

菰蓝属植物化学成分及药理作用研究进展

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摘要: 菰蓝属植物在中国药用历史悠久, 其中菰蓝的根和叶即为板蓝根和大青叶。该属植物化学成分多样, 主要包括生物碱类、硫代葡萄糖苷类、木脂素类、黄酮类等, 具有抗菌、抗病毒、抗内毒素、抗肿瘤、抗炎、免疫增强等药理作用。本文对近40年来国内外有关菰蓝属植物化学成分和药理作用的文献进行系统的总结, 为该属植物的进一步研究开发提供参考。

关键词: 菰蓝属; 化学成分; 生物碱类; 硫代葡萄糖苷类; 木脂素类; 黄酮类; 药理作用

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Research Progress on Chemical Constituents and Pharmacological Effects of *Isatis*

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ABSTRACT: *Isatis* has a long history of medicinal use in China, among which the roots and leaves of *Isatis indigotica* are Banlangen and Daqingye. Genus *Isatis* plants have a variety of chemical constituents, including alkaloids, glucosinolates, lignans and flavonoids, which have the pharmacological activities of antibacterial, antiviral, antitoxin, antitumor, anti-inflammatory, immune regulation, etc. The paper made a systematic summary about research on the chemical constituents and pharmacological effects of *Isatis* in China and abroad for forty years to provide the references for further studies.

KEYWORDS: *Isatis*; chemical constituents; alkaloids; glucosinolates; lignans; flavonoids; pharmacological effects

菰蓝属(*Isatis*)全世界约有30个种, 分布在欧洲、地中海地区、西亚及中亚, 中国有6个种及1个变种, 即菰蓝(*I. indigotica* Fort.)、欧洲菰蓝(*I. tinctoria* L.)、宽翅菰蓝(*I. violascens* Bunge)、三肋菰蓝(*I. costata* C. A. Mey)、小果菰蓝(*I. minima* Bunge)、长圆果菰蓝(*I. oblongata* DC.)和毛果菰蓝[*I. tinctoria* L. var. *praecox* (Kit.) Koch]^[1]。其中, 宽翅菰蓝、三肋菰蓝、小果菰蓝、长圆果菰蓝和毛果菰蓝化学成分和药理作用研究较少, 欧洲菰蓝和菰蓝化学成分和药理作用研究较多。欧洲菰蓝原产自欧洲, 目前中国有引种栽培。菰蓝原产自中国, 主产于内蒙古、陕西、甘肃和河北等地, 其根和叶均可入药, 即板蓝根和大青叶^[2]。几十年来, 国内外学者对菰蓝属植物的化学成分进行了较为深入的研究, 主要有以下几类: 生物碱类, 硫代葡萄糖苷类, 木脂素类, 黄酮类, 有机酸类, 甾醇类, 氨基酸、碱基及核苷类, 蒽醌、香豆素及其他类化合物。现代药理学研究表明菰蓝属植

物具有抗菌、抗病毒、抗内毒素、抗肿瘤、抗炎、免疫增强和活血化瘀等作用。本文对菰蓝属现有的化学成分和药理作用相关文献进行总结, 以期后续研究该属植物提供参考。

1 化学成分

1.1 生物碱类

作为菰蓝属植物的特征性成分, 生物碱类成分可归纳为3类: 吲哚类生物碱、喹啉类生物碱和喹啉类生物碱。

1.1.1 吲哚类生物碱 吲哚类生物碱是菰蓝属植物中较为常见的一类化学成分(表1)。该类成分的结构根据3-位取代基的类型可分为以下几类: 吲哚甲醛类(1, 4)、吲哚乙腈类(2, 3)、吲哚乙酸类(5)、吲哚乙酰胺类(14~17)和吲哚甲磺酸类(58, 60, 61)等。1-位和4-位经常被甲氧基取代(1, 3, 13, 15), 2-位有时被氧化形成2-羟基吲哚或吲哚酮(6~17)。2-、3-、4-、6-位可形成单糖或双糖苷(氧苷、碳苷、硫苷)(27~45)。此外, 吲哚环与喹啉环之间可通过

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表1 菰蓝属植物中的吲哚类生物碱

Tab. 1 Indole alkaloids isolated from *Isatis*

序号	名称	物种	参考文献	序号	名称	物种	参考文献
1	1-methoxy-3-indolecarbaldehyde(1-甲氧基-3-吲哚甲醛)	<i>I. indigotica</i> (菰蓝)	[3]	39	isatigotindoleoside A	<i>I. indigotica</i> (菰蓝)	[20]
2	indole-3-acetonitrile(吲哚-3-乙腈)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]	40	isatigotindoleoside C	<i>I. indigotica</i> (菰蓝)	[20]
3	1-methoxy-3-indoleacetonitrile(1-甲氧基-3-吲哚乙腈)	<i>I. indigotica</i> (菰蓝)	[3]	41	isatigotindoleoside D	<i>I. indigotica</i> (菰蓝)	[20]
4	3-formyl indole(吲哚-3-甲醛)	<i>I. indigotica</i> (菰蓝)	[3]	42	isatigotindoleoside E	<i>I. indigotica</i> (菰蓝)	[20]
5	3-indoleacetic acid(吲哚-3-乙酸)	<i>I. indigotica</i> (菰蓝)	[5]	43	isatigotindoleoside F	<i>I. indigotica</i> (菰蓝)	[20]
6	2,5-dihydroxy indole(2,5-二羟基吲哚)	<i>I. indigotica</i> (菰蓝)	[6]	44	calanthoside	<i>I. indigotica</i> (菰蓝)	[20]
7	2,3-dihydro-4-hydroxy-2-oxo-indole-3-acetonitrile(2,3-二氢-4-羟基-2-氧代吲哚-3-乙腈)	<i>I. indigotica</i> (菰蓝)	[6]	45	α -L-rhamnopyranosyl-(1 $\rightarrow$ 6)- β -D-glucopyranosyl 3-indolecarbonate	<i>I. indigotica</i> (菰蓝)	[20]
8	2,3-dihydro-5-hydroxy-2-oxo-indole(2,3-二氢-5-羟基-2-氧代吲哚)	<i>I. tinctoria</i> (欧洲菰蓝)	[7]	46	indirubin(靛玉红)	<i>I. indigotica</i> (菰蓝)	[21]
9	isatin(吲哚醌)	<i>I. indigotica</i> (菰蓝)	[8]	47	indigotin(靛蓝)	<i>I. indigotica</i> (菰蓝)	[22]
10	(E)-2-(4-hydroxy-2-oxoindolin-3-ylidene)acetonitrile	<i>I. indigotica</i> (菰蓝)	[9]	48	hydroxyindirubin(羟基靛玉红)	<i>I. indigotica</i> (菰蓝)	[23]
11	(S)-2-(3,4-dihydroxy-2-oxoindolin-3-yl)-acetonitrile	<i>I. indigotica</i> (菰蓝)	[9]	49	isoindigotin(异靛蓝)	<i>I. tinctoria</i> (欧洲菰蓝)	[16]
12	(R)-2-(4-hydroxy-2-oxoindolin-3-yl)-acetonitrile	<i>I. indigotica</i> (菰蓝)	[9]	50	3'-[3''-(2'''-hydroxybut-3'''-en-1'''-yl)-1'',2'',4''-thiadiazol-5''-yl]-5',6'-dihydrospiro[indoline-3,2'-thiopyran]-2-one	<i>I. indigotica</i> (菰蓝)	[24]
13	(S)-2-(3-hydroxy-4-methoxy-2-oxoindolin-3-yl)-acetonitrile	<i>I. indigotica</i> (菰蓝)	[9]	51	(-)-(R)-2-(3-cyanomethyl-4-methoxy-1H-indol-7-yl)-2-(1H-indol-3-yl)-acetonitrile	<i>I. indigotica</i> (菰蓝)	[9]
14	(S)-2-(3-hydroxy-2-oxoindolin-3-yl)-acetamide	<i>I. indigotica</i> (菰蓝)	[9]	52	(-)-(R)-2-(3-cyanomethyl-4-methoxy-1H-indol-7-yl)-2-(4-methoxy-1H-indol-3-yl) acetonitrile	<i>I. indigotica</i> (菰蓝)	[9]
15	(S)-2-(3-hydroxy-4-methoxy-2-oxoindolin-3-yl)-acetamide	<i>I. indigotica</i> (菰蓝)	[9]	53	insatindibisindolamide A	<i>I. indigotica</i> (菰蓝)	[25]
16	(R)-2-(4-hydroxy-2-oxoindolin-3-yl)-acetamide	<i>I. indigotica</i> (菰蓝)	[9]	54	isatibisindosulfonic acid A 3-O- β -D-glucopyranoside	<i>I. indigotica</i> (菰蓝)	[26]
17	($\pm$)-2-(2-oxoindolin-3-yl)-acetamide	<i>I. indigotica</i> (菰蓝)	[9]	55	isatibisindosulfonic acid B	<i>I. indigotica</i> (菰蓝)	[26]
18	(Z)-2-(1H-indol-3-ylmethylidene)-1,2-dihydro-3H-indol-3-one	<i>I. indigotica</i> (菰蓝)	[9]	56	isatindosulfonic acid A 3-O- β -D-glucopyranoside	<i>I. indigotica</i> (菰蓝)	[26]
19	(E)-[(3'-indole)-cyanomethylene]-3-indolinone	<i>I. indigotica</i> (菰蓝)	[10]	57	isatindosulfonic acid B	<i>I. indigotica</i> (菰蓝)	[26]
20	costinone A	<i>I. costata</i> (三肋菰蓝)	[11-12]	58	isatindosulfonic acid C	<i>I. indigotica</i> (菰蓝)	[26]
21	costinone B	<i>I. costata</i> (三肋菰蓝)	[11-12]	59	isatindosulfonic acid D	<i>I. indigotica</i> (菰蓝)	[26]
22	isatinone A	<i>I. costata</i> (三肋菰蓝)	[11,13]	60	isatindosulfonic acid E	<i>I. indigotica</i> (菰蓝)	[26]
23	isatidifoliumindolinone A	<i>I. indigotica</i> (菰蓝)	[14]	61	isatindosulfonic acid F	<i>I. indigotica</i> (菰蓝)	[26]
24	indiforine B	<i>I. indigotica</i> (菰蓝)	[15]	62	isatindigobisindolide A	<i>I. indigotica</i> (菰蓝)	[27]
25	isatinone B	<i>I. costata</i> (三肋菰蓝)	[11,13]	63	isatindigobisindolide C	<i>I. indigotica</i> (菰蓝)	[27]
26	trisindoline	<i>I. costata</i> (三肋菰蓝)	[11]	64	isatindigobisindolide D	<i>I. indigotica</i> (菰蓝)	[27]
27	indican(靛苷)	<i>I. tinctoria</i> (欧洲菰蓝)	[16]	65	isatindigobisindolide E	<i>I. indigotica</i> (菰蓝)	[27]
28	isatan B	<i>I. tinctoria</i> (欧洲菰蓝)	[16]	66	isatindigobisindolide F	<i>I. indigotica</i> (菰蓝)	[27]
29	indole-3-acetonitrile-6-O- β -D-glucopyranoside(吲哚-3-乙腈-6-O- β -D-葡萄糖苷)	<i>I. indigotica</i> (菰蓝)	[6]	67	isatindigobisindolide G	<i>I. indigotica</i> (菰蓝)	[27]
30	N-methoxy-indole-3-acetonitrile-2-C- β -D-glucopyranoside(N-甲氧基-吲哚-3-乙腈-2-C- β -D-葡萄糖苷)	<i>I. indigotica</i> (菰蓝)	[17]	68	isatindigoside C	<i>I. indigotica</i> (菰蓝)	[28]
31	indole-3-acetonitrile-4-methoxy-2-C- β -D-glucopyranoside(吲哚-3-乙腈-4-甲氧基-2-C- β -D-葡萄糖苷)	<i>I. indigotica</i> (菰蓝)	[17]	69	isatindigotindoline A	<i>I. indigotica</i> (菰蓝)	[29]
32	indole-3-acetonitrile-2-S- β -D-glucopyranoside(吲哚-3-乙腈-2-S- β -D-葡萄糖苷)	<i>I. indigotica</i> (菰蓝)	[18]	70	isatindigotindoline C	<i>I. indigotica</i> (菰蓝)	[29]
33	indole-3-acetonitrile-4-methoxy-2-S- β -D-glucopyranoside(吲哚-3-乙腈-4-甲氧基-2-S- β -D-葡萄糖苷)	<i>I. indigotica</i> (菰蓝)	[18]	71	isatindigotindoline D	<i>I. indigotica</i> (菰蓝)	[29]
34	N-methoxy-indole-3-acetonitrile-2-S- β -D-glucopyranoside(N-甲氧基-吲哚-3-乙腈-2-S- β -D-葡萄糖苷)	<i>I. indigotica</i> (菰蓝)	[18]	72	(+)-(S)-2-{7-[1-(4-hydroxyphenyl)-ethyl]-4-methoxy-1H-indol-3-yl}-acetonitrile	<i>I. indigotica</i> (菰蓝)	[9]
35	isatindigotindolide A	<i>I. indigotica</i> (菰蓝)	[19]	73	bisindigotin	<i>I. indigotica</i> (菰蓝)	[30]
36	isatindigotindolide B	<i>I. indigotica</i> (菰蓝)	[19]	74	isatindigodiphindoside	<i>I. indigotica</i> (菰蓝)	[31]
37	isatindigotindolide C	<i>I. indigotica</i> (菰蓝)	[19]	75	isatindolignanose A	<i>I. indigotica</i> (菰蓝)	[32]
38	isatindigotindolide E	<i>I. indigotica</i> (菰蓝)	[19]				

2-位、3-位或侧链相互并联形成二聚体(18, 19, 46~49, 51~55, 62~68)、三聚体(26)甚至四聚体(73)。另外, 吡啶环 3-位可形成螺环化合物(50, 69~71)。值得一提的是, 吡啶环还能和苯丙素或木脂素聚合形成吡啶-苯丙素聚合物或吡啶-木脂素聚合物(74~75)。代表性吡啶类生物碱结构式见图 1。

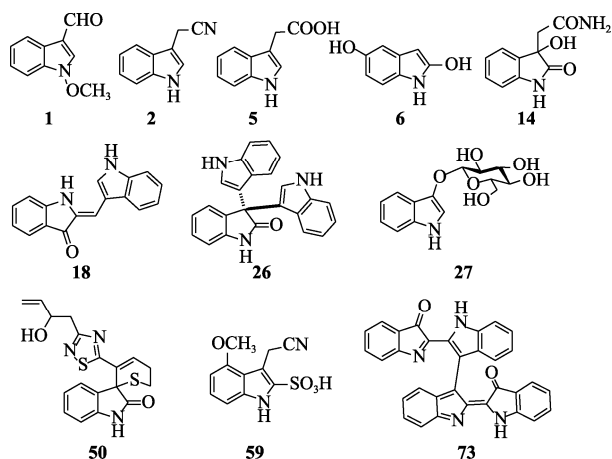


图 1 菰蓝属植物中的代表性吡啶类生物碱结构
Fig. 1 Structures of representative indole alkaloids isolated from *Isatis*

1.1.2 喹啉酮类生物碱 喹啉酮为喹啉的衍生物, 一般 4-位或 2-形成酮(76~77), 2-位和 3-位较活泼, 容易被脂肪链或芳香环取代(78~80, 82, 86)或与其他活泼基团并联(83~85), 有时 1-位也参与成环(87~88)。该类化合物以广泛存在于产蓝植物中的色胺酮(吡啶喹啉酮, 83)为代表, 见表 2。代表性喹啉酮类生物碱结构式见图 2。

表 2 菰蓝属植物中的喹啉酮类生物碱
Tab. 2 Quinazolinone alkaloids isolated from *Isatis*

序号	名称	物种	参考文献
76	4(3H)-quinazolinone[4(3H)-喹啉酮]	<i>I. indigotica</i> (菰蓝)	[21]
77	1H,3H-quinazolinone-2,4-diones [2,4(1H,3H)-喹啉二酮]	<i>I. tinctoria</i> (欧洲菰蓝)	[7]
78	indiforine C	<i>I. indigotica</i> (菰蓝)	[15]
79	indiforine D	<i>I. indigotica</i> (菰蓝)	[15]
80	isatisindigoticanine C	<i>I. indigotica</i> (菰蓝)	[33]
81	Deoxyvasicinone(脱氧鸭嘴花酮碱)	<i>I. indigotica</i> (菰蓝)	[21]
82	3-(2'-hydroxyphenyl)-4-(3H)- quinazolinone(3-羟苯基喹啉酮)	<i>I. indigotica</i> (菰蓝)	[34]
83	tryptanthrin(色胺酮)	<i>I. indigotica</i> (菰蓝)	[21]
84	isaindigotone	<i>I. indigotica</i> (菰蓝)	[23]
85	qingdainone(青黛酮)	<i>I. indigotica</i> (菰蓝)	[21]
86	3-(2'-caboxyphenyl)-4(3H)-quinazolinone [3-(2'-羧基苯基)-4(3H)-喹啉酮]	<i>I. indigotica</i> (菰蓝)	[21]
87	3-hydroxy-2H-pyrrolo[2,3-b]indolo[5, 5a,6-b,a]quinazolinone-9(8H)-7'-dione	<i>I. indigotica</i> (菰蓝)	[9]
88	phaitanthrin A	<i>I. indigotica</i> (菰蓝)	[35]

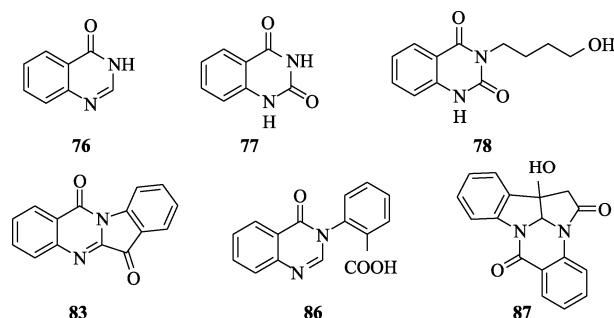


图 2 菰蓝属植物中的代表性喹啉酮类生物碱结构
Fig. 2 Structures of representative quinazolinone alkaloids isolated from *Isatis*

1.1.3 喹啉及其他类生物碱 在菰蓝属植物中, 除了吡啶类和喹啉酮类生物碱, 还存在喹啉类(89~91 等)、异喹啉类(92)及其他类生物碱(100)。喹啉类生物碱一般 2-位形成酮, 3-和 4-位被取代或成环(94~98), 见表 3。代表性喹啉和其他类生物碱结构式见图 3。

表 3 菰蓝属植物中的喹啉及其他类生物碱
Tab. 3 Quinoline and other alkaloids isolated from *Isatis*

序号	名称	物种	参考文献
89	10H-indolo-[3,2-b]quinoline	<i>I. indigotica</i> (菰蓝)	[36]
90	isatan A	<i>I. indigotica</i> (菰蓝)	[37]
91	isaindigotidione	<i>I. indigotica</i> (菰蓝)	[38]
92	3-[2-(5-hydroxymethyl)furyl]-1(2H)- isoquinolinone-7-O-β-D-glucopyranoside	<i>I. indigotica</i> (菰蓝)	[39]
93	methyl-2-(4-oxo-1,4-dihydroquinoline-3- carboxamido)-benzoate	<i>I. indigotica</i> (菰蓝)	[9]
94	isatindigoticoic acid A	<i>I. indigotica</i> (菰蓝)	[35]
95	6-hydroxy-4-(5-hydroxymethylfuran-2-yl) quinolin-2(1H)-one	<i>I. indigotica</i> (菰蓝)	[9]
96	(R)-2-oxo-1,2,3,4-tetrahydroquinoline-4- carboxamide	<i>I. indigotica</i> (菰蓝)	[9]
97	isatisindigoticanine B	<i>I. indigotica</i> (菰蓝)	[33]
98	isatisindigoticanine D	<i>I. indigotica</i> (菰蓝)	[33]
99	(R)-2-methyl-7,8-dihydropyrano[4,3-b] [1,4]oxazine-3,5(2H,4H)-dione	<i>I. indigotica</i> (菰蓝)	[9]
100	2,3-dihydro-1H-pyrrolo[2,1-c][1,4] benzodiazepine-5,11(10H,11aH)-dione	<i>I. indigotica</i> (菰蓝)	[21]

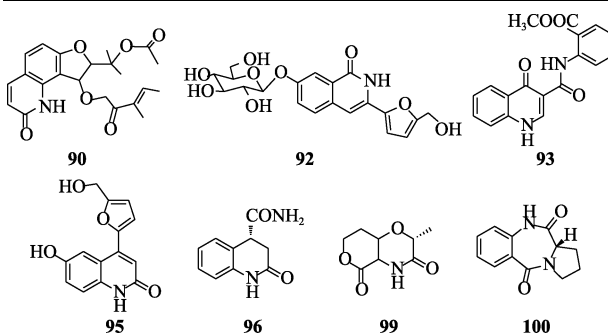


图 3 菰蓝属植物中的代表性喹啉和其他类生物碱结构
Fig. 3 Structures of representative quinoline and other alkaloids isolated from *Isatis*

1.2 硫代葡萄糖苷类

硫代葡萄糖苷类化合物是一类广泛存在于菘蓝属植物中的次级代谢产物。该类化合物的结构由 3 部分构成： $-S-\beta-D$ -葡萄糖基团，磺酰基团和由氨基酸衍生而来的侧链。根据侧链的不同又可将硫代葡萄糖苷类化合物分成 3 类：脂肪硫代葡萄糖苷类(101~105)，芳香硫代葡萄糖苷类和吲哚硫代葡萄糖苷类(106~114)，见表 4。代表性硫代葡萄糖苷类结构式见图 4。

表 4 菘蓝属植物中的硫代葡萄糖苷类

Tab. 4 Glucosinolates isolated from *Isatis*

序号	名称	物种	参考文献
101	epiprogoitrin(表原告依春)	<i>I. tinctoria</i> (欧洲菘蓝)	[40]
102	progoitrin(原告依春)	<i>I. tinctoria</i> (欧洲菘蓝)	[40]
103	sinigrin(黑芥子苷)	<i>I. indigotica</i> (菘蓝)	[41]
104	gluconapin	<i>I. tinctoria</i> (欧洲菘蓝)	[40]
105	glucoraphanin	<i>I. indigotica</i> (菘蓝)	[42]
106	glucobrassicin	<i>I. indigotica</i> (菘蓝)	[41]
107	4-hydroxy-glucobrassicin	<i>I. tinctoria</i> (欧洲菘蓝)	[40]
108	4-methoxy-glucobrassicin	<i>I. indigotica</i> (菘蓝)	[41]
109	neoglucobrassicin	<i>I. tinctoria</i> (欧洲菘蓝)	[40]
110	sulphoglucobrassicin	<i>I. tinctoria</i> (欧洲菘蓝)	[43]
111	5-hydroxy-glucobrassicin	<i>I. tinctoria</i> (欧洲菘蓝)	[44]
112	5-methoxy-glucobrassicin	<i>I. tinctoria</i> (欧洲菘蓝)	[44]
113	glucoisatisin	<i>I. indigotica</i> (菘蓝)	[41]
114	epiglucosatisin	<i>I. indigotica</i> (菘蓝)	[41]

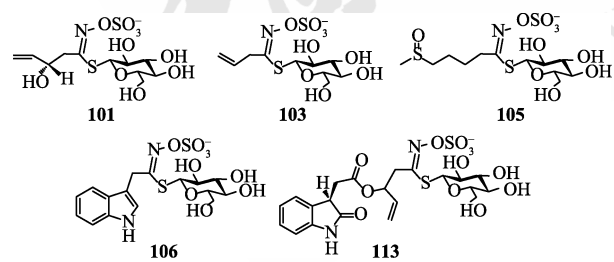


图 4 菘蓝属植物中的代表性硫代葡萄糖苷类结构

Fig. 4 Structures of representative glucosinolates isolated from *Isatis*

1.3 木脂素类

木脂素亦是菘蓝属植物中的一类重要的次级代谢产物。截至目前，已从菘蓝属植物中发现以下几类木脂素成分：四氢呋喃类(115, 118~122)、芳基四氢萘类(116~117)、双四氢呋喃类(123)、8-O-4' 新木脂素类(124~125)和环新木脂素类(126)，见表 5。代表性木脂素类结构式见图 5。

表 5 菘蓝属植物中的木脂素类

Tab. 5 Lignans isolated from *Isatis*

序号	名称	物种	参考文献
115	lariciresinol(落叶松脂醇)	<i>I. indigotica</i> (菘蓝)	[3]
116	isolariciresinol(异落叶松脂醇)	<i>I. indigotica</i> (菘蓝)	[45]
117	isatindigosquilligan A	<i>I. indigotica</i> (菘蓝)	[46]
118	lariciresinol-4-O- β -D-glucopyranoside (落叶松脂醇-4-O- β -D-葡萄糖苷)	<i>I. indigotica</i> (菘蓝)	[39]
119	lariciresinol-4,4'-di-O- β -D-glucopyranoside(落叶松脂醇-4,4'-二-O- β -D-葡萄糖苷)	<i>I. indigotica</i> (菘蓝)	[3]
120	lariciresinol-4'-O- β -D-glucopyranoside (落叶松脂醇-4'-O- β -D-葡萄糖苷)	<i>I. indigotica</i> (菘蓝)	[3]
121	lariciresinol-9-O- β -D-glucopyranoside (落叶松脂醇-9-O- β -D-葡萄糖苷)	<i>I. indigotica</i> (菘蓝)	[3]
122	indigoticoside A	<i>I. indigotica</i> (菘蓝)	[47]
123	pinoresinol(松脂醇)	<i>I. tinctoria</i> (欧洲菘蓝)	[4]
124	isatioxyneolignoside A	<i>I. indigotica</i> (菘蓝)	[48]
125	isatioxyneolignoside E	<i>I. indigotica</i> (菘蓝)	[48]
126	isatiscycloneolignan A	<i>I. indigotica</i> (菘蓝)	[49]

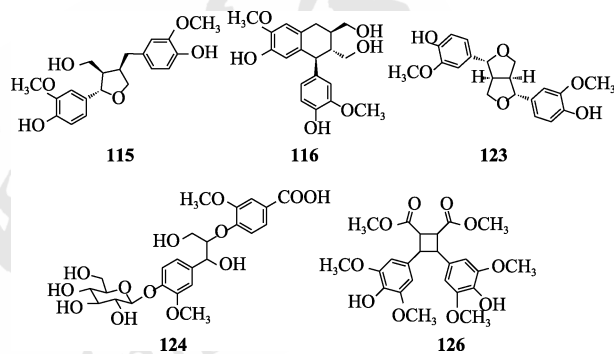


图 5 菘蓝属植物中的代表性木脂素类结构

Fig. 5 Structures of representative lignans isolated from *Isatis*

1.4 黄酮类

从菘蓝属植物中还分离得到了黄酮类化合物，它们或以苷元的形式存在(127~128, 133~134)，或与糖结合形成氧苷或碳苷(129~132)，见表 6。代表性黄酮类结构式见图 6。

表 6 菘蓝属植物中的黄酮类

Tab. 6 Flavonoids isolated from *Isatis*

序号	名称	物种	参考文献
127	liquiritigenin(甘草素)	<i>I. indigotica</i> (菘蓝)	[50]
128	isoliquiritigenin(异甘草素)	<i>I. indigotica</i> (菘蓝)	[50]
129	neohesperidin(新橙皮苷)	<i>I. indigotica</i> (菘蓝)	[50]
130	linarin(蒙花苷)	<i>I. indigotica</i> (菘蓝)	[51]
131	isovitexin(异牡荆素)	<i>I. indigotica</i> (菘蓝)	[51]
132	apigenin 6-C- β -D-glucopyranosyl-(1 $\rightarrow$ 3)- β -D-glucopyranoside	<i>I. tinctoria</i> (欧洲菘蓝)	[52]
133	Eupatorin(半齿泽兰素)	<i>I. indigotica</i> (菘蓝)	[53]
134	sinensetin(甜橙黄酮)	<i>I. indigotica</i> (菘蓝)	[53]

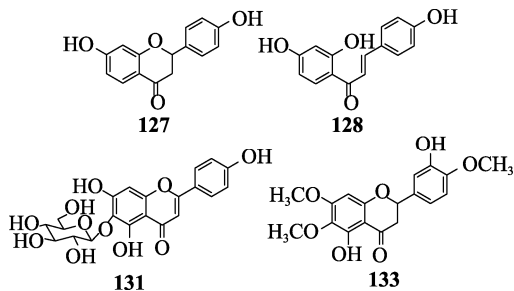


图6 菰蓝属植物中的代表性黄酮类结构

Fig. 6 Structures of representative flavonoids isolated from *Isatis*

1.5 有机酸及其衍生物类

菰蓝属植物中还存在大量的有机酸类化合物。有机酸类化合物可分为2大类:芳香酸类(135~156)和脂肪酸类(157~168)。通常认为,芳香酸类具有解热镇痛的活性,而脂肪酸类具有降血脂活性,见表7。代表性有机酸及其衍生物类结构式见图7。

表7 菰蓝属植物中的有机酸及其衍生物类

Tab. 7 Organic acids and its derivatives isolated from *Isatis*

序号	名称	物种	参考文献
135	3-pyridinecarboxylic acid(吡啶-3-羧酸)	<i>I. indigotica</i> (菰蓝)	[54]
136	2-hydroxy-1,4-benzenedicarboxylic acid(2-羟基-1,4-苯二甲酸)	<i>I. indigotica</i> (菰蓝)	[54]
137	5-hydroxymethylfuroic acid(5-羟甲基糠酸)	<i>I. indigotica</i> (菰蓝)	[45]
138	benzoic acid(苯甲酸)	<i>I. indigotica</i> (菰蓝)	[54]
139	salicylic acid(水杨酸)	<i>I. indigotica</i> (菰蓝)	[54]
140	<i>N</i> -formyl anthranilic acid	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
141	<i>N</i> -carbamoylanthranilic acid methyl ester	<i>I. tinctoria</i> (欧洲菰蓝)	[55]
142	syringic aldehyde	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
143	vanillin(香草醛)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
144	syringic acid(丁香酸)	<i>I. indigotica</i> (菰蓝)	[54]
145	sinapic acid(芥子酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
146	ferulic acid(阿魏酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
147	2-amino benzoic acid(2-氨基苯甲酸)	<i>I. indigotica</i> (菰蓝)	[56]
148	maleic acid(马来酸)	<i>I. indigotica</i> (菰蓝)	[54]
149	isatisaloids A	<i>I. indigotica</i> (菰蓝)	[57]
150	isatisaloids B	<i>I. indigotica</i> (菰蓝)	[57]
151	isatisaloids C	<i>I. indigotica</i> (菰蓝)	[57]
152	isatisaloids D	<i>I. indigotica</i> (菰蓝)	[57]
153	isatisaloids E	<i>I. indigotica</i> (菰蓝)	[57]
154	indiforine E	<i>I. indigotica</i> (菰蓝)	[15]
155	indiforine F	<i>I. indigotica</i> (菰蓝)	[15]
156	indiforine A	<i>I. indigotica</i> (菰蓝)	[15]
157	corchorifatty acid B	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
158	9-oxo-(10 <i>E</i> , 12 <i>Z</i> , 15 <i>Z</i>)-octadecatrienoic acid	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
159	9-hydroxy-(10 <i>E</i> , 12 <i>Z</i> , 15 <i>Z</i>)-octadecatrienoic acid	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
160	palmitic acid(软脂酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
161	palmitoleic acid(棕榈酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
162	(7 <i>Z</i> , 10 <i>Z</i> , 13 <i>Z</i>)-hexadecatrienoic acid	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
163	stearic acid(硬脂酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
164	oleic acid(油酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
165	linoleic acid(亚油酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
166	linolenic acid(亚麻酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
167	eicosanoic acid(廿烷酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
168	eicosenoic acid(二十碳烯酸)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]

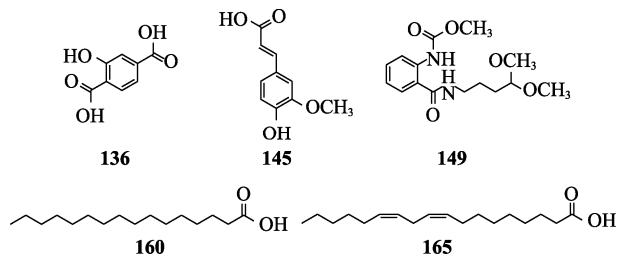


图7 菰蓝属植物中的代表性有机酸及其衍生物类结构

Fig. 7 Structures of representative organic acids and its derivatives isolated from *Isatis*

1.6 甾醇类

甾醇类化合物也存在于菰蓝属植物中,目前,从菰蓝属植物中分离得到的甾醇类化合物包括:谷甾醇(170)、扶桑甾醇(169)、豆甾醇(173)和胆甾醇(172)等,见表8。代表性甾醇类结构式见图8。

表8 菰蓝属植物中的甾醇类

Tab. 8 Sterols isolated from *Isatis*

序号	名称	物种	参考文献
169	β -rosasterol(扶桑甾醇)	<i>I. tinctoria</i> (欧洲菰蓝)	[7]
170	β -sitosterol(谷甾醇)	<i>I. indigotica</i> (菰蓝)	[51]
171	daucosterol(胡萝卜苷)	<i>I. indigotica</i> (菰蓝)	[51]
172	cholesterol(胆甾醇)	<i>I. indigotica</i> (菰蓝)	[22]
173	stigmasterol(豆甾醇)	<i>I. indigotica</i> (菰蓝)	[58]

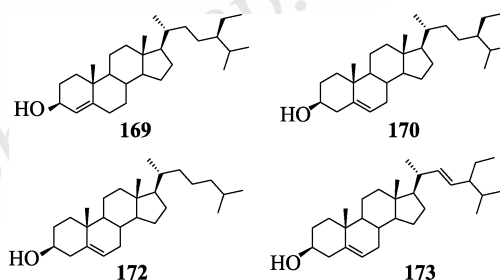


图8 菰蓝属植物中的代表性甾醇类结构

Fig. 8 Structures of representative sterols isolated from *Isatis*

1.7 氨基酸、碱基及核苷类

除“1.1~1.6”项下提到的各种次级代谢产物外,还从菰蓝属植物中分离得到一些初级代谢产物,他们包括:氨基酸类(174~179),碱基(180~182)及核苷酸类(183~186),见表9。代表性氨基酸、碱基和核苷类结构式见图9。

1.8 蒽醌、香豆素及其他类化合物

菰蓝属植物中还存在蒽醌(187~188)和香豆素类化合物(189),但为数不多。此外,还存在一些不太常见的化合物,见表10。代表性蒽醌、香豆素和其他类结构式见图10。

表 9 菰蓝属植物中的氨基酸、碱基和核苷类

Tab. 9 Amino acids, bases and nucleosides isolated from *Isatis*

序号	名称	物种	参考文献
174	arginine(精氨酸)	<i>I. indigotica</i> (菰蓝)	[59]
175	threonine(苏氨酸)	<i>I. indigotica</i> (菰蓝)	[59]
176	alanine(丙氨酸)	<i>I. indigotica</i> (菰蓝)	[59]
177	γ -aminobutyric acid(γ -氨基丁酸)	<i>I. indigotica</i> (菰蓝)	[59]
178	proline(脯氨酸)	<i>I. indigotica</i> (菰蓝)	[59]
179	valine(缬氨酸)	<i>I. indigotica</i> (菰蓝)	[59]
180	guanine(鸟嘌呤)	<i>I. indigotica</i> (菰蓝)	[21]
181	uracil(尿嘧啶)	<i>I. indigotica</i> (菰蓝)	[21]
182	hypoxanthine(次黄嘌呤)	<i>I. indigotica</i> (菰蓝)	[21]
183	uridine(尿苷)	<i>I. indigotica</i> (菰蓝)	[21]
184	cytidine(胞苷)	<i>I. indigotica</i> (菰蓝)	[60]
185	guanosine(鸟苷)	<i>I. indigotica</i> (菰蓝)	[60]
186	adenosine(腺苷)	<i>I. indigotica</i> (菰蓝)	[21]

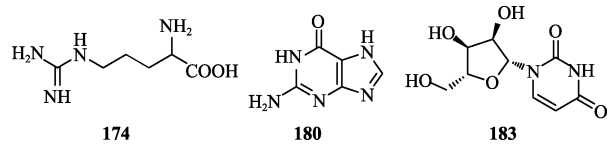


图 9 菰蓝属植物中的代表性氨基酸、碱基和核苷类结构
Fig. 9 Structures of representative amino acid, base and nucleoside isolated from *Isatis*

表 10 菰蓝属植物中的蒽醌、香豆素和其他类

Tab. 10 Anthraquinones, coumarins and other compounds isolated from *Isatis*

序号	名称	物种	参考文献
187	emodin(大黄素)	<i>I. indigotica</i> (菰蓝)	[51]
188	emodin-8-O- β -D-glucoside	<i>I. indigotica</i> (菰蓝)	[51]
189	indigotiscoumarin A	<i>I. indigotica</i> (菰蓝)	[61]
190	6,9-dihydroxy-4,7-megastigmadien-3-one	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
191	epigoitrin(表告依春)	<i>I. indigotica</i> (菰蓝)	[62]
192	isatithioetherin A	<i>I. indigotica</i> (菰蓝)	[63]
193	isatithioetherin E	<i>I. indigotica</i> (菰蓝)	[63]
194	isatindopyrromizol A	<i>I. indigotica</i> (菰蓝)	[35]
195	1-thiocyano-2-hydroxy-3-butenen	<i>I. indigotica</i> (菰蓝)	[62]
196	α -lysolecithin(α -溶血卵磷脂)	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
197	1-O- β -D-galactopyranosyl-3-O-linolenylglycerol	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
198	(2S,3R)-3-hydroxymethyl-N-(2'-hydroxynonacosanoyl)-trideca-9E-sphingene	<i>I. indigotica</i> (菰蓝)	[64]
199	1-O- β -D-glucopyranosyl-(2S,3R)-3-hydroxymethyl-N-(2-hydroxynonacosanoyl)-trideca-9E-sphingene	<i>I. indigotica</i> (菰蓝)	[64]
200	1-O- β -D-glucopyranosyl-(2S,3R)-N-(2'-hydroxyhexacosanoyl)-octadec asphingene	<i>I. indigotica</i> (菰蓝)	[65]
201	(all-E)-lutein	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
202	(all-E)- β -carotene	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
203	violaxanthin	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
204	(all-E)-neochrome	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
205	phaeophorbide a	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
206	10-hydroxy phaeophorbide	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
207	phaeophorbide a	<i>I. tinctoria</i> (欧洲菰蓝)	[4]
208	pyropheophorbide a	<i>I. tinctoria</i> (欧洲菰蓝)	[4]

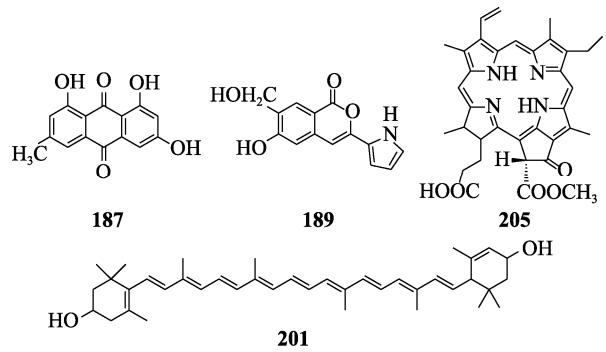


图 10 菰蓝属植物中的代表性蒽醌、香豆素和其他类结构
Fig. 10 Structures of representative anthraquinone, coumarin and other compounds isolated from *Isatis*

2 药理作用

2.1 菰蓝药理作用

现代药理研究表明：菰蓝具有抗菌、抗病毒、抗内毒素、抗肿瘤、抗炎、免疫增强和活血化瘀作用。

2.1.1 抗菌作用 宋兆友等^[66]从青黛中分离得到色胺酮，经研究表明其对羊毛状小孢子菌、断发癣菌、石膏样小孢子菌、紫色癣菌、石膏样癣菌、红色癣菌、絮状表皮癣菌等 7 种皮肤病真菌有较高的抑菌作用。郑剑玲等^[67]对大青叶和板蓝根提取物的抑菌作用进行了研究，发现大青叶和板蓝根的各个极性提取物对金黄色葡萄球菌、肠炎杆菌和大肠埃希菌具有显著的抑制作用。孔维军等^[68]通过微量热技术对 4 种芳香酸的抗菌活性进行了评价，发现 4 种芳香酸具有抑制大肠埃希菌生长能力，并对四者抗菌活性的构效关系进行了分析。姜晓文等^[69]研究发现板蓝根微粉水提物可以通过破坏细胞壁、细胞膜的完整性进而抑制大肠杆菌。Wu 等^[70]研究发现板蓝根多肽具有显著的抗细菌及真菌作用。

2.1.2 抗病毒作用 杨子峰等^[71]通过实验证实板蓝根水提取物中的多糖具有体外抑制流感病毒的作用，其作用机制可能是通过结合流感病毒的血凝素，从而抑制流感病毒的侵入和复制。刘思贞等^[72]利用鸡胚羊膜腔半体内法对板蓝根抗流感病毒的有效部位进行了筛选，发现板蓝根 70% 乙醇水提取物被强酸型阳离子吸附树脂吸附部分具有抗流感病毒活性。刘盛等^[73]对 15 个不同种质的板蓝根和大青叶的抗甲型流感病毒作用进行了研究，发现各个种质的板蓝根和大青叶在对甲型流感病毒的直接作用、治疗作用和预防作用 4 个方面均有效，但不同种质间的活性和强度有明显差异。

Ye^[74]对板蓝根中的 11 个化学成分的抗呼吸道合胞病毒活性进行了评价,发现靛玉红和异牡荆素具有很强的抗呼吸道合胞病毒活性。Yang 等^[75]对板蓝根粗提物抗病毒作用的机制进行了研究,发现板蓝根通过干扰病毒颗粒,阻止病毒与宿主细胞吸附,进而发挥抗病毒作用。Liang 等^[76]对板蓝根中的芥子酸进行了研究,发现其具有广谱抗病毒作用。Luo 等^[77]对板蓝根中的主要成分表没食子儿茶素没食子酸酯的抗病毒机制进行了研究,发现其可通过线粒体信号降低病毒敏感性,进而发挥抗病毒作用。

2.1.3 抗内毒素作用 刘云海^[78]通过家兔热源法、鲎试验法及在电子显微镜下观察内毒素结构形态变化的研究表明,板蓝根氯仿提取物具有抗大肠杆菌内毒素作用。赖伟华等^[79]采用体外和体内 2 种实验研究发现板蓝根具有明显的抗内毒素作用。

2.1.4 抗肿瘤作用 板蓝根中的靛玉红具有抗癌作用,能够治疗慢性粒细胞白血病。籍秀娟等^[80]为了克服靛玉红生物利用度低及胃肠道不良反应等缺点,寻找比靛玉红活性更强的化合物,对靛玉红进行了结构修饰,合成了一系列靛玉红衍生物,并对靛玉红类化合物的抗肿瘤作用及构效关系进行了研究。李成章等^[81]也对靛玉红进行了衍生化,制备得到了 19 种靛玉红的衍生物,并对衍生物产物的抗肿瘤活性进行了研究,发现了多种活性较好的衍生物。吴克美等^[82]设计合成了靛玉红及靛蓝和异靛蓝的衍生物,对它们的生物活性进行了研究,并在此基础上对构效关系进行了总结。杜军等^[83]通过对靛玉红进行结构改造,发现靛玉红衍生物在治疗慢性粒细胞白血病方面明显优于靛玉红,很有应用前景。高雪等^[84]研究了靛玉红衍生物抗慢性粒细胞白血病活性,发现其具有显著逆转耐药作用。

2.1.5 抗炎作用 卫琮玲等^[85]对板蓝根 70% 乙醇提取液的抗炎作用进行了研究,发现板蓝根对二甲苯所致的小鼠耳肿胀、角叉菜胶所致的大鼠足跖肿有显著的抑制作用,并可抑制大鼠棉球肉芽肿及降低醋酸引起的毛细血管通透性的增加。赵泽军等^[86]研究发现板蓝根及 4 倍板蓝根具有明显的抗炎活性。

2.1.6 免疫调节作用 路平成等^[87]通过研究发现,腹腔注射板蓝根多糖可明显增强小鼠对二硝基氯苯的迟发型变态反应,诱导体内淋巴细胞转化和增强脾细胞的自然杀伤活性,从而发挥免疫

调节作用。李吉萍等^[88]研究发现板蓝根多糖能够增强荷瘤小鼠的免疫功能,延长荷瘤小鼠的生存时间。You 等^[89]研究发现,板蓝根提取液能够明显降低由辐射所致的黏膜损伤,并推测很可能是靛玉红发挥了该种作用。

2.1.7 活血化癥作用 游松等^[90]从板蓝根中分离得到尿苷、次黄嘌呤、尿嘧啶和水杨酸,并证实他们对二磷酸腺苷诱导的家兔血小板聚集表现出一定的抑制活性。

2.2 欧洲菰蓝药理作用

欧洲菰蓝提取物或其中单体成分具有抗炎活性、镇痛活性、抗肿瘤活性、抗菌活性、抗病毒活性及抗氧化活性。上述药理活性已经由意大利学者 Speranza 等^[91]详尽系统综述,本文不再展开。

2.3 三肋菰蓝药理作用

三肋菰蓝药理学相关研究很少,仅有巴基斯坦学者 Ahmad 等^[11]对其开展了黄嘌呤氧化酶及酪氨酸酶抑制活性、抗氧化及抗菌活性研究。

3 讨论

菰蓝属植物化学成分研究主要集中在菰蓝和欧洲菰蓝,三肋菰蓝化学成分研究较少,而对宽翅菰蓝、小果菰蓝、长圆果菰蓝和毛果菰蓝的化学成分研究几乎没有。通过综述近 40 年菰蓝属植物化学成分相关研究,发现菰蓝属植物主要化学成分包括生物碱类,硫代葡萄糖苷类,木脂素类,黄酮类,有机酸类,甾醇类,氨基酸、碱基及核苷类,萜醌、香豆素及其他类等 8 大类共 200 余个化学成分,其中约一半为生物碱类成分。菰蓝属植物化学成分多样性,决定了其药理作用的多样性,包括抗菌作用、抗病毒作用、抗内毒素作用、抗肿瘤作用、抗炎作用、免疫调节作用、活血化癥作用、镇痛作用及黄嘌呤氧化酶及酪氨酸酶抑制活性等,这也体现了中药多成分、多靶点、多通路的特点^[92-93],上述总结为菰蓝属植物药效物质基础及作用机制深入研究提供了一定参考。

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