Review

Chemical constituents and biological activities of *Scutellaria barbata*

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Abstract

***Scutellaria barbata* D.Don (*S. barbata*), is a perennial herb of *Labiatae scutellaria*, with a variety of chemical constituents and biological activities. Its chemical constituents include terpenoids, flavonoids, polysaccharides, volatile compounds and trace elements. Among the terpenoids, diterpenoids are abundant, particularly neocrotane diterpenoids. More than 70 flavonoids have been identified as important pharmacological components and quality control markers. Polysaccharides play an important role in its anti-tumor efficacy. Volatile compounds have antibacterial effects, and trace elements are associated with active ingredients. In terms of pharmacological activity, *S. barbata* exhibits anti-tumor, hepatoprotective, anti-inflammatory, immunomodulatory, antioxidant and antibacterial effects. This review aims to summarize the research progress of *S. barbata* and provide a theoretical basis for its clinical application.**

Keywords: *Scutellaria barbata*; chemical constituent; biological activity

1 Introduction

Scutellaria barbata D.Don (*S. barbata*), also known as *Penthorum chinense*, brushgrass, or Hanxincao, is a perennial herb of the genus *Scutellaria* in the family *Labiatae*. According to the *Chinese Pharmacopoeia* (2025), it exhibits spicy, bitter, and cold properties, and is associated with the lung, liver and kidney meridians. The stem is erect, quadrangular, 15-55 cm high, branched or unbranched. The leaves are triangular-ovate or lanceolate, with sparse obtuse teeth along the margins and short or absent petioles. The flowers are lip-shaped, blue-purple, solitary in leaf axils, and arranged in a lateral raceme. The flowering period extends from April to July, followed by the production of small oblate nuts with small verrucous protrusions. It is widely distributed across South, East, and Southwest China, as well as in Hebei, Shaanxi and other regions. It commonly grows in fields, streams or humid grasslands. The main components of *S. barbata* are terpenoids, flavonoids, polysaccharides, volatile compounds, and trace elements [1]. It has the effects of clearing heat and detoxifying, removing blood stasis and diuresis. Modern pharmacological studies have shown that it has anti-tumor, hepatoprotective,

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anti-inflammatory, immunomodulatory, antioxidant and antibacterial effects. In clinical practice, it is often used in combination with *Hedyotis diffusa* for the treatment of hepatitis and liver cancer, with which it exhibits notable therapeutic efficacy [2].

To systematically review the research progress on *S. barbata*, this study examined literature retrieved from databases including PubMed, Web of Science, CNKI, and Wanfang Data. A total of 582 relevant articles were identified, among which 326 focused on chemical constituents (e.g., isolation, identification, and structural analysis of terpenoids, flavonoids, etc.) and 256 focused on biological activities (e.g., *in vitro*/*in vivo* studies on anti-tumor, hepatoprotective, and anti-inflammatory effects). This review aims to integrate the existing research findings on the chemical constituents and biological activities of *S. barbata.* By elucidating the intrinsic connection between its chemical components and pharmacological effects, this study seeks to establish a theoretical foundation for more rational clinical application, in-depth development of medicinal value and subsequent scientific research.

2 Chemical composition

S. barbata contains a variety of compounds, including terpenoids, flavonoids, polysaccharides, volatile compounds, trace elements, and so on.

2.1 Terpenoids

Terpenoids represent the most abundant class of compounds in *S. barbata* and exhibit significant pharmacological activities. These compounds can be categorized into diterpenoids and triterpenes. Diterpenoids are the predominant constituents, with over 160 compounds identified to date. In addition, several triterpenoids such as ursolic acid and oleanolic acid have also been isolated from this species.

2.1.1 Diterpenoids

The main type of diterpenoids in *S. barbata* is neo-clerodane diterpenoids, including *S. barbata* diterpenoids, *S. barbata* lactones, and *S. barbata* alkaloids. The mother nucleus structure of diterpenoids in *S. barbata* can be divided into three categories according to the variations of C11-C16, as shown in Fig. 1. Type I is features an unsaturated lactone ring formed by C13-C16 form, type II features a spiro ring formed by C11-C16 and C8, often in the form of lactone, and type III Features a double bridge structure of hexahydrofuran-furan ring type formed by C11-C16. Further structural diversity arises from variations in the side chains, leading to the subdivision into seven structural types, as shown in Fig. 2 [3]. A comprehensive summary of the diterpenoids identified to date is provided in Table 1 and Fig. 3.

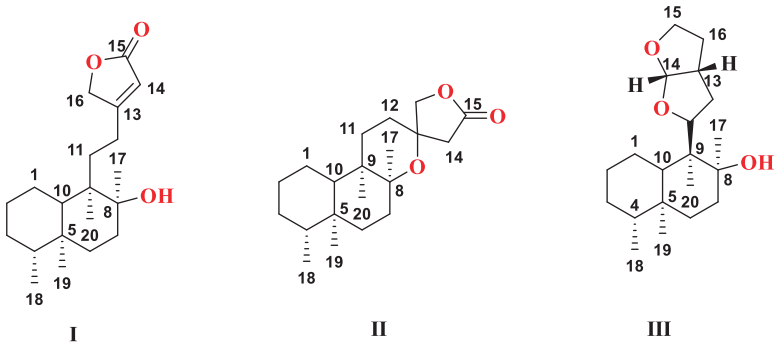


Fig. 1 Structures of the three main types of diterpenoids in *S. barbata*

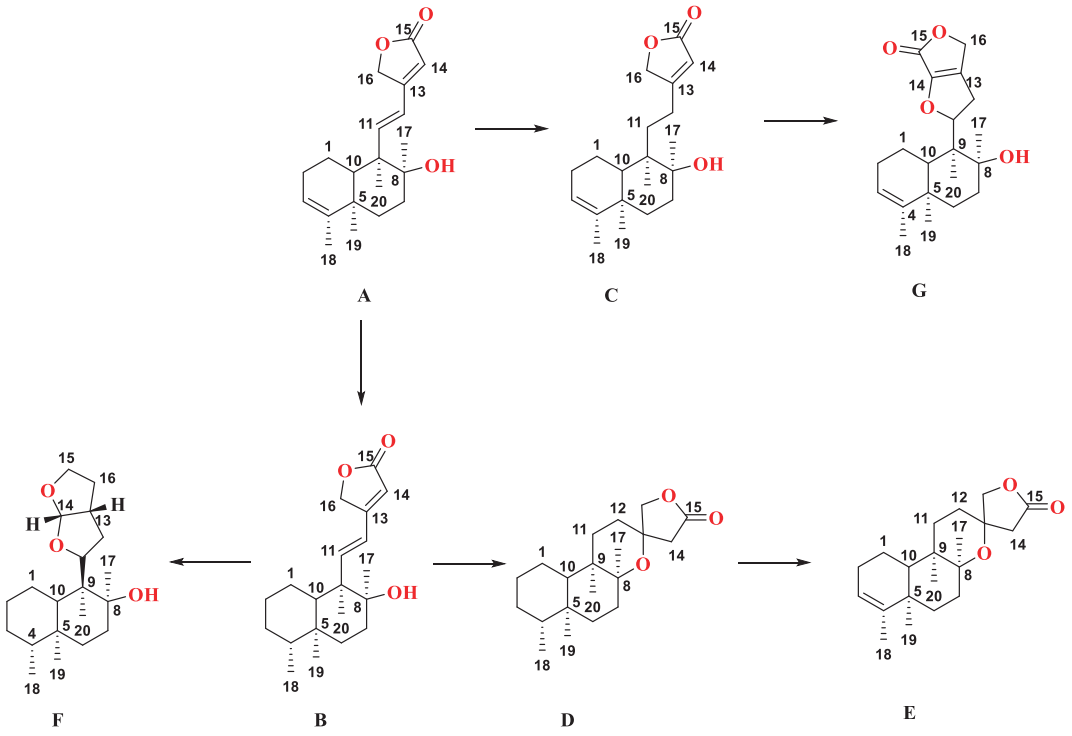


Fig. 2 Side chain variations of the core structure of diterpenoids in *S. barbata*

Table 1 The neo-clerodane-type diterpenoids isolated from *S. barbata*

No.	Compound	R_1	R_2	R_3	Ref.
	Type A				
1	barbaolide M	Nic	Nic		[4]
2	barbatin C	H	H		[5]
3	scutebarbatine B	Nic	Bz		[5]
4	barbatin D	Bz	Bz		[6]
5	barbatin E	Hs	Ht		[6]
6	barbatin F	Ht	Bz		[7]
7	scutebarbatine A	Nic	Nic		[8]
8	scutebarbatine K	Nic	Ac		[9]
9	scutebarbatine L	Nic	Hs		[10]
10	scutebarbatine Y	Bz	Nic		[11]
11	scutebata I	Ac	H		[12]
12	scutebata J	Bz	H		[12]
13	scutebata K	Su	H		[12]
14	scutebata T	Ac	H		[13]

(to be continued)

Continued Table 1

No.	Compound	R_1	R_2	R_3	Ref.
15	scutebata X	Nic	Bz	O	[14]
16	scutebata Y	Nic	Bz	*β*-OH, H	[14]
17	scutebarbolide J	Su	OH		[15]
18	scutebarbolide K	OH	Su		[15]
19	scutebarbolide I				[15]
20	scutebartine F	Nic	Bz	*Z*(RΔ11–12)	[16]
21	scutebartine G	Nic	Nic	*Z*(RΔ11–12)	[16]
22	scutolide A	Ac	De	*Z*(RΔ11–12)	[17]
23	scutolide B				[17]
24	scutolide C	Bz	De		[17]
25	scutolide D	Bz	Hs		[17]
26	scutolide E	Ac	Bz		[17]
27	6-*O*-(2-carbonyl-3-methylbutanoyl) scutehenanine A	Ht	Nic		[18]
28	6-*O*-acetylScutehenanine A	Ac	Nic		[18]
29	6-(2,3-epoxy-2-isopropyl-n-propoxy) barbatin C				[19]
30	scutelinquanine C	Nic	Ht		[20]
31	8-*O*-nicotinoylbarbatin A				[21]
32	6-*O*-nicotinoylbarbatin A	Nic	H		[21]
33	6,7-di-*O*-acetoxybarbatin A	Ac	Ac		[21]
34	scutebarbatolide A	Bz	Ac		[21]
35	2-carbonylscutebartatin A	Nic	Nic	O	[21]
	Type B				
36	scutebarbatine E	Nic	Bz	=O	[10]
37	scutebarbatine O	Nic	Nic	OH	[10]
38	scutebata L	Bz	Bz	H	[12]
39	scutehenanine A	H	Nic		[18]
40	scutebarbatine C				[22]
41	scutebarbatine D	Nic	Bz	OH	[22]
42	scuterivulactone D (scutellone D)	OH			[23]
43	scutellone E				[24]
44	scutellone F				[24]
45	scutellone H	OEt			[24]
46	scutellone I	OMe			[24]

(to be continued)

Continued Table 1

No.	Compound	R_1	R_2	R_3	Ref.
		Type C			
47	barbaolide J	Nic	H	OH	[4]
48	barbaolide K				[4]
49	barbaolide L	Niv	Ac	H	[4]
50	barbatin G	H	Nic	OH	[7]
51	scutebarbatine X	Nic	Nic	OH	[11]
52	scutebarbatine Z	Nic	Nic	H	[11]
53	scutebata M	Nic	Hs	OH	[12]
54	scutebarbolide D	Bz	Nic	OH	[15]
55	scutebarbolide E	Bz	De	OH	[15]
56	scutebarbolide C	H	OH		[15]
57	scutebarbolide A	Ac	H		[15]
58	scutebarbolide B				[15]
59	scutebarbolide F				[15]
60	scutebarbolide G				[15]
61	scutebarbolide H				[15]
62	scutolide F	Bz	H	H	[17]
63	scutolide G	Ac	De	H	[17]
64	scutolide H	Nic	De	H	[17]
65	scutolide I	Ac	Ac	H	[17]
66	scutolide J	Nic	Nic	H	[17]
67	scutebata A	Bz	Bz	OH	[25]
68	scutebata B	Nic	Bz	OH	[25]
69	scutebata C	Nic	H	OH	[25]
70	scutebata W	Su	H	H	[26]
71	barbatellarine B	Nic	Bz	H	[27]
72	scuttenline A	Nic	OB		[28]
73	scuttenline C	Bz	H		[28]
74	scuttenline B				[28]
75	scuttenline D				[28]
76	6-acetoxybarbatin C	Ac	H	OH	[29]
77	scutebarbatolide B	Nic			[30]
78	scutebarbatolide C	Bz			[30]

(to be continued)

Continued Table 1

No.	Compound	R_1	R_2	R_3	Ref.
		Type D			
79	barbatin B				[5]
80	scutebata N	Bz	H	Bz	[12]
81	scutehenanine C	Nic	H	Nic	[18]
82	scuterivulactone C1 (scutellone A)	Nic	H	Nic	[23]
83	scuterivulactone C2				[23]
84	scutellone C				[24]
85	scutellone G				[24]
86	barbatellarine A				[27]
87	scutebata P	Bz	H	OBz(13*S*)	[31]
88	scutebata Q	Bz	OBz	H(13*R*)	[31]
89	barbatellarine C				[32]
90	barbatellarine D				[32]
91	barbatellarine E				[32]
92	barbatellarine F				[33]
		Type E			
93	barbaolide A	H	Nic	Ac	[4]
94	barbaolide B	ONic	Nic	MePr	[4]
95	barbaolide C	ONic	Ac	MePr	[4]
96	barbaolide E	H	Ac	MePr	[4]
97	barbaolide D				[4]
98	barbaolide G				[4]
99	barbaolide F	Ac	MePr	H	[4]
100	barbaolide H	Bz	Ac	OH	[4]
101	barbaolide I	Ac	Ac	ONic	[4]
102	barbatin A	Bz	H	Bz	[5]
103	scutebarbatine G	H	H	Nic	[9]
104	scutebarbatine W	Nic	H	OBz	[11]
105	scutebata O	Bz	H	H	[12]
106	scutebata S	Ac	De	Bz	[13]
107	scutebata Z	Ac	Nic	H(13*S*)	[14]
108	scutebata A1	Ac	Nic	H(13*R*)	[14]
109	scutebata B1	Ac	Nic	Nic	[14]
110	scutebata C1	Bz	H	Bz	[14]

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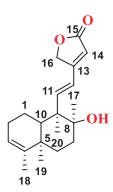
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No.	Compound	R_1	R_2	R_3	Ref.
111	scutebarbolide L	Ac	Ac	Ac	[15]
112	scutebarbolide M	Ac	Ac	Ac	[15]
113	scutebartine A	Nic	H	Bz	[16]
114	scutebartine B	Ac	Ac	Nic	[16]
115	scutebartine C	Nic	Nic	H	[16]
116	scutebartine D	Nic	Nic	OH	[16]
117	scutebartine E				[16]
118	scutolide K	Bz	Bz	H	[17]
119	scutolide L	Bz	Bz	OH	[17]
120	scutehenanine B (scutebarbatine W)	Nic	H	Nic	[18]
121	scutehenanine H				[19]
122	scutelinquanine A	Ac	H	Nic	[20]
123	scutebarbatine F	Nic	Ac	Ac	[22]
124	scutebata D	Ac	Ac	Bz	[25]
125	scutebata E	Ac	Ac	MePr	[25]
126	scutebata F	Ac	Ac	Nic	[25]
127	scutebata G	Nic	Bz	Bz	[25]
128	scutebata V	Nic	Nic	H	[26]
129	scutebata U				[26]
130	scutelinquanine D	H	Nic	H	[29]
131	scutebata R	Ac	Ac	De	[31]
132	barbatin H	C	Nic	Nic	[34]
133	scubatine D	Ac	Ac	Ac	[35]
134	scubatine E	Ac	Bz	Bz	[35]
135	scubatine F	Bz	Ac	Bz	[35]
136	scutebatin A	Nic	Bz	Nic	[36]
137	scutebatin B	Nic	Nic	Bz	[36]
138	scutebatin C	Nic	H	Nic	[36]
139	barbatine A	Nic	Ac	Nic	[37]
140	barbatine B	Nic	Nic	Nic	[37]
141	barbatine C	Ac	Ac	Nic	[37]
142	barbatine D	Nic	Ac	Nic	[37]
143	scutellone J	Ac	H	Ac	[38]

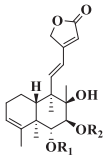
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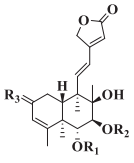
No.	Compound	R_1	R_2	R_3	Ref.
		Type F			
144	scutebarbatine I	H	OEt		[9]
145	scutebarbatine J	OEt	H		[9]
146	scutebata H	OH	Bz	Ac	[12]
147	scutebartine J	OH	Nic	Ac	[16]
148	scutebartine H	OMe	H	Nic	[16]
149	scutebartine I	H	OMe	Nic	[16]
150	scutellin A				[39]
		Type G			
151	scutebarbatine H	Nic	H		[9]
152	scutehenanine D	Nic		Bz	[18]
		Others			
153	scutebarbatine M	Nic	Nic	OH	[10]
154	scutebarbatine N	Nic	Nic	CH_2OH	[10]
155	(14*R*)-14*β*-hydroxyscutolide K				[17]
156	scutelinquanine B				[20]
157	scuterivulactone A				[23]
158	scuterivulactone B (scutellone B)				[23]
159	14-deoxy-11,12-didehydroandrographolide				[30]
160	scubatine A				[35]
161	scubatine B				[35]
162	scubatine C				[35]



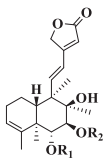
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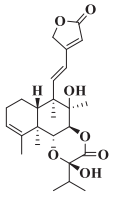
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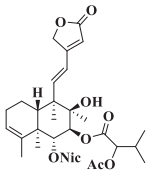
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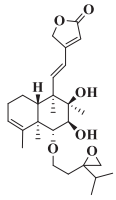
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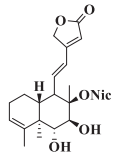
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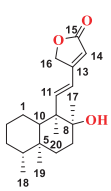
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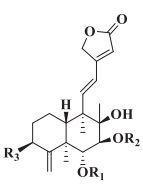
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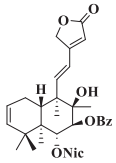
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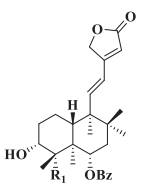
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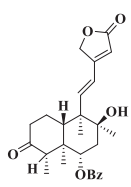
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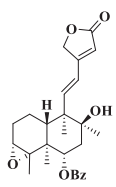
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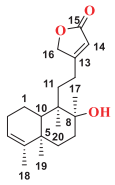
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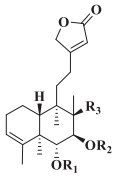
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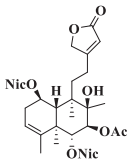
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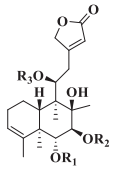
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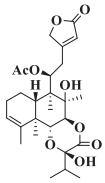
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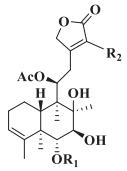
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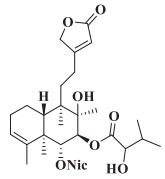
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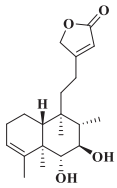
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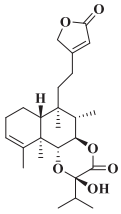
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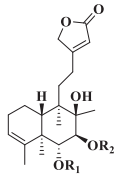
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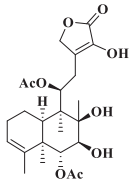
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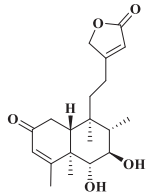
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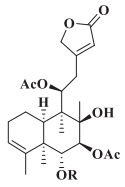
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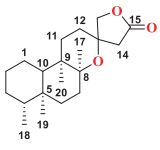
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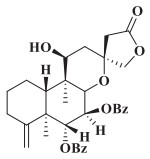
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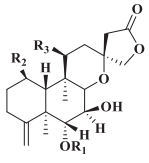
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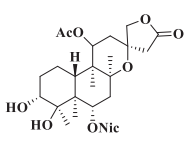
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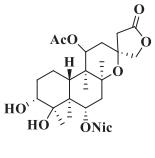
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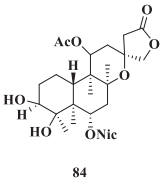
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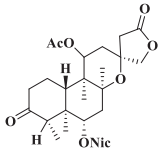
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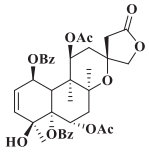
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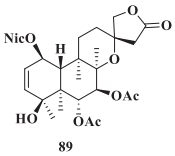
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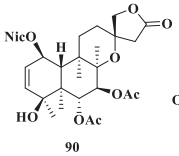
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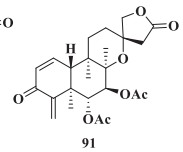
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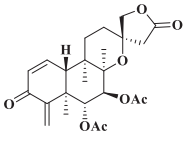
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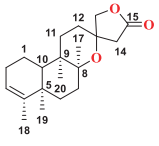
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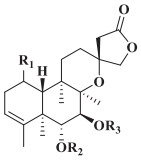
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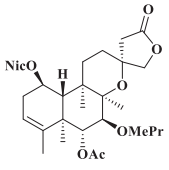
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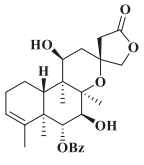
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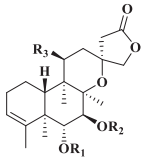
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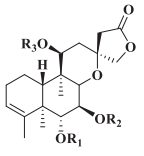
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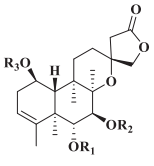
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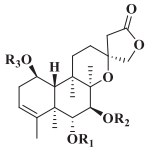
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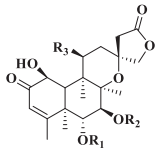
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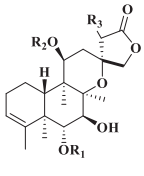
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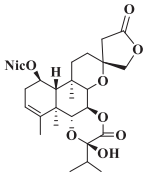
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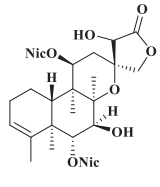
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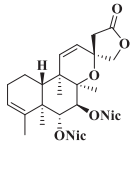
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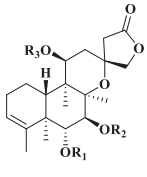
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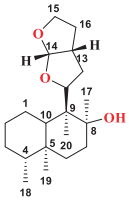
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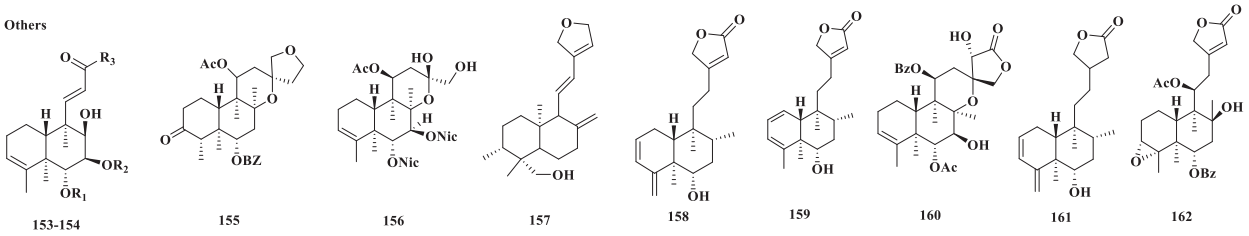


Fig. 3 Chemical structures of diterpenoids isolated from terpenoids

2.1.2 Triterpenoids

In 1988, the triterpene compound-scutellaric acid was extracted from *S. barbata* for the first time [40]. Subsequent investigations led to the isolation of additional triterpenoids, including oleanolic acid, ursolic acid [41], and 9,29-cyclolanosta-24-en-3-ol [42].

2.2 Flavonoids

Flavonoids represent another major class of bioactive constituents in *S. barbata* and serve as both key pharmacological components and chemical markers for quality control. According to the current research literature, over 70 flavonoids have been identified in *S. barbata*. The main types include flavones, flavonols, flavonones and chalcone [43], as shown in Fig. 4. The chemical structures of these flavonoids are summarized in Table 2.

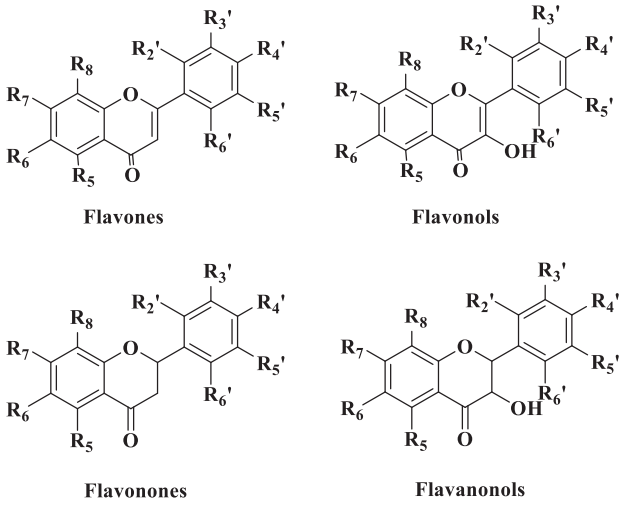


Fig. 4 Core structures of flavones, flavonols, flavonones and flavononols in *S. barbata*

Table 2 Flavonoids in *S. barbata*

No.	Compound	R_5	R_6	R_7	R_8	R_2'	R_3'	R_4'	R_5'	R_6'	Ref.
					Flavones						
1	luteolin	OH	H	OH	H	H	H	OH	OH	H	[44]
2	apigenin	OH	H	OH	H	H	H	OH	H	H	[44]

(to be continued)

Continued Table 2

No.	Compound	R_5	R_6	R_7	R_8	R_2'	R_3'	R_4'	R_5'	R_6'	Ref.
3	scutellarein	OH	OH	OH	H	H	H	OH	H	H	[44]
4	wogonin	OH	H	OH	OMe	OMe	H	H	H	H	[45]
5	baicalin	OH	OH	O-GIcA	H	H	H	H	H	H	[45]
6	6-*O*-methylscutellarein	OH	OMe	OH	H	H	H	OH	H	H	[46]
7	4′,5-dihydroxy-3′,5′,6,7-tetramethoxyflavone	OH	OMe	OMe	H	H	OMe	OH	OMe	H	[47]
8	5-hydroxy-7,8-dimethoxyflavone	OH	H	OMe	OMe	OMe	H	H	H	H	[48]
9	rivularin	OH	H	OMe	OMe	OMe	H	H	H	OH	[48]
10	5,7,3′,4′,5′-pentamethoxyflavone	OMe	H	OMe	H	H	OMe	OMe	OMe	H	[49]
11	5-hydroxy-7,3′,4′,5′-tetramethoxyflavone	OH	H	OMe	H	H	OMe	OMe	OMe	H	[49]
12	5-hydroxy-7,4′-dimethoxy	OH	H	OMe	H	H	H	OMe	H	H	[50]
13	5-hydroxy-7,8,4′-trimethoxyflavone	OH	H	OMe	OMe	H	H	OMe	H	H	[50]
14	salvigenin	OH	OMe	OMe	H	H	H	OMe	H	H	[50]
15	baicalein	OH	OH	OH	H	H	H	H	H	H	[51]
16	isoscutellarein	OH	H	OH	OH	H	H	OH	H	H	[52]
17	6-hydroxyluteolin	OH	OH	OH	H	H	H	OH	OH	H	[52]
18	5-hydroxy-6,7,3′,4′-tetramethoxyflavone	OH	OMe	OMe	H	H	H	H	H	H	[52]
19	isoscutellarein-8-*O*-*β*-D glucuronide-6″-methylester	OH	H	OH	Glu-Me Ester	H	H	OH	H	H	[52]
20	apigenin-7-*O*-*β*-D-glucuronide-6″-methylester	OH	H	O-GlcA Meester	H	H	H	OH	H	H	[52]
21	isoscutellarein-8-*O*-glucuronide	OH	H	OH	O-GlcA	H	H	OH	H	H	[52]
22	scutellarein-7-*O*-*β*-D glucuronide methyl este	OH	OH	O-GlcA Meester	H	H	H	OH	H	H	[52]
23	hispidulin-7-*O*-*β*-D methylgluzcuronide	OH	OMe	O-GlcA	H	H	H	OH	H	H	[52]
24	5,6,7,3′,4′,5′-hexahydroxyflavone	OH	OH	OH	H	H	OH	OH	OH	H	[53]
25	6-methoxyluteolin	OH	OMe	OH	H	H	H	OH	OH	H	[53]
26	chrysoeriol	OH	H	OH	H	H	H	OH	OMe	H	[53]
27	cirsiliol	OH	OMe	OMe	H	H	OH	OH	H	H	[53]
28	tenaxin	OH	OMe	OMe	OMe	H	H	H	H	OH	[53]
29	wogonoside	OH	H	OGlcA	H	H	H	H	H	H	[53]

(to be continued)

Continued Table 2

No.	Compound	R_5	R_6	R_7	R_8	R_2'	R_3'	R_4'	R_5'	R_6'	Ref.
30	scutellarein-7-*O*-glucoside	OH	OH	O-Glu	H	H	H	H	H	H	[53]
31	luteolin-7-*O*-glucuronide	OH	H	O-GlcA	H	H	OH	OH	H	H	[53]
32	isoscutellarein-7-*O*-glucuronide	OH	H	O-GlcA	OH	H	H	OH	H	H	[53]
33	4-hydroxy-wogonin-7-*O* glucuronide	OH	H	O-GlcA	OMe	H	H	OH	H	H	[53]
34	8-hydroxyluteolin-7-*O* glucuronide	OH	H	O-GlcA	OH	H	OH	OH	H	H	[53]
35	6-hydroxyluteolin-7-*O* glucuronide	OH	OH	O-GlcA	H	H	OH	OH	H	H	[53]
36	apigenin-5-*O*-*β*-D glucopyranoside	Glu	H	OH	H	H	H	OH	H	H	[54]
37	apigenin-7-*O*-*β*-D-glucoside	OH	H	O-Glu	H	H	H	OH	H	H	[55]
38	luteolin-7-*O*-*β*-D glucopyranoside	OH	H	O-Glu	H	H	OH	OH	H	H	[55]
39	apigenin-7-*O*-neohesperidoside	OH	H	O-Neo	H	H	H	OH	H	H	[56]
40	apigenin-7-*O*-*β*-D-glucuronide	OH	H	O-GlcA Meester	H	H	H	OH	H	H	[56]
41	5-hydroxy-4′-methoxyflavone-7-*O*-*α*-Lrhamnosyl-(1→6)-*β*-D-glucopyranoside	OH	H	O-Rha-Glu	H	H	H	OMe	H	H	[57]
42	scutellarin	OH	OH	O-GlcA	H	H	H	OMe	H	H	[58]
43	5,8,2′-trihydroxy-7-*O*-flavonoid glucuronide	OH	H	O-GlcA	OH	OH	H	H	H	H	[59]
44	kaempferol-3-*O*-*β*-D-rutinoside	Refer to Fig. 2									[49]
45	hyperoside	Refer to Fig. 2									[60]
	Flavonols										
46	isorhamnetin	OH	H	OH	H	H	H	OH	OMe	H	[51]
47	quercetin	OH	H	OH	H	H	OH	OH	OH	H	[58]
48	quercetin-4′-*O*-glucuronide	OH	H	OH	H	H	OH	GlcA	H	H	[58]
	Flavonones										
49	naringeni	OH	H	OH	H	H	H	OH	H	H	[46]
50	6-methoxynaringenin	OH	OMe	OH	H	H	H	OH	H	H	[46]
51	5,7,4′-trihydroxy-8-methoxyflavanone	OH	H	OH	OMe	H	H	OH	H	H	[46]
52	dihydrooroxylin A	OH	OMe	OH	H	H	H	H	H	H	[46]
53	isocarthamidin	OH	H	OH	OH	H	H	OH	H	H	[46]

(to be continued)

Continued Table 2

No.	Compound	R_5	R_6	R_7	R_8	R_2'	R_3'	R_4'	R_5'	R_6'	Ref.
54	naringenin-4′-*O*-glucuronide	OH	H	OH	H	H	H	O-GlcA	H	H	[53]
55	8-methoxynaringenin-7-*O* glucuronide	OH	H	O-GlcA	OMe	H	H	OH	H	H	[53]
56	naringenin-7-*O*-glucuronide	OH	H	O-GlcA	H	H	H	OH	H	H	[53]
57	6-methoxynaringenin-7-*O* glucuronide	OH	OMe	O-GlcA	H	H	H	OH	H	H	[53]
58	isocarthamidin-7-*O*-glucuronide	OH	H	O-GlcA	OH	H	H	OH	H	H	[53]
59	carthamidin-7-*O*-glucuronide	OH	OH	O-GlcA	H	H	H	OH	H	H	[53]
60	5,6,7,3′,4′ -pentahydroxyflavanone-3-*O* glucuronide	OH	OH	O-GlcA	H	H	OH	OH	H	H	[53]
61	carthamidin	OH	OH	OH	H	H	H	OH	H	H	[54]
62	eriodictyol	OH	H	OH	H	H	OH	OH	H	H	[61]
					Flavanonols						
63	3,5,6,7,4′-pentahydroxyflavanone	OH	H	H	OH	H	OH	OH	H	H	[53]
64	3,5,7,8,4′-pentahydroxyflavanone	OH	H	OH	OH	H	H	OH	H	H	[53]
65	3,5,7,4′-tetrahydroxy-6-methoxyflavanone	OH	OMe	OH	H	H	H	OH	H	H	[53]
66	3,5,7,4′-tetrahydroxy-8-methoxyflavanone	OH	H	OH	OMe	H	H	OH	H	H	[53]
67	3,5,8,3′,4′-pentahydroxyflavanone-3-*O* glucuronide	OH	H	O-GlcA	OH	H	OH	OH	H	H	[53]
68	2(*S*)-2′,7-dihydroxy-5,8-dimethoxyflavanone	OMe	H	OH	OMe	OH	H	H	H	H	[54]
69	7-hydroxy-2′,5,8-trimethoxyflavanone	OMe	H	OH	OMe	OMe	H	H	H	H	[61]
					Chalcones						
70	2′,4′ -dihydroxy-2,3′,6′-trimethoxy-chalcone	Refer to Fig. 2									[61]

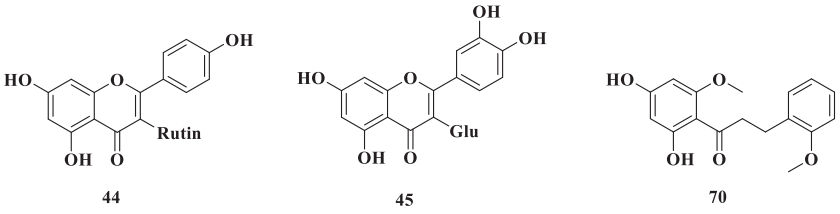


Fig. 5 Structures of **44**, **45**, and **70**

2.3 Polysaccharides

Carbohydrates are widely distributed in nature and are the most common components in plant medicines. They can be divided into three categories: monosaccharides, oligosaccharides and polysaccharides, as well as their derivatives. Plant polysaccharides are formed through dehydration and condensation of multiple different or identical monosaccharide molecules. They are characterized by complex structures, high molecular weight and strong biological activities. In clinical practice, they are frequently associated with anti-tumor, anti-oxidation, hypoglycemic and other physiological activities. *S. barbata* is a medicinal plant with anti-tumor effect, and polysaccharide is one of the main components to play its role. Polysaccharides are widely distributed in different parts of various medicinal plants, such as whole grass, roots, stems, leaves and flowers. Their contents vary among these different medicinal plant parts, with the roots typically exhibiting the highest polysaccharide accumulation [62].

2.4 Volatile compounds

S. barbata is rich in volatile compounds and has significant antibacterial effect. Previous studies have identified 70 volatile oil components in *S. barbata*. The volatile compounds in *S. barbata* roughly include monoterpenes, alcohols, phenolic compounds, acids and other compounds. Among them, aromatic terpenoids have long been utilized in aromatherapy, or in teas and medicated diets to treat various diseases. In addition, terpenes have been shown to possess antibacterial, antiviral, anti-inflammatory, anti-tumor effects, and can also be used in dental and dermatological treatments. For example, thymol can be used as antibacterial surface cleaners and insecticides [63]. Volatile compounds can also be used as raw materials for the manufacture of drugs, such as thymol. Thymol is a monoterpene phenol, a derivative of cymene, and an isomer of carvacrol. Characterized by a fresh aroma and strong bactericidal effect, it is used to eliminate mold spores and is also an important raw material for the manufacture of drugs and spices [64].

2.5 Microelements

S. barbata is rich in iron, copper, zinc, manganese, magnesium, calcium and other elements, and the contents of these elements are higher than those found in other traditional Chinese medicinal materials. In addition, *S. barbata* contains selenium, molybdenum and other trace elements [65]. Research showed that the total flavonoid content had a significant positive correlation with Zn content and a highly significant positive correlation with Mn content. There was a significant positive correlation between polysaccharide and Zn, Mn content [66].

3 Pharmacological activities

Pharmacological activities of *S. barbata* are shown in Fig. 6.

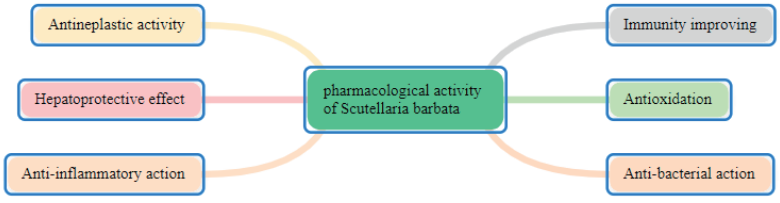


Fig. 6 Pharmacological activities of *S. barbata*

3.1 Antineoplastic activity

A variety of components in *S. barbata* have certain effects on cancer cells, and most of them are drug pairs (SH) composed of *Hedyotis diffusa*. Its main mechanisms include inhibition of cancer cell proliferation, invasion, metastasis and differentiation, induction of cancer cell autophagy and apoptosis, regulation of immune function, and anti-tumor angiogenesis [67]. Research shows *S. barbata* can be used for a variety of cancer cell lesions, including liver cancer, breast cancer, ovarian cancer and prostate cancer.

Hepatocellular Carcinoma (HCC) is a common malignant tumor, which seriously threatens human health. The current treatment methods have limitations, prompting growing interest in the role of traditional Chinese medicine. Researchers used network pharmacology, molecular docking technology and cell experiments to explore the methanism of SH in the treatment of HCC. Hou et al. screened 217 active components and corresponding targets of SH and 1196 HCC-related targets from multiple databases, and 63 intersection targets were obtained by analysis. Quercetin, luteolin and baicalein were identified as core components by network analysis, and TP53, CDK2, XPO1 and APP were identified as core targets. Enrichment analysis found that SH mainly involved biological processes and molecular functions such as oxidative stress response and ubiquitin-like protein ligase binding, and acted on multiple key signaling pathways such as P53 signaling pathway. Molecular docking showed that the core components were well combined with the core targets. In cell experiments, CCK-8 assay showed that these three components could inhibit the proliferation of HepG2 and Huh7 cells in a concentration-and time-dependent manner. The results of qRT-PCR and Western blot showed that they could regulate the expression of related genes and proteins, reduce the levels of XPO1 and CDK2, and increase the levels of TP53 and APP. In summary, SH may up-regulate TP53 expression by inhibiting XPO1, thereby increasing APP level, inhibiting CDK2 and ultimately inhibiting HCC cell proliferation. This study reveals the multi-component, multi-target, and multi-pathway characteristics of SH in the treatment of HCC, which provides an important theoretical basis for its application in clinical treatment of HCC and subsequent in-depth research [68].

S. barbata also shows certain potential in the treatment of breast cancer. In the treatment of triple-negative breast cancer (TNBC), Pan et al. found that cancer-associated fibroblasts (CAFs) and their secreted interleukin-6 (IL-6) were closely related to the prognosis of TNBC. A high proportion of CAFs and high levels of IL6 are associated with poor patient survival, with IL6 mainly secreted by CAFs. SH can inhibit the progression of TNBC. *In vitro* experiments demonstrated that CAFs and IL6 enhanced the colony formation and migration ability of MDA-MD-231 cells, while SH significantly reduced this promoting effect. The underlying mechanism is related to the inhibition of NF-κB activation induced by CAFs-derived IL6, which is known to promote tumor cell proliferation and immune escape. Similar results were obtained by interfering with cell experiments with recombinant human IL6 protein. *In vivo* experiments also confirmed the role of SH. It was found that the tumor volume and weight of TNBC mice treated with SH were significantly reduced. At the same time, SH can reduce the level of IL6 in serum and tumor tissues and inhibit the activation of NF-κB pathway. Despite these promising results, there are some limitations in the current research, such as the small sample size of bioinformatics analysis, the absence of clinical sample verification, a lack of immunohistochemical results of tumor tissue *in vivo*, insufficient dose-response data from *in vitro* experiments, and the need for verification of mechanism research at the

level of gene expression. Overall, *S. barbata* has shown potential value in the treatment of breast cancer, underscoring the need for further research and optimization [69].

Research showed that the optimal ratio of SH to inhibit the proliferation of ovarian cancer cells was 2: 1 [70]. When combined with cisplatin (DDP), it synergistically reduced cancer cell viability, inhibited colony formation, promoted cell cycle arrest and apoptosis, and inhibited cell migration and invasion *in vitro*. *In vivo*, it significantly inhibited the growth of subcutaneous tumors in BALB/c nude mice and reduced the side effects of DDP. The mechanism of action involves mainly the regulation of oxidative stress, promotion of oxidative stress response, reduction of mitochondrial membrane potential, inhibition of ATP production, decrease of ROS level and increase of SOD activity, and regulation of the expression of related proteins to promote FTH1 degradation through autophagy. 3-MA and Fer-1 reversed the expression of key target proteins. In addition, bioinformatics analysis showed that the abnormal expression levels of NRF2 and FTH1 mRNA had a high predictive value for the prognosis of ovarian cancer, and other related proteins also played an important role in the occurrence and development of ovarian cancer. This provides a new strategy for improving the sensitivity of DDP chemotherapy and reducing the side effects. SH is expected to become a potential combination and provide new ideas for the clinical treatment of ovarian cancer.

Zhu et al. found that *S. barbata* and its active ingredients exhibited a significant therapeutic effect on prostate cancer [71]. For example, the diterpenoid alkaloids in *S. barbata* inhibited the progression of prostate cancer cells and combated their invasion and metastasis; baicalin (SCU) promoted the apoptosis of prostate cancer cells and inhibited their invasion and metastasis by regulating the proportion of related proteins; luteolin reduced the expression of vascular endothelial growth factor, inhibited endothelial cell angiogenesis, and weakened the invasiveness of prostate cancer. Through network pharmacology research, a total of 212 potential targets of *S. barbata* for the treatment of prostate cancer were identified. These targets are closely related to multiple specific pathways, such as prostate cancer pathway, AGE-RAGE signaling pathway, lipid and atherosclerosis pathway. The treatment of prostate cancer by *S. barbata* involves a series of biological processes, such as response to exogenous stimuli, lipopolysaccharide and metal ions. It also involves a variety of molecular functions, including DNA binding transcription factor binding. This fully reflects the characteristics of multi-component, multi-target and multi-pathway synergy in the treatment of prostate cancer by *S. barbata*, which provides an important theoretical basis for further research on the mechanism of prostate cancer treatment and the development of new therapeutic approaches.

3.2 Hepatoprotective effect

S. barbata also showed a significant role in liver protection. Li et al. showed that *S. barbata* could effectively inhibit the apoptosis of hepatocytes in the process of liver fibrosis [72]. *In vitro*, the supernatant of hepatic stellate cells (HSCs) treated with transforming growth factor-β1 (TGF-β1) induced liver fibrosis-like state in hepatocytes BRL-3A, while the serum containing *S. barbata* as an intervention method restored cell proliferation and reduced the apoptosis activity induced by fibrosis model. Specifically, it significantly down-regulated apoptosis-related proteins (such as cleaved-Caspase-3 and Bax), up-regulated anti-apoptotic protein BCL-2, and increased mitochondrial membrane potential (MMP) levels. Bioinformatics analysis showed that *S. barbata* played a hepatoprotective role through PI3K-Akt

and other signaling pathways. In the GO analysis of related gene sets, it was found that the biological processes involved were mainly related to DNA template-mediated transcription, positive regulation of gene expression and negative regulation of apoptosis. Cell components implicated mainly included the nucleus and cytoplasm while molecular functions were mainly related to the binding of proteins, enzymes, and DNA. Using UHPLC-QE-MS technology, 29 chemical components were identified in the serum containing *S. barbata*, which may constitute the material basis for its anti-hepatic fibrosis effect. Compared with common anti-hepatic fibrosis traditional Chinese medicines such as *Radix Bupleuri*, *R. Salviae* Miltiorrhizae and *R. Astragali* seu Hedysari, *S. barbata* not only alleviates oxidative stress and inflammatory response, but also exhibits more pronounced anti-cancer effect. Its potential advantages in regulating apoptosis and extracellular matrix offers a new research direction and a promising therapeutic strategy for liver fibrosis.

3.3 Anti-inflammatory activity

In addition, *S. barbata* has a significant anti-inflammatory effect, which is closely related to its chemical composition. Li et al. used UPLC/IM-QTOF-MS technology to predict the key targets and main pathways of its anti-inflammatory effect through network pharmacological analysis [73]. The study identified tumor necrosis factor (TNF), protein kinase B (AKT1), and epidermal growth factor receptor (EGFR) as the key targets for the anti-inflammatory effect of *S. barbata*. GO enrichment analysis showed that its anti-inflammatory mechanism involved multiple biological processes, such as positive regulation of protein phosphorylation and vasoconstriction, and response to oxidative stress and hypoxia. The effects are related to cell surface and extracellular region. At the molecular function level, processes such as enzyme binding and ATPase activity were implicated. KEGG pathway enrichment analysis showed that the anti-inflammatory effect of *S. barbata* involved a wide range of signaling pathways, among which cancer-related signaling pathways accounted for a large proportion, and inflammation-related signaling pathways such as TNF signaling pathways were also involved. Based on the results of network pharmacological analysis and content information, five components were determined as the key indicators for the quality control of *S. barbata*, namely scutellarin, scutellarin, luteolin, apigenin and homoplantaginin. These components play an important role in the anti-inflammatory effect of *S. barbata*. For example, luteolin, apigenin and homoplantaginin showed high anti-inflammatory activity in network pharmacology analysis. Overall, *S. barbata* plays an anti-inflammatory role through multi-component, multi-target and multi-pathway synergy, which provides an important basis for in-depth understanding of its medicinal value and quality control.

3.4 Immunomodulatory activity

S. barbata also shows a unique mechanism and effect in enhancing immunity. Ran et al. found that *S. barbata* extract positively regulated the immune system through two-way immune regulation, thereby enhancing immune function [74]. In the context of SARS-CoV-2 infection, *S. barbata* extract significantly alleviated virus-induced acute lung injury. In the mouse model infected with SARS-CoV-2, it reduced the weight loss of mice, decreased the lung index, and attenuated lung tissue damage, including interstitial pneumonia, alveolar collapse, septal thickening, and monocyte infiltration. Pathological changes such as infiltration indicate that it has a positive regulatory effect on the pulmonary immune microenvironment. At the same time, *S.*

barbata extract reduced lung viral load, suppressed the expression of pro-inflammatory cytokines TNF-*α* and IL-6, inhibited excessive inflammatory response, avoided the damage caused by cytokine storm, maintained immune balance, and then enhanced the body's immune defense ability during viral infection. From the perspective of mechanism of action, a variety of active ingredients in *S. barbata* extract play a key role. Through virtual docking analysis, it was found that 20 of the 141 components had potential inhibitory activity against 3CLpro and 24 had potential inhibitory activity against PLpro. Some components such as ursolic acid and apigenin have anti-SARS-CoV-2 activity. These components may indirectly enhance immune function by inhibiting viral protease activity, blocking viral replication, and reducing virus damage to the immune system. In addition, *S. barbata* extract has a two-way regulatory effect on the host inflammatory response. In the absence of exogenous stimulation or low-intensity stimulation, the lower concentration of the extract can up-regulate the expression of pro-inflammatory cytokines such as IL-6 and TNF-*α*, enhance the activity of immune cells, and enhance the body's immune defense. Under high-intensity stimulation, high-concentration extracts down-regulate the expression of these factors to avoid damage to the body caused by excessive inflammatory response. This two-way regulation helps to maintain host immune homeostasis and enhance the overall immune function of the body, which is of great significance in the prevention and treatment of infectious diseases.

3.5 Antioxidant activity

S. barbata also has significant antioxidant effect, and its antioxidant capacity is closely related to the content of total flavonoids. Chi et al. collected 12 kinds of *S. barbata* from different producing areas, evaluated the antioxidant activity by measuring the scavenging ability of ABTS and DPPH free radicals, and determined the content of total flavonoids by ultraviolet spectrophotometry [75]. The results showed considerable difference in the content of total flavonoids in *S. barbata* from different regions, ranging from 2.331% to 6.284%. The highest content was found in *S. barbata* from Zhumadian, Henan, and lowest in that from Yulin, Guangxi. The 50% ethanol extract of *S. barbata* had certain ability to scavenge ABTS and DPPH free radicals, with the scavenging rate positively correlated with the concentration of the extract. The higher the concentration, the stronger the scavenging ability. Among all samples, *S. barbata* from Henan Zhumadian exhibited the strongest antioxidant capacity, while that from Guangdong Jieyang showed the weakest. Correlation analysis revealed a negative relationship between the IC_{50} value of semi-scavenging concentration of oxidative free radicals and the content of total flavonoids, indicating that the higher the content of total flavonoids, the stronger the antioxidant capacity. This suggests that the total flavonoids in *S. barbata* is an important material basis for its antioxidant effect. However, the study also found that although the total flavonoid content of *S. barbata* produced in Jieyang, Guangdong was higher than that of other areas, the antioxidant effect was comparatively weaker. This finding suggests that *S. barbata* may have other antioxidant components in addition to flavonoids, which needs to be further explored. Overall, the antioxidant capacity of *S. barbata* from different habitats is different, and the content of total flavonoids plays a key role. As a traditional Chinese medicine with antioxidant potential, the in-depth study of its antioxidant effect not only helps to reveal its pharmacological mechanism, but also provides a theoretical basis for its rational development and utilization in the fields of medicine and food.

3.6 Anti-bacterial activity

Similarly, *S. barbata* also has significant antibacterial effect, which can be further enhanced through combination with nanocarriers. The study of Raghu et al. showed that the extract of *S. barbata* had certain antibacterial activity against Pseudomonas aeruginosa, and its minimum inhibitory concentration (MIC) was 1700 μg/mL [76]. However, to achieve effective inhibition of bacterial growth, relatively high concentrations were still required. When the extract of *S. barbata* was encapsulated in a lipid nanocarrier composed of DSPE-PEG, span 40 and cholesterol, the antibacterial efficacy was significantly enhanced. The MIC of the extract/nanocarrier combination against *P. aeruginosa* was reduced to 700 μg/mL, suggesting that the nanocarrier improved the delivery or stability of the extract, thereby enabling effective bacerial inhibition at lower concentrations. Although the mechanism of action remains to be elucidated, it is hypothesized that nanocarriers may help *S. barbata* extract act more accurately on bacteria, or protect the extract from premature degradation, thereby improving the antibacterial effect. In practical applications, this nanocarrier containing *S. barbata* extract offers a promising alternative for antibacterial therapy, especially in the context of Pseudomonas aeruginosa infection When combined with other antibiotics or therapies, it is expected to further optimize the antibacterial treatment plan and improve the clinical treatment effect. However, broader clinical application necessitates additional research, including investigations into long-term stability, *in vivo* efficacy, and comprehensive safety evaluations.

4 Conclusion

As a traditional Chinese medicine, *S. barbata* has shown rich research value in chemical composition and pharmacological activity. It contains terpenoids, flavonoids, polysaccharides and other chemical components, which are the material basis for exerting anti-tumor, liver protection, anti-inflammatory and other biological activities. In the field of tumor therapy, the drug pair of *S. barbata* and *Hedyotis diffusa* has shown certain effects in the treatment of various cancers such as liver cancer, breast cancer, ovarian cancer and prostate cancer, exhibiting the characteristic features of multi-component, multi-target and multi-pathway. Moreover, *S. barbata* also exerts notable effects in anti-tumor, hepatoprotective, anti-inflammatory, immunomodulatory, antioxidant and antibacterial activity through unique mechanisms. However, there are still some limitations in the current research, such as the small sample size of some experiments and the lack of clinical verification. Future efforts should focus on optimizing research methods, expanding sample size, and strengthening clinical research to fully explore the medicinal potential of *S. barbata.* Such work will provide a solid theoretical and practical basis for its wider and more reasonable application in clinical practice.

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