

• 综 述 •

茄属植物化学成分及生物活性研究进展

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摘 要: 茄属植物含有生物碱类、黄酮类、甾类等多种化学成分且其具有器官保护活性, 抗真菌、抗病毒活性, 抗肿瘤活性, 抗氧化活性。综述近 20 年来国内外对茄属植物化学成分和生物活性方面的研究概况, 为进一步开发利用茄属植物提供相关参考。

关键词: 茄属; 生物碱; 黄酮; 抗肿瘤; 抗病毒; 抗氧化

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Research progress on chemical constituents in plants of *Solanum* L. and their biological activities

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Abstract: The plants of genus *Solanum* L. contain alkaloids, flavonoids, steroids, and other various chemical constituents which exhibit protective activity, antifungal, antiviral, antitumor, and anti-oxidant activities. This paper reviews the research survey of the chemical constituents and biological activities of the plants of *Solanum* L. from domestic and foreign over the last 20 years, and provides the relative reference for the further development of the plants in *Solanum* L.

Key words: *Solanum* L.; alkaloids; flavonoids; antitumor; antiviral; anti-oxidation

茄属 *Solanum* L. 为被子植物门茄科 (Solanaceae) 植物, 草本, 多为亚灌木, 灌木至小乔木, 有时为藤本。全世界有 2 000 余种, 分布于热带及亚热带, 少数达到温带地区, 主产于南美洲的热带, 我国有 39 种, 14 变种^[1]。其中茄 *S. melongena* L. 和马铃薯 *S. tuberosum* L. 为很重要的经济作物, 部分可入药。但有些植物有毒, 如发芽的马铃薯^[2]。

近年来, 茄属植物因其重要的食用和药用价值, 日益受到关注, 也逐渐成为研究热点。研究表明, 茄属植物中含有生物碱类、黄酮类、甾类、萜类以及香豆素类、有机酸类等化学成分。许多茄属植物有清热、解毒、活血、消肿、化瘀的功效, 对疮痍、痈肿、跌打损伤、慢性气管炎、急性肾炎、风湿性关节炎、白带过多、水肿、淋病等都有一定的疗效^[3]。本文对 1996 年至今国内外对茄属植物的化学成分及

生物活性的研究进展进行综述, 以期为该属植物的开发利用提供相关参考。

1 化学成分

1.1 生物碱类化合物

茄属植物中生物碱类成分丰富, 结构复杂多样, 主要包括有机胺类生物碱 (I): 苯丙素类、苯丙酰胺类等; 甾体类生物碱 (II): 胆甾烷类等, 该类生物碱按骨架又可分为胆甾烷类生物碱和异胆甾烷类生物碱 (其主要区别在于五元环与六元环异位); 吡咯生物碱 (III) 以及其他类型的生物碱类成分。1996 年, Kim 等^[4]在 *S. umbelliferum* Eschsch. 中发现了 2 个新的天然产物 (26、27)。2007 年, Yoshikawa 等^[5]在 *S. lycocarpum* A. St. -Hil. 果实中分离出 2 个新的甾体生物碱 (22、23), 并发现其具有抗糖尿病的作用。2011 年, Torres 等^[6]在 *S. capaniforme* Roem. & Schult. 的叶子中分离得到了 7 个化合物, 其中包

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括 3 个新的生物碱类化合物 (54、55、77)。2013 年的龙葵次碱烷类甾体生物碱 (55~62)。茄属植物中
年, Torres 等^[7]又在该植物的叶子中分离出 8 个新的生物碱类化合物见表 1 和图 1。

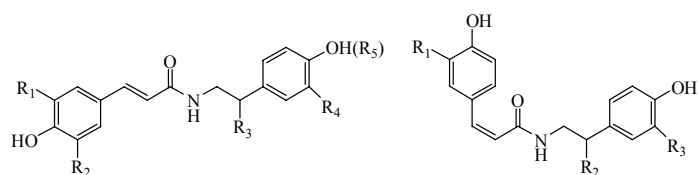
表 1 茄属植物中的生物碱类化合物

Table 1 Alkaloid compounds from plants of *Solanum* L.

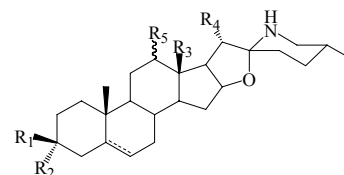
类型	编号	化合物	来源
I	1	<i>N-trans-p-coumaroyloctopamine</i>	茄 ^[8] 、水茄 <i>S. torvum</i> Sw. ^[9]
	2 a	<i>N-trans-p-coumaroyltyramine</i>	茄 ^[8] 、水茄 ^[9] 、白英 <i>S. lyratum</i> Thunb. ^[10]
	b	<i>N-cis-p-coumaroyltyramine</i>	紫花茄 <i>S. violaceum</i> Ortega ^[11] 、茄 ^[12]
	3	<i>N-trans-feruloyltyramine</i>	茄 ^[8] 、水茄 ^[9] 、白英 ^[10] 、青杞 <i>S. septemlobum</i> Bunge ^[13]
	4	<i>N-trans-feruloyloctopamine</i>	茄 ^[8] 、刺天茄 ^[11]
	5	3-(4-hydroxyphenyl)- <i>N</i> -[2-(4-hydroxyphenyl)-2-methoxyethyl]-acrylamide	茄 ^[8] 、水茄 ^[9]
	6	3-(4-hydroxy-3-methoxyphenyl)- <i>N</i> -[2-(4-hydroxyphenyl)-2-methoxy-ethyl]-acrylamide	茄 ^[8]
	7 a	<i>N-trans-feruloyl-3-methoxytyramine</i>	茄 ^[8]
	b	<i>N-cis-feruloyl-3-methoxytyramine</i>	茄 ^[14]
	8	<i>N-trans-sinapoyltyramine</i>	茄 ^[8]
	9	<i>N-trans-sinapoyloctopamine</i>	茄 ^[8]
	10	<i>N-trans-caffeoyloctopamine</i>	茄 ^[8]
	11	<i>N-trans-p-coumaroylnoradrenline</i>	茄 ^[8]
	12	<i>N-trans-feruloylnoradrenline</i>	茄 ^[8]
	13	<i>N-cis-feruloyltyramine</i>	茄 ^[8]
	14	<i>N-cis-feruloyloctopamine</i>	茄 ^[8]
	15	<i>N-cis-p-coumaroyloctopamine</i>	茄 ^[8]
	16	<i>N-cis-feruloylnoradrenline</i>	茄 ^[8]
	17	<i>N-trans-feruloyl-3-methyldopamine</i>	白英 ^[10]
	20	<i>N-trans-feruloyl-4-O-methyldopamine</i>	茄 ^[14]
	21	7'-(3',4'-dihydroxyphenyl)- <i>N</i> -[(4-methoxyphenyl) ethyl]-propenamide	茄 ^[14]
II	20	澳洲茄边碱 (solamargine)	<i>S. aculeastrum</i> Dunal ^[15] 、 <i>S. lycocarpum</i> A. St. -Hil. ^[5,16] 、牛茄子 <i>S. surattense</i> Burm. f. ^[17] 、黄水茄 <i>S. incanum</i> L. ^[18] 、 <i>S. heteracanthum</i> Merrill & L. M. Perry ^[18] 、 <i>S. sycophanta</i> Dunal ^[19] 、 <i>S. suaveolens</i> Kunth & C. D. Bouché ^[20]
	21	lobofrutoside	<i>S. lycocarpum</i> ^[16]
	22	robeneoside A	<i>S. lycocarpum</i> ^[5,16]
	23	robeneoside B	<i>S. lycocarpum</i> ^[5,16]
	24	澳洲茄碱 (solasonine)	<i>S. umbelliferum</i> ^[4] 、 <i>S. lycocarpum</i> ^[5,16] 、 <i>S. sycophanta</i> ^[19] 、龙葵 <i>S. nigrum</i> L. ^[21] 、 <i>S. coccineum</i> Jacq. ^[22]
	25	12-hydroxysolasonine	<i>S. lycocarpum</i> ^[5,16]
	26	<i>O</i> -acetylsolasodine	<i>S. umbelliferum</i> ^[4]
	27	solasodine 3- <i>O</i> -β- <i>D</i> -glucopyranoside	<i>S. umbelliferum</i> ^[4]
	28	(22 <i>R</i> ,25 <i>R</i>)-3α-aminospirosol-5-ene	<i>S. triste</i> Jacq. Enum. ^[23] 、 <i>S. arboreum</i> Dunal ^[24]
	29	(22 <i>R</i> ,25 <i>R</i>)-3β-aminospirosol-5-ene	<i>S. triste</i> ^[23] 、 <i>S. arboreum</i> ^[24]
	30	(22 <i>R</i> ,25 <i>R</i>)-16β <i>H</i> -22α- <i>N</i> -spirosol-3β-ol-5-ene-3- <i>O</i> -α- <i>L</i> -rhamnopyranosyl-(1→2)-[α- <i>L</i> -rhamnopyranosyl-(1→4)]-β- <i>D</i> -glucopyranoside	牛茄子 ^[17]
	31	khasianine	牛茄子 ^[17] 、 <i>S. suaveolens</i> ^[20]
	32	β ₁ -澳洲茄碱 (solasonine)	龙葵 ^[21]
	33	β ₂ -澳洲茄边碱 (solamargine)	龙葵 ^[21]
	34	γ-澳洲茄边碱 (solamargine)	龙葵 ^[21]
	35	solanigroside P	龙葵 ^[21]
	36	澳洲茄胺 (solasodine)	<i>S. umbelliferum</i> ^[4] 、 <i>S. abutiloides</i> (Griseb.) Bitter & Lillo ^[25]

续表 1

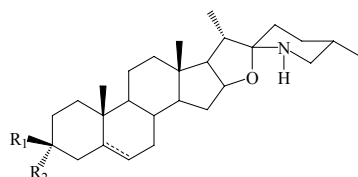
类型	编号	化合物	来源
	37	sycophantine	<i>S. sycophanta</i> ^[19]
	38	21-hydroxysycophantine	<i>S. sycophanta</i> ^[19]
	39	solasuaveoline	<i>S. suaveolens</i> ^[20]
	40	dihydrosolasuaveoline	<i>S. suaveolens</i> ^[20]
	41	isosolasuaveoline	<i>S. suaveolens</i> ^[20]
	42	xyiosyl-solamargine	<i>S. coccineum</i> ^[22]
	43	isoanguivine	<i>S. coccineum</i> ^[22]
	44	solaculine A	<i>S. aculeastrum</i> ^[15]
	45	β -苦茄碱 (solamarine)	<i>S. aculeastrum</i> ^[15] 、龙葵 ^[21]
	46	(2 <i>S</i> ,25 <i>S</i>)-3 α -aminospirosol-5-ene	<i>S. triste</i> ^[23] 、 <i>S. arboreum</i> ^[24]
	47	(2 <i>S</i> ,25 <i>S</i>)-3 α -amino-5 α -spirosolane	<i>S. arboreum</i> ^[24]
	48	(2 <i>S</i> ,25 <i>S</i>)-3 β -aminospirosol-5-ene	<i>S. arboreum</i> ^[24]
	49	罗茄胺 (soladunalinidine)	<i>S. arboreum</i> ^[24]
	50	tomatidine 3- <i>O</i> - β - <i>D</i> -glucopyranoside	<i>S. arboreum</i> ^[26]
	51	tomatidine 3- <i>O</i> -[<i>O</i> - β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 6)- β - <i>D</i> -glucopyranoside]	<i>S. arboreum</i> ^[26]
	52	22,25-diepisycophantine	<i>S. sycophanta</i> ^[19]
	53	xylosyl- β -solamarine	<i>S. coccineum</i> ^[22]
	54	22 α ,23 α -epoxy-solanida-1,4,9-trien-3-one	<i>S. campaniforme</i> Roem. & Schult. ^[6]
	55	22 α ,23 α -epoxy-solanida-1,4-dien-3-one	<i>S. campaniforme</i> ^[6]
	56	22 β ,23 β -epoxy-solanida-1,4-dien-3-one	<i>S. campaniforme</i> ^[7]
	57	22 α ,23 α -epoxy-10- <i>epi</i> -solanida-1,4,9-trien-3-one	<i>S. campaniforme</i> ^[7]
	58	22 α ,23 α -epoxy-solanida-4-en-3-one	<i>S. campaniforme</i> ^[7]
	59	22 β ,23 β -epoxy-solanida-4-en-3-one	<i>S. campaniforme</i> ^[7]
	60	(<i>E</i>)- <i>N</i> -[8' (4-hydroxyphenyl)ethyl]-22 α ,23 α -epoxy-solanida-1,4,9-trien-3-imine	<i>S. campaniforme</i> ^[7]
	61	(<i>E</i>)- <i>N</i> -[8' (4-hydroxyphenyl)ethyl]-22 α ,23 α -epoxy-solanida-1,4-dien-3-imine	<i>S. campaniforme</i> ^[7]
	62	(<i>Z</i>)- <i>N</i> -[8' (4-hydroxyphenyl)ethyl]-22 α ,23 α -epoxy-solanida-1,4,9-trien-3-imine	<i>S. campaniforme</i> ^[7]
	63	(<i>Z</i>)- <i>N</i> -[8' (4-hydroxyphenyl)ethyl]-22 α ,23 α -epoxy-solanida-1,4-dien-3-imine	<i>S. campaniforme</i> ^[7]
	64	solanoside A	牛茄子 ^[27]
	65	solanoside B	牛茄子 ^[27]
	66	α -卡茄碱 (chaconine)	<i>S. chacoense</i> Bitter. ^[28] 、马铃薯 ^[29]
	67	α -茄碱 (solanine)	<i>S. chacoense</i> ^[21]
	68	次勒帕茄碱 I (leptinine I)	<i>S. chacoense</i> ^[28] 、 <i>S. orbignianum</i> ^[30]
	69	次勒帕茄碱 II (leptinine II)	<i>S. chacoense</i> ^[28] 、 <i>S. orbignianum</i> ^[30]
	70	勒帕茄碱 I (leptine I)	<i>S. chacoense</i> ^[28]
	71	勒帕茄碱 II (leptine II)	<i>S. chacoense</i> ^[28]
	72	dehydrocommersonine	<i>S. chacoense</i> ^[28]
	73	solanopubamine	<i>S. schimperianum</i> Hochst ^[31]
	74	leptinidine 3- <i>O</i> - β - <i>D</i> -glucopyranoside	<i>S. orbignianum</i> ^[30]
	75	莱普亭定 (leptinidine)	<i>S. orbignianum</i> ^[30]
	76	茄啉 (solanidine)	茄 ^[32]
	77	3,9 β -hydroxy-22 α ,23 α -epoxy-9(10)-seco-solanida-1,3,5(10)-triene	<i>S. campaniforme</i> ^[6]
	78	solafloridine	<i>S. abutiloides</i> ^[25]
	79	20-isosolafloridine [(20 <i>R</i> ,25 <i>R</i>)-22,26-epiminocholest-22(<i>N</i>)-ene-3 β ,16 α -diol]	<i>S. abutiloides</i> ^[25]
III	80	solsodamine A	<i>S. sodomaeum</i> L. ^[33]
	81	solsodamine B	<i>S. sodomaeum</i> ^[33]
其他	82	solaspiralidine	<i>S. spirale</i> Roxb. ^[34]
	83	etioline	<i>S. spirale</i> ^[34]
	84	(25 <i>S</i>)-22,26-epimino-3 β -(β - <i>D</i> -glucopyranosyloxy) cholesta-5,22(<i>N</i>)-dien-16 α -ol	<i>S. spirale</i> ^[34]
	85	8-hydroxy-3-methoxy-5 <i>H</i> -pyrido [2,1- <i>c</i>]pyrazin-5-one	<i>S. cathayanum</i> C. Y. Wu & S. C. Huang ^[35]



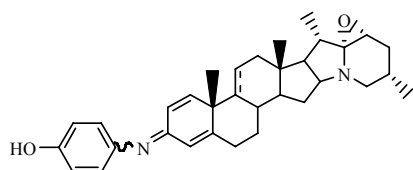
	R ₁	R ₂	R ₃	R ₄	R ₅		R ₁	R ₂	R ₃
1	H	H	OH	H		13	OCH ₃	H	H
2	H	H	H	H		14	OCH ₃	OH	H
3	OCH ₃	H	H	H		15	H	OH	H
4	OCH ₃	H	OH	H		16	OCH ₃	OH	OH
5	H	H	OCH ₃	H					
6	OCH ₃	H	OCH ₃	H					
7	OCH ₃	H	H	OCH ₃					
8	OCH ₃	OCH ₃	H	H					
9	OCH ₃	OCH ₃	OH	H					
10	OH	H	OH	H					
11	H	H	OH	OH					
12	OCH ₃	H	OH	OH					
17	OCH ₃	H	H	CH ₃					
18	OCH ₃	H	H	OH	OCH ₃				
19	H	OH	H	H	OCH ₃				



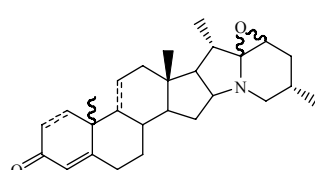
	R ₁	R ₂	R ₃	R ₄	R ₅	构型
20	S1	H	CH ₃	CH ₃	H	Δ^5 22 α 25R
21	S1	H	CH ₃	CH ₃	β -OH	Δ^5
22	S1	H	CH ₃	CH ₃	H	Δ^5 3 β 12 α 22 α 25R
23	S2	H	CH ₃	CH ₃	H	Δ^5 3 β 12 α 22 α 25R
24	S2	H	CH ₃	CH ₃	H	Δ^5 solasonine
25	S2	H	CH ₃	CH ₃	β -OH	Δ^5
26	OAc	H	CH ₃	CH ₃	H	Δ^5
27	S3	H	CH ₃	CH ₃	H	Δ^5
28	NH ₂	H	CH ₃	CH ₃	H	Δ^5
29	H	NH ₂	CH ₃	CH ₃	H	Δ^5
30	S1	H	CH ₃	CH ₃	H	Δ^5 3 β 16 β 22 α 22R 25R
31	S4	H	CH ₃	CH ₃	H	Δ^5
32	S5	H	CH ₃	CH ₃	H	Δ^5
33	S4	H	CH ₃	CH ₃	H	Δ^5 22 α 25R
34	S3	H	CH ₃	CH ₃	H	Δ^5 22 α 25R
35	S4	H	OH	CH ₃	H	Δ^5 17CH ₃
36	H	H	CH ₃	CH ₃	H	Δ^5
37	S7	H	CH ₃	C ₂ H ₅	H	Δ^5
38	S7	H	CH ₃	CH ₂ OH	H	Δ^5
39	S8	H	CH ₃	CH ₃	H	Δ^5
40	S8	H	CH ₃	CH ₃	H	5 α -H
41	S9	H	CH ₃	CH ₃	H	Δ^5
42	S10	H	CH ₃	CH ₃	H	Δ^5
43	S2	H	CH ₃	CH ₃	H	Δ^5



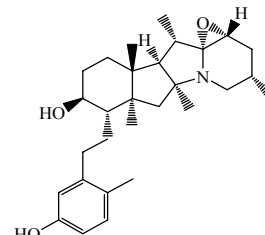
	R ₁	R ₂	构型		R ₁	R ₂	构型
44	S6	H	Δ^5	49	NH ₂	H	5 α -H
45	S1	H	Δ^5	50	S3	H	5 α -H
46	H	NH ₂	Δ^5	51	S15	H	5 α -H
47	H	NH ₂	5 α -H	52	S7	H	Δ^5
48	NH ₂	H	Δ^5	53	S10	H	Δ^5



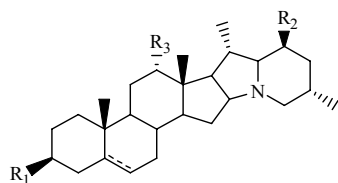
60	Δ^9	$E = (C = N)$
61		$E = (C = N)$
62	Δ^9	$Z = (C = N)$
63		$Z = (C = N)$



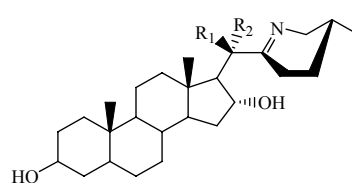
54	$\Delta^1 \Delta^9$	19 β 22 α 23 α
55	Δ^1	19 β 22 α 23 α
56	Δ^1	19 β 22 β 23 β
57	$\Delta^1 \Delta^9$	19 α 22 α 23 α
58		19 β 22 α 23 α
59		19 β 22 β 23 β



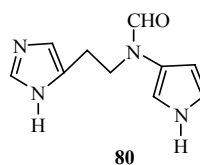
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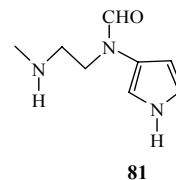
	R ₁	R ₂	R ₃		R ₁	R ₂	R ₃
64	S4	H	OH Δ^5	71	S2	OCOCH ₃	H Δ^5
65	S11	H	OH Δ^5	72	S12	H	H Δ^5
66	S1	H	H Δ^5	73	NH ₂	OH	H Δ^5
67	S2	H	H Δ^5	74	S3	CH ₃	H Δ^5
68	S1	OH	H Δ^5	75	H	CH ₃	H Δ^5
69	S2	OH	H Δ^5	76	OH	H	H Δ^5
70	S1	OCOCH ₃	H Δ^5				



78 R₁=H R₂=CH₃ 5 α -H 79 R₁=CH₃ R₂=H 5 α -H



80



81

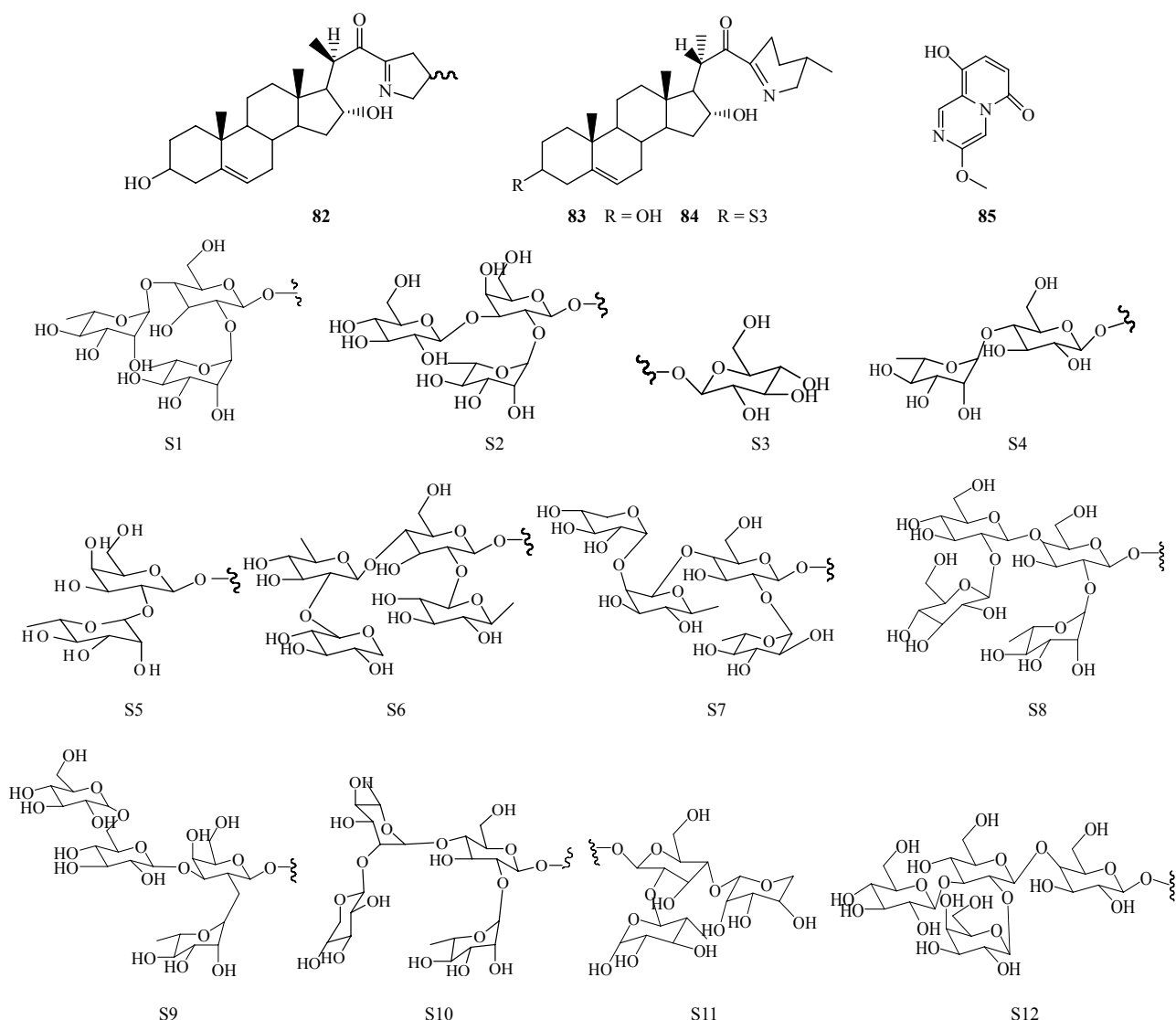


图 1 茄属植物中的生物碱类化合物的结构

Fig. 1 Structures of alkaloid compounds from plants of *Solanum* L.

1.2 黄酮类化合物

黄酮类化合物在茄属植物中作为一种活性成分也广泛存在, 如白英^[10]、疏刺茄 *S. nienkui* Merr.^[36-37]、水茄^[38]等中已发现黄酮类成分。茄属中的黄酮类成分以山柰酚(kaempferol)、芦丁(rutin)、槲皮素(querceetin)居多, 且按照结构可分为黄酮类(I)、黄酮醇类(II)、异黄酮类(III)、花色色素类(IV)以及其他类型。2010年, Ohtsuki等^[39]在假烟叶树 *S. verbascifolium* L. 的叶子中发现了1个新的黄酮苷类化合物(86)。2011年, Lu等^[38]首次在龙葵中分离出芦丁(98)、山柰酚(102)、槲皮素(100)以及异槲皮素(isoquerceetin, 101)。2012年, 吴丹等^[37]在疏刺茄中分离出5个黄酮类化合物(96、100、102、117、122)。这些化合物均

为首次从该植物中分离得到, 其中化合物117是首次从茄科植物中分离得到。茄属植物中的黄酮类化合物见表2和图2。

1.3 甾体类化合物

茄属植物中的甾体成分更是丰富, 多是以成苷形式存在, 且以甾体皂苷类型为主。按骨架分为螺甾类(I), 包括螺甾烷类(C-25为S构型)、螺甾烯类、异螺甾烷类(C-25为R构型); 呋甾烷类(II, F环为开链衍生物); 变形螺甾烷类(III, F环为五元四氢呋喃环); C-21甾类(IV, 母核含有21个碳原子, 如孕甾烷类); 还有植物甾醇类(V, 17位侧链为含有9~10个碳原子的脂肪烃)。Li等^[52]在水茄的果实中分离出5个新的具有细胞毒活性的甾体皂苷类化合物(236~238、264、265)。2009

年, Lu 等^[53]在水茄的地上部分中分离得到了 2 个新的 C-22 甾体苷类化合物(287、288)。Chang 等^[54]在紫花茄的地上部分分离鉴定了 12 个甾体化合物, 有 4 个是具有独特结构的新化合物(164~167), 其中 indioside L 含有罕见的 1,4-2-烯-3-酮

结构。有学者在 *S. abutiloides* 的果实中发现了 *abutiloides* 系列化合物, 以及在 *S. macaonense* Dunal 中发现了 *macaosides* 系列化合物。茄属植物中的甾体化合物日益丰富。茄属植物中的甾体化合物见表 3 和图 3。

表 2 茄属植物中的黄酮类化合物
Table 2 Flavonoid compounds from plants of *Solanum* L.

类型	编号	化合物	来源
I	86	7,4'-dimethyl-apigenin-6-C- β -glucopyranosyl-2''-O- α -L-arabinopyranoside	<i>S. verbascifolium</i> ^[39]
	87	isocytiside 7-O- β -D-glucoside	<i>S. verbascifolium</i> ^[39]
	88	embinoidin	<i>S. verbascifolium</i> ^[39]
	89	5-hydroxy-3,7,4'-trimethoxyflavone	<i>S. schimperianum</i> ^[40]
	90	retusin	<i>S. schimperianum</i> ^[40]
	91	quercetin 3-methyl ether	蓝花茄 <i>S. rantonnetii</i> Carrière ^[41]
	92	牡荆黄素(vitexin)	蓝花茄 ^[41]
	93	异牡荆黄素(isovitexin)	蓝花茄 ^[41]
	94	acacetin 7-O-rutinoside	白英 ^[42]
	95	芹黄素(apigenin)	白英 ^[10]
	96	香叶木素(diosmetin)	疏刺茄 ^[37]
II	97	isorhamnetin-3-O- α -L-rhamnopyranosyl (1 $\rightarrow$ 6) β -D-glucopyranoside	<i>S. glabratum</i> Dunal ^[43]
	98	芦丁(rutin)	<i>S. paniculatum</i> L. ^[44] 、水茄 ^[38] 、茄 ^[43]
	99	quercetin 3-O- α -L-rhamnopyranosyl (1''' $\rightarrow$ 6'')-O- β -D-galactopyranoside	<i>S. paniculatum</i> ^[44]
	100	槲皮素(quercetin)	茄 ^[45] 、白英 ^[46] 、疏刺茄 ^[36-37] 、水茄 ^[9,38]
	101	异槲皮素(isoquercetin)	水茄 ^[38] 、刺萼龙葵 <i>S. rostratum</i> Dunal ^[47]
	102	山柰酚(kaempferol)	水茄 ^[19] 、蓝花茄 ^[41] 、疏刺茄 ^[36-37]
	103	kaempferol-3-O- β -D-glucopyranoside	<i>S. schimperianum</i> ^[40]
	104	kaempferol 8-methyl ether	蓝花茄 ^[41]
	105	kaempferol 3-O- α -rhamnoside	蓝花茄 ^[41]
	106	kaempferol 3-O- β -glucoside	蓝花茄 ^[41] 、刺萼龙葵 ^[47]
	107	quercetin 3-O- β -galactoside	蓝花茄 ^[41]
	108	quercetin-3-O- β -D-glucopyranoside	水茄 ^[48]
	109	isorhamnetin-3-O- β -D-glucopyranoside	水茄 ^[48]
	110	异槲皮苷(isoquercitrin)	刺萼龙葵 ^[47]
	111	isorhamnetin-3-O- β -D-galactopyranoside	刺萼龙葵 ^[47]
	112	5,7,4'-trihydroxy-flavonol (W4)	天星子 <i>S. indicum</i> L. ^[49]
III	113	芒柄花黄素(formononetin)	白英 ^[10]
	114	染料木素(genistein)	白英 ^[10]
	115	黄豆苷(daidzin)	白英 ^[10]
	116	黄豆苷元(daidzein)	白英 ^[10]
	117	7,2',4'-trihydroxy-5-methoxyisoflavanone	疏刺茄 ^[37]
IV	118	牵牛花色素(petunidin)	马铃薯 ^[50]
	119	天竺葵色素(pelargonidin)	马铃薯 ^[50]
	120	芍药花色素(peonidin)	马铃薯 ^[50]
	121	锦葵色素(malvidin)	马铃薯 ^[50]
其他	122	柚皮素(naringenin)	疏刺茄 ^[36-37] 、天星子 ^[49]
	123	torvanol A	水茄 ^[51]

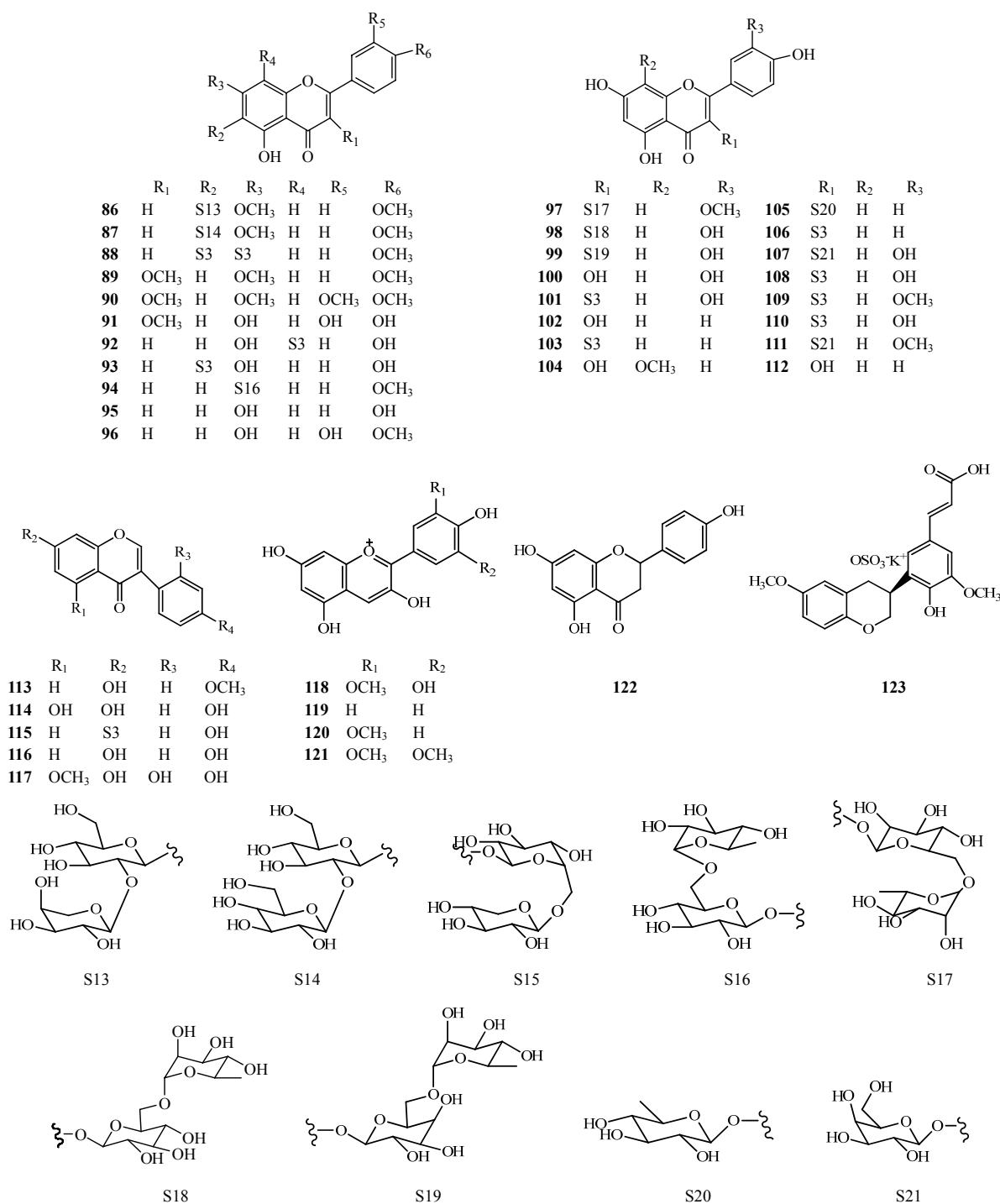


图 2 茄属植物中的黄酮类化合物结构

Fig. 2 Structures of flavonoid compounds from plants of *Solanum* L.

1.3 其他成分

茄属植物中除了以上 3 种成分以外还包含其他类型的化合物, 如萜类化合物^[81-82]、有机酸^[10,44]及其衍生物^[83]、香豆素类^[77,84]、木脂素^[77]、苯丙素类^[85]等。2013 年, Li 等^[82]在白英中发现了 2 个新的桉烷型倍半萜类化合物

solajiangxin F 和 G, 并发现其具有细胞毒活性。同年, Yao 等^[86]在白英中发现了 3 个新的倍半萜类化合物 solajiangxin A~C。Herrera-Salgado 等^[87]在 *S. lanceolatum* Cav. 中分离出 2 个系列的新的肌醇衍生的糖脂类似物 lanceolitol A1~A7 和 B1~B7。

表 3 茄属植物中的甾类化合物
Table 3 Steroidal compounds from plants of *Solanum* L.

类型	编号	化合物	来源
I	124	solagenin 6- <i>O</i> -(β - <i>D</i> -quinovopyranoside)	水茄 ^[9]
	125	6 α - <i>O</i> -[β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranosyl]-(25 <i>S</i>)-5 α -spirostan-3 β -ol	水茄 ^[9]
	126	紫花茄皂苷 (indioside) G	紫花茄 ^[11]
	127	紫花茄皂苷 (indioside) H	紫花茄 ^[11]
	128	紫花茄皂苷 (indioside) I	紫花茄 ^[11]
	129	borassoside D	紫花茄 ^[11]
	130	borassoside E	紫花茄 ^[11]
	131	yamogenin 3- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 2)- β - <i>D</i> -glucopyranoside	紫花茄 ^[11]
	132	3- <i>O</i> -chacotriosyl-25(<i>S</i>)-spirost-5-en-3 β -ol	紫花茄 ^[11]
	133	lyconoside Ia	<i>S. lycocarpum</i> ^[16]
	134	lyconoside Ib	<i>S. lycocarpum</i> ^[16]
	135	lyconoside II	<i>S. lycocarpum</i> ^[16]
	136	lyconoside III	<i>S. lycocarpum</i> ^[16]
	137	lyconoside IV	<i>S. lycocarpum</i> ^[16]
	138	26- <i>O</i> -(β - <i>D</i> -glucopyranosyl) nuatigenin 3- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 4)- β - <i>D</i> -glucopyranoside	牛茄子 ^[17]
	139	aculeatiside A	牛茄子 ^[17]
	140	(23 <i>S</i> ,25 <i>R</i>)-spirost-5-en-3 β ,23-diol 3- <i>O</i> -[β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 2)- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 4)-[<i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 2)]- β - <i>D</i> -glucopyranoside}	黄水茄 ^[18] 、 <i>S. heteracanthum</i> ^[18]
	141	薯蓣皂苷 (dioscin)	黄水茄 ^[18] 、刺萼龙葵 ^[47] 、 <i>S. heteracanthum</i> ^[18]
	142	neochlorogenin 6- <i>O</i> - β - <i>D</i> -quinovopyranoside	水茄 ^[38]
	143	neochlorogenin 6- <i>O</i> - β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranoside	水茄 ^[38]
	144	neochlorogenin 6- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranoside	水茄 ^[38]
	145	solagenin 6- <i>O</i> - β - <i>D</i> -quinovopyranoside	水茄 ^[38]
	146	solagenin 6- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranoside	水茄 ^[38]
	147	剑麻皂素 (tigogenin)	白英 ^[42]
	148	diosgenin-3- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 2)- β - <i>D</i> -glucuroniduronic acid methyl ester	白英 ^[42,55]
	149	23- β - <i>D</i> -glucopyranosyl (23 <i>S</i> ,25 <i>R</i>)-spirost-5-en-3,23-diol 3- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 2)- <i>O</i> -[α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 4)]- β - <i>D</i> -glucopyranoside	<i>S. glabratum</i> var. <i>sepicula</i> ^[43]
	150	(25 <i>R</i>)-spirost-5-en-3-ol 3- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 2)- <i>O</i> -[β - <i>D</i> -glucopyranosyl-(1 $\rightarrow$ 3)]- β - <i>D</i> -galactopyranoside	<i>S. glabratum</i> var. <i>sepicula</i> ^[43]
	151	(23 <i>S</i> ,25 <i>R</i>)-spirost-5-en-3,23-diol 3- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 2)- <i>O</i> -[α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 4)]- β - <i>D</i> -glucopyranoside	<i>S. glabratum</i> var. <i>sepicula</i> ^[43]
	152	(22 <i>R</i> ,23 <i>S</i> ,25 <i>R</i>)-3 β ,6 α ,23-trihydroxy-5 α -spirostane 6- <i>O</i> - β - <i>D</i> -xylopyranosyl-(1''' $\rightarrow$ 3''')- <i>O</i> -[β - <i>D</i> -quinovopyranosyl(1''' $\rightarrow$ 2')]- <i>O</i> -[α - <i>L</i> -rhamnopyranosyl(1'' $\rightarrow$ 3')]- <i>O</i> - β - <i>D</i> -quinovopyranoside	<i>S. paniculatum</i> ^[44]
	153	diosgenin 3- <i>O</i> - β - <i>D</i> -glucopyranosyl (1'' $\rightarrow$ 6')- <i>O</i> - β - <i>D</i> -glucopyranoside	<i>S. paniculatum</i> ^[44]
	154	diosgenin β - <i>D</i> -glucopyranoside	<i>S. paniculatum</i> ^[44]
	155	neochlorogenin 6- <i>O</i> -[α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 3)- <i>O</i> - β - <i>D</i> -quinovopyranoside]	水茄 ^[48]

续表 3

类型	编号	化合物	来源
I	156	(25 <i>S</i>)-6 α -hydroxy-5 α -spirostan-3-one-6- <i>O</i> -[α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranoside]	水茄 ^[9,52]
	157	torvoside C	水茄 ^[51-52]
	158	torvoside D	水茄 ^[56]
	159	torvoside J	牛茄子 ^[17] 、水茄 ^[57]
	160	torvoside K	牛茄子 ^[17] 、水茄 ^[48,57]
	161	torvoside M	水茄 ^[9,53]
	162	torvoside N	水茄 ^[53]
	163	torvoside Q	水茄 ^[57]
	164	紫花茄皂苷 L (indioside L)	紫花茄 ^[54]
	165	紫花茄皂苷 M (indioside M)	紫花茄 ^[54]
	166	紫花茄皂苷 N (indioside N)	紫花茄 ^[54]
	167	紫花茄皂苷 O (indioside O)	紫花茄 ^[54]
	168	(25 <i>S</i>)-neospirost-4-en-3-one	紫花茄 ^[54]
	169	yamogenin	紫花茄 ^[54]
	170	paniculonin B	水茄 ^[57]
	171	neochlorogenin 6- <i>O</i> -[α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranoside]	水茄 ^[57]
	172	(22 <i>R</i> ,23 <i>S</i> ,25 <i>S</i>)-3 β ,6 α ,23-trihydroxy-5 α -spirostane 6- <i>O</i> - β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- <i>O</i> - β - <i>D</i> -quinovopyranoside	水茄 ^[57]
	173	(22 <i>R</i> ,23 <i>S</i> ,25 <i>R</i>)-3 β ,6 α ,23-trihydroxy-5 α -spirostane 6- <i>O</i> - β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- <i>O</i> - β - <i>D</i> -quinovopyranoside	水茄 ^[57]
	174	(22 <i>R</i> ,23 <i>R</i> ,25 <i>S</i>)-3 β ,6 α ,23-trihydroxy-5 α -spirostane 6- <i>O</i> - β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- <i>O</i> - β - <i>D</i> -quinovopyranoside	水茄 ^[57]
	175	neochlorogenin 6- <i>O</i> -[β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranoside]	水茄 ^[57]
	176	6 α - <i>O</i> - β - <i>D</i> -quinovo-pyranosyl-(25 <i>S</i>)-5 α -spirostan-3 β -ol	水茄 ^[57]
	177	3- <i>O</i> -{ α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 4)-[α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 2)]- β - <i>D</i> -glucopyranosyl}-(25 <i>S</i>)-spirost-5-en-3 β -ol	水茄 ^[57]
	178	(25 <i>S</i>)-3 β -hydroxy-5 α -spirostan-6 α -yl- <i>O</i> - β - <i>D</i> -xylopyranoside	水茄 ^[58]
	179	(25 <i>S</i>)-3-oxo-5 α -spirostan-6 α -yl- <i>O</i> - β - <i>D</i> -xylopyranoside	水茄 ^[58]
	180	(25 <i>S</i>)-3 β -hydroxy-5 α -spirostan-6 α -yl- <i>O</i> - β - <i>D</i> -glucopyranoside	水茄 ^[58]
	181	(25 <i>S</i>)-3 β ,27-dihydroxy-5 α -spirostan-6 α -yl- <i>O</i> - β - <i>D</i> -glucopyranoside	水茄 ^[58]
	182	薯蓣皂苷元 (diosgenin)	紫花茄 ^[54] 、白英 ^[42,55]
	183	diosgenone	紫花茄 ^[54] 、 <i>S. nudum</i> Dunal ^[59-60]
	184	macaoside A	<i>S. macaonense</i> ^[61]
	185	macaoside B	<i>S. macaonense</i> ^[61]
	186	macaoside C	<i>S. macaonense</i> ^[61]
	187	macaoside D	<i>S. macaonense</i> ^[61]
	188	macaoside E	<i>S. macaonense</i> ^[61]
	189	macaoside F	<i>S. macaonense</i> ^[61]
	190	macaoside G	<i>S. macaonense</i> ^[61]
	191	macaoside H	<i>S. macaonense</i> ^[61]
	192	chlorogenin	<i>S. macaonense</i> ^[61] 、 <i>S. chrysotrichum</i> Schltdl. ^[62]
	193	6 α - <i>O</i> - β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranosyl-(25 <i>R</i>)-5 α -spirostan-3 β -ol	<i>S. macaonense</i> ^[61]
	194	chlorogenin 6- <i>O</i> - β - <i>D</i> -glucopyranoside	<i>S. macaonense</i> ^[61]
	195	chlorogenin 6- <i>O</i> - β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -glucopyranoside	<i>S. macaonense</i> ^[61]

续表 3

类型	编号	化合物	来源
I	196	anguivoside III	<i>S. anguivi</i> Lam. ^[63]
	197	紫花茄皂苷 D (indioside D)	黄水茄 ^[64]
	198	紫花茄皂苷 E (indioside E)	黄水茄 ^[64]
	199	sc-1	<i>S. chrysotrichum</i> ^[62]
	200	sc-2	<i>S. chrysotrichum</i> ^[62,65]
	201	sc-3	<i>S. macaonense</i> ^[61] 、 <i>S. chrysotrichum</i> ^[62,65]
	202	sc-4	<i>S. macaonense</i> ^[61] 、 <i>S. chrysotrichum</i> ^[62,65]
	203	sc-5	<i>S. chrysotrichum</i> ^[62,65]
	204	sc-6	<i>S. chrysotrichum</i> ^[62,65]
	205	3- <i>O</i> - β - <i>D</i> -sitosterol glycoside	<i>S. chrysotrichum</i> ^[62]
	206	3- <i>O</i> - β - <i>D</i> -stigmasterol glycoside	<i>S. chrysotrichum</i> ^[62]
	207	(23 <i>S</i> ,25 <i>R</i>)-spirost-5-en-3 β ,23-diol-3- <i>O</i> -{ β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 2)- <i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 4)-[<i>O</i> - α - <i>L</i> -rhamnopyranosyl-(1 $\rightarrow$ 2)]- β - <i>D</i> -glucopyranoside}	黄水茄 ^[18] 、 <i>S. heteracanthum</i> ^[18]
	208	6 α - <i>O</i> - β - <i>D</i> -quinovopyranosyl-(25 <i>S</i>)-5 α -spirostan-3 β -ol	<i>S. hispidum</i> Pers. ^[66]
	209	6 α - <i>O</i> -[β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranosyl]-(25 <i>S</i>)-5 <i>R</i> -spirostan-3 β -ol	水茄 ^[55] 、 <i>S. hispidum</i> ^[66]
	210	6 α - <i>O</i> -[β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranosyl]-(25 <i>S</i>)-5 <i>R</i> -spirostan-3 β ,23 β -ol	水茄 ^[55] 、 <i>S. hispidum</i> ^[66]
	211	6 α - <i>O</i> -[β - <i>D</i> -xylopyranosyl-(1 $\rightarrow$ 3)- β - <i>D</i> -quinovopyranosyl]-(25 <i>S</i>)-5 <i>R</i> -spirostan-3 β ,23 α -ol	<i>S. hispidum</i> ^[66] 、 <i>S. paniculatum</i> ^[66]
	212	degalactotigonin	龙葵 ^[67]
	213	solanigroside C	龙葵 ^[67]
	214	solanigroside D	龙葵 ^[67]
	215	solanigroside E	龙葵 ^[67]
	216	solanigroside F	龙葵 ^[67]
	217	solanigroside G	龙葵 ^[67]
	218	solanigroside H	龙葵 ^[67]
	219	laxumin A	<i>S. laxum</i> Spreng. ^[68]
	220	laxumin B	<i>S. laxum</i> ^[68]
	221	isonuatigenin-3- <i>O</i> - β -solatriose	<i>S. sisymbriifolium</i> Lam. ^[69]
	222	solakhasoside	<i>S. khasianum</i> C. B. Clarke ^[70]
II	223	紫花茄皂苷 J (indioside J)	紫花茄 ^[11]
	224	紫花茄皂苷 K (indioside K)	紫花茄 ^[11]
	225	原薯蓣皂苷 (protodioscin)	黄水茄 ^[18] 、 <i>S. heteracanthum</i> ^[18]
	226	methyl-protodioscin	黄水茄 ^[18] 、 <i>S. heteracanthum</i> ^[18]
	227	紫花茄皂苷 D (indioside D)	黄水茄 ^[18-64] 、 <i>S. heteracanthum</i> ^[18]
	228	smilaxchinoside A	刺萼龙葵 ^[47]
	229	26- <i>O</i> - β - <i>D</i> -glucopyranosyl-3 β ,20 α ,26-triol-(25 <i>R</i>)- $\Delta^{5,22}$ -dienofurostan-3- <i>O</i> - α - <i>L</i> -rhamnopyranosyl (1 $\rightarrow$ 2)-[α - <i>L</i> -rhamnopyranosyl(1 $\rightarrow$ 4)]- β - <i>D</i> -glucopyranoside	刺萼龙葵 ^[47]
	230	torvoside A	水茄 ^[51-52,55]
	231	torvoside B	水茄 ^[51-52,55]
	232	torvoside E	水茄 ^[51-52,55]
	233	torvoside F	水茄 ^[51-52]
	234	torvoside G	水茄 ^[51-52]

续表 3

类型	编号	化合物	来源
II	235	torvoside H	水茄 ^[52]
	236	(25S)-26-O-β-D-glucopyranosyl-5α-furost-22(20)-en-3β,6α,26-triol-6-O-[α-L-rhamnopyranosyl-(1→3)-O-β-D-quinovopyranoside]	水茄 ^[52]
	237	(25S)-26-O-β-D-glucopyranosyl-5α-furost-22(20)-en-3-one-6α,26-diol-6-O-[α-L-rhamnopyranosyl-(1→3)-O-β-D-quinovopyranoside]	水茄 ^[52]
	238	(25S)-26-O-β-D-glucopyranosyl-5α-furost-22(20)-en-3β,6α,26-triol-6-O-β-D-quinovopyranoside	水茄 ^[52]
	239	(25S)-26-(β-D-glucopyranosyloxy)-3-oxo-5α-furost-20(22)-en-6α-yl-O-β-D-xylopyranoside	水茄 ^[57]
	240	(25S)-26-(β-D-glucopyranosyloxy)-3-oxo-22α-methoxy-5α-furostan-6α-yl-O-β-D-xylopyranoside	水茄 ^[57]
	241	(25S)-26-(β-D-glucopyranosyloxy)-3β-hydroxy-22α-methoxy-5α-furostan-6α-yl-O-α-L-rhamnopyranosyl-(1→3)-β-D-glucopyranoside	水茄 ^[57]
	242	tumaquenone	<i>S. nudum</i> ^[60]
	243	macaoside I	<i>S. macaonense</i> ^[61]
	244	macaoside M	<i>S. macaonense</i> ^[61]
	245	macaoside N	<i>S. macaonense</i> ^[61]
	246	macaoside O	<i>S. macaonense</i> ^[61]
	247	macaoside P	<i>S. macaonense</i> ^[61]
	248	macaoside Q	<i>S. macaonense</i> ^[61]
	249	macaoside R	<i>S. macaonense</i> ^[61]
	250	anguivioside XI	<i>S. anguivi</i> ^[63]
	251	紫花茄皂苷 B (indioside B)	黄水茄 ^[64]
	252	紫花茄皂苷 C (indioside C)	黄水茄 ^[64]
	253	aethioside A	<i>S. aethiopicum</i> L. ^[71]
	254	aethioside B	<i>S. aethiopicum</i> ^[71]
	255	aethioside C	<i>S. aethiopicum</i> ^[71]
	256	uttroside A	龙葵 ^[72]
	257	uttroside B	龙葵 ^[72]
	258	22α,25R-26-O-β-D-glucopyranosyl-22-hydroxy-furost-Δ ⁵ -3β,26-diol-3-O-β-D-glucopyranosyl-(1→2)-O-[β-D-xylopyranosyl-(1→3)]-O-β-D-glucopyranosyl-(1→4)-O-β-D-glucopyranoside	龙葵 ^[72]
	259	5α,22α,25R-26-O-β-D-glucopyranosyl-22-hydroxy-furost-3β,26-diol-3-O-β-D-glucopyranosyl-(1→2)-O-[β-D-glucopyranosyl-(1→3)]-O-β-D-glucopyranosyl-(1→4)-O-β-D-galactopyranoside	龙葵 ^[72]
	260	22α,25R-26-O-β-D-glucopyranosyl-22-methoxy-furost-Δ ⁵ -3β,26-diol-3-O-β-D-glucopyranosyl-(1→2)-O-[β-D-xylopyranosyl-(1→3)]-O-β-D-glucopyranosyl-(1→4)-O-β-D-galactopyranoside	龙葵 ^[72]
III	261	abutiloside L	<i>S. abutiloides</i> ^[73]
	262	abutiloside M	<i>S. abutiloides</i> ^[73]
	263	abutiloside N	<i>S. abutiloides</i> ^[73]
IV	264	5α-pregn-16-en-20-one-3β,6α-diol-6-O-[α-L-rhamnopyranosyl-(1→3)-β-D-quinovopyranoside]	水茄 ^[52]
	265	5α-pregn-16-en-3,20-dione-6α-ol-6-O-[α-L-rhamnopyranosyl-(1→3)-β-D-quinovopyranoside]	水茄 ^[52]
	266	torvpregnanoside A	水茄 ^[56]

续表 3

类型	编号	化合物	来源
IV	267	torvpregnanoside B	水茄 ^[56]
	268	dumoside	龙葵 ^[72]
	269	5 α ,20S-3 β ,16 β -dihydroxy pregn-22-carboxylic acid (22,16)-lactone-3- O- β -D-glucopyranosyl-(1 $\rightarrow$ 2)-O-[β -D-xylopyranosyl-(1 $\rightarrow$ 3)]-O- β -D- glucopyranosyl-(1 $\rightarrow$ 4)-O- β -D-galactopyranoside	龙葵 ^[72]
	270	solanigroside A	龙葵 ^[74]
	271	solanigroside B	龙葵 ^[74]
	272	5 α -pregn-16-en-3 β -ol-20-one-3-O- β -D-glucopyranosyl-(1 $\rightarrow$ 2)-O-[β -D- xylopyranosyl-(1 $\rightarrow$ 3)]-O- β -D-glucopyranosyl-(1 $\rightarrow$ 4)-O- β -D-galacto- pyranoside	龙葵 ^[74]
	273	pregna-5,16-dien-3 β -ol-20-one-3-O- α -L-rhamnopyranosyl-(1 $\rightarrow$ 2)-O-[α -L- rhamnopyranosyl-(1 $\rightarrow$ 4)]-O- β -D-glucopyranoside	龙葵 ^[74]
V	274	sitosterol 3-O- β -D-glucopyranoside	紫花茄 ^[11]
	275	7-hydroxysitosterol-3-O- β -D-glucopyranoside	紫花茄 ^[11]
	276	9 α ,11 α -epidioxyergosta-6,22-dien-3 β -ol	青杞 ^[13]
	277	β -stigmasteryl-3-O- β -D-(6-palmityl) glucopyranoside	青杞 ^[13]
	278	stigmastero	青杞 ^[13]
	279	β -谷甾醇 (β -sitosterol)	青杞 ^[13] 、 <i>S. schimperianum</i> ^[40] 、白英 ^[46] 、 疏刺茄 ^[51] 、刺萼龙葵 ^[47] 、龙葵 ^[75]
	280	胡萝卜苷 (daucosterol)	青杞 ^[13] 、疏刺茄 ^[36] 、白英 ^[46] 、刺萼龙 葵 ^[47]
	281	β -sitosterol glucoside	<i>S. schimperianum</i> ^[40]
	282	(22E,24R)-5 α ,8 α -epidioxyergosta-6,22-dien-3 β -ol	紫花茄 ^[54]
	283	(22E,24R)-5 α ,8 α -epidioxyergosta-6,9(11),22-trien-3 β -ol	紫花茄 ^[54]
	284	7-oxostigmasterol	紫花茄 ^[54]
	285	7-oxositosterol	紫花茄 ^[54]
C-22	286	solanolide	水茄 ^[48]
	287	solanolactoside B	水茄 ^[53]
	288	solanolactoside A	水茄 ^[52-53,56]
其他	289	tigogenone	白英 ^[42]
	290	4-methyl-cholesta-7-ene-3 β -ol	白英 ^[42]
	291	tumacone A (SN1)	<i>S. nudum</i> ^[59-60,76]
	292	tumacone B (SN2)	<i>S. nudum</i> ^[59-60,76]
	293	tumacoside A (SN3)	<i>S. nudum</i> ^[59-60]
	294	tumacoside B (SN4)	<i>S. nudum</i> ^[59-60]
	295	anguivoside XI	<i>S. anguivi</i> ^[63]
	296	anguivoside XV	<i>S. anguivi</i> ^[63]
	297	anguivoside XVI	<i>S. anguivi</i> ^[63]
	298	abutiloside O	<i>S. abutiloides</i> ^[73]
	299	cilistol a	<i>S. cilistum</i> ^[77]
	300	cilistol b	<i>S. cilistum</i> ^[77]
	301	cilistol d	<i>S. cilistum</i> ^[77]
	302	cilistol q	<i>S. cilistum</i> ^[77]
	303	cilistol g	<i>S. cilistum</i> ^[77]
	304	cilistol f	<i>S. cilistum</i> ^[77]
	305	黄果茄甾醇 (carpesterol)	<i>S. sisymbriifolium</i> Lam. ^[78]
	306	abutiloside A	<i>S. abutiloides</i> ^[79]
	307	abutiloside B	<i>S. abutiloides</i> ^[79]
	308	abutiloside C	<i>S. abutiloides</i> ^[79]
	309	abutiloside D	<i>S. abutiloides</i> ^[80]
	310	abutiloside E	<i>S. abutiloides</i> ^[80]
	311	abutiloside F	<i>S. abutiloides</i> ^[80]
	312	abutiloside G	<i>S. abutiloides</i> ^[80]

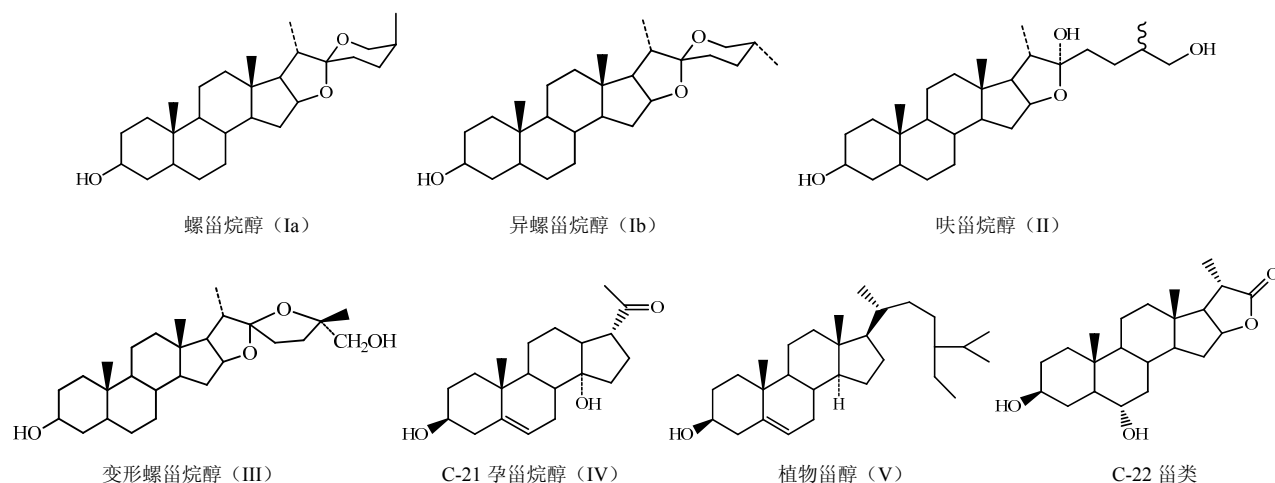


图3 茄属植物中甾类化合物的结构类型

Fig. 3 Structure types of steroidal compounds from plants of *Solanum* L.

2 生物活性

茄属植物是茄科中一类重要的植物，常作为民间草药广泛使用。该属下多种植物早在《本草纲目》《新修本草》等古籍中就有记载，具有悠久的药用历史。如龙葵，《本草纲目》中介绍其苦、微甘，滑，寒，无毒；主治去热少睡、小便不通、坠伤、背痛等。

2.1 肝保护作用

2008年，Lin等^[88]研究发现龙葵水提取物(SNE)能够逆转CCl₄诱导的氧化肝损伤大鼠的肝纤维化组织学特点和血清中天冬氨酸转氨酶(AST)、丙氨酸转氨酶(ALT)、碱性磷酸酶及总胆红素水平。这种保护能力部分是由于其调节解毒酶和抗氧化酶的作用(抑制自由基的产生和随后的肝损伤)。Hsieh等^[89]研究表明在硫代乙酰胺(TAA)诱导的小鼠肝损伤中，血浆ALT活性和总胆红素浓度增加，经过SNE治疗后降低了血浆ALT活性和总胆红素水平，且通过抑制转化生长因子(TGF-β1)分泌减慢肝纤维化。

2.2 肾保护作用

Hussain等^[90]发现黄果茄果实提取物对庆大霉素引起的肾毒性和肾功能不全大鼠有保护作用。其作用机制可能为黄果茄果实提取物作为一种有效的自由基清除剂作用于肾脏，保护其不受庆大霉素的毒性作用。Kumar等^[91]进行了龙葵全草提取液对庆大霉素诱导的肾细胞损伤的体外研究。通过台盼蓝拒染试验和MTT法评估线粒体脱氢酶活性实验得出：庆大霉素的细胞毒性明显被抑制且龙葵全草

提取液也表现出显著的潜在羟基自由基清除能力，从而表现出细胞保护活性。

2.3 胃保护作用

Mesia-Vela等^[92]通过研究*S. paniculatum*的不同部分的水提取物对小鼠(幽门结扎)胃酸分泌的抑制作用，发现其根、茎和花的水提取物抑制小鼠胃酸分泌，叶的水提取物不影响胃酸的分泌，而果实的水提取物刺激胃酸分泌。总的来说这一结果验证了民间使用*S. paniculatum*来治疗胃病的科学性。Jainu等^[93]研究了龙葵的抗溃疡和促进溃疡愈合的作用。实验证明，SNE在高剂量时具有显著的抗冷束缚应激(CRU)、吲哚美辛(ID)、幽门结扎(PL)以及乙醇引起的大鼠胃溃疡的活性，与奥美拉唑相比具有相同或更高的治疗效果。其作用机制可能是通过抑制H⁺, K⁺-ATP酶活性，减少胃酸分泌从而起到抗胃溃疡作用；进一步研究表明SNE同样具有促进胃溃疡伤口愈合的作用。

2.4 抗肿瘤作用

Wang等^[94]研究发现SNE在小鼠体内外均可抑制黑色素瘤细胞(B16-F1)的转移和侵袭，其机制可能是使蛋白激酶失活。Li等^[95]研究发现SNE能通过调节小鼠免疫能力和诱导细胞凋亡抑制宫颈癌细胞的生长。Son等^[96]研究了龙葵的成熟果实对乳腺癌(MCF)的作用。实验证明，龙葵的成熟果实乙醇提取物可抑制MCF-7细胞的增殖，诱导其凋亡。此提取物是羟基自由基、1,1-二苯-2-苦基肼(DPPH)自由基清除剂，可以作为抗氧化剂和防癌物质。Nzaramba等^[97]研究发现*S. jamesii* Torr. 块茎

提取物在体外对人体结肠癌和前列腺癌具有细胞毒性和抗增殖活性。研究表明,该提取物可显著降低结肠癌细胞 HT-29 和前列腺癌细胞的增殖率,且抑制前列腺癌细胞增殖所需的浓度较高。

2.5 抗氧化活性

自由基是机体氧化反应中产生的有害物质,具有强氧化性,可损害机体的组织和细胞,进而引起慢性疾病和衰老效应。茄属植物的抗氧化活性主要源于其中含有的酚类化合物且其作用机制主要是抑制自由基的产生和清除自由基。Chellaram 等^[98]研究了马铃薯中酚类物质的量,并对其抗氧化能力进行了分析。研究表明, DPPH 自由基清除活性实验表明,酚类物质是马铃薯产生抗自由基活性的主要物质。Jeong 等^[99]研究了龙葵中的露那辛(lunasin)多肽可阻断芬顿反应,抑制羟基自由基的产生,保护 DNA 免受氧化性损伤。Pihlanto 等^[100]研究发现,从马铃薯块茎中分离出来的蛋白质具有抑制血管紧张素转换酶(ACE)活性和自由基清除的能力。研究结果表明:其水解物的 ACE 抑制能力较高,且所有的样品均表现出较低的自由基清除活性。Oszmianski 等^[101]研究了 *S. scabrum* Mill. 和 *S. burbankii* Bitter 的浆果中的酚类化合物及其抗氧化活性,实验证明,前者含有更多的酚类化合物且具有更高的抗氧化活性。

2.6 抗真菌、抗病毒活性

Javed 等^[102]研究发现龙葵种子的氯仿提取物可降低丙型肝炎病毒(HCV) NS3 蛋白酶的表达且呈剂量依赖的关系。Harikrishnan 等^[103]发现龙葵提取物可增强斑节对虾免疫反应和抵抗疾病的能力。龙葵提取物在 0.1% 和 1.0% 剂量下可作为免疫增强剂,抵抗哈维氏弧菌。

2.7 调血脂、降血糖活性

Elekofehinti 等^[104]研究了 *S. anguivi* (African eggplant) 果实中的皂苷对四氧嘧啶诱导的糖尿病大鼠的作用,研究结果表明该果实中的皂苷可以显著地降低血糖及调节血脂水平,并可用于糖尿病的预防和治疗。Poongothai 等^[105]进行了龙葵叶水提取物在四氧嘧啶诱导的糖尿病大鼠中潜在的抗糖尿病和调血脂作用的评价研究。结果表明,龙葵叶水提取物治疗组的糖尿病大鼠血糖水平与糖尿病对照组相比显著降低,且血脂水平得到显著控制。

2.8 其他作用

茄属植物的生物活性还有灭螺^[106]、抗炎^[61,68,107]、

抗惊厥^[108]等。Lee 等^[61]从 *S. macaonense* 中分离得到了 8 个新的螺甾皂苷和 10 个新的呋甾皂苷,并进行了体外抗中性粒细胞炎症实验,其中化合物 193、201、202 表现出显著的抑制超氧阴离子的产生和弹性蛋白酶的释放的能力,从而表现出抗炎活性,而 macaoside A、D 只抑制弹性蛋白酶的释放,192 只抑制超氧阴离子的产生。Emmanuel 等^[108]研究了 *S. trilobatum* L. 的抗炎活性。通过实验研究证明,澳洲茄胺、 β -谷甾醇以及 *S. trilobatum* 的甲醇提取物对角叉菜胶诱导的大鼠爪水肿均具有抗炎活性(炎症反应显著减少),且 *S. trilobatum* 的甲醇提取物的抗炎效果接近于保泰松。

3 毒性

茄属植物中毒表现为胃肠刺激和中枢神经系统的抑制反应。张海华^[2]报道了食用马铃薯引起龙葵素中毒 20 例分析。分析结果表明,吃极少量的龙葵素(solanine)对人体不一定有明显的害处,多食(约 200 mg)可发生龙葵素中毒。龙葵素具有腐蚀性,对胃肠道黏膜具有强刺激作用,轻者可出现恶心、呕吐、腹痛、腹泻等症状;重者血压下降;严重者出现抽搐、休克、昏迷甚至死亡。Vireque 等^[106]研究了 *S. lycocarpum* 对雄性小鼠和大鼠生殖系统的毒性。结果表明,该植物对小鼠可能存在抗雄性激素作用,但对于大鼠在实验中给予剂量条件下无明显的抗生育作用。

4 结语

茄属植物常作为我国的传统中药材而广泛使用,各省均出产,其物种在全世界也都有分布。茄属植物对于人类来说是非常重要的一类植物,提供给人类多种食物和药物。茄属植物品种繁多,化学成分复杂,一般都含有不同量的生物碱,具有一定的毒性。近年来其丰富的化学成分与多样的生物活性引起了众多学者的研究热情,国内外学者对其不断探索,已取得相当可观的研究成果,为今后的研究奠定了深厚的基础。

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