

Review

## Natural Products from the Genus *Tephrosia*

Yinning Chen <sup>1</sup>, Tao Yan <sup>2</sup>, Chenghai Gao <sup>3</sup>, Wenhao Cao <sup>2</sup> and Riming Huang <sup>1,\*</sup>

<sup>1</sup> Key Laboratory of Plant Resources Conservation and Sustainable Utilization, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510650, China; E-Mail: chendianyu3356@163.com

<sup>2</sup> South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China; E-Mails: yantao@scsio.ac.cn (T.Y.); chromo@163.com (W.C.)

<sup>3</sup> Guangxi Key Laboratory of Marine Environmental Science, Guangxi Academy of Sciences, Nanning 530007, China; E-Mail: gaochenghai@aliyun.com

\* Author to whom correspondence should be addressed; E-Mail: huang\_riming@hotmail.com; Tel.: +86-20-3525-2958.

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**Abstract:** The genus *Tephrosia*, belonging to the Leguminosae family, is a large pantropical genus of more than 350 species, many of which have important traditional uses in agriculture. This review not only outlines the source, chemistry and biological evaluations of natural products from the genus *Tephrosia* worldwide that have appeared in literature from 1910 to December 2013, but also covers work related to proposed biosynthetic pathways and synthesis of some natural products from the genus *Tephrosia*, with 105 citations and 168 new compounds.

**Keywords:** *Tephrosia*; chemical constituents; proposed biosynthetic pathways; synthesis; biological activity

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### 1. Introduction

The genus *Tephrosia*, belonging to the Leguminosae family, is a large pantropical genus of more than 350 species, many of which have important traditional uses [1,2]. Phytochemical investigations have revealed the presence of glucosides, rotenoids, isoflavones, chalcones, flavanones, flavanols, and prenylated flavonoids [1–9] of chemotaxonomic importance in the genus [10]. Moreover, bioactivity

has been studied extensively, indicating that chemical constituents and extracts of the genus *Tephrosia* exhibited diverse bioactivities, such as insecticidal [11], antiviral [12], antiprotozoal [13], antiplasmodial [14] and cytotoxic [15] activities.

So far, the reviews on natural products isolated from the genus *Tephrosia* are limited [16]. To gain a comprehensive and systematic understanding of this genus, this review outlines the chemistry, proposed biosynthetic pathways, synthesis, and biological evaluations of natural products from the genus *Tephrosia* worldwide that have appeared in literature from 1971 to December 2013, with 105 citations and 168 new compounds from them.

## 2. Chemical Constituents

The chemical constituents of the genus *Tephrosia* reported since 1910 (compounds **1–168**) are shown in Table 1 and Figures 1–10 below with their names, and their biological sources. As listed in the table and Figures 1–7, flavonoids are the predominant constituents of this genus.

**Figure 1.** Flavones from genus *Tephrosia*.

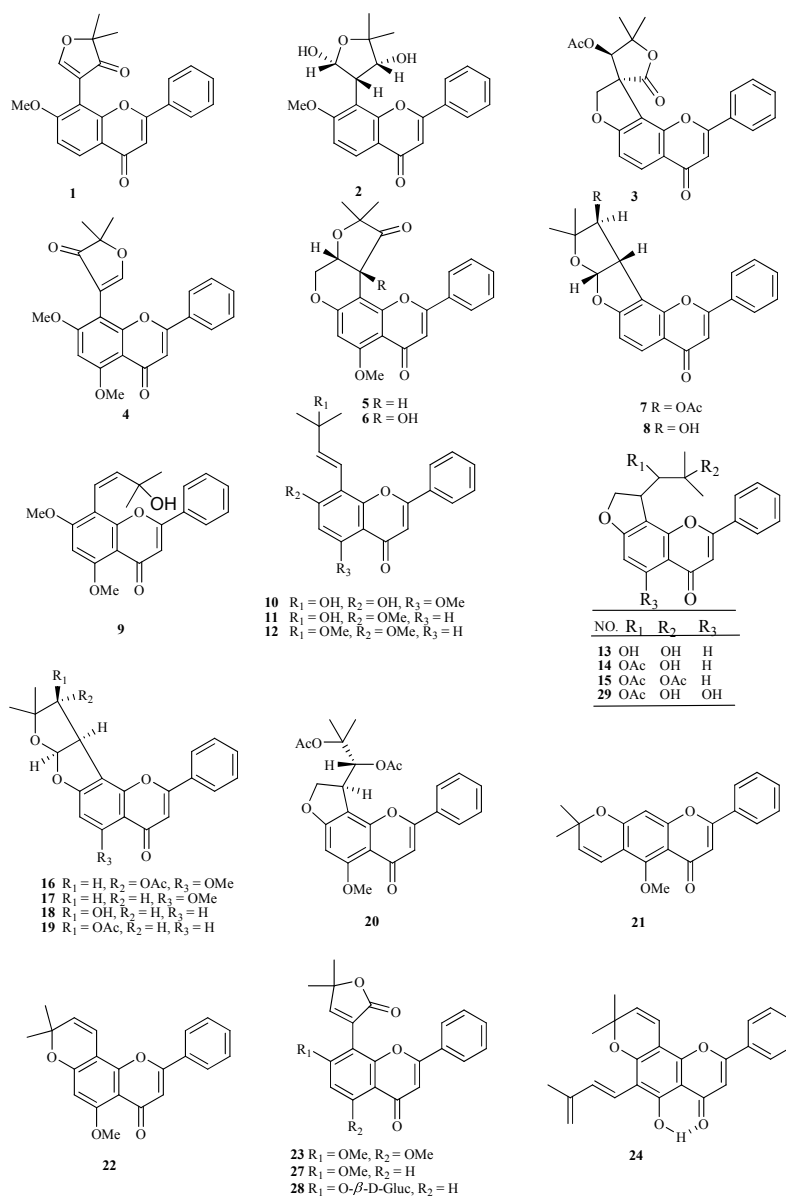
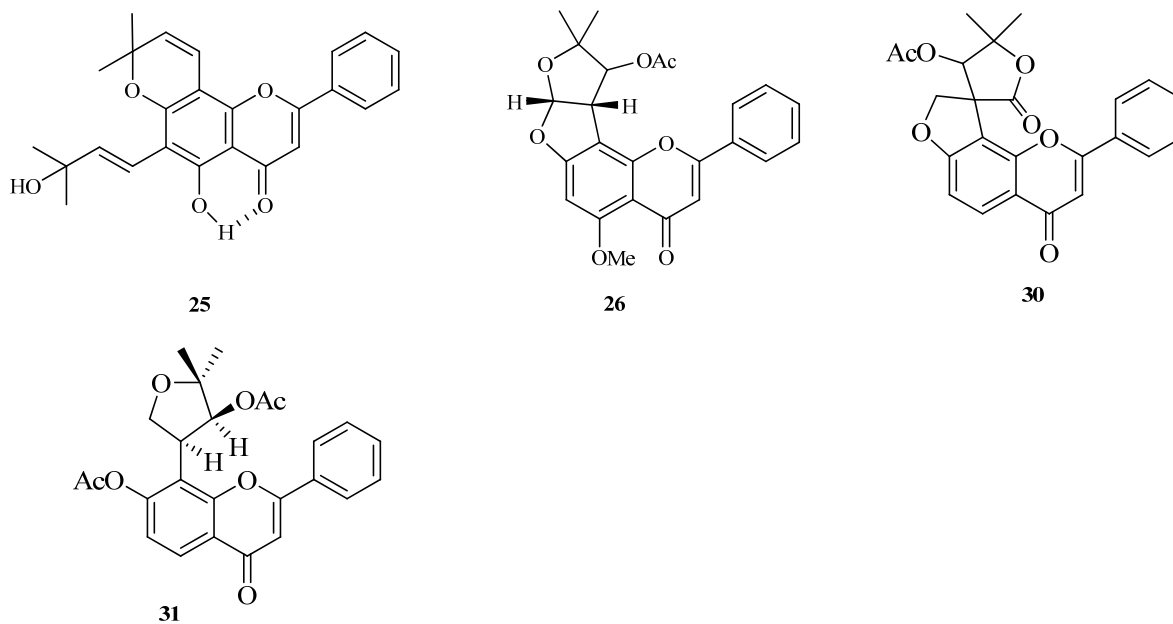


Figure 1. Cont.

Figure 2. Flavonols from genus *Tephrosia*.

32  $R_1 = O-(\alpha\text{-Rha})$ ,  $R_2 = O-(\alpha\text{-Rha}(1\rightarrow2)-[\alpha\text{-Rha}(1\rightarrow6)]-\beta\text{-Gal-}$

33  $R_1 = O-(\alpha\text{-Rha})$ ,  $R_2 = O-(\alpha\text{-Rha}(1\rightarrow6)-\beta\text{-Gal-}$

34  $R_1 = \text{OH}$ ,  $R_2 = O-(\alpha\text{-Rha}(1\rightarrow2)-[\alpha\text{-Rha}(1\rightarrow6)]-\beta\text{-Gal-}$

35  $R_1 = \text{OH}$ ,  $R_2 = O-(\alpha\text{-Rha}(1\rightarrow2)-[(3-O-E\text{-feruloyl})-\alpha\text{-Rha}(1\rightarrow6)]-\beta\text{-Gal-}$

NO.	$R_1$	$R_2$	$R_3$	$R_4$	$R_5$	$R_6$	$R_7$
36	H	ORha	OH	OH	ORha	OMe	H
37	H	OMe	OMe	OMe	OH	OH	H
38	OMe	H	OMe	OH	OMe	OH	H
39	H	OEt	H	H	OH	OH	OH

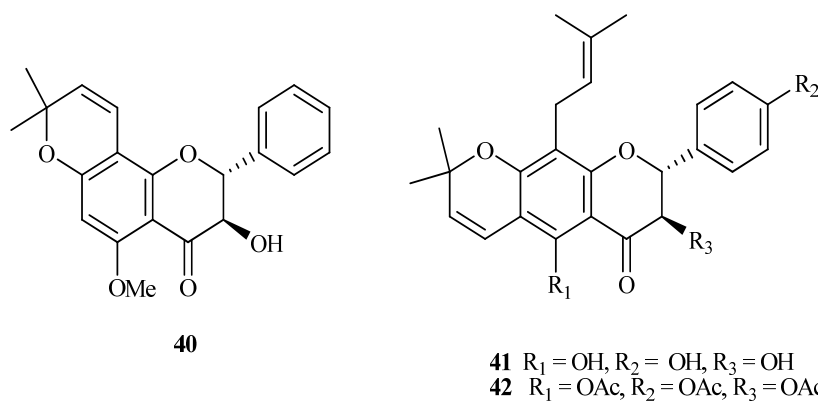
Figure 3. Flavanonols from genus *Tephrosia*.

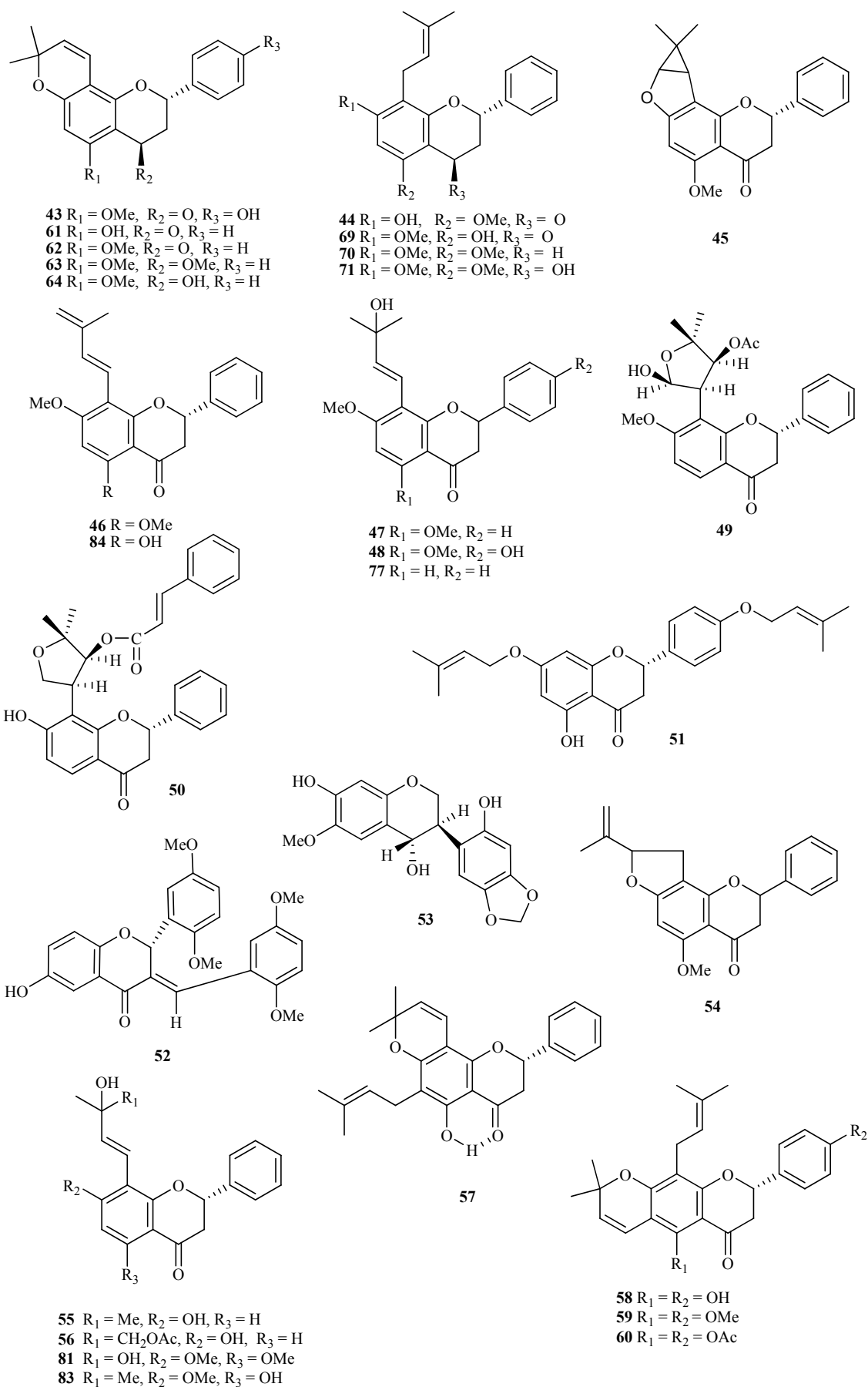
Figure 4. Flavans from genus *Tephrosia*.

Figure 4. Cont.

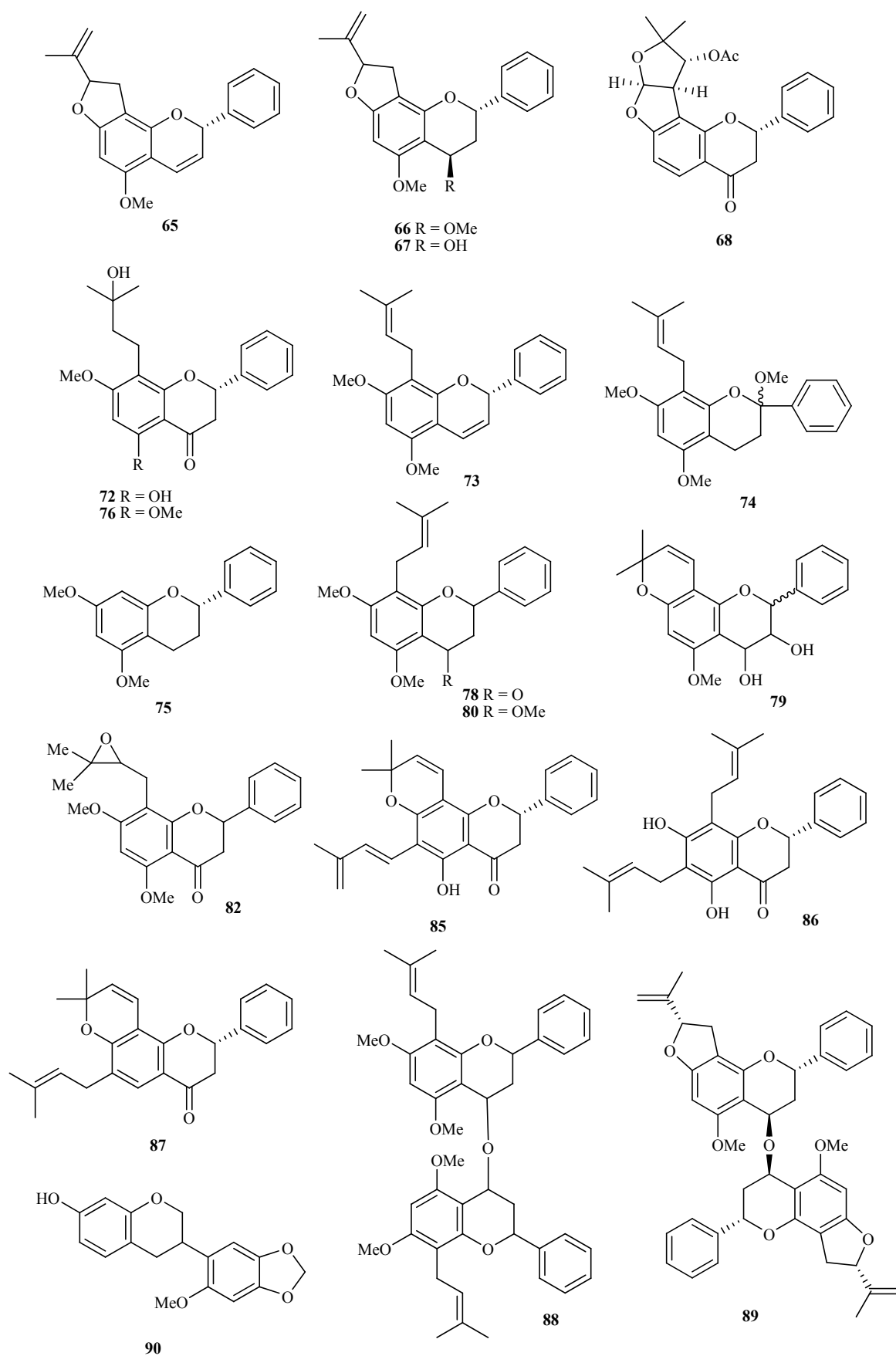


Figure 4. Cont.

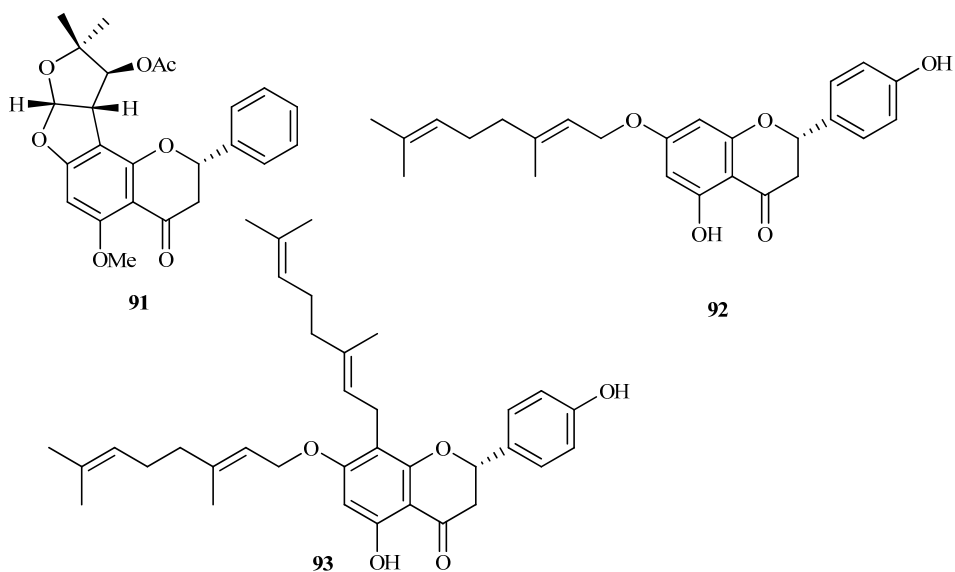
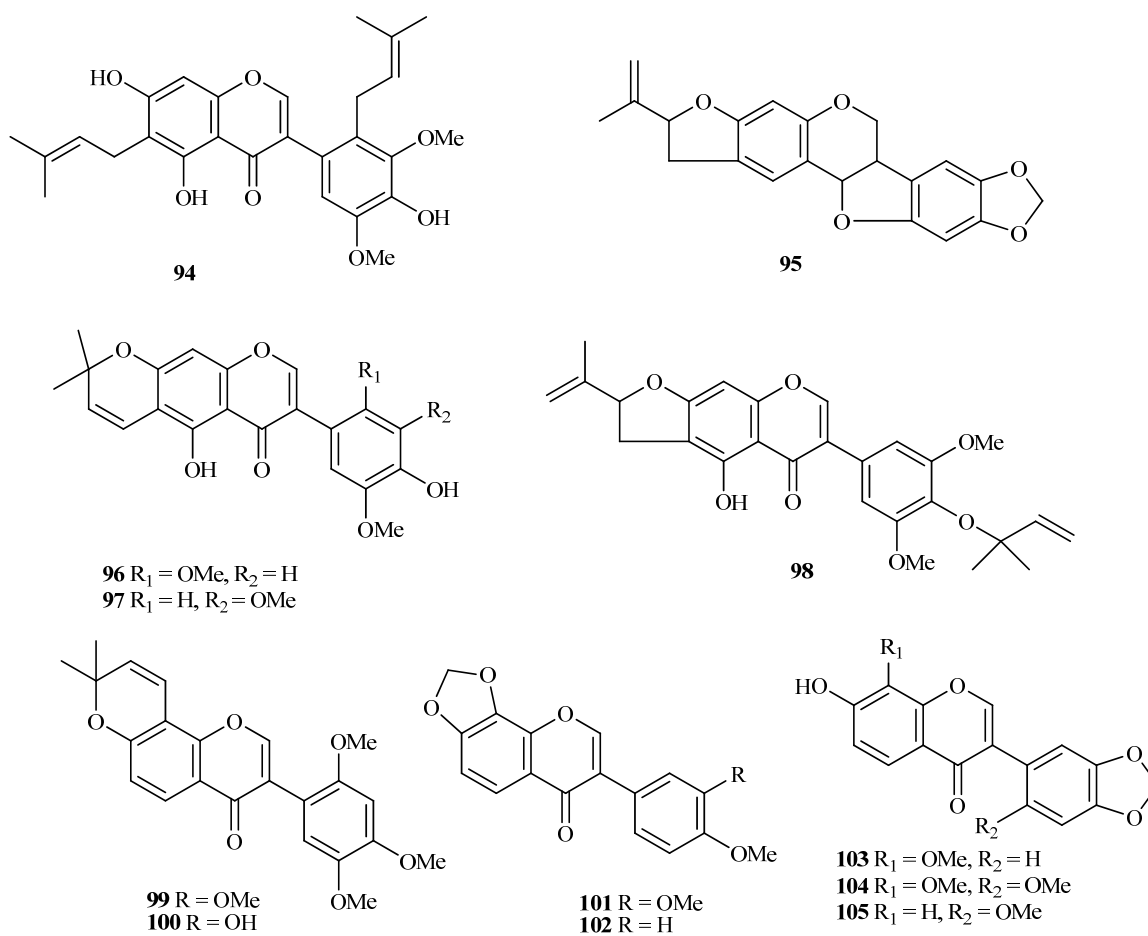
Figure 5. Isoflavones from genus *Tephrosia*.

Figure 5. Cont.

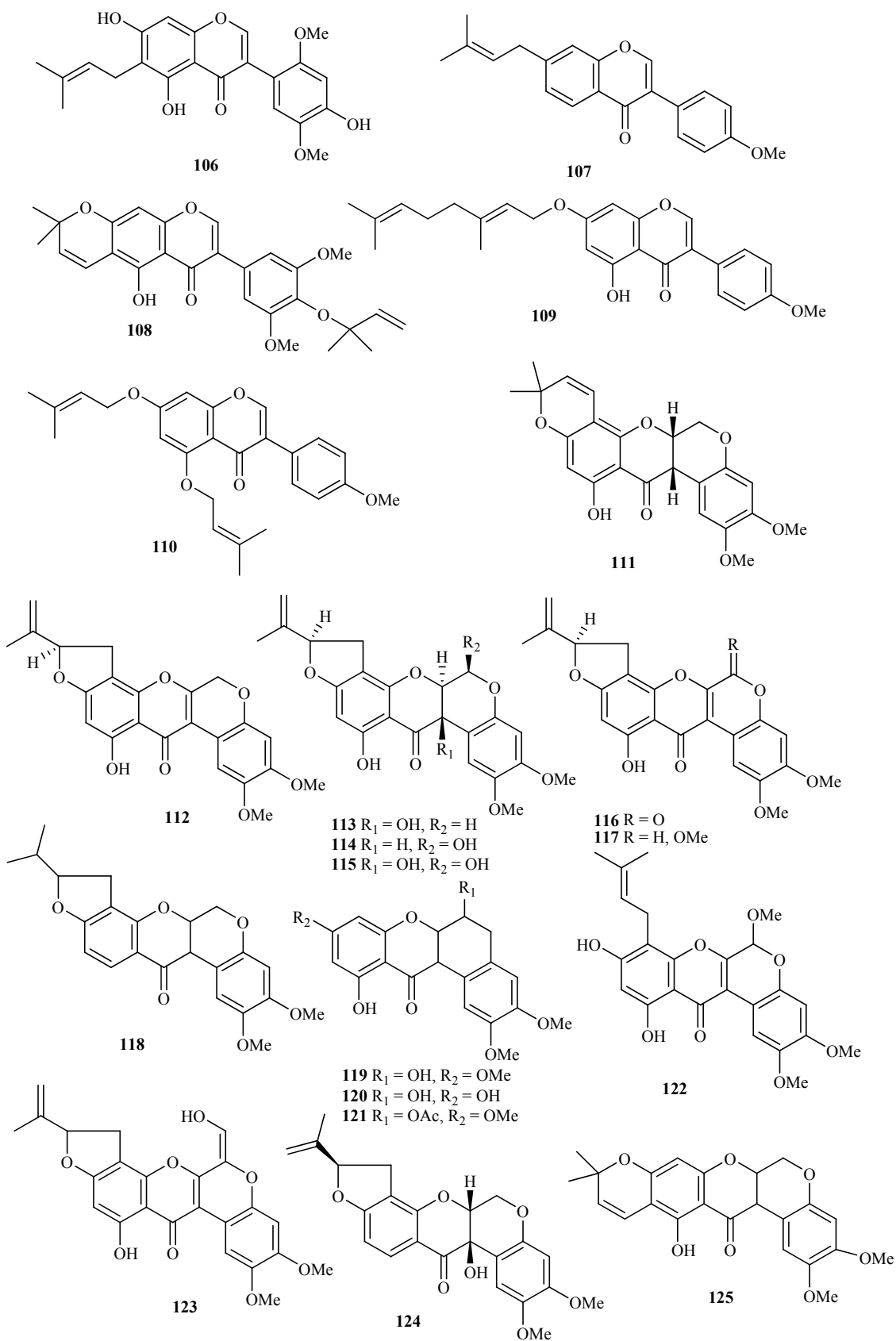


Figure 5. Cont.

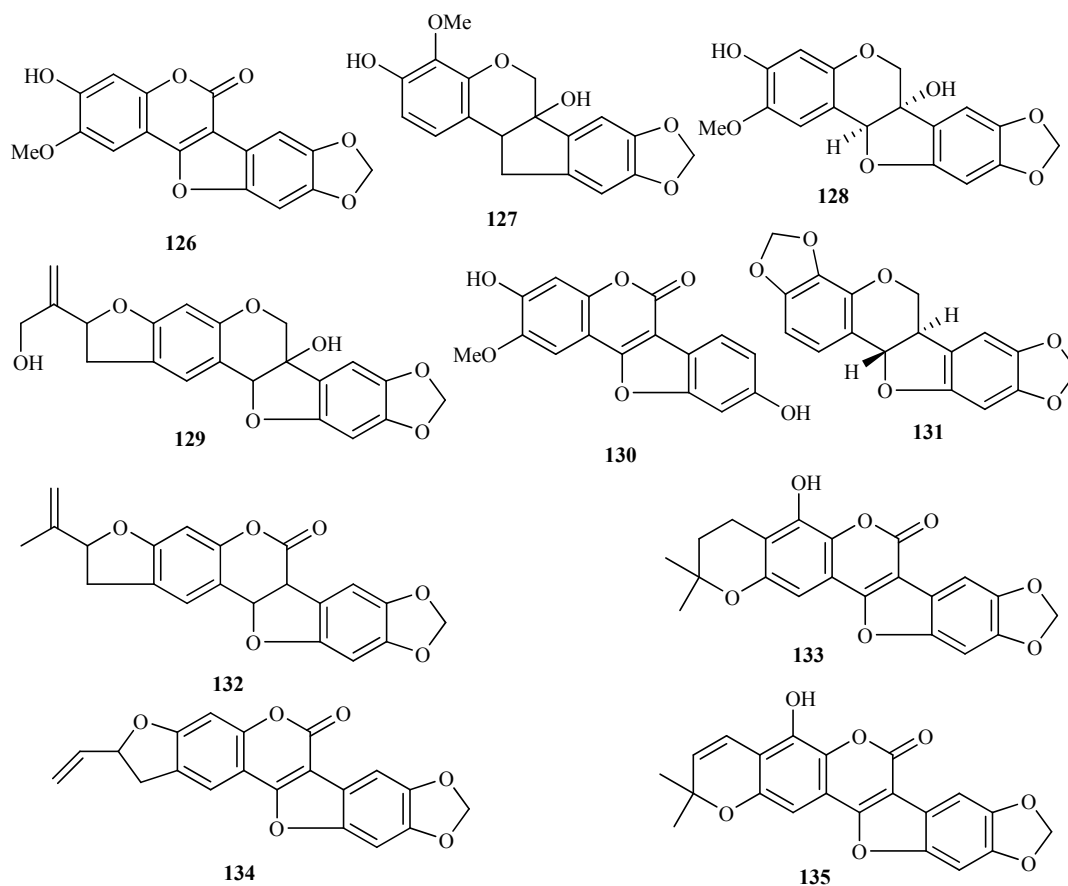
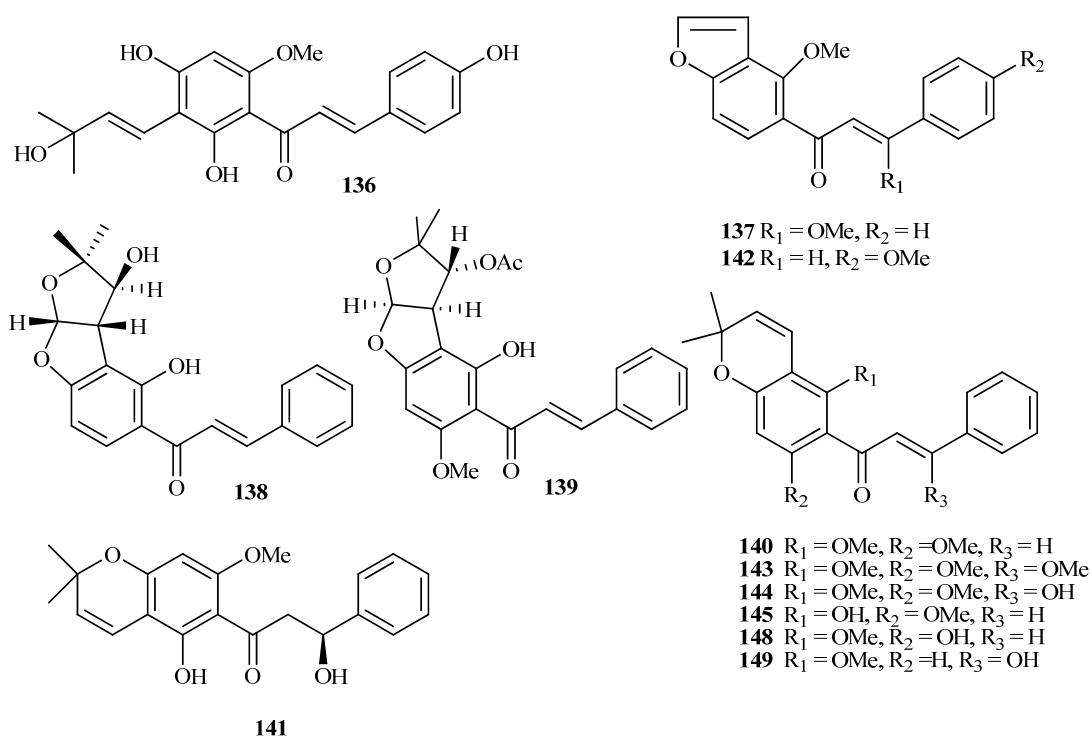
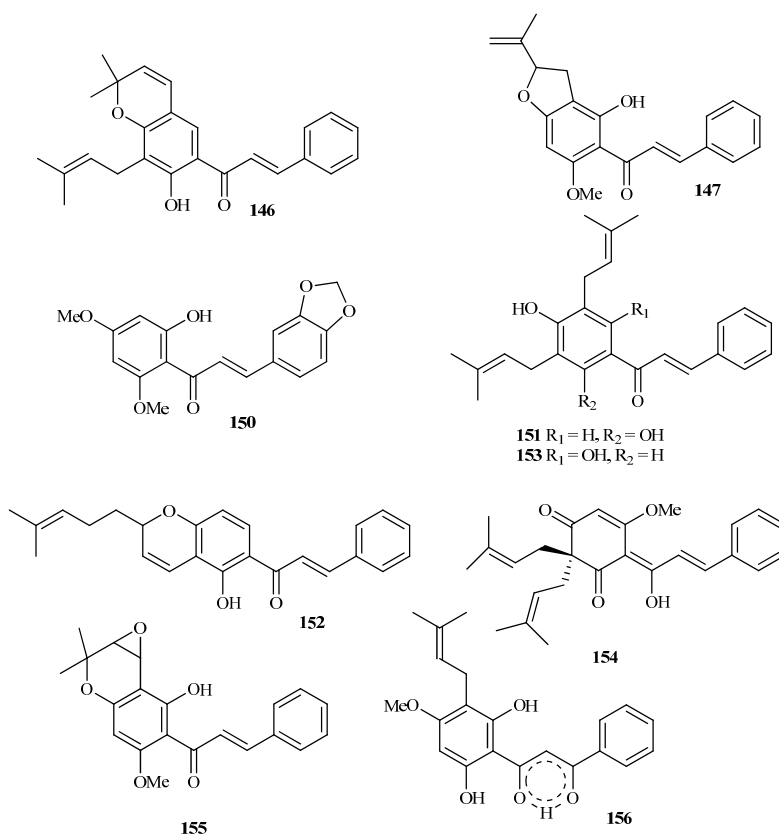
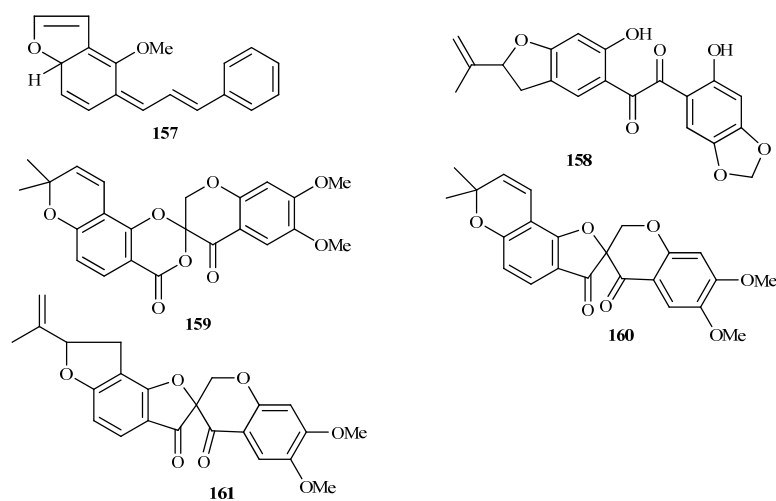
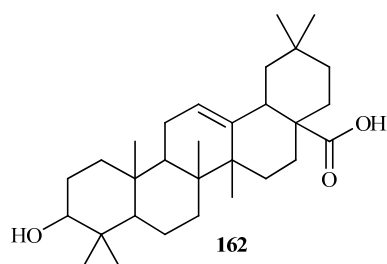
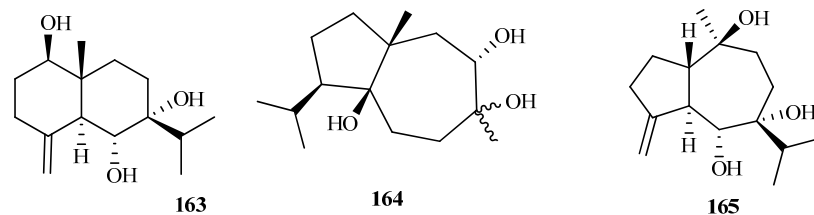
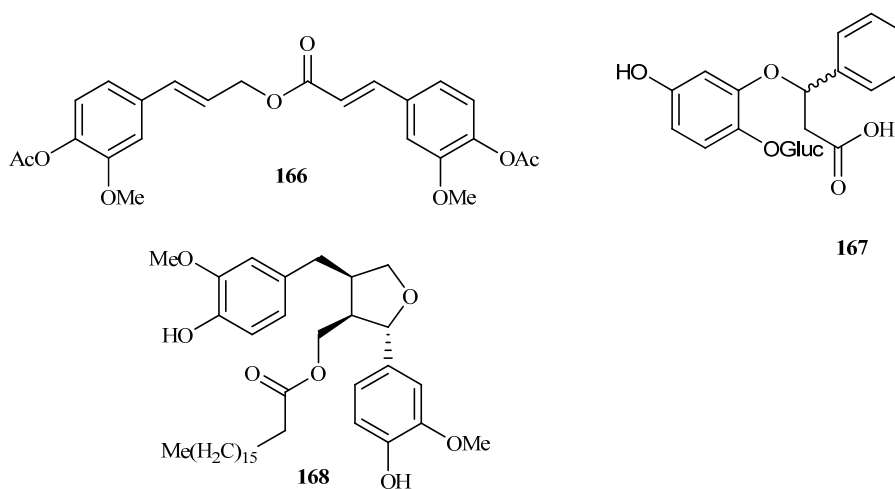
Figure 6. Chalcones from genus *Tephrosia*.



Figure 6. Cont.

Figure 7. Other flavonoids from genus *Tephrosia*.Figure 8. Triterpenoid from genus *Tephrosia*.

**Figure 9.** Sesquiterpenes from genus *Tephrosia*.**Figure 10.** Other compounds from genus *Tephrosia*.**Table 1.** Chemical constituents from the genus *Tephrosia*.

No.	Compound class and name	Source	Ref.
<b>Flavones</b>			
1	tephroglabrin	<i>T. purpurea</i>	[3]
2	tepurindiol	<i>T. purpurea</i>	[3]
3	glabratephrin	<i>T. apollinea</i>	[10]
4	tachrosin	<i>Tephrosia polystachyoides</i>	[17]
5	staohyoidin	<i>T. polystachyoides</i>	[18]
6	tephrodin	<i>T. polystachyoides</i>	[18]
7	semiglabrin	<i>T. semiglabra</i> , <i>T. apollinea</i>	[19,20]
8	semiglabinol	<i>T. semiglabra</i> , <i>T. apollinea</i>	[10,19]
9	tephrostachin	<i>T. polystachyoides</i>	[21]
10	emoroidone	<i>T. emoroides</i>	[22]
11	tephroapollin C	<i>T. apollinea</i>	[23]
12	tephroapollin D	<i>T. apollinea</i>	[23]
13	tephroapollin E	<i>T. apollinea</i>	[23]
14	tephroapollin F	<i>T. apollinea</i>	[23]
15	tephroapollin G	<i>T. apollinea</i>	[23]
16	multijugin	<i>T. multijuga</i>	[24]
17	multijuninol	<i>T. multijuga</i>	[24]
18	pseudosemiglabrinol	<i>T. apollinea</i>	[25]
19	(-)-pseudosemiglabrin	<i>T. semiglabra</i>	[26]

Table 1. Cont.

No.	Compound class and name	Source	Ref.
20	polystachin	<i>T. polystachya</i>	[27]
21	5-methoxy-6,6-dimethylpyrano[2,3:7,6]flavone	<i>T. praecans</i>	[28]
22	candidin	<i>T. candida</i>	[29]
23	hookerianin	<i>T. hookeriana</i>	[30]
24	fulvinervin B	<i>T. fulvinervis</i>	[31]
25	fulvinervin C	<i>T. fulvinervis</i>	[32]
26	enantiomultijugin	<i>T. viciodes</i>	[33]
27	apollinine	<i>T. purpurea</i>	[34]
28	demethylapollinin 7- <i>O</i> - $\beta$ -D-glucopyranoside	<i>T. cinerea</i>	[35]
29	tephropurpulin A	<i>T. apollinea</i> , <i>T. purpurea</i>	[36,37]
30	isoglabratephrin	<i>T. purpurea</i>	[37]
31	terpurinflavone	<i>T. purpurea</i>	[38]
<b>Flavonols</b>			
32	6-hydroxykaempferol 6-methyl ether 3- <i>O</i> - $\alpha$ -rhamnopyranosyl(7 $\rightarrow$ 6)- $\beta$ -galactopyranoside-7- <i>O</i> - $\alpha$ -rhamnopyranoside	<i>T. vogelii</i>	[1]
33	6-hydroxykaempferol 6-methyl ether 3- <i>O</i> - $\alpha$ -rhamnopyranosyl(1 $\rightarrow$ 2)[ $\alpha$ -rhamnopyranosyl(1 $\rightarrow$ 6)- $\beta$ -galactopyranoside	<i>T. vogelii</i>	[1]
34	6-hydroxykaempferol 6-methyl ether 3- <i>O</i> - $\alpha$ -rhamnopyranosyl(1 $\rightarrow$ 2)[ $\alpha$ -rhamnopyranosyl(1 $\rightarrow$ 6)]- $\beta$ -galactopyranoside-7- <i>O</i> - $\alpha$ -rhamnopyranoside	<i>T. vogelii</i>	[1]
35	6-hydroxykaempferol 6-methyl ether 3- <i>O</i> - $\alpha$ -rhamnopyranosyl(1 $\rightarrow$ 2)[(3- <i>O</i> - <i>E</i> -feruloyl)- $\alpha$ -rhamnopyranosyl(1 $\rightarrow$ 6)]- $\beta$ -galactopyranosides	<i>T. vogelii</i>	[1]
36	6-hydroxykaempferol 4'-methyl ether	<i>T. candida</i>	[39]
37	candidol		[40]
38	candirone	<i>T. candida</i>	[41,42]
39	7-ethoxy-3,3',4'-trihydroxyflavone	<i>T. procumbens</i>	[43]
<b>Flavanonols</b>			
40	(2 <i>R</i> ,3 <i>R</i> )-3-hydroxy-5-methoxy-6",6"-dimethylpyrano[2",3":7,8]flavanone	<i>T. vogelii</i>	[1]
41	lupinifolinol	<i>T. lupinifolia</i>	[44]
42	lupinifolinol triacetate	<i>T. lupinifolia</i>	[44]
<b>Flavans</b>			
43	(2 <i>S</i> )-4'-hydroxy-5-methoxy-6",6"-dimethylpyrano[2",3":7,8]-flavanone	<i>T. vogelii</i>	[1]
44	(2 <i>S</i> )-7-hydroxy-5-methoxy-8-prenylflavanone	<i>T. vogelii</i>	[1]
45	(2 <i>S</i> )-5-methoxy-6",6"-dimethyl-4",5"-dihydrocyclopropa-[4",5"]furano[2",3":7,8]flavanone	<i>T. vogelii</i>	[1]
46	(2 <i>S</i> )-5,7-dimethoxy-8-(3-methylbut-1,3-dienyl)flavanone	<i>T. vogelii</i>	[1]
47	tephrocandidin A	<i>T. candida</i>	[2]
48	tephrocandidin B	<i>T. candida</i>	[2]
49	(+)-tephrorin A	<i>T. purpurea</i>	[4]

Table 1. Cont.

No.	Compound class and name	Source	Ref.
50	(+)-tephrorin B	<i>T. purpurea</i>	[4]
51	(2 <i>S</i> )-5-hydroxy-7,4'-di- <i>O</i> -( $\gamma,\gamma$ -dimethylallyl)flavanone	<i>T. calophylla</i>	[6]
52	6-hydroxy- <i>E</i> -3-(2,5-dimethoxybenzylidene)-2',5'-dimethoxyflavanone	<i>T. calophylla</i>	[6]
53	pumilanol	<i>T. pumila</i>	[13]
54	emoroidenone	<i>T. emoroides</i>	[22]
55	tephroapollin A	<i>T. apollinea</i>	[23]
56	tephroapollin B	<i>T. apollinea</i>	[23]
57	fulvinervin A	<i>T. fulvinervis</i>	[30]
58	lupinifolin	<i>T. lupinifolia</i>	[44]
59	5,4'- <i>O,O</i> -dimethyl-lupinifolin	<i>T. lupinifolia</i>	[44]
60	lupinifolin diacetate	<i>T. lupinifolia</i>	[44]
61	obovatin	<i>T. obovata</i>	[45]
62	obovatin methyl-ether	<i>T. obovata</i>	[45]
63	methylhildardtoll B	<i>T. hildebrandtii</i>	[46]
64	hildgardtol B	<i>T. hildebrandtii</i>	[46]
65	hildgardtene	<i>T. hildebrandtii</i>	[46]
66	methylhildgardtol A	<i>T. hildebrandtii</i>	[46]
67	hildgardtol A	<i>T. hildebrandtii</i>	[46]
68	purpurin	<i>T. purpurea</i>	[47]
69	tephrinone	<i>T. villosa</i>	[48]
70	5,7-dimethoxy-8-prenylflavan	<i>T. madrensis</i>	[49]
71	tephrowatsin A	<i>T. watsoniana</i>	[50]
72	tephrowatsin C	<i>T. watsoniana</i>	[50]
73	tephrowatsin B	<i>T. watsoniana</i>	[50]
74	tephrowatsin D	<i>T. watsoniana</i>	[50]
75	tephrowatsin E	<i>T. watsoniana</i>	[50]
76	nitentin	<i>T. nitens</i>	[51]
77	falciformin	<i>T. falciformis</i>	[52]
78	candidone	<i>T. candida</i>	[53]
79	quercetol A	<i>T. quercetorum</i>	[54]
80	quercetol B	<i>T. quercetorum</i>	[54]
81	quercetol C	<i>T. quercetorum</i>	[54]
82	5,7-dimethoxy-8-(2,3-epoxy-3-methylbutyl)-flavanone	<i>T. hamiltonii</i>	[55]
83	tephroleocarpin A	<i>T. leiocarpa</i>	[56]
84	tephroleocarpin B	<i>T. leiocarpa</i>	[56]
85	spinoflavanone A	<i>T. spinosa</i>	[57]
86	spinoflavanone B	<i>T. spinosa</i>	[57]
87	maxima flavanone A	<i>T. maxima</i>	[58]
88	tepicanol A	<i>T. tepicana</i>	[59]
89	crassifolin	<i>T. crassifolia</i>	[60]
90	astraciceran	<i>T. strigosa</i>	[61]
91	(+)-apollineanin	<i>T. apollinea</i>	[62]
92	(2 <i>S</i> )-5,4'-dihydroxy-7- <i>O</i> -[ <i>E</i> -3,7-dimethyl-2,6-octadienyl]flavanone	<i>T. villosa</i>	[63]

Table 1. Cont.

No.	Compound class and name	Source	Ref.
<b>Isoflavones</b>			
93	(2S)-5,4'-dihydroxy-7-O-[E-3,7-dimethyl-2,6-octa-dienyl]-8-C-[E-3,7-dimethyl-2,6-octadienyl]flavanone	<i>T. villosa</i>	[63]
94	7,4'-dihydroxy-3',5'-dimethoxyisoflavone	<i>T. purpurea</i>	[5]
95	emoroidocarpan	<i>T. emoroides</i>	[22]
96	elongatin	<i>T. elongate</i>	[64]
97	pumilaisoflavone D	<i>T. pumila</i>	[65]
98	pumilaisoflavone C	<i>T. pumila</i>	[65]
99	barbigerone	<i>T. barbigerana</i>	[66]
100	4'-demethyltoxicarol isoflavone	<i>T. polyphylla</i>	[67]
101	maxima isoflavone D	<i>T. maxima</i>	[68]
102	maxima isoflavone E	<i>T. maxima</i>	[68]
103	maxima isoflavone F	<i>T. maxima</i>	[68]
104	maxima isoflavone G	<i>T. maxima</i>	[68]
105	viridiflorin	<i>T. viridiflora</i>	[69]
106	maxima isoflavone J	<i>T. maxima</i>	[70]
107	pumilaisoflavone A	<i>T. pumila</i>	[71]
108	pumilaisoflavone B	<i>T. pumila</i>	[71]
109	7-O-geranylbiochanin A	<i>T. tinctoria</i>	[72]
110	5,7-di-O-prenylbiochanin A	<i>T. tinctoria</i>	[73]
111	toxicarol	<i>T. toxicaria</i>	[74]
112	villosinol	<i>T. villosa</i>	[75]
113	villosol	<i>T. villosa</i>	[75]
114	villosin	<i>T. villoss</i>	[76]
115	villol	<i>T. villoss</i>	[76]
116	villosone	<i>T. villoss</i>	[76]
117	villinol	<i>T. villoss</i>	[76]
118	dehydrodihydrorotenone	<i>T. candida</i>	[77]
119	dihydrostemonal	<i>T. pentaphylla</i>	[78]
120	9-demethyldihydrostemonal	<i>T. pentaphylla</i>	[78]
121	6-acetoxydihydrostemonal	<i>T. pentaphylla</i>	[78]
122	6a,12a-dehydro-2,3,6-trimethoxy-8-(3',3'-dimethylallyl)-9,11-dihydroxyrotenone	<i>T. villosa</i>	[79]
123	12a-dehydro-6-hydroxysumatrol	<i>T. villosa</i>	[80]
124	12a-hydroxyrotenone	<i>T. uniflora</i>	[81]
125	12a-hydroxy- $\beta$ -toxicarol	<i>T. candida</i>	[82]
126	tephrosol	<i>T. villosa</i>	[83]
127	tephrocarpin	<i>T. bidwilli</i>	[84]
128	hildecarpin	<i>T. hildebrandtii</i>	[85,86]
129	hildecarpidin	<i>T. hildebrandtii</i>	[87]
130	2-methoxy-3,9-dihydroxy coumestone	<i>T. hamiltonii</i>	[88]
131	3,4:8,9-dimethylenedioxypterocarpan	<i>T. aequilata</i>	[89]
132	tephcalostan	<i>T. calophylla</i>	[90]
133	tephcalostan B	<i>T. calophylla</i>	[91]

Table 1. Cont.

No.	Compound class and name	Source	Ref.
<b>Chalcones</b>			
134	tephcalostan C	<i>T. calophylla</i>	[91]
135	tephcalostan D	<i>T. calophylla</i>	[91]
136	candidachalcone	<i>T. candida</i>	[2]
137	<i>O</i> -methylpongamol	<i>T. purpurea</i>	[3]
138	(+)-tephrosone	<i>T. purpurea</i>	[4]
139	(+)-tephropurpurin	<i>T. purpurea</i>	[5]
140	2',6'-dimethoxy-4',5'-(2''dimethyl)-pyranochalcone	<i>T. pulcherrima</i>	[7]
141	( <i>S</i> )-elatadihydrochalcone	<i>T. elata</i>	[14]
142	purpuritenin	<i>T. purpurea</i>	[15]
143	praecansone A	<i>T. praecans</i>	[28]
144	praecansone B	<i>T. praecans</i>	[28]
145	obovatachalcone	<i>T. obovata</i>	[45]
146	spinochalcone C	<i>T. spinosa</i>	[57]
147	crassichalone	<i>T. crassifolia</i>	[60]
148	oaxacacin	<i>T. woodii</i>	[92]
149	6'-demethoxypraecansone B	<i>T. purpurea</i>	[93]
150	tephrone	<i>T. candida</i>	[94]
151	spinochalcone A	<i>T. spinosa</i>	[95]
152	spinochalcone B	<i>T. spinosa</i>	[95]
153	3',5'-diisopentenyl-2',4'-dihydroxychalcone	<i>T. spinosa</i>	[96]
154	tunicatachalcone	<i>T. tunicate</i>	[97]
155	epoxyobovatachalcone	<i>T. carrollii</i>	[98]
156	2',6'-dihydroxy-3'-prenyl-4'-methoxy- $\beta$ -hydroxychalcone	<i>T. major</i>	[99]
<b>Other Flavonoids</b>			
157	purpureamethied	<i>T. purpurea</i>	[15]
158	calophione A	<i>T. calophylla</i>	[91]
159	tephrospirolactone	<i>T. candida</i>	[100]
160	tephrospiroketone I	<i>T. candida</i>	[100]
161	tephrospiroketone II	<i>T. candida</i>	[100]
<b>Triterpenoid</b>			
162	oleanolic acid	<i>T. strigosa</i>	[61]
<b>Sesquiterpenes</b>			
163	1 $\beta$ -hydroxy-6,7 $\alpha$ -dihydroxyeudesm-4(15)-ene	<i>T. candida</i>	[2]
164	linkitriol	<i>T. purpurea</i>	[34]
165	1 $\beta$ ,6 $\alpha$ ,10 $\alpha$ -guai-4(15)-ene-6,7,10-triol	<i>T. vogelii</i>	[101]
<b>Others</b>			
166	2-propenoic acid, 3-(4-(acetyloxy)-3-methoxyphenyl)-3(4-actyloxy)-3-methoxyphenyl)-2-propenyl ester	<i>T. purpurea</i>	[34]
167	cinoside A	<i>T. cinerea</i>	[35]
168	(+)-lariciresinol-9'-stearate	<i>T. vogelii</i>	[101]

## 2.1. Flavonoids

Flavonoids were the most main constituents of the genus *Tephrosia*, even of the Leguminosae family. From the year of 1971, 161 flavonoids isolated from the genus *Tephrosia* are divided into several categories depending on their skeletons (Figures 1–7).

### 2.1.1. Flavones

Thirty-one flavones (**1–31**), were isolated from *T. polystachyoides*, *T. semiglabra*, *T. multijuga*, *T. polystachya*, *T. praecans*, *T. apollinea*, *T. candida*, *T. purpurea*, *T. fulvinervis*, *T. viciodes*, *T. emoroids* and *T. hookeriana* [3,10,17–38].

### 2.1.2. Flavonols

Eight flavonols (**32–39**), were isolated, four, *i.e.*, **32–34** were obtained from *T. vogelii* [1], one, *i.e.*, **35–38**, from *T. candida* [39–42] and **39** from *T. procumbens* [43].

### 2.1.3. Flavanonols

Only three flavanonols, **40**, **41** and **42** were isolated from *T. vogelii* and *T. lupinifolia*, respectively [1,44].

### 2.1.4. Flavans

Fifty-one flavans, **43–93**, were isolated from twenty-three species of the genus *Tephrosia*, *i.e.*, *T. obovata*, *T. villosa*, *T. madrensis*, *T. nitens*, *T. watsoniana*, *T. hildebrandtii*, *T. falciformis*, *T. hamiltonii*, *T. quercetorum*, *T. leiocarpa*, *T. spinosa*, *T. maxima*, *T. emoroides*, *T. tepicana*, *T. crassifolia*, *T. strigosa*, *T. pumila*, *T. calophylla*, *T. vogelii*, *T. apollinea*, *T. candida*, *T. purpurea* and *T. fulvinervis* [1,2,4,6,13,22,23,44–63].

### 2.1.5. Isoflavones

Forty-two isoflavones, **94–135**, have been isolated and identified from this genus [5,22,64–91]. Among them, **111–125** were identified as rotenoids [74–82], **94** and **126–135** were identified as coumestan derivatives [22,83–91].

### 2.1.6. Chalcones

Twenty-one chalcones, **136–156**, isolated from twelve species of genus *Tephrosia*, *i.e.*, *T. obovata*, *T. praecans*, *T. purpurea*, *T. candida*, *T. woodii*, *T. spinosa*, *T. crassifolia*, *T. tunicate*, *T. carrollii*, *T. major*, *T. pulcherrima* and *T. elata* [2–5,7,14,15,28,45,57,60,92–99].

### 2.1.7. Other Flavonoids

**157** was isolated from *T. purpurea* seeds [15]. **158** was isolated from *T. calophylla* [91]. **159–161** were isolated from *T. candida* [100].

## 2.2. Triterpenoid

Only one triterpenoid has been isolated from this genus, that is **162** from *T. strigosa* [61].

### 2.3. Sesquiterpenes

Three sesquiterpenes, **163**, **164** and **165** were isolated from *T. candida* [2], *T. purpurea* [33] and *T. vogelii* [101], respectively.

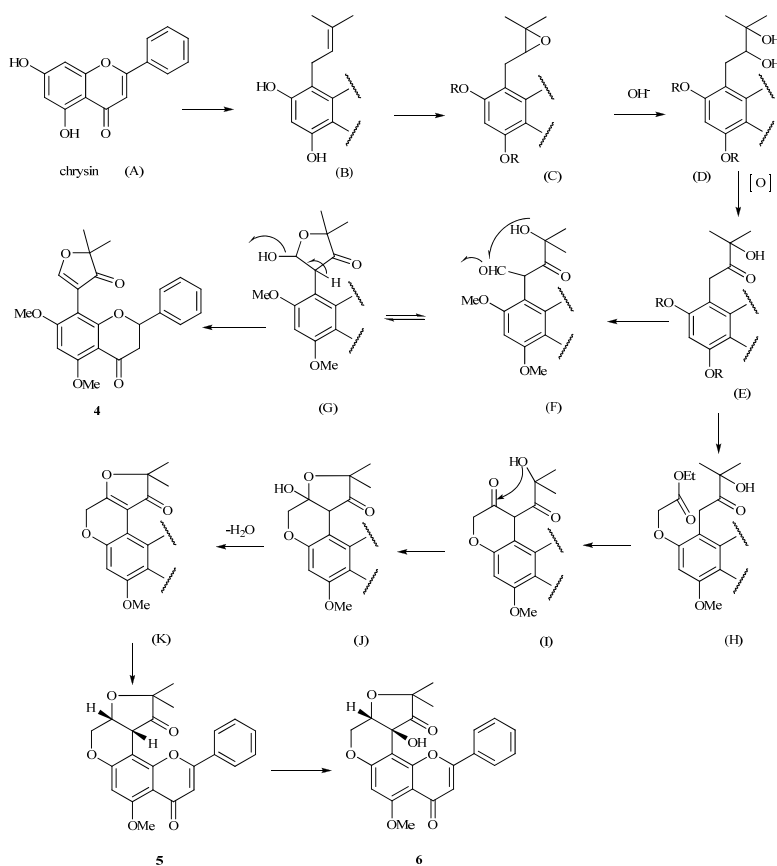
### 2.4. Others

**166–168** have been isolated from *T. purpurea* [34], *T. cinerea* [35] and *T. vogelii* [101], respectively.

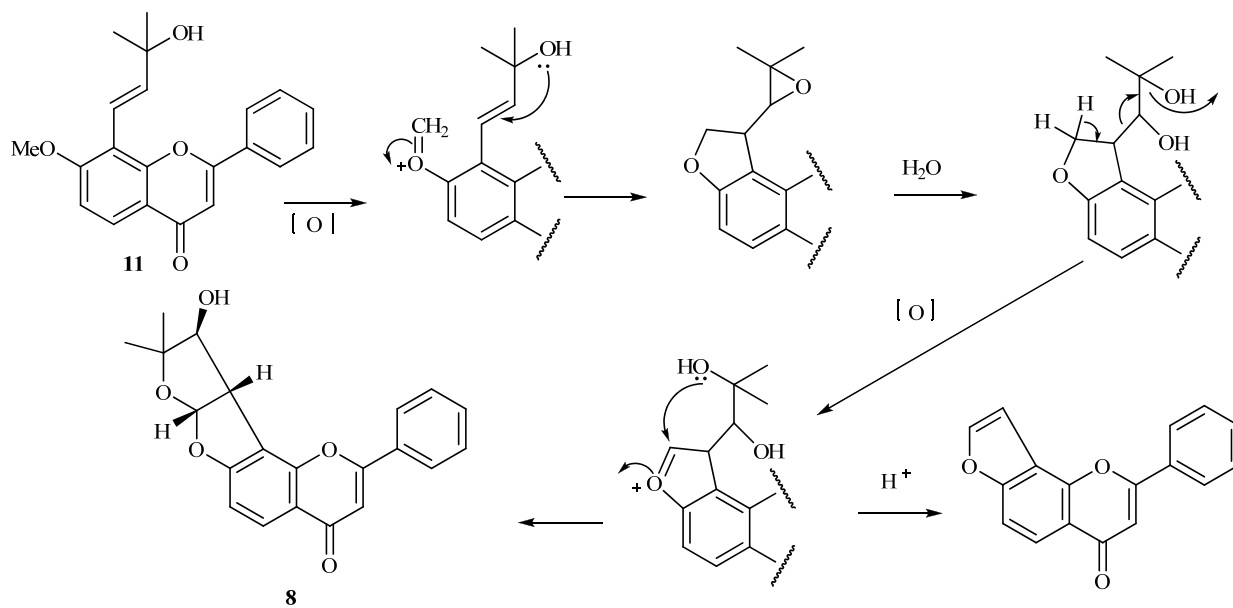
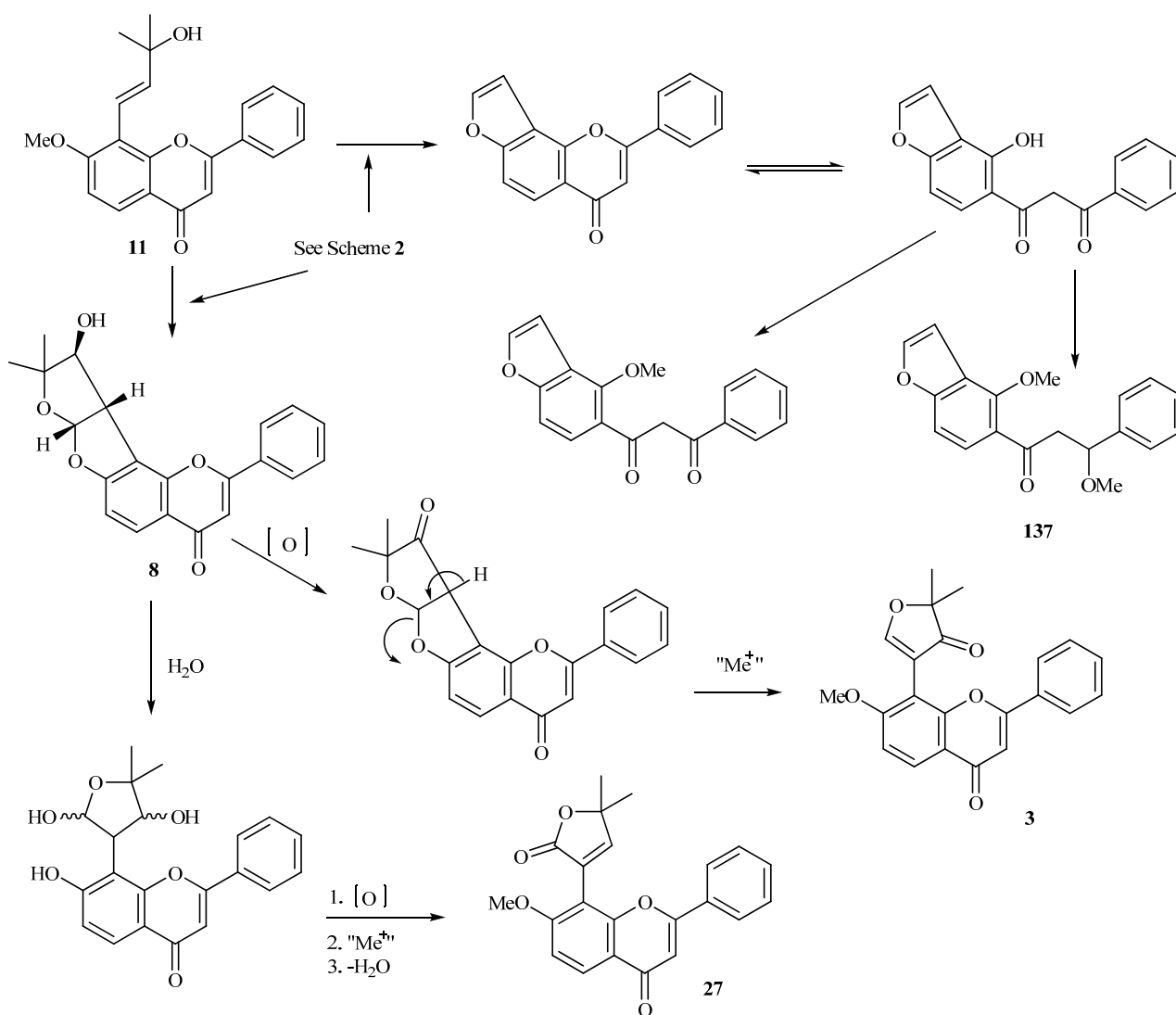
## 3. Proposed Biosynthetic Pathways and Synthesis

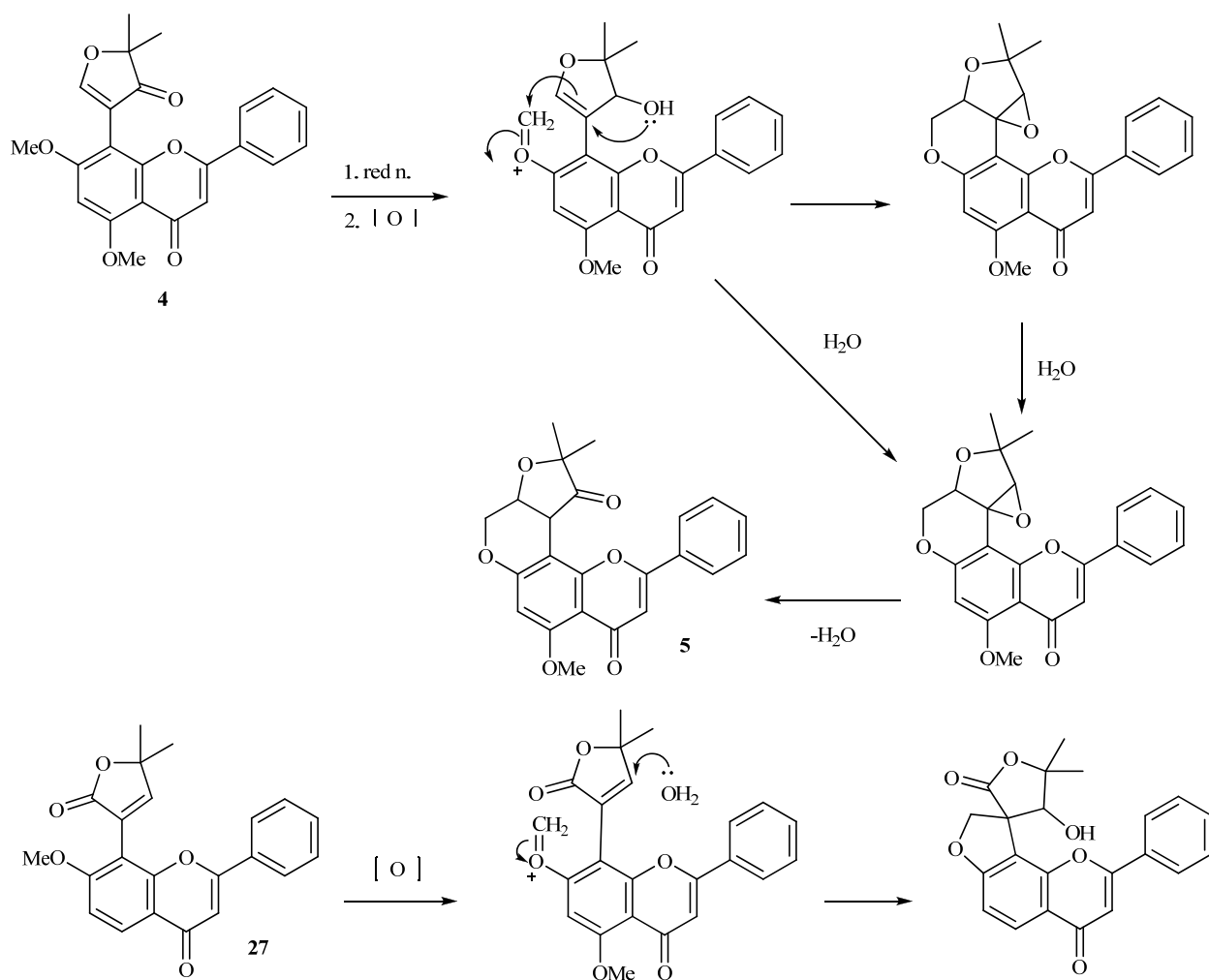
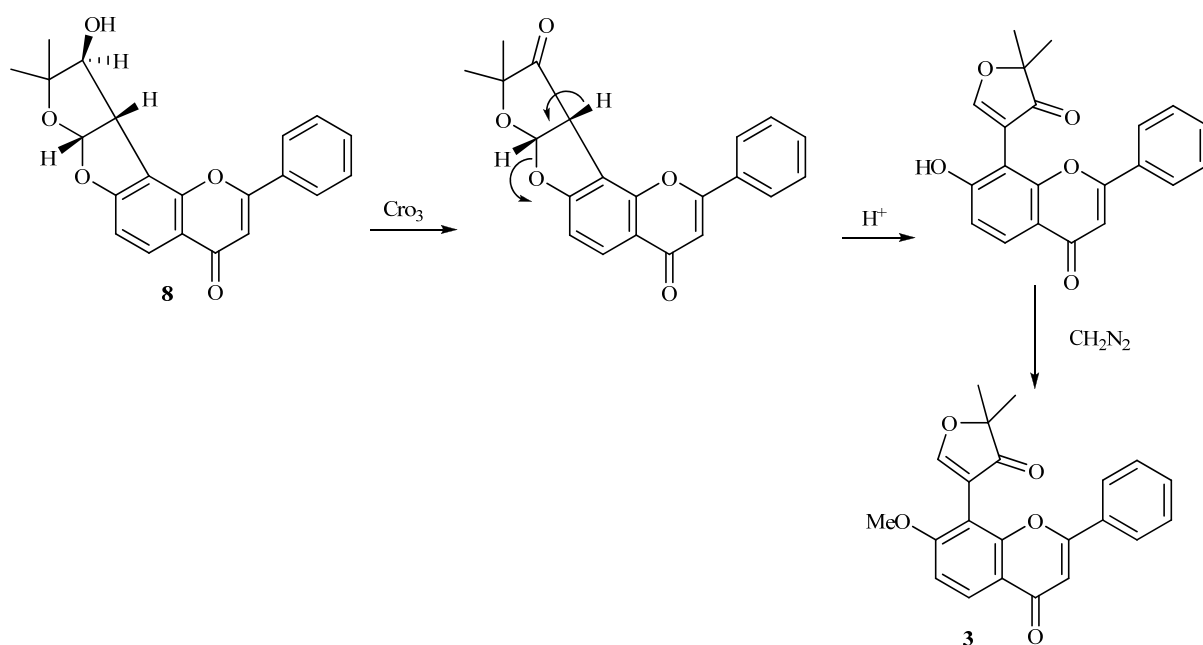
8-Substituted isoflavonoids such as toxicarol isoflavone and rotenoids are well known [3]. Compounds **4–6** from *T. polystachyoides* could be explained to be evolved biogenetically from naturally occurring chrysin (A) as illustrated in the Scheme 1 [102]. It would appear that the complex substituents at C-8 arise from the ability of *Tephrosia* species to oxidise a 7-OMe group to a  $-O^+=CH_2$  group (Scheme 2), in the same way that closely related species of Leguminosae oxidise the 2'-OMe group of isoflavonoids to yield rotenoids [103]. A pattern that explains the various C-8 substituents in *T. purpurea* and *T. apollinea* is shown in Scheme 3. In *T. polystachyoides* this process is taken even further and the carbon of yet another 7-OMe group is incorporated into the additional rings attached to C-7 and C-8 (Scheme 4) [3]. We could confirm the structures of compounds **7** and **8** by their conversion into semiglabinone, isoemiglabinone and tephroglabrin (**3**) as shown in Scheme 5 [3]. Purpuritenin (**142**) was isolated from *T. purpurea* has been synthesised as showed in Scheme 6 [104].

**Scheme 1.** Possible biogenetic pathway of compounds **4–6** of *T. polystachyoides*.

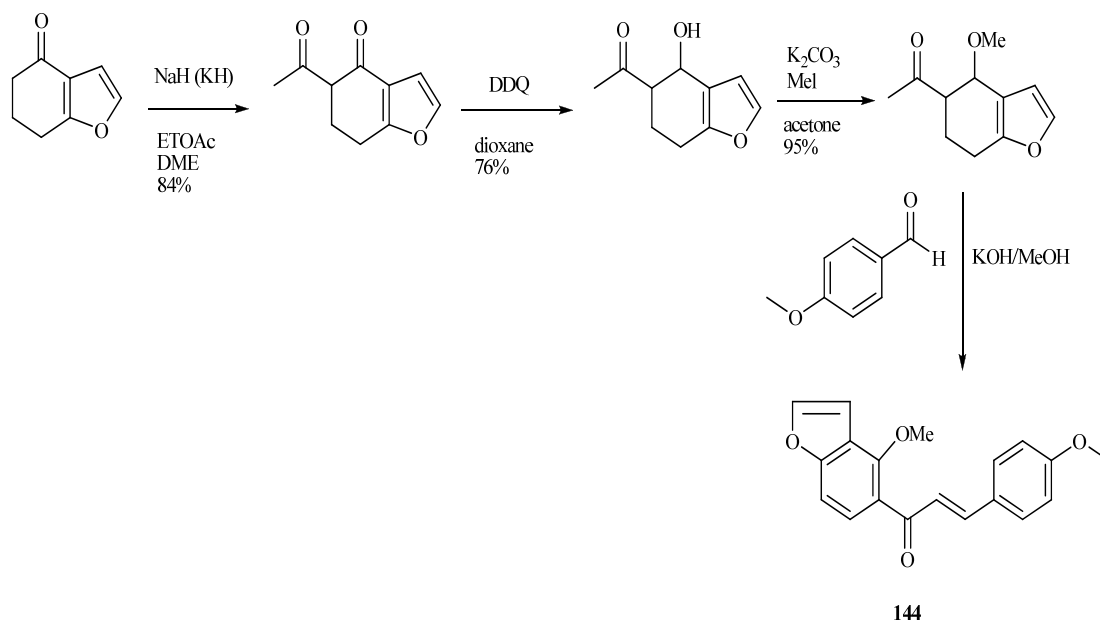




**Scheme 2.** Possible biogenetic pathway of compounds **8** and **11**.**Scheme 3.** Possible biogenetic pathway of compounds **3**, **8**, **11**, **27** and **137**.

**Scheme 4.** Possible biogenetic pathway of compounds **4**, **5** and **137**.**Scheme 5.** Transform of compounds **3** and **8**.

Scheme 6. The synthesis of 144.



#### 4. Biological Activities

The chemical constituents from the genus *Tephrosia* have been shown to exhibit various bioactivities, such as estrogenic, antitumor, antimicrobial, antiprotozoal, and antifeedant activities [2,105].

##### 4.1. Estrogenic Activity

Candidachalcone (**136**) isolated from *T. candida* exhibited estrogenic activity with  $IC_{50}$  value of 80  $\mu$ M, compared with 18  $\mu$ M for the natural steroid 17  $\beta$ -estradiol [2].

##### 4.2. Antitumor Activities

Calophione A (**158**) and tephcalostans B–D (**133–135**) from *T. calphylla* were evaluated for cytotoxicity against RAW (mouse macrophage cells) and HT-29 (colon cancer cells) cancer cell lines. **158** exhibited significant cytotoxicity with  $IC_{50}$  of 5.00 (RAW) and 2.90  $\mu$ M (HT-29), respectively, while **133–135** showed moderated cytotoxicity against both RAW and HT-29 cell lines [91]. (+)-Tephrorins A (**49**) and B (**50**), and (+)-tephrosone (**138**) isolated from *T. purpurea* were evaluated for their potential cancer chemopreventive properties using a cell-based quinone reductase induction assay [4]. 7,4'-dihydroxy-3',5'-dimethoxyisoflavone (**94**), and (+)-tephropurpurin (**139**), were obtained as active compounds from *T. purpurea*, using a bioassay based on the induction of quinone reductase (QR) activity with cultured Hepa 1c1c7 mouse hepatoma cells [5].

##### 4.3. Antimicrobial Activities

2',6'-Dimethoxy-4',5'-(2'',2''-dimethyl)-pyranochalcone (**140**) from *T. pulcherrima* showed significant antimicrobial activity when tested against a series of micro-organisms [7]. 3,4:8,9-Dimethylenedioxypterocarpan (**131**) from *T. aequilata* exhibited low activity against

gram-positive bacteria, *Bacillus subtilis* and *Micrococcus lutea* [89]. Hildecarpin (**128**) from *T. hildebrandtii* had exhibited antifungal activity against *Cladosporium cucumerinum* [85,86].

#### 4.4. Antiprotozoal Activities

Terpurinflavone (**31**) isolated from *T. purpurea* showed the highest antiplasmodial activity against the chloroquine-sensitive (D6) and chloroquine-resistant (W2) strains of *Plasmodium falciparum* with  $IC_{50}$  values of  $3.12 \pm 0.28 \mu\text{M}$  (D6) and  $6.26 \pm 2.66 \mu\text{M}$  (W2) [38]. The crude extract of the seedpods of *T. elata* showed antiplasmodial activities against D6 and W2 strains of *P. falciparum* with  $IC_{50}$  values of  $8.4 \pm 0.3$  and  $8.6 \pm 1.0 \mu\text{g/mL}$ , respectively [14]. Obovatin (**61**) and obovatin methyl ether (**62**) from *T. obovata* [45] showed antiplasmodial activities against D6 and W2 strains of *P. falciparum* with  $IC_{50}$  values of  $4.9 \pm 1.7$  and  $6.4 \pm 1.1 \mu\text{g/mL}$ , and  $3.8 \pm 0.3$  and  $4.4 \pm 0.6 \mu\text{g/mL}$ , respectively [14]. (S)-Elatadihydrochalcone (**141**) from *T. elata* exhibited good antiplasmodial activity against the D6 and W2 strains of *P. falciparum* with  $IC_{50}$  values of  $2.8 \pm 0.3$  (D6) and  $5.5 \pm 0.3 \mu\text{g/mL}$  (W2), respectively [14]. Tephcalostans C (**134**) and D (**135**) from *T. calphylla* were found to be weakly antiprotozoal activity *in vitro* [91]. Pumilanol (**53**) from *T. pumila* exhibited significant antiprotozoal activity against *T. b. rhodensiense*, *T. cruzi* and *L. donovani* with  $IC_{50}$  of 3.7, 3.35 and 17.2  $\mu\text{g/mL}$ , respectively, but displayed high toxicity towards L-6 ( $IC_{50}$  of 17.12  $\mu\text{g/mL}$ ) rat skeletal myoblasts [13]. Tephtrinone (**69**) from *T. villosa* [48] also exhibited high degree of activity and selectivity against both *T. b. rhodensiense*, *T. cruzi* and *L. donovani* with  $IC_{50}$  of 3.3 and 16.6  $\mu\text{g/mL}$  [13].

#### 4.5. Antifeedant Activities

Emoroidenone (**54**) from *T. emoroides* showed strong feeding deterrent activity against *Chilo partellus* larvae with a mean percentage deterrence of 66.1% at a dose of 100  $\mu\text{g/disc}$  [22]. Hildecarpin (**128**) from *T. hildebrandtii* had exhibited insect antifeedant activity against the legume pod-borer *Maruca testulalis*, and important pest of cowpea (*Vigna*) [85,86].

#### 4.6. Other Activities

(-)-Pseudosemiglabrin (**19**) from *T. semiglabra* displayed *in vitro* inhibitory effects on human platelet aggregation [26]. Obovatin (**61**), obovatin methyl-ether (**62**) and obovatachalcone (**145**) from *T. obovata* displayed moderate piscicidal activity against loach fish *Misgurnus angullicaudatus*. The TLM (median tolerance limit) values of **61**, **62** and **145** were 1.25, 1.55 and 1.35 ppm, respectively [45]. Toxicarol (**111**) was a constituent of the South American fish poison *T. toxicaria* [74].

## 5. Conclusions

The genus *Tephrosia*, including *ca.* 400 species, with *ca.* 52 species being investigated worldwide, was reported to possess various chemical constituents and to display diverse bioactivities, especially antiplasmodial, estrogenic, antitumor, antimicrobial, antiprotozoal, antifeedant activities. Although the number of natural compounds was isolated from this genus, there are still many *Tephrosia* species that received no little attention further, phytochemical and biological studies on this genus are needed in the future. In addition, the biosynthetic pathways and synthesis of these bioactive molecules in the

genus remained largely unexplored. Thus, much more chemical, biosynthetic, synthetic and biological studies should be carried out on natural compounds in *Tephrosia* species in order to disclose their potency, selectivity, toxicity, and availability.

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### Author Contributions

In this paper, Yinning Chen was in charge of writing the manuscript; Tao Yan was responsible for drawing the structures of the compounds; Chenghai Gao was in charge of correcting the revised manuscript; Wenhao Cao was responsible for searching for the literature; Riming Huang is the corresponding author who was responsible for arranging, checking and revising the manuscript.

### Conflicts of Interest

The authors declare no conflict of interest.

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