181.9	182.4	178.3	178.5	178.9	179.1
5	144.0	141.0	143.1	143.7	144.1	139.5	140.1	141.3	144.1
6	112.8	111.5	112.2	112.6	113.1	116.9	116.3	111.9	118.5
7	162.5	160.0	162.3	162.1	162.7	160.2	159.5	160.3	159.0
8	113.3	112.8	116.1	113.1	113.7	107.1	110.0	113.1	106.2
9	158.8	157.2	160.0	158.9	159.1	155.9	157.8	157.3	159.6
10	117.4	115.9	118.5	117.0	117.6	114.3	114.7	115.9	113.9
11	124.7	43.2	44.3	44.2	76.2	47.2	47.7	47.8	48.2
12	139.0	63.8	66.7	66.3	69.5	202.5	202.4	202.5	200.7
13	18.4	23.8	23.6	23.6	19.7	22.2	22.6	30.0	30.2
14	23.6	22.8	23.3	23.6	23.7	29.9	29.9	23.0	23.1
15	56.9	56.4	-	56.7	56.9	-	-	56.6	-
1′	75.1	73.0	76.0	74.6	74.9	80.2	73.5	72.9	68.1
2′	72.4	70.9	73.2	72.7	72.9	77.5	71.0	71.1	73.7
3′	80.3	78.8	80.1	80.0	80.3	74.8	78.7	79.1	73.7
4′	72.3	70.8	71.8	71.9	72.2	80.5	70.4	70.7	70.2
5′	82.9	81.8	82.7	82.4	82.6	68.3	81.5	81.8	76.6
6′	63.0	61.7	62.8	63.0	63.3	63.8	61.4	61.8	61.6
2′-OCOCH$_3$	-	-	-	-	-	-	-	-	168.6, 20.7
3′-OCOCH$_3$	-	-	-	-	-	-	-	-	169.4, 20.7
4′-OCOCH$_3$	-	-	-	-	-	-	-	-	170.3, 20.7
6′-OCOCH$_3$	-	-	-	-	-	-	-	-	170.6, 20.7
Solvent	CD_3OD	DMSO-d_6	CD_3OD	CD_3OD	CD_3OD	DMSO-d_6	DMSO-d_6	CD_3OD	$CDCl_3$
References	[80]	[159]	[160]	[82]	[160]	[94]	[94]	[96]	[93]

Table 30. The ^{13}C-NMR spectral data of compounds **103–110** except which has no reported ^{13}C-NMR data.

C	103	104	106	107	108	109	110
2	165.0	165.0	167.4	167.2	167.4	167.1	167.2
3	111.3	111.3	112.5	112.6	112.6	111.9	111.9
4	178.6	178.8	182.3	182.2	182.2	181.9	182.0
5	141.7	141.8	144.6	144.8	144.6	144.3	144.3
6	111.0	111.3	112.7	112.6	112.5	112.3	112.4
7	159.5	159.8	162.1	162.0	162.0	161.6	161.6
8	110.6	110.7	111.8	111.4	111.8	111.6	111.3
9	157.4	157.5	159.8	159.6	159.6	159.3	159.1
10	115.8	115.8	117.2	117.2	117.2	116.9	116.9
11	43.1	43.3	44.6	44.9	44.6	44.5	44.3
12	64.4	63.9	65.9	66.3	66.0	66.6	66.5
13	23.3	23.7	23.6	23.7	23.6	23.5	23.6
14	22.8	22.9	23.7	23.7	23.6	23.5	23.3
15	56.5	56.5	57.0	57.1	57.0	56.9	57.0
1′	70.6	70.6	72.8	72.8	72.8	71.9	71.8
2′	72.6	72.3	73.4	73.7	73.9	74.0	73.7
3′	75.7	75.9	77.7	77.7	77.9	77.6	77.4
4′	70.4	70.9	72.4	72.4	72.3	72.4	72.4
5′	81.8	82.0	83.0	80.1	82.9	82.7	82.4
6′	61.5	61.6	63.1	64.4	63.1	62.9	62.7
1″	133.9	125.0	127.0	127.0	128.2	135.3	126.7
2″	128.9	130.3	133.2	131.1	130.9	128.9	130.9
3″	128.2	115.8	115.7	116.9	115.4	129.7	116.6
4″	130.4	159.6	160.0	161.3	163.2	131.3	160.7
5″	128.2	115.8	115.7	116.9	115.4	129.7	116.6
6″	128.9	130.3	133.2	131.1	130.9	128.9	130.9
7″	144.1	144.4	145.0	146.6	146.1	146.1	146.4
8″	117.8	114.0	115.7	114.6	115.6	118.1	114.2
9″	165.0	165.4	167.6	168.0	167.8	167.2	167.8
OCH_3	-	-	-	-	55.9	-	-
$COCH_3$	-	-	-	173.0, 20.9	-	-	-
Solvent	DMSO-d_6	DMSO-d_6	CD_3OD	CD_3OD	CD_3OD	CD_3OD	CD_3OD
References	[99]	[159]	[80]	[100]	[100]	[82]	[82]

Table 31. The ^{13}C-NMR spectral data of compounds **111–122** except which has no reported ^{13}C-NMR data.

C	111	112	113	114	115	116	117	119	120	121	122
2	167.2	167.6	169.7	160.3	163.0	160.1	163.1	160.6	164.0	167.6	166.8
3	112.1	112.2	110.5	1125	113.8	112.5	111.0	112.5	112.4	112.2	112.2
4	182.2	182.3	182.4	178.6	182.1	178.4	181.8	178.6	182.0	182.3	182.3
5	143.5	144.6	144.8	141.0	144.7	140.4	146.1	141.8	144.9	144.6	144.8
6	116.3	112.6	112.7	115.8	112.2	115.7	128.3	111.5	113.1	112.6	112.7
7	161.3	162.0	162.1	159.l	162.1	159.4	161.1	159.7	162.3	161.0	162.2
8	110.0	111.9	111.8	110.2	112.0	110.7	121.1	110.8	111.6	111.9	111.9
9	160.4	159.6	159.4	158.3	159.6	157.9	157.9	157.4	159.5	159.6	159.6
10	117.0	117.3	117.5	114.8	117.1	114.8	114.3	115.6	117.6	117.2	117.3
11	44.3	44.6	75.7	48.1	49.1	47.8	48.5	47.9	98.6	44.6	44.6
12	66.7	66.8	69.2	202.4	204.7	202.3	204.6	202.1	203.7	66.8	66.8
13	23.5	23.6	19.7	30.4	29.9	29.6	30.7	29.6	23.7	23.7	24.0
14	23.5	23.6	23.7	22.7	23.7	22.6	23.3	22.7	25.0	23.6	23.5
15	-	57.1	57.1	-	57.1	-	55.8	55.5	57.2	57.1	57.1
1′	73.0	72.1	72.8	70.2	72.1	73.3	75.6	70.4	72.6	72.6	72.6
2′	74.0	74.0	74.1	72.3	73.9	70.8	72.3	72.2	74.3	74.1	73.6
3′	77.9	77.9	77.8	76.0	77.9	78.5	79.9	75.8	78.0	77.8	77.6
4′	72.1	72.7	72.3	70.2	72.6	70.4	72.1	70.6	71.9	78.3	78.1
5′	82.8	82.9	83.0	81.8	82.8	78.4	78.5	81.9	83.3	82.9	82.9
6′	63.1	63.1	63.1	61.8	63.3	64.8	65.4	61.5	63.5	63.0	63.0
1″	128.3	127.5	135.7	125 I	127.0	125.0	128.3	125.5	135.7	129.8	129.7
2″	131.0	115.1	129.2	1301	130.8	130.3	131.0	111.1	129.3	130.8	132.6
3″	116.7	149.9	130.1	115.8	116.7	115.7	115.3	147.9	130.1	118.0	116.7
4″	161.2	146.6	131.6	159.6	161.3	159.7	160.4	149.2	131.6	163.8	159.7
5″	116.7	116.6	130.1	115.8	116.7	115.7	115.3	115.5	130.1	-	-
6″	131.0	123.0	129.2	1301	130.8	130.3	131.0	122.9	129.3	-	-
7″	146.2	147.1	146.4	144.4	145.3	144.9	146.2	144.6	146.3	146.0	144.7
8″	115.8	114.5	118.4	114.1	115.1	114.0	116.0	114.2	118.5	116.5	117.6
9″	168.0	168.2	167.4	165.4	168.1	166.7	169.1	165.4	167.4	167.8	167.7
OCH_3	56.1	-	-	-	-	-	-	56.3	-	-	-
1‴	-	-	-	-	-	-	-	-	-	101.9	101.7
2‴	-	-	-	-	-	-	-	-	-	74.8	74.9
3‴	-	-	-	-	-	-	-	-	-	72.1	72.6

Table 31. *Cont.*

C	111	112	113	114	115	116	117	119	120	121	122
4‴	-	-	-	-	-	-	-	-	-	71.3	71.2
5‴	-	-	-	-	-	-	-	-	-	78.0	77.9
6‴	-	-	-	-	-	-	-	-	-	62.5	62.4
Solvent	CD_3OD	CD_3OD	CD_3OD	DMSO-d_6	DMSO-d_6	DMSO-d_6	CD_3OD	DMSO-d_6	CD_3OD	CD_3OD	CD_3OD
References	[80]	[82]	[160]	[161]	[162]	[163]	[74]	[164]	[81]	[160]	[160]

Table 32. The ^{13}C-NMR spectral data of compounds **123–129** except which has no reported ^{13}C-NMR data.

C	123	124	126	127	128	129
2	167.7	168.3	171.3	170.7	167.7	169.9
3	108.0	108.5	105.6	105.5	108.3	108.4
4	182.2	182.4	184.3	183.0	182.7	182.4
5	158.8	157.8	160.2	158.1	159.5	159.6
6	110.4	111.1	112.5	112.8	107.4	105.2
7	162.3	163.1	163.8	161.0	162.9	163.1
8	93.2	90.5	94.4	93.0	92.8	92.9
9	156.1	156.6	157.8	156.1	156.7	156.4
10	103.3	104.4	106.8	105.6	103.4	103.8
11	19.9	19.9	61.6	60.0	18.8	60.0
OCH_3	-	56.5	-	-	-	-
1′	20.5	20.5	22.1	20.5	26.4	26.4
2′	126.9	126.4	128.7	124.6	79.9	79.8
3′	131.8	132.3	132.9	134.1	143.7	143.7
4′	66.1	66.1	68.4	61.0	114.2	114.2
5′	21.2	21.3	21.9	20.0	15.2	15.2
1″	101.5	101.6	102.7	100.1	99.4	99.4
2″	73.6	73.6	75.3	73.2	73.6	73.6
3″	76.9	77.0	78.3	76.7	76.3	76.3
4″	70.2	70.2	71.8	67.7	70.2	70.2
5″	77.0	77.0	77.9	77.0	76.7	76.7
6″	61.1	61.1	62.9	60.1	61.2	61.2
Solvent	DMSO-d_6	DMSO-d_6	CD_3OD	CD_3OD	CD_3OD	CD_3OD
References	[104]	[104]	[106]	[60]	[60]	[60]

Table 33. The ^{13}C-NMR spectral data of compounds **130**–**139**.

C	130	131	132	133	134	135	136	137	138	139
2	170.7	167.6	170.7	168.3	171.4	168.9	165.0	171.0	171.5	171.8
3	105.5	107.4	104.9	108.1	105.5	113.9	*	110.4	110.7	110.7
4	183.0	181.8	181.9	182.5	182.5	176.6	*	179.3	180.4	180.6
5	158.8	158.8	158.9	159.5	159.5	132.6	*	106.6	119.2	126.2
6	111.4	97.6	97.8	98.3	98.4	111.4	99.3	150.7	126.2	126.6
7	162.1	159.9	160.1	160.6	160.8	158.2	162.9	153.1	122.1	135.6
8	93.3	107.5	107.4	108.1	108.2	103.6	94.8	106.9	147.8	119.3
9	156.3	153.8	153.5	154.4	154.1	163.4	*	149.8	149.0	158.0
10	105.7	104.3	104.8	105.0	105.4	112.7	*	116.2	125.0	124.3
11	60.0	19.5	59.3	20.2	59.5	127.9	121.6	102.2	141.4	136.2
1′	28.2	20.3	20.3	21.0	20.9	131.9	128.5	74.3	129.5	114.0
2′	74.6	120.5	120.4	121.1	121.0	115.7	115.7	78.1	129.6	150.7
3′	147.9	134.9	134.9	135.6	135.7	157.1	161.5	71.5	127.4	146.4
4′	109.5	65.9	65.8	66.5	66.5	115.7	115.7	78.0	129.6	118.1
5′	16.6	13.1	13.1	13.8	13.7	131.9	128.5	62.8	129.5	122.0
6′	-	-	-	-	-	39.3	39.1	-	33.8	33.6
7′	-	-	-	-	-	86.3	37.5	-	37.0	37.1
8′	-	-	-	-	-	127.9	121.6	102.2	141.4	136.2
1″	101.2	100.1	100.1	100.7	100.7	101.8	100.3	131.5	103.0	102.9
2″	73.6	72.9	72.9	73.5	73.5	74.6	*	133.0	75.0	74.9
3″	76.5	76.7	76.7	76.7	76.7	78.4	*	116.3	78.2	77.8
4″	69.8	69.2	69.2	69.8	69.8	71.2	*	164.1	71.3	71.3
5″	77.1	76.1	76.1	77.3	77.3	78.2	*	116.3	78.2	78.1
6″	61.1	60.2	60.2	60.8	60.8	62.5	*	120.9	62.5	62.4
7″	-	-	-	-	-	-	-	33.9	-	-
8″	-	-	-	-	-	-	-	37.1	-	-
OCH_3	-	-	-	-	-	-	-	6-OCH_3 56.3 4″-OCH_3 55.1	-	56.6
Solvent	CD_3OD	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6	CD_3OD	DMSO-d_6	DMSO-d_6	CD_3OD	CD_3OD
References	[60]	[108]	[108]	[109]	[109]	[110]	[111]	[112]	[113]	[114]

* The authors missed assigning these positions.

Table 34. The ^{13}C-NMR spectral data of compounds **140**–**148**.

C	140	141	142	143	144	145	146	147	148
2	147.2	146.9	147.3	89.9	89.0	92.9	92.1	92.3	88.2
3	106.1	105.0	104.9	24.3	28.3	28.1	27.9	28.0	30.1
4	153.7	160.5	159.2	165.5	164.5	160.3	165.3	156.3	158.5
5	177.2	185.9	184.7	176.9	176.4	184.7	176.6	176.6	182.9
6	109.7	107.8	107.2	111.9	109.8	109.5	110.9	111.4	107.2
7	163.7	169.0	168.7	163.3	164.0	169.7	162.7	162.6	166.7
9	95.8	92.0	92.0	94.8	95.2	90.4	94.0	94.2	88.8
10	157.8	156.1	154.5	159.9	160.1	168.3	159.7	165.4	166.6
11	117.0	114.3	113.4	118.7	117.2	111.3	118.1	118.5	108.7
12	152.8	106.9	106.3	112.3	111.4	106.6	112.5	112.8	102.9
13	155.6	155.7	155.2	156.4	157.7	157.9	156.1	159.9	158.6
14	65.7	67.8	66.3	21.4	20.7	20.8	66.4	66.8	66.1
4-OCH$_3$	61.9	-	-	-	*	-	60.8	61.0	-
1′	103.0	104.4	104.4	77.3	74.3	79.7	70.8	70.8	143.7
2′	74.0	75.0	74.2	23.4	24.1	24.3	26.0	26.2	115.5
3′	77.2	77.9	77.6	22.3	23.5	23.0	25.6	25.8	15.7
4′	70.6	71.6	70.9	-	-	-	-	-	-
5′	77.1	78.0	76.7	-	-	-	-	-	-
6′	61.7	68.7	69.5	-	-	-	-	-	-
1″	-	111.1	103.3	98.9	100.1	99.5	104.0	104.4	102.8
2″	-	77.2	74.4	75.1	74.6	75.6	74.8	75.0	73.7
3″	-	80.6	77.4	78.8	78.6	78.5	78.4	78.3	76.7
4″	-	74.9	70.9	71.3	71.4	72.0	71.4	71.3	70.3
5″	-	65.5	77.7	77.1	78.2	76.8	78.1	75.7	76.9
6″	-	-	61.9	62.4	63.1	68.5	62.6	64.5	61.4
1‴	-	-	-	-	-	111.2	-	126.5	-
2‴	-	-	-	-	-	78.6	-	111.4	-
3‴	-	-	-	-	-	81.0	-	149.0	-
4‴	-	-	-	-	-	75.6	-	151.2	-
5‴	-	-	-	-	-	66.2	-	116.8	-
6‴	-	-	-	-	-	-	-	123.9	-
7‴	-	-	-	-	-	-	-	145.9	-
8‴	-	-	-	-	-	-	-	115.1	-
9‴	-	-	-	-	-	-	-	167.8	-
3‴-OCH$_3$	-	-	-	-	-	-	-	55.9	-
Solvent	DMSO-d_6, C_6D_6	CD_3OD	DMSO-d_6	$CDCl_3$, CD_3OD	$CDCl_3$, CD_3OD	CD_3OD	C_5D_5N	C_5D_5N	CD_3OD
References	[117]	[118]	[109]	[122]	[122]	[119]	[121]	[132]	[60]

* The authors missed assigning this position.

Table 35. The ^{13}C-NMR spectral data of compounds **149**–**155**.

C	149	150	151	152	153	154	155
2	167.4	169.5	162.7	167.6	167.6	170.9	168.7
3	108.7	108.0	111.1	107.5	107.4	105.6	108.6
4	182.7	184.2	175.3	181.9	181.8	182.5	182.6
5	160.0	160.9	160.7 *	158.6	158.5	159.2	160.3
6	104.1	105.0	104.9	103.1	103.1	103.8	102.5
7	159.6	160.4	152.7 *	163.5	163.3	164.1	164.3
8	94.9	95.8	91.1	109.8	109.9	110.5	105.8
9	156.3	157.7	157.8	152.9	152.7	153.1	155.0
10	104.4	105.0	107.7	105.5	105.4	106.5	106.1
2′	78.4	79.3	76.6	69.6	69.6	70.2	74.2
3′	74.3	75.0	72.4	135.2	135.0	135.8	73.5
4′	22.3	22.7	22.4	124.7	124.7	125.2	132.7
5′	-	-	-	20.6	20.3	20.9	117.3
1″	102.4	102.0	100.4	101.2	100.9	101.9	103.9
2″	74.9	74.9	**	72.8	72.6	73.3	73.7
3″	78.4	78.1	76.9	76.8	76.1	76.8	76.5
4″	71.8	71.9	70.2	70.1	69.4	70.1	70.9
5″	78.4	75.0	76.9	76.6	75.2	76.6	76.0
6″	63.0	68.8	61.3	60.6	67.7	61.6	68.5
1‴	-	111.0	-	-	102.7	-	103.4
2‴	-	77.9	-	-	72.8	-	73.7
3‴	-	80.5	-	-	76.1	-	76.9
4‴	-	75.0	-	-	69.4	-	70.0
5‴	-	65.7	-	-	75.9	-	77.0
6‴	-	-	-	-	60.4	-	61.1
2a	20.1	20.4	19.0	19.4	19.2	59.7	20.1
2′a	22.3	22.4	21.2	-	-	-	-
2′b	25.7	26.1	25.2	-	-	-	-
3′a	-	-	-	69.6	69.6	70.2	73.0
7-OCH$_3$	-	-	56.0	-	-	-	-
Solvent	$CDCl_3$	CD_3OD	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6	DMSO-d_6
References	[121]	[119]	[123]	[108]	[108]	[108]	[109]

* Interchangeable data. ** The authors missed the assignment of this position.

Table 36. The ^{13}C-NMR spectral data of compounds **157–165**.

C	157	158	159	160	161	162	163	164	165
Chromone moiety									
2′	92.4	92.2	92.2	92.2	92.2	92.2	92.2	92.2	92.2
3′	27.9	27.8	27.8	27.8	27.8	27.8	27.8	27.8	27.8
4′	156.3	156.2	156.2	156.2	156.2	156.2	156.2	156.2	156.1
5′	176.2	176.2	176.2	176.2	176.2	176.2	176.3	176.3	176.3
6′	111.5	110.9	111.1	110.9	110.9	110.8	111.1	111.2	111.1
7′	162.1	162.5	162.4	162.4	162.7	162.5	162.6	162.6	162.5
9′	94.1	94.0	94.0	94.0	94.1	94.0	94.0	94.1	94.0
10′	165.4	165.2	165.2	165.2	165.2	165.2	165.2	165.2	165.2
11′	118.5	118.4	118.4	118.4	118.4	118.4	118.4	118.4	118.4
12′	112.9	112.8	112.8	112.5	112.8	112.8	112.8	112.8	112.7
13′	159.9	159.8	159.8	159.7	159.8	159.7	159.8	159.9	159.8
14′	66.3	66.3	66.5	66.2	66.4	66.2	66.5	66.3	66.5
4-OCH$_3$	60.9	60.9	60.9	60.8	60.9	60.9	60.9	60.9	60.8
1″	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.7	70.6
2″	26.0	26.1	26.1	26.1	26.1	26.1	26.1	26.2	26.1
3″	25.6	25.7	25.7	25.6	25.7	25.7	25.6	25.6	25.7
Glu-1	101.7	104.1	104.2	104.1	104.1	104.0	104.2	103.9	104.3
Glu-2	74.5	74.9	74.8	74.8	74.9	74.9	74.9	74.8	74.9
Glu-3	79.1	78.3	78.1	78.4	78.4	78.4	78.4	78.2	78.1
Glu-4	69.3	71.2	71.4	71.4	71.5	71.3	71.5	72.0	71.9
Glu-5	78.4	76.9	75.4	77.1	77.1	76.7	77.0	76.8	76.7
Glu-6	62.4	63.5	64.2	62.7	62.7	62.8	62.6	62.9	62.7
Triterpene moiety									
1	31.8	31.9	31.9	32.3	30.3	32.0	27.4	31.9	31.9
2	29.8	29.8	30.0	30.0	29.5	30.0	29.8	29.6	29.8
3	87.8	88.0	88.3	88.4	88.1	88.3	88.3	88.0	88.0
4	41.1	40.3	41.2	41.2	41.2	41.2	40.7	41.1	41.1
5	47.1	47.0	47.4	47.4	42.6	47.4	43.8	47.0	46.9
6	20.5	20.4	20.8	20.9	21.7	20.8	22.0	20.4	20.3
7	25.6	25.8	25.9	26.4	113.2	26.3	114.0	25.8	25.7

Table 36. *Cont.*

C	157	158	159	160	161	162	163	164	165
8	46.0	45.9	47.1	49.0	149.1	47.3	148.6	45.8	46.4
9	19.8	19.9	19.2	19.9	21.1	19.5	27.6	20.0	20.5
10	26.5	26.6	26.6	26.5	28.2	26.4	29.1	26.6	27.0
11	36.7	36.6	26.3	26.4	25.4	26.1	63.2	36.7	36.4
12	77.2	76.8	31.4	34.0	33.9	33.3	48.3	77.2	76.9
13	48.8	48.7	42.2	41.8	41.2	46.6	45.4	48.7	48.8
14	47.2	47.4	45.2	46.5	49.8	45.1	48.1	47.8	47.8
15	43.4	43.4	50.8	82.5	80.4	42.8	45.2	43.8	45.6
16	70.7	72.8	218.6	103.0	103.3	72.5	114.5	71.1	74.6
17	55.7	55.6	60.4	60.5	60.3	51.4	61.0	56.8	52.4
18	13.5	13.5	18.8	20.3	22.5	20.5	20.7	13.5	12.9
19	29.9	30.7	30.0	30.7	28.2	30.1	18.7	29.8	30.0
20	26.9	25.4	29.1	27.6	27.5	34.2	23.7	26.0	24.6
21	21.1	20.8	19.9	21.4	21.6	17.3	19.6	21.1	25.7
22	41.5	38.6	40.3	33.6	33.6	86.2	37.8	41.9	106.0
23	104.2	102.9	173.4	74.2	74.4	109.6	71.7	101.9	152.9
24	83.1	212.4	-	80.5	80.4	77.3	88.5	77.7	75.9
25	79.1	35.0	-	76.4	76.5	83.5	76.4	81.3	78.2
26	19.4	19.2	-	21.6	21.6	27.3	23.2	23.7	22.3
27	29.8	19.7	-	24.1	24.1	24.5	20.2	24.9	23.1
28	19.4	19.4	19.6	11.8	18.2	19.4	27.4	19.5	20.7
29	25.6	25.6	25.6	25.5	25.6	25.6	25.8	25.6	25.6
30	15.2	15.2	15.2	15.5	14.2	15.3	14.5	15.2	15.2
Xyl-1	107.4	107.5	107.5	107.4	107.4	107.4	107.4	107.5	107.5
Xyl-2	75.5	75.5	75.5	75.5	75.5	75.5	75.5	75.5	75.5
Xyl-3	78.5	78.6	78.5	78.5	78.5	78.5	78.5	78.5	78.5
Xyl-4	71.1	71.0	71.1	71.1	71.2	71.1	71.1	71.2	71.1
Xyl-5	67.0	67.0	67.1	67.0	67.0	67.0	67.0	67.0	67.0
$COCH_3$	170.4 21.5	170.4 21.5	-	171.0 21.1	171.0 21.1	-	-	170.5 21.6	170.6 21.1
Solvent	C_5D_5N	C_5D_5N	C_5D_5N	C_5D_5N	C_5D_5N	C_5D_5N	C_5D_5N	C_5D_5N	C_5D_5N
References	[130]	[130]	[130]	[130]	[130]	[130]	[130]	[136]	[136]

Table 37. The ^{13}C-NMR spectral data of compounds **166** and **167**.

C	166	167
1	98.1	98.1
3	154.5	154.5
4	105.6	105.6
5	28.7	28.6
6	30.0	29.9
7	75.1	75.0
8	133.3	133.3
9	43.9	43.8
10	121.1	121.1
11	168.6	168.5 [a]
1′	99.8	99.7
2′	74.8	74.7 [b]
3′	77.9	77.8 [c]
4′	71.6	71.2 [d]
5′	78.5	78.4 [e]
6′	62.7	62.4 [f]
2″	167.5	168.1 [a]
3″	118.2	118.6
4″	181.6	181.8
5″	163.5	163.1
6″	100.2	101.1
7″	166.2	164.9
8″	94.7	95.7
9″	159.2	158.7
10″	104.9	106.6
-CH_3	18.9	19.0
1‴	-	101.6
2‴	-	74.8 [b]
3‴	-	77.9 [c]
4‴	-	71.6 [d]
5‴	-	78.5 [e]
6‴	-	62.7 [f]
NMR	CD_3OD	CD_3OD
References	[43]	[43]

[a−f] Values with the same superscript are interchangeable.

Table 38. The ^{13}C-NMR spectral data of compounds **168**–**180** except those which have no reported ^{13}C-NMR data.

C	168	169	170	171	172	178	179	180
2	163.7	159.3	168.0	159.6	167.5	170.2	166.3	166.3
3	108.7	108.8	109.7	109.9	110.0	110.8	110.0	110.0
4	179.2	179.5	178.9	178.8	179.0	179.0	178.7	178.8
4a	125.8	126.2	125.9 *	126.4	125.9 *	125.8 *	125.8 *	126.5
5	149.6	149.6	149.9	150.0	149.8	150.1	149.7	149.9
6	125.4	125.4	125.8	125.9	125.9 *	125.8 *	125.9	126.0
6a	137.0	137.2	137.0	137.0	137.4	137.2	137.3	136.3
7	183.0	183.3	183.2	183.5	183.3	183.1	183.1	181.5
7a	125.8	127.3	126.3 *	126.5	126.4 *	126.1 *	126.2 *	130.7
8	140.0	140.6	139.7	140.0	140.1	139.9	140.2	119.3
9	133.0	132.6	132.9	132.2	133.1	133.3	133.1	133.2
10	138.4	138.5	137.8	137.0	138.5	138.6	138.6	140.7
11	159.7	163.9	159.7	167.6	159.9	159.9	159.8	159.5
11a	116.0	115.8	116.1	116.0	116.2	116.0	116.1	116.1
12	188.1	188.0	187.9	187.7	188.1	188.3	188.0	187.7
12a	118.9	118.9	119.1	119.1	119.2	118.9	119.2	119.8
12b	155.7	155.8	156.0	156.0	156.2	155.8	156.1	156.2
13	24.0	24.1	24.3	24.2	24.1	24.2	24.1	24.1
14	127.2	125.9	57.6	60.3	59.1	75.6	57.7	57.7
15	12.1	15.0	13.8	14.9	14.5	23.5	14.5	14.4
16	134.2	134.2	62.0	61.7	61.6	71.7 *	63.9	63.9
17	14.9	12.1	14.1	123.3	123.3	127.4	55.4	55.4
18	-	-	-	134.1	134.0	130.2	51.8	51.8
19	-	-	-	14.4	13.8	13.5	17.2	17.2
2′	77.3	77.7	77.2	77.6	77.3	77.2	77.3	67.9
3′	71.9	71.8	71.3	70.6	71.9	71.7 *	71.9	71.0
4′	67.4	67.5	67.8	68.1	67.4	67.3 *	67.4	57.7
5′	28.3	41.0	28.8	38.8	28.4	28.4	28.3	35.0
6′	75.2	75.4	74.8	74.0	75.2	75.0	75.2	68.2
7′	18.9	18.9	18.8	18.5	18.9	18.9	18.9	17.5
8′	-	-	-	-	-	-	-	13.2

Table 38. *Cont.*

C	168	169	170	171	172	178	179	180
4′-N(CH$_3$)$_2$	40.4	40.5	40.3	40.4	40.4	40.3	40.4	37.1
2″	67.2	69.8	67.5	69.8	67.2	67.4 *	67.3	-
3″	70.8	76.4	70.3	74.5	70.9	70.7	70.9	-
4″	57.4	57.6	57.6	59.1	57.3	57.9	57.3	-
5″	33.6	28.6	33.3	30.4	33.6	33.3	33.7	-
6″	69.5	64.9	69.4	65.7	69.7	69.6	69.6	-
7″	17.6	15.0	17.4	15.1	17.7	17.6	17.6	-
8″	12.3	13.7	13.1	13.9	12.3	12.6	12.3	-
3″-COCH$_3$	-	170.6 21.3	-	171.0 21.5	-	-	-	-
4″-N(CH$_3$)$_2$	36.8	39.3	36.9	38.8	36.8	36.8	36.8	-
Solvent	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$
References	[165]	[140]	[141]	[140]	[142]	[143]	[165]	[146]

* Interchangeable values.

Table 39. The ^{13}C-NMR spectral data of compounds **181**–**183**.

C	181	182	183
2	168.4	176.4	176.5
3	112.0	111.1	111.3
4	180.3	181.3	178.4
4a	126.1	126.0	124.7
5	150.4	150.4	149.6
6	121.3	121.0	121.2
6a	138.3	138.1	139.0
7	182.7	182.7	182.4
7a	133.2	133.2	133.2
8	120.1	120.0	119.8
9	135.4	135.5	135.6
10	137.4	137.4	137.0
11	161.1	161.0	161.3
11a	118.1	118.0	118.0

Table 39. *Cont.*

C	181	182	183
12	189.1	189.2	189.2
12a	122.0	121.9	121.6
12b	157.7	157.4	156.9
13	70.8	70.8	175.3
14	61.2	77.7	77.7
15	63.7	72.6	72.6
16	20.2	23.9	23.9
17	13.7	17.0	17.1
1′	98.9	98.9	-
2′	37.2	37.2	-
3′	58.3	58.4	-
4′	71.2	71.1	-
5′	70.4	70.4	-
6′	17.2	17.2	-
7′	24.6	24.5	-
1″	70.2	70.1	70.3
2″	28.0	27.7	27.4
3″	65.2	65.1	64.9
4″	75.1	75.0	75.2
5″	72.6	72.6	72.3
6″	18.1	18.2	18.3
3″-N(CH_3)$_2$	43.2 41.7	43.3 41.4	42.5 42.5
1‴	101.4	101.4	101.4
2‴	33.4	33.4	33.4
3‴	66.6	66.6	66.6
4‴	72.0	72.0	72.0
5‴	69.5	69.5	69.5
6‴	17.5	17.5	17.5
Solvent	CD_3OD	CD_3OD	CD_3OD
References	[147]	[147]	[147]

Table 40. The ^{13}C-NMR spectral data of compounds **184**–**192**.

C	184	185	186	187	188	189	190	191	192
2	167.5	167.4	167.0	167.0	165.7	165.7	167.5	169.3	169.3
3	111.1	110.9	110.9	110.8	111.3	111.3	111.1	109.1	109.1
4	180.2	180.0	179.4	179.4	178.5	178.6	180.2	182.4	182.5
4a	126.6	126.4	126.5	126.4	126.3	126.3	126.6	113.3	113.3
5	149.2	149.1	149.4	149.2	148.2	148.2	149.3	166.7	166.7
6	122.5	122.4	122.9	122.8	124.1	124.0	122.5	110.7	110.7
6a	137.2	137.1	137.0	136.9	136.9	136.9	137.2	139.8	139.9
7	181.2	181.0	181.2	181.2	181.5	181.4	181.2	180.8	180.8
7a	130.3	130.2	130.4	130.3	130.5	130.5	130.5	130.6	130.4
8	119.8	119.7	119.7	119.7	119.5	119.5	119.8	119.4	119.5
9	133.6	133.7	133.4	133.6	133.3	133.5	133.7	132.4	132.8
10	141.3	141.1	141.0	140.9	141.0	140.9	140.7	140.2	140.9
11	159.1	159.2	159.3	158.9	159.3	159.3	159.4	159.1	159.1
11a	115.8	115.6	115.9	115.7	115.9	115.9	115.9	115.6	115.4
12	186.9	186.9	187.1	186.9	187.5	187.4	186.9	186.2	186.3
12a	121.8	121.6	121.6	121.6	120.8	120.8	121.8	112.3	112.4
12b	156.8	156.7	156.6	156.5	156.1	156.1	156.8	156.6	156.6
13	80.9	80.0	79.0	78.9	48.3	48.2	80.9	-	-
14	59.8	59.7	59.8	59.7	59.8	59.7	59.8	60.0	60.0
15	19.7	19.6	19.8	19.7	20.0	19.9	19.6	19.6	19.7
16	62.7	62.5	62.5	62.5	62.5	62.5	62.7	62.7	62.7
17	13.4	13.3	13.4	13.3	13.5	13.4	13.3	13.2	13.2
18	170.5	170.4	170.9	170.9	170.4	170.4	170.5	-	-
19	52.6	52.5	52.4	52.3	52.3	52.3	52.6	-	-
2′	73.8	73.8	74.9	74.9	74.3	74.2	73.8	-	-
3′	68.9	68.9	68.5	68.2	68.8	68.8	69.0	-	-
4′	80.2	80.1	74.8	74.9	81.5	81.4	80.2	-	-
5′	67.9	67.9	26.1	26.0	68.0	67.9	68.0	-	-
6′	73.7	73.6	70.3	70.2	73.9	74.0	73.7	-	-
7′	14.1	14.0	14.7	14.7	14.7	14.6	14.0	-	-
4′-OCH$_3$	57.9	57.8	55.6	55.5	57.1	57.1	58.0	-	-
2″	70.3	70.7	70.2	70.8	70.3	70.8	70.0	70.0	70.7
3″	77.7	82.6	77.8	82.7	77.8	82.8	76.0	77.3	82.8
4″	54.9	58.1	55.1	58.1	54.9	58.1	51.7	56.1	58.1

Table 40. *Cont.*

C	184	185	186	187	188	189	190	191	192
5″	40.3	44.7	40.4	44.7	40.4	44.8	44.9	38.5	44.8
6″	62.1	62.2	62.3	62.2	62.2	62.3	62.3	63.6	62.3
7″	14.7	13.5	14.8	13.5	14.7	13.6	14.1	15.4	13.6
8″	24.1	14.0	23.8	13.9	24.2	14.1	32.6	22.6	14.0
4″-N(CH$_3$)$_n$	27.9	40.3	27.8	40.3	28.1	40.4	-	27.2	40.3
1‴	93.4	94.4	93.7	94.5	93.4	94.5	93.3	94.5	94.5
2‴	30.8	31.1	30.9	31.1	30.9	31.1	30.8	31.1	31.1
3‴	74.8	74.9	74.8	74.9	74.9	75.0	74.8	75.0	75.0
4‴	72.1	72.1	72.1	72.0	72.2	72.2	72.2	71.5	72.2
5‴	65.4	65.0	65.7	65.0	65.4	65.1	65.4	66.6	65.0
6‴	17.7	17.6	17.7	17.6	17.8	17.7	17.8	17.5	17.7
3‴-OCH$_3$	55.9	56.1	56.1	56.1	55.9	56.2	56.0	56.4	56.1
Solvent	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$	CDCl$_3$
References	[149]	[149]	[149]	[149]	[137]	[137]	[137]	[137]	[137]

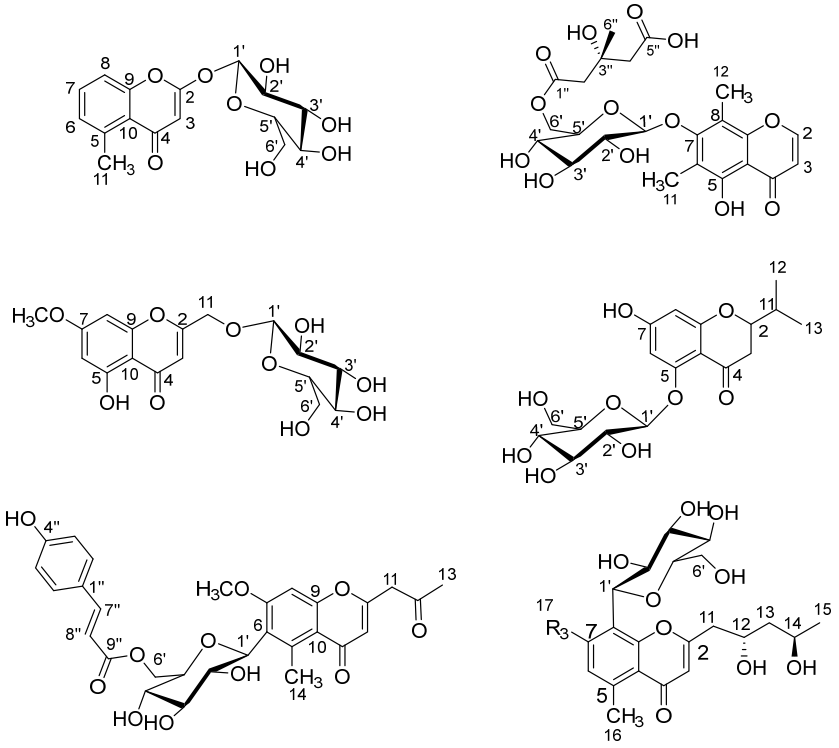


Figure 25. Representative guide figure for numbering of chromone glycosides attached to different substituents.

6. Conclusions

Chromone glycosides are one of the most important classes of secondary metabolites. In this review, we summarized 192 naturally occurring chromone glycosides with their

sources, reported activities, and spectroscopic features. Basically, they were categorized into several classes: chromone-*O*-glycosides including compounds **1**–**59**, among them, four chromanone glycosides (**60**–**63**), chromone-*C*-glycosides including compounds **64**–**122**, prenyl and isoprenyl chromone glycosides including compounds **123**–**134**, phenyl ethyl chromone glycosides including compounds **135**–**139**, furano-chromone glycosides including compounds **140**–**148**, pyrano-chromone glycosides including compounds **149**–**151**, oxepino-chromone glycosides including compounds **152**–**155**, Pyrido-chromone glycoside including compound **156**, furanochromones with cycloartane triterpenes including compounds **157**–**165**, glycoside derivatives of chromones with secoiridoids including compounds **166** and **167**, and chromone alkaloids aminoglycosides including compounds **168**–**192**. Diverse bioactivities were discovered for most of the reported chromone glycosides. Several chromone glycosides show potent biological activities as anti-viral, acetylcholinesterase inhibition, anti-tumor, anti-inflammatory, etc. This review directs the attention for further deep investigation of chromone glycosides for drug discovery.

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Abbreviations

All	Allose
Api	Apiose
Ara	Arabinose
Caf	Caffeic acid
Cin	Cinnamic acid
Cou	Coumaric acid
Fer	Ferulic acid
Gall	Gallic acid
Glu	Glucose
Rha	Rhamnose
Xyl	Xylose

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