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Review

Natural Products from the Genus *Tephrosia*

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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 because they possess the bioactivity of phytoalexins. This review not only outlines the sources, 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; phytoalexins; 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*.

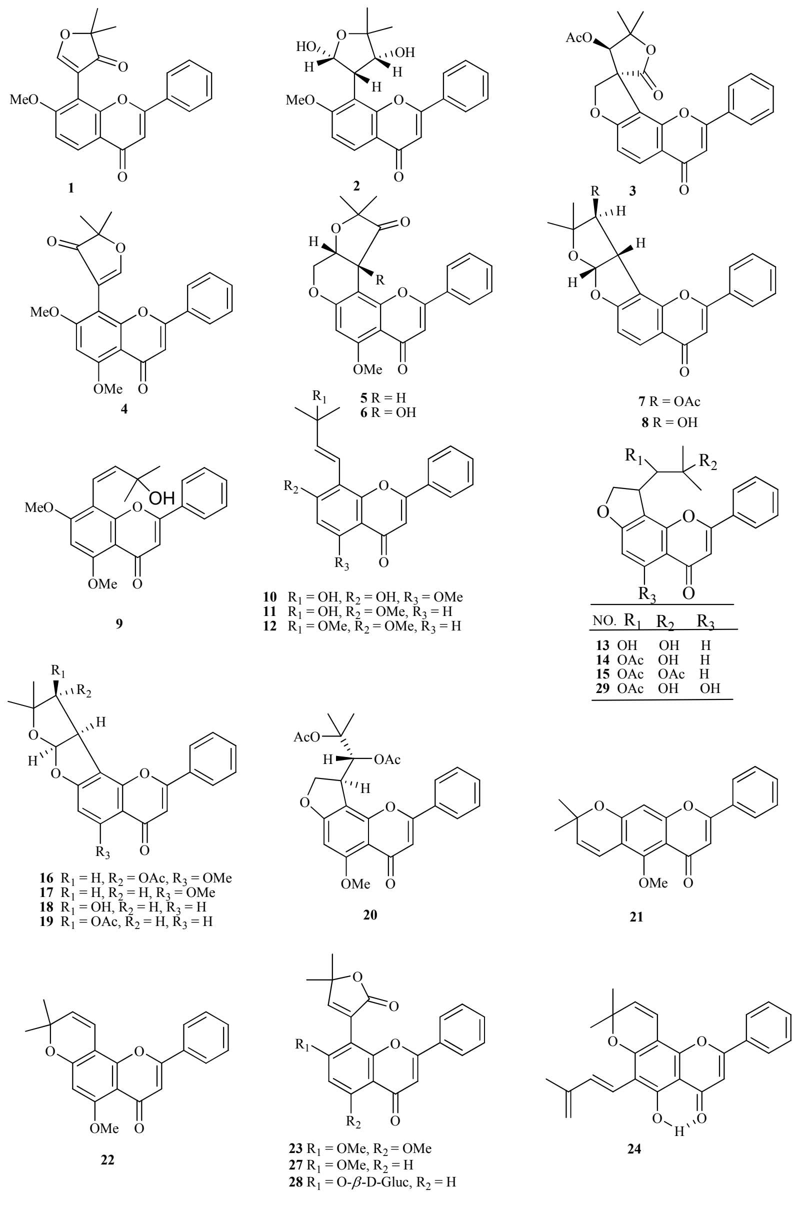
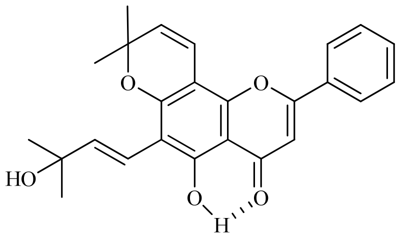


Figure 1. *Cont.*



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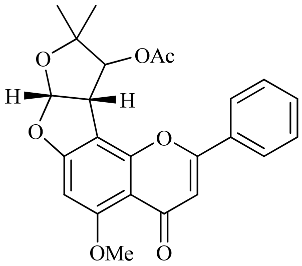

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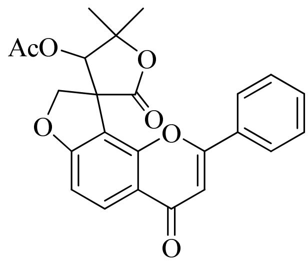

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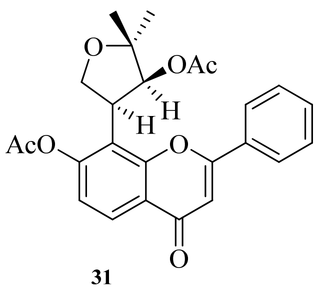

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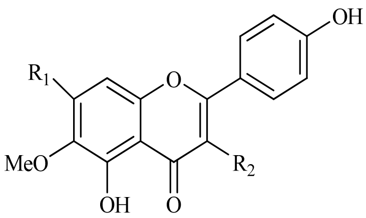
Figure 2. Flavonols from genus *Tephrosia*.

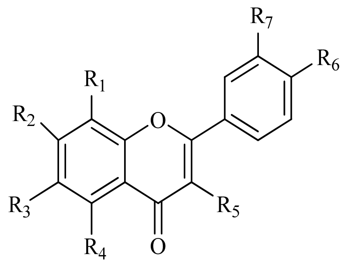


32 R_1 = O-(α-Rha), R_2 = O-(α-Rha-(1→2)-[α-Rha-(1→6)]-β-Gal-

33 R_1 = O-(α-Rha), R_2 = O-(α-Rha-(1→6)-β-Gal-

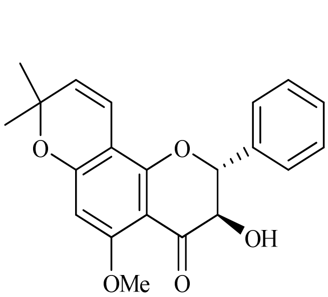
34 R_1 = OH, R_2 = O-(α-Rha-(1→2)-[α-Rha-(1→6)]-β-Gal-

35 R_1 = OH, R_2 = O-(α-Rha-(1→2)-[(3-*O*-*E*-feruloyl)-α-Rha-(1→6)]-β-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*.



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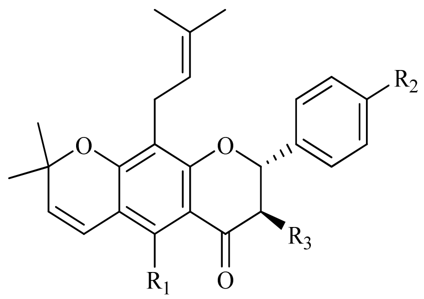
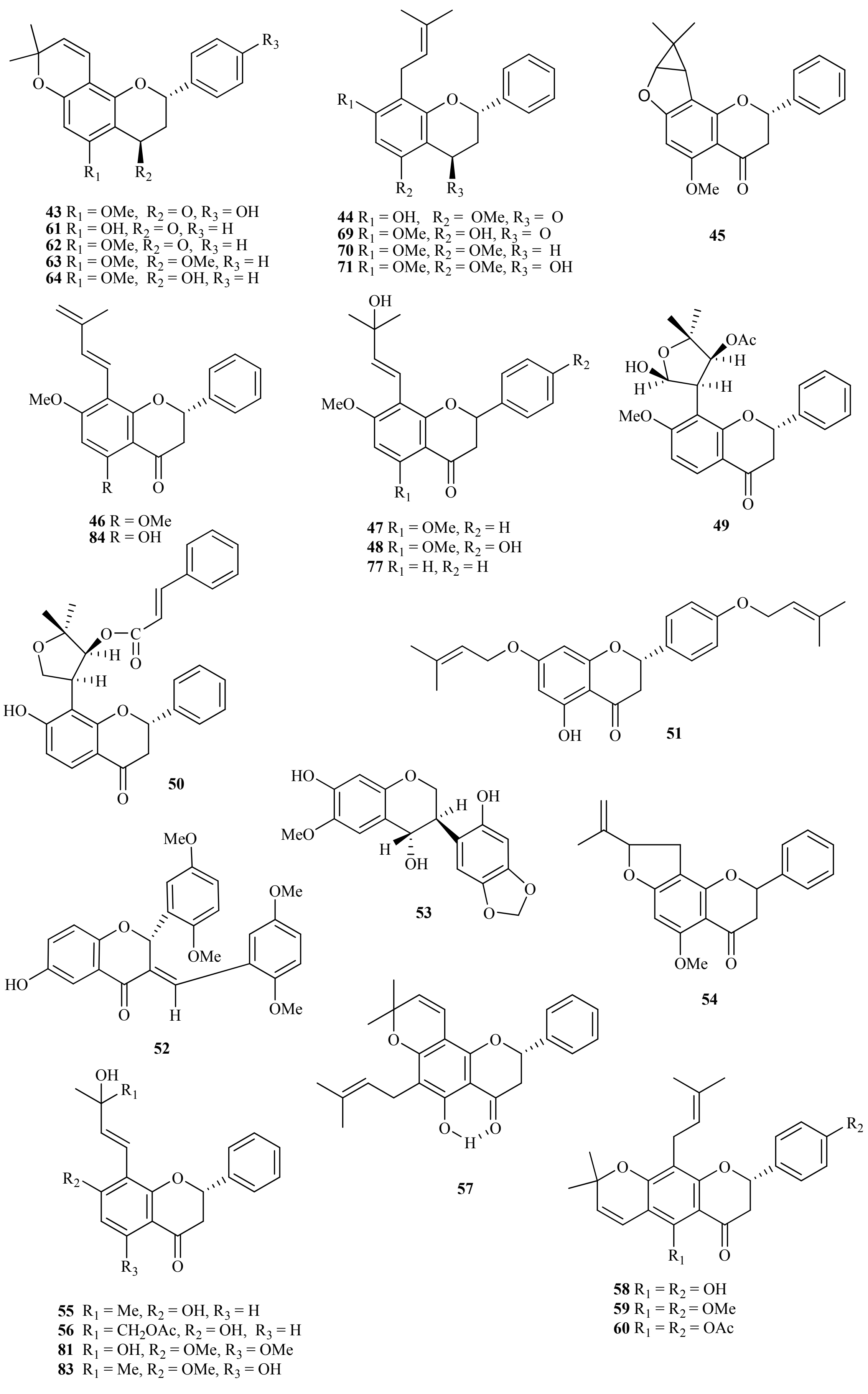


41 R_1 = OH, R_2 = OH, R_3 = OH
42 R_1 = OAc, R_2 = OAc, R_3 = OAc

Figure 4. Flavans from genus *Tephrosia*.



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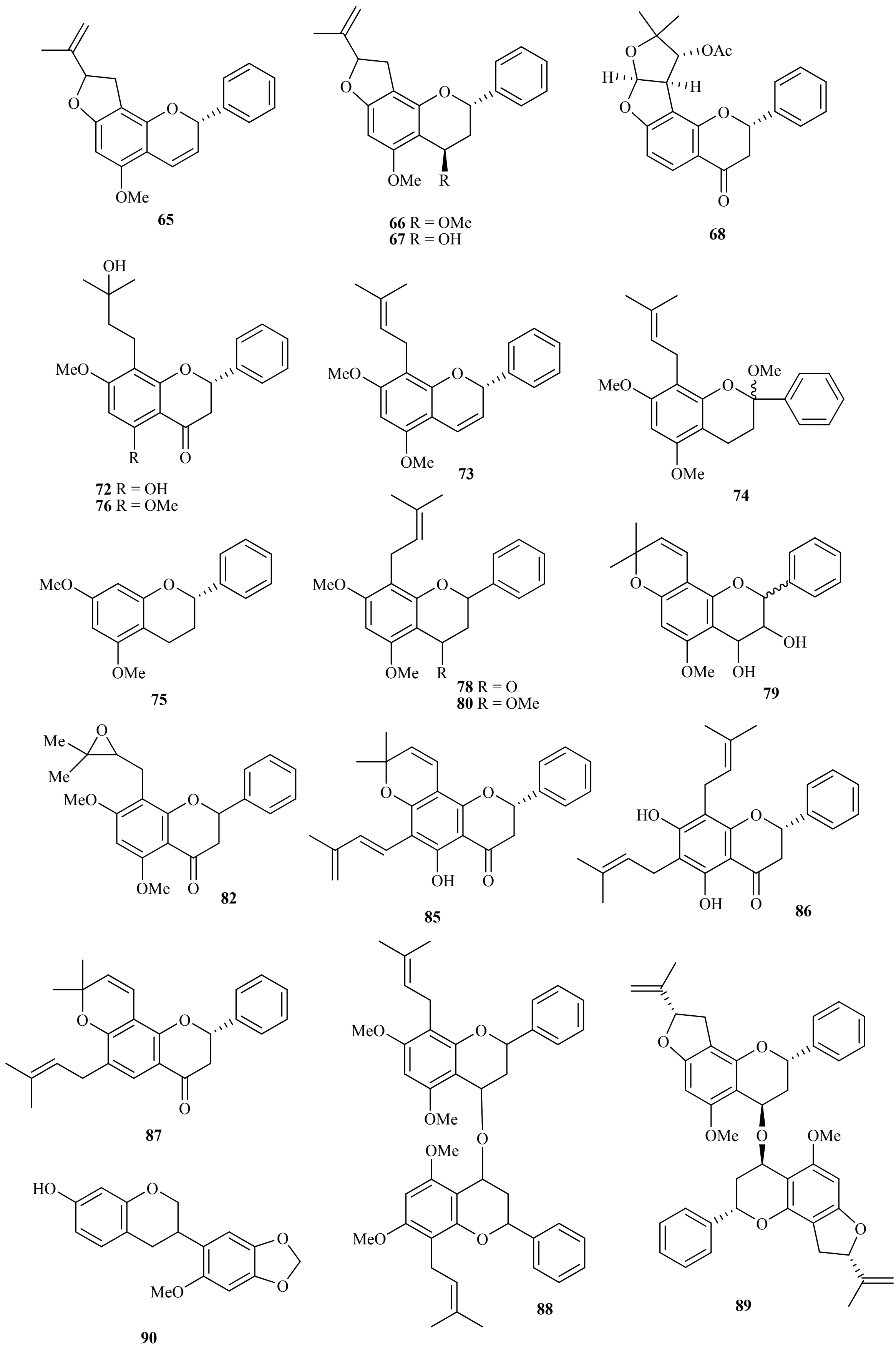

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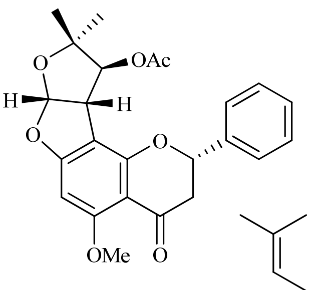

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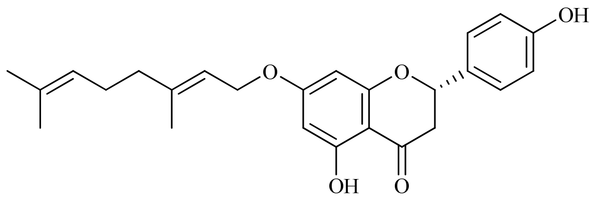

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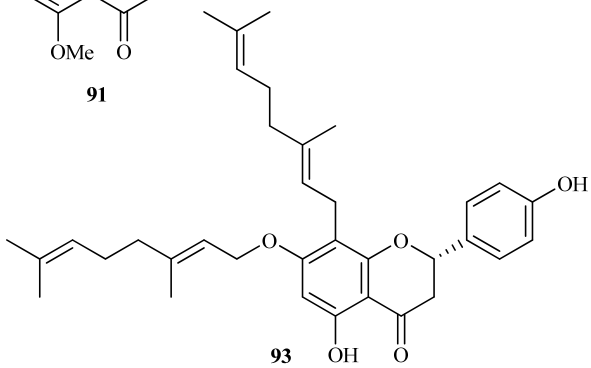

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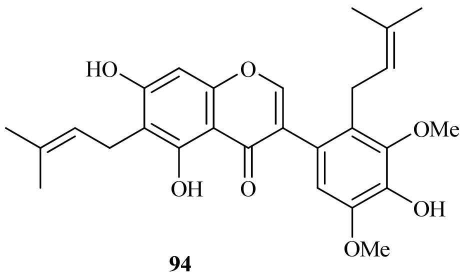
Figure 5. Isoflavones from genus *Tephrosia*.



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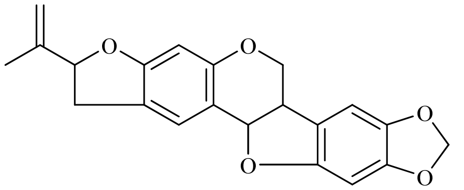

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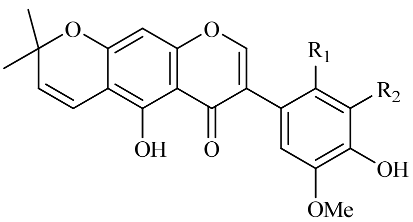
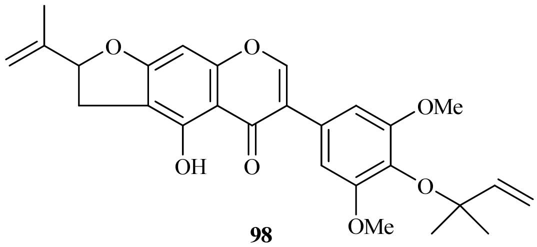


96 R_1 = OMe, R_2 = H
97 R_1 = H, R_2 = OMe



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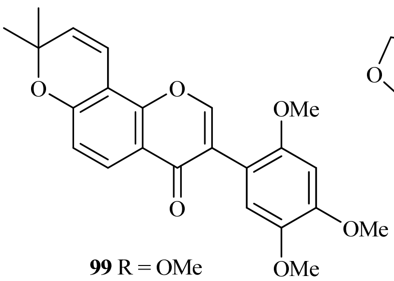
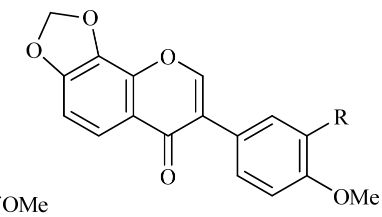
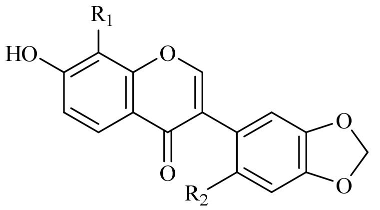


99 R = OMe
100 R = OH

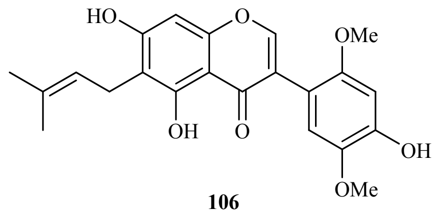


101 R = OMe
102 R = H



103 R_1 = OMe, R_2 = H
104 R_1 = OMe, R_2 = OMe
105 R_1 = H, R_2 = OMe

Figure 5. *Cont.*



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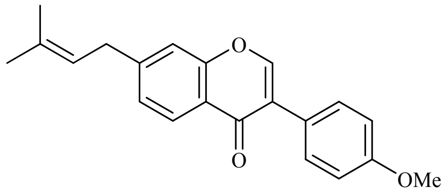

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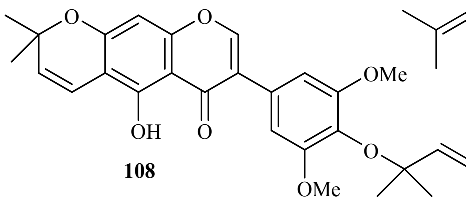

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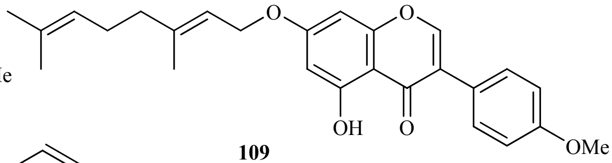

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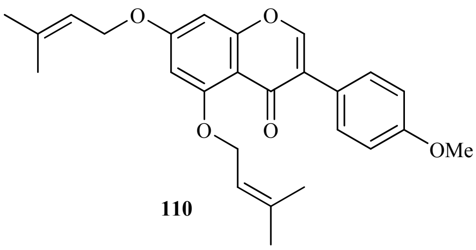

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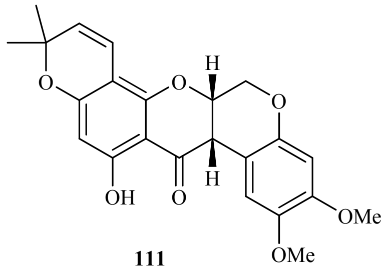

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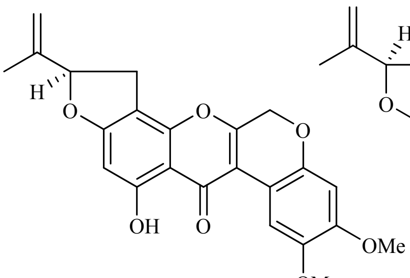

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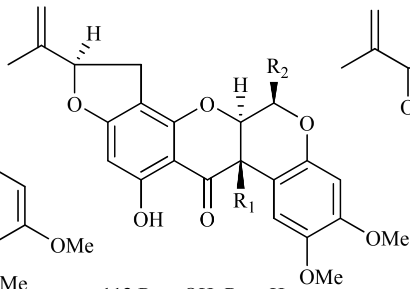
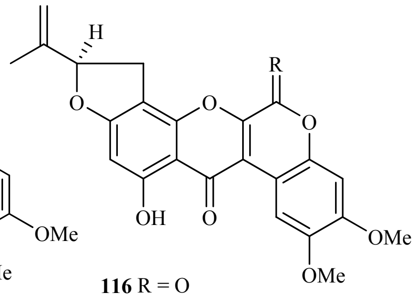
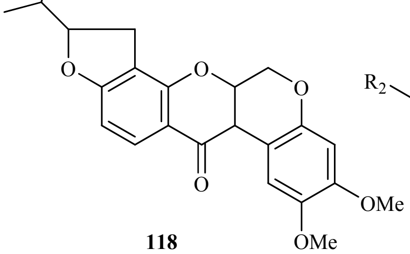


113 R_1 = OH, R_2 = H
114 R_1 = H, R_2 = OH
115 R_1 = OH, R_2 = OH



116 R = O
117 R = H, OMe



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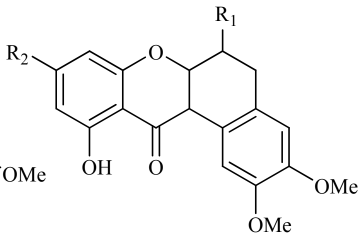
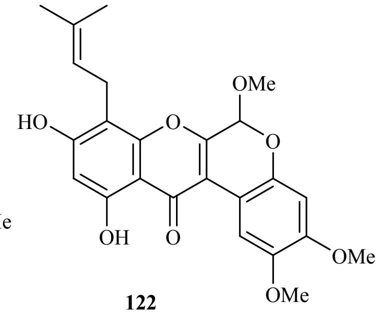


119 R_1 = OH, R_2 = OMe
120 R_1 = OH, R_2 = OH
121 R_1 = OAc, R_2 = OMe



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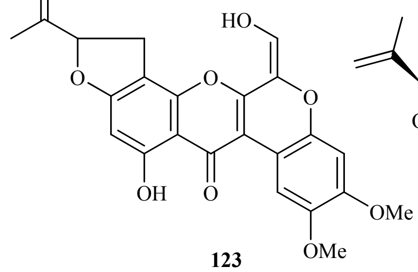

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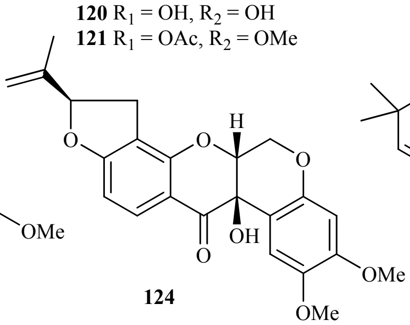

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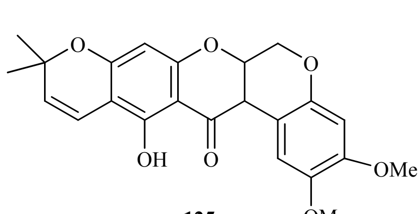

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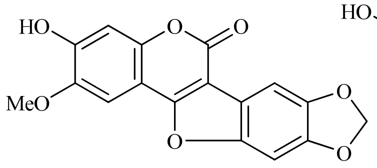

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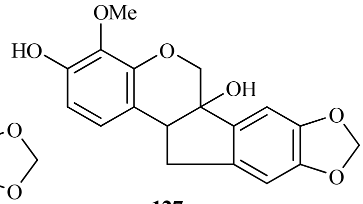

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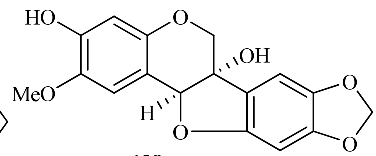

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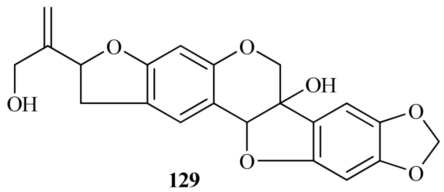

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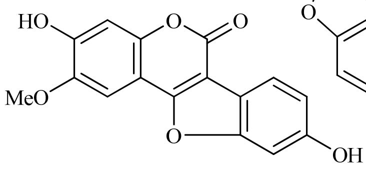

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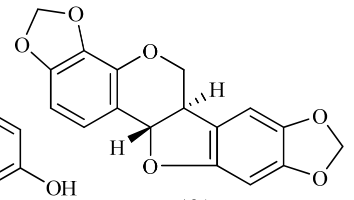

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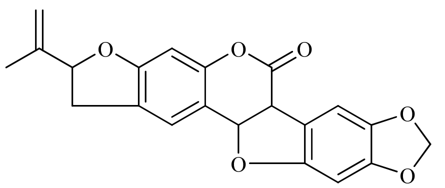

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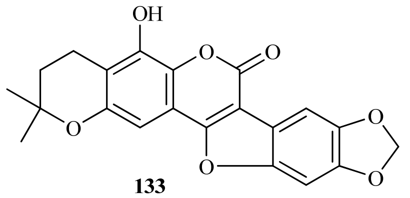

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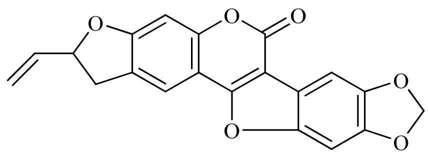

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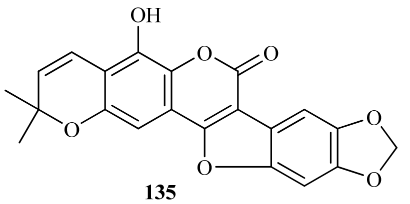

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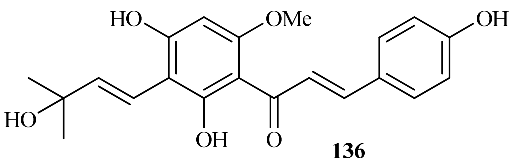
Figure 6. Chalcones from genus *Tephrosia*.



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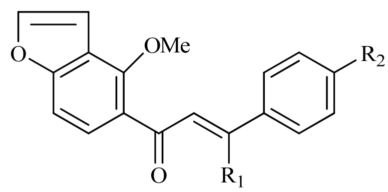
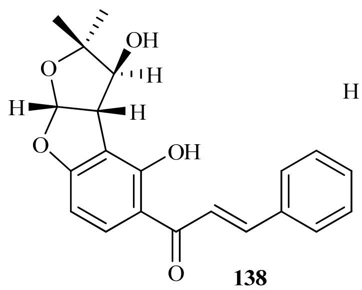


137 R_1 = OMe, R_2 = H
142 R_1 = H, R_2 = OMe



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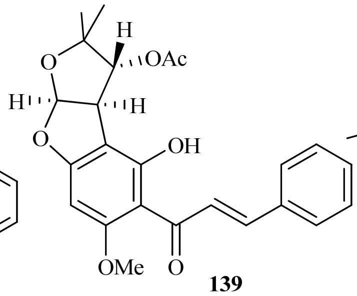

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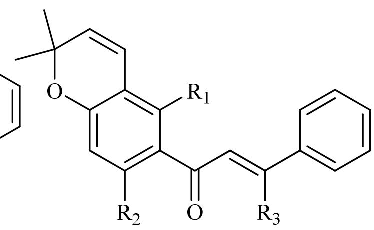

140 R_1 = OMe, R_2 =OMe, R_3 = H
143 R_1 = OMe, R_2 = OMe, R_3 = OMe
144 R_1 = OMe, R_2 = OMe, R_3 = OH
145 R_1 = OH, R_2 = OMe, R_3 = H
148 R_1 = OMe, R_2 = OH, R_3 = H
149 R_1 = OMe, R_2 =H, R_3 = OH

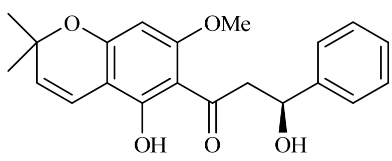

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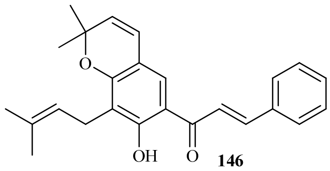
Figure 6. *Cont.*



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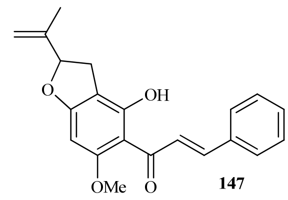

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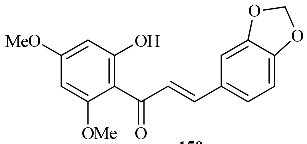

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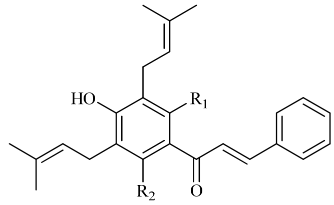
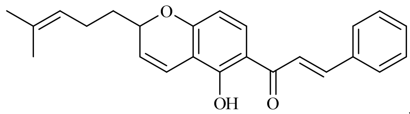


151 R_1 = H, R_2 = OH
153 R_1 = OH, R_2 = H



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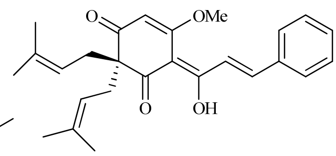

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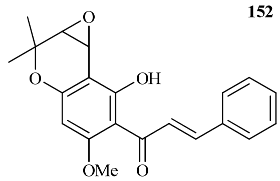

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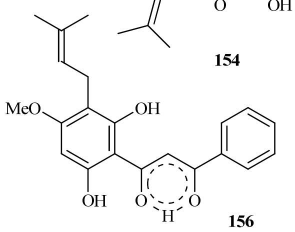

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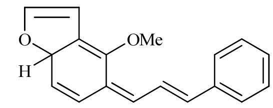
Figure 7. Other flavonoids from genus *Tephrosia*.



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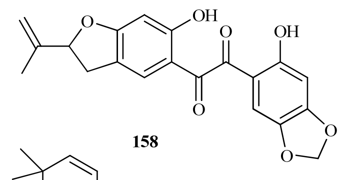

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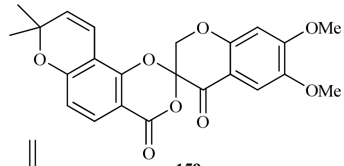

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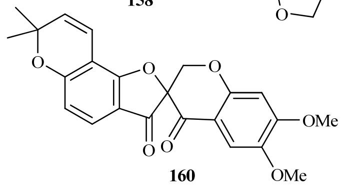

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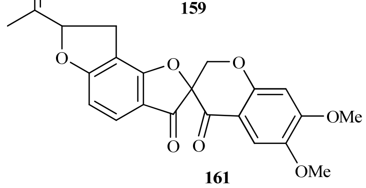
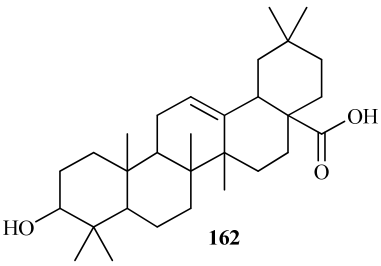


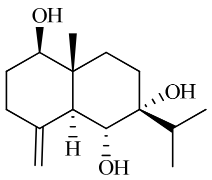
161

Figure 8. Triterpenoid from genus *Tephrosia*.



162

Figure 9. Sesquiterpenes from genus *Tephrosia*.



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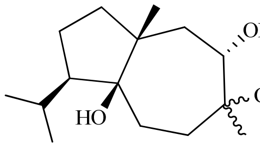

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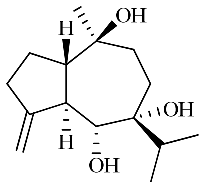
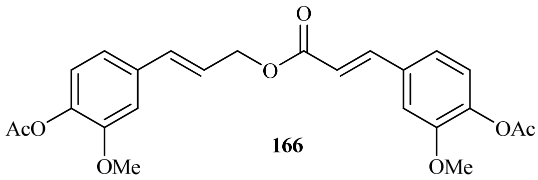


165

Figure 10. Other compounds from genus *Tephrosia*.



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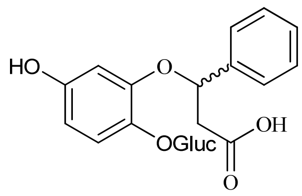

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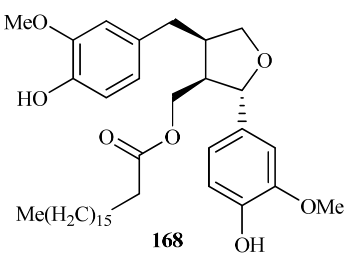

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Table 1. Chemical constituents from the genus *Tephrosia*.

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

Table 1. *Cont.*

No.	Compound class and name	Source	Ref.
20	polystachin	*T. polystachya*	[27]
21	5-methoxy-6,6-dimethylpyrano[2,3:7,6]flavone	*T. praecans*	[28]
22	candidin	*T. candida*	[29]
23	hookerianin	*T. hookeriana*	[30]
24	fulvinervin B	*T. fulvinervis*	[31]
25	fulvinervin C	*T. fulvinervis*	[32]
26	enantiomultijugin	*T. viciodes*	[33]
27	apollinine	*T. purpurea*	[34]
28	demethylapollinin 7-*O*-*β*-D-glucopyranoside	*T. cinerea*	[35]
29	tephropurpulin A	*T. apollinea*, *T. purpurea*	[36,37]
30	isoglabratephrin	*T. purpurea*	[37]
31	terpurinflavone	*T. purpurea*	[38]
	Flavonols		
32	6-hydroxykaempferol 6-methyl ether 3-*O*-*α*-rhamno-pyranosyl(7→6)-*β*-galactopyranoside-7-*O*-*α*-rhamno-pyranoside	*T. vogelii*	[1]
33	6-hydroxykaempferol 6-methyl ether 3-*O*-*α*-rhamno-pyranosyl(1→2)[*α*-rhamnopyranosyl(1→6)-*β*-galacto-pyranoside	*T. vogelii*	[1]
34	6-hydroxykaempferol 6-methyl ether 3-*O*-*α*-rhamno-pyranosyl(1→2)[*α*-rhamnopyranosyl(1→ 6)]-*β*-galacto-pyranoside-7-*O*-*α*-rhamnopyranoside	*T. vogelii*	[1]
35	6-hydroxykaempferol 6-methyl ether 3-*O*-*α*-rhamnopyranosyl (1→2)[(3-*O*-*E*-feruloyl)-*α*-rhamnopyranosyl(1→6)]-*β*-galacto-pyranosides	*T. vogelii*	[1]
36	6-hydroxykaempferol 4'-methyl ether	*T. candida*	[39]
37	candidol		[40]
38	candirone	*T. candida*	[41,42]
39	7-ethoxy-3,3',4'-trihydroxyflavone	*T. procumbens*	[43]
	Flavanonols		
40	(2*R*,3*R*)-3-hydroxy-5-methoxy-6",6"-dimethylpyrano-[2",3":7,8]flavanone	*T. vogelii*	[1]
41	lupinifolinol	*T. lupinifolia*	[44]
42	lupinifolinol triacetate	*T. lupinifolia*	[44]
	Flavans		
43	(2*S*)-4'-hydroxy-5-methoxy-6",6"-dimethylpyrano[2",3":7,8]-flavanone	*T. vogelii*	[1]
44	(2*S*)-7-hydroxy-5-methoxy-8-prenylflavanone	*T. vogelii*	[1]
45	(2*S*)-5-methoxy-6",6"-dimethy1-4",5"-dihydrocyclopropa-[4",5"]furano[2",3":7,8]flavanone	*T. vogelii*	[1]
46	(2*S*)-5,7-dimethoxy-8-(3-methylbut-1,3-dienyl)flavanone	*T. vogelii*	[1]
47	tephrocandidin A	*T. candida*	[2]
48	tephrocandidin B	*T. candida*	[2]
49	(+)-tephrorin A	*T. purpurea*	[4]

Table 1. *Cont.*

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

Table 1. *Cont.*

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

Table 1. *Cont.*

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

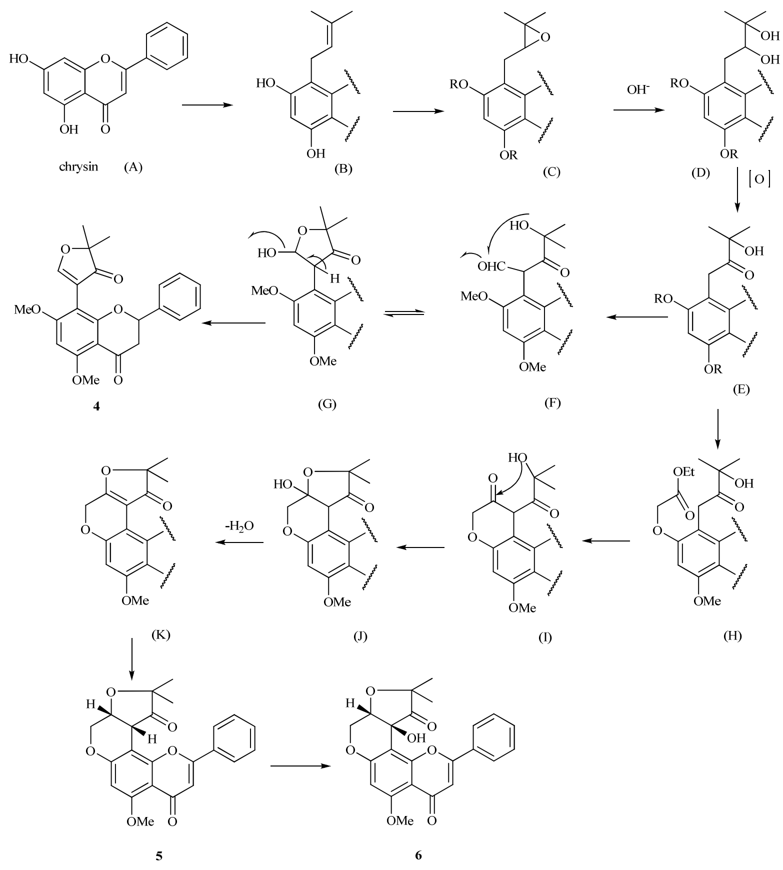
2.4. Others

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

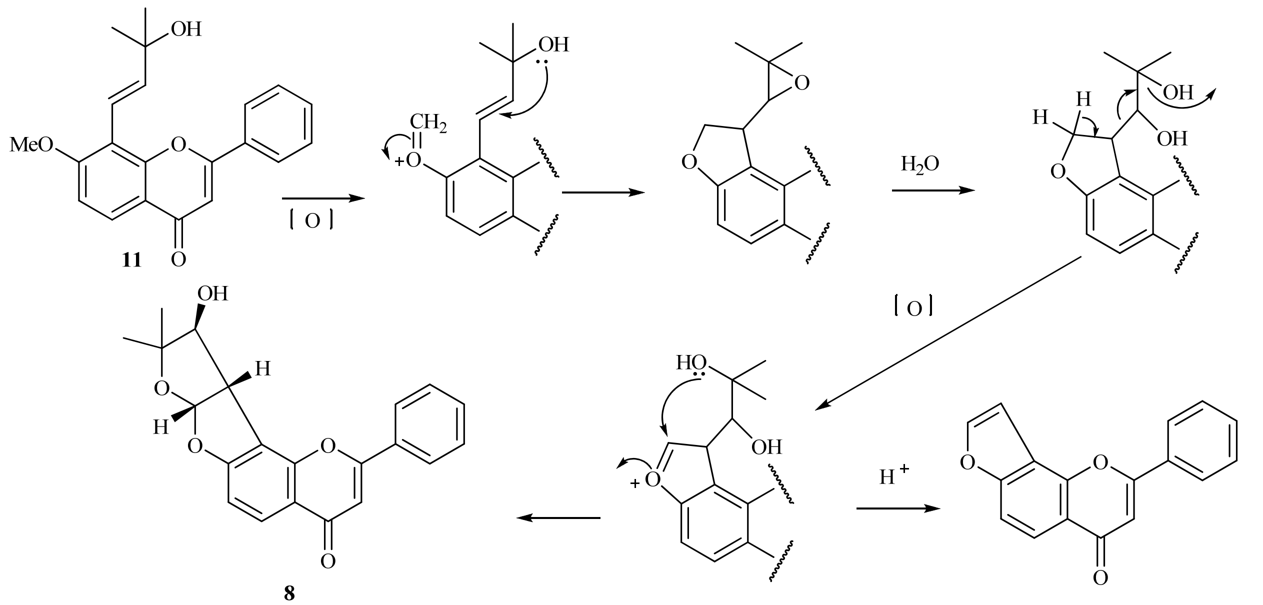
3. Proposed Biosynthetic Pathways and Synthesis

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 chrysins (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. polystachoides* 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 semiglabrinone, isoemiglabrinone and tephroglabrin (**3**) as shown in Scheme 5 [3]. Purpuritenin (**142**) was isolated from *T. purpurea* has been synthetized as showed in Scheme 6 [104].

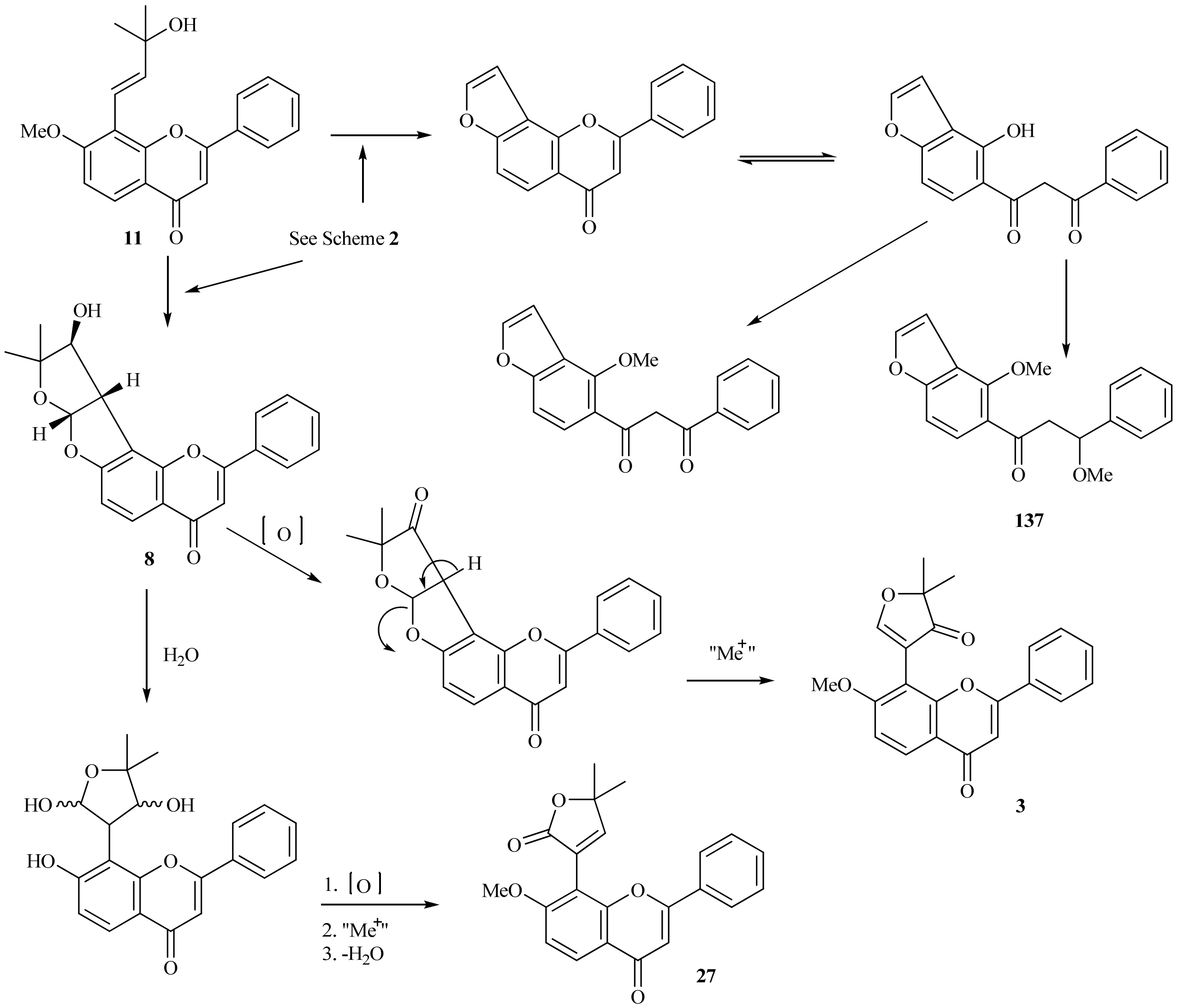
Scheme 1. Possible biogenetic pathway of compounds **4–6** of *T. polystachyoides*.



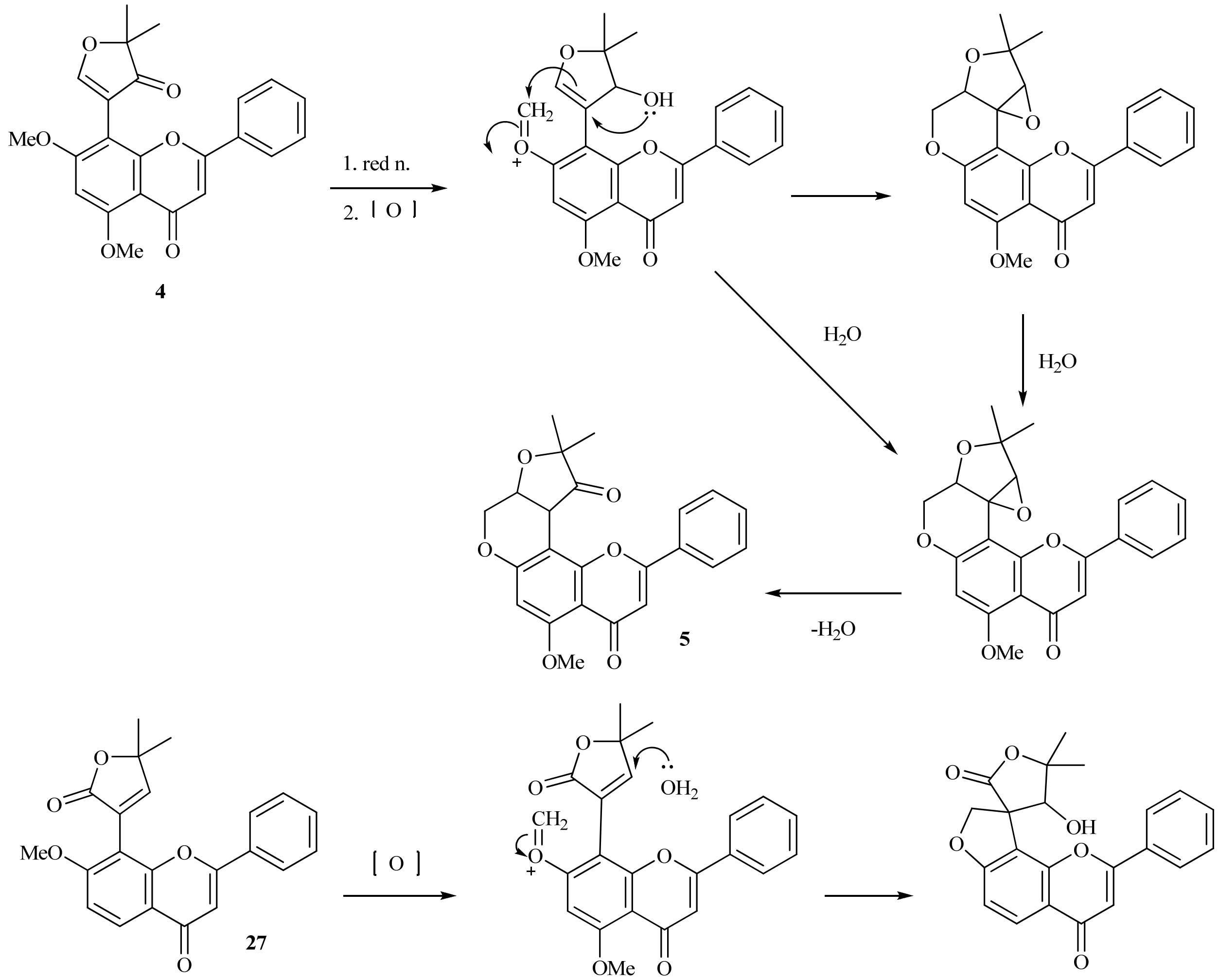
Scheme 2. Possible biogenetic pathway of compounds **8** and **11**.



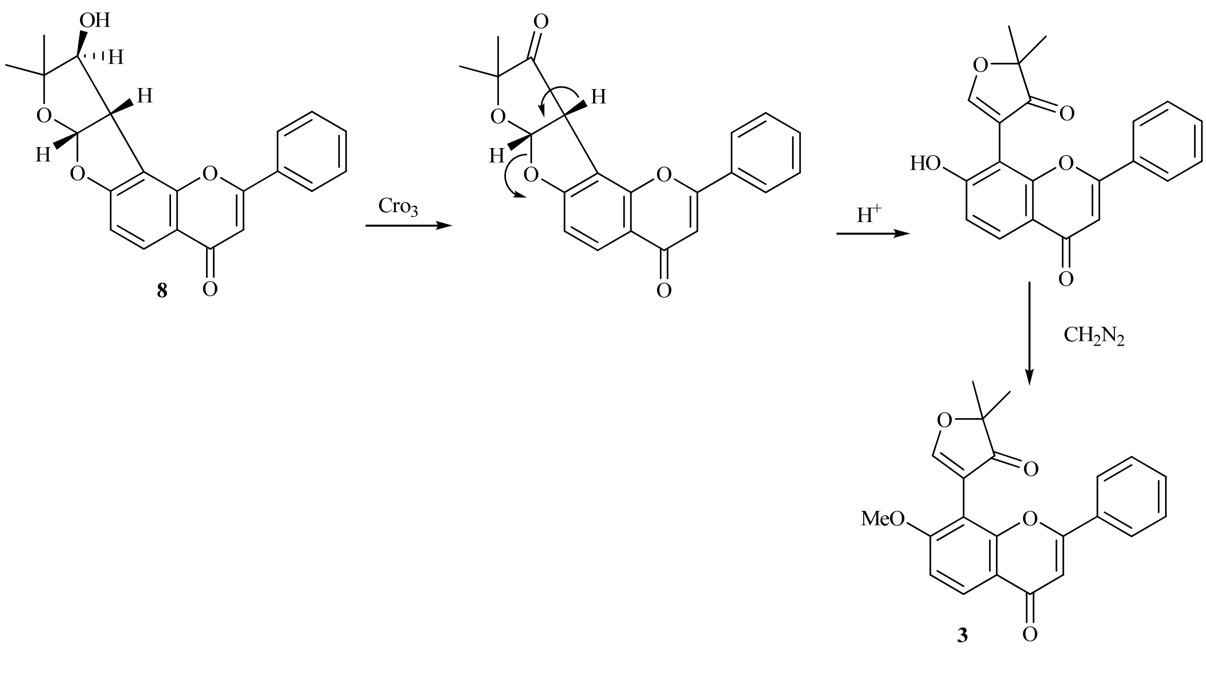
Scheme 3. Possible biogenetic pathway of compounds **3**, **8**, **11**, **27** and **137**.



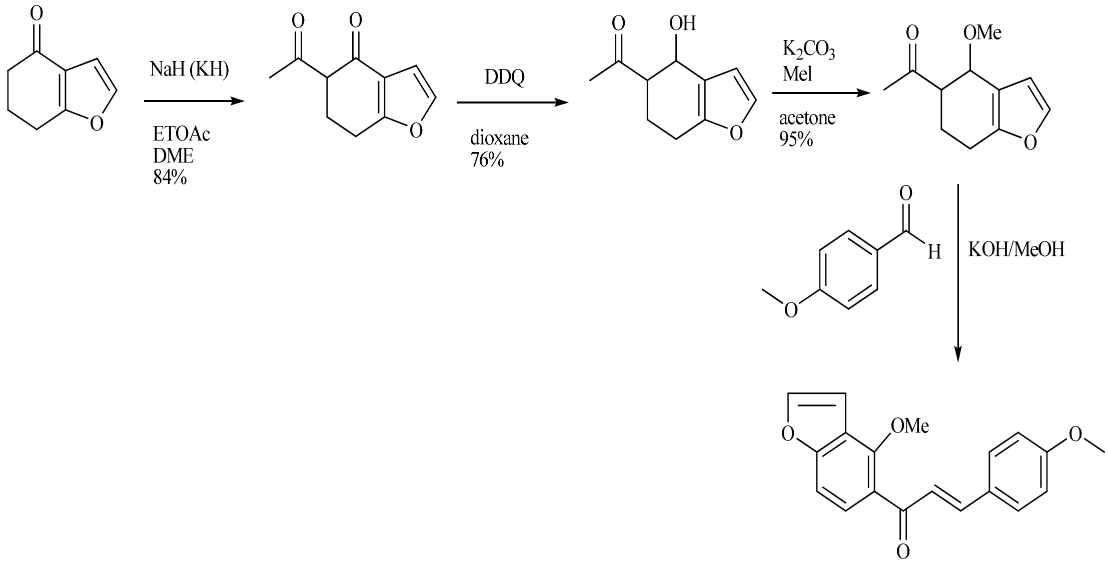
Scheme 4. Possible biogenetic pathway of compounds **4**, **5** and **137**.



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, antifeedant activities [2,105].

4.1. Estrogenic Activity

Candidachalcone (**136**) isolated from *T. candida* exhibited estrogenic activity with IC_{50} value of 80 µM, compared with 18 µM for the natural steroid 17 *β*-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 µM (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 ± 0.28 µM (D6) and 6.26 ± 2.66 µM (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 ± 0.3 and 8.6 ± 1.0 µg/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 ± 1.7 and 6.4 ± 1.1 µg/mL, and 3.8 ± 0.3 and 4.4 ± 0.6 µg/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 ± 0.3 (D6) and 5.5 ± 0.3 µg/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. rhodensiense*, *T. cruzi* and *L. donovani* with IC_{50} of 3.7, 3.35 and 17.2 µg/mL, respectively, but displayed high toxicity towards L-6 (IC_{50} of 17.12 µg/mL) rat skeletal myoblasts [13]. Tephrinone (**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 µg/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 µg/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. Plants of the genus *Tephrosia* have important traditional uses in agriculture, because they possess the bioactivity of phytoalexins. Some compounds isolated from these plants also have the bioactivity of phytoalexins according to the reported literature, which we have list in the part of the manuscript “Biological

Activities". We think that there will be many phytoalexin-type compounds isolated from plants of the genus *Tephrosia*. 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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