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番荔枝科生物碱类成分及其生物活性研究进展

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摘 要:生物碱为番荔枝科植物中含有的特征性成分,具有多种骨架类型和广泛的生物活性。本文系统综述了番荔枝科植物中该类成分及生物活性的国内外研究进展,以期为它们的深度开发和利用提供参考。

关键词:番荔枝科;生物碱;生物活性;研究进展

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Research Progress of Alkaloids and their Bioactivity of Annonaceae Family

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Abstract: Alkaloids are characteristic constituents in family Annonaceae, which possess a variety of changeable skeletons. And most of them showed marked bioactivities. In this paper, we reviewed the structures and bioactivities of alkaloids in Annonaceae to provide a reference for future research and development of this family.

Key words: Annonaceae; alkaloid; bioactivity; review

番荔枝科(Annonaceae)属双子叶植物纲木兰亚纲,是木兰目(Magnoliales)中最大的一个科。全球约 120 余属,2100 种植物,广泛分布于世界热带、亚热带地区,以东半球为多。我国产 24 属,103 个种,6 个变种,主要分布于西南部至台湾地区,大部份产于华南,少数分布于华东[1]。

对于番荔枝科的化学成分和活性研究始于上个世纪六十年代。国内外学者先后从该科植物中发现了多种类型的化学成分,如生物碱类[2]、萜类[3]、黄酮类[4]、聚酯类[5]等[6]。其中,生物碱类成分广泛分布于番荔枝科各属植物中,是迄今为止该科中研究最多的一大类成分。其结构多样,生物活性广泛,特别是抗肿瘤、抗寄生虫方面显示出了良好的活性,颇具研究价值。本文现对番荔枝科植物中生物碱类成分的结构类型和生物活性的研究进展进行综述,以期为该科植物中该类成分的开发利用提供参考。

1 生物碱类成分

目前,从番荔枝科已有研究报道的各属植物中,按照生物碱结构类型分类,得到最多的是阿朴啡类,其次为异喹啉类,另外还有原小檗碱类、马兜铃内酰胺类、吲哚类、氮杂芴酮类、氮杂啡类、噁呤类等。

1.1 阿朴啡类生物碱(Aporphine)

该类生物碱主要分布于番荔枝属、瓜馥木属和鹰爪花属,结构类型有一般阿朴啡类(Aporphin),如 **1**、**2**、**3** 等,氧化阿朴啡类(Oxoaporphin),如 **8**、**10**、**23**,双阿朴啡类(Bisaporphin),如 **29**、**30**、**31** 等。

1.2 马兜铃内酰胺类生物碱(Aristolactam)

该类生物碱主要分布于瓜馥木属。迄今为止,主要从番荔枝科 4 个属中分离得到 16 个该类生物碱。

1.3 原小檗碱类生物碱(Protoberberinium)

该类生物碱主要分布于番荔枝属和瓜馥木属。迄今为止,主要从番荔枝科 7 个属中分离得到 16 个该类生物碱。

1.4 异喹啉类生物碱(Isoquinoline)

目前,研究报道该类生物碱主要分布于番荔枝属和木瓣树属,共分离得到 15 个该类生物碱,分别为番荔枝属(*Annona*)的(+)-*O*-methylarmepavine(polysignine, **109**)[9,67,47]、N-methylcorydaldine(**110**)[9]、(+)-anomuricine(**111**)[9]、N-methyl-6,7-dimethoxyisoquinolone(**112**)[9,67]、6,7-dimethoxy-2-methylisoquinolinium(**113**)[9]、Thalifoline(**114**)[12]、Promucosine(**115**)[13]、Annocherine A

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表 1 阿朴啡类生物碱及其来源植物

Table 1 Aporphine alkaloids and their biological sources

编号 No.	化合物名称 Name	植物来源 Source	文献 Ref.
1	7-hydroxy-dehydrothalicsimidine	*Annona purpurea*	7
2	7-formyl-dehydrothalicsimidine	*Annona purpurea*	7
3	Thalicsimidine	*Annona purpurea*	7
4	Norpurpureine	*Annona purpurea*	7
5	N-methyllaurotetanine	*Annona purpurea*	7
6	Lirinidine	*Annona purpurea*	7
7	N-methylasimilobine	*Annona purpurea*	7
8	(-)-roemerine	*Annona senegalensis*	8
9	(-)-isocorydine	*Annona senegalensis*	8
10	Lanuginosine	*Annona squamosa*	9,67
11	Isocorydine	*Annona squamosa*	9
12	Oxopurpureine	*Annona purpurea*	10
13	Oxonuciferine	*Annona purpurea*	10
14	Oxoglaucine	*Annona purpurea*	10
15	(+)-predicentrine	*Annona purpurea*	10
16	(-)-glaucine	*Annona purpurea*	10
17	Thalbaicalidine	*Annona purpurea*	10
18	*N*-formyl-purpureine	*Annona purpurea*	10
19	Thalicpureine	*Annona purpurea*	10
20	Dehydrolirinidine	*Annona purpurea*	10
21	7-hydroxy-dehydroglaucine	*Annona purpurea*	10
22	*O*-methylmoschatoline	*Annona foetida*	11
23	Liriodenine	*Annona foetida*	11
24	Demethylsonodione	*Annona squamosa*	12
25	Annobraine	*Annona squamosa*	12
26	Romucosine F	*Annona purpurea*	13
27	Romucosine G	*Annona purpurea*	13
28	Romucosine H	*Annona cherimola*	14
29	bis-7,7′-dehydroanonaine	*Polyalthia debilis*	15
30	7-dehydroanonaine-7-dehydro-8-methoxyanonaine	*Polyalthia debilis*	15
31	bis-7,7′-dehydro-8,8′-dimethoxyanonaine	*Polyalthia debilis*	15
32	bis-7,7′-dehydro-10,10′-dimethoxyanonaine	*Polyalthia debilis*	15
33	7,7’-bisdehydro-*O*-methylisopiline	*Polyalthia bullata*	16
34	7-dehydeonornuciferinyl-7’-dehydro-*O*-methylisopiline	*Polyalthia bullata*	16
35	Urabain	*Polyalthia bullata*	16
36	(-)-nordicentrine	*Goniothalamus laoticus*	17
37	Goniotamirine	*Goniothalamus tamirensis*	18
38	Griffithdione	*Goniothalamus griffithii*	19

39	(-)-N-methylguattescidine	*Fissistigma latifolium*	20
40	(-)-asimilobine	*Fissistigma latifolium*	20
41	(-)-anonaine	*Fissistigma latifolium*	20
42	Lysicamine	*Fissistigma latifolium*	20
43	Fissilandione	*Fissistigma balansae*	21
44	Norfissilandione	*Fissistigma balansae*	21
45	Oxodiscoguattine	*Fissistigma oldhamii*	22
46	Oxocalycinine	*Fissistigma oldhamii*	22
47	Calycinine	*Fissistigma oldhamii*	22
48	Xylopine	*Fissistigma oldhamii*	22
49	Crebanine	*Fissistigma oldhamii*	22
50	Isolaureline	*Fissistigma oldhamii*	22
51	Asimilobine	*Fissistigma oldhamii*	22
52	Duguevanine	*Fissistigma oldhamii*	22
53	Corytuberine	*Fissistigma oldhamii*	22
54	4,5-dioxodehydro asimilobine	*Fissistigma oldhamii*	22
55	Isoboldine	*Fissistigma oldhamii*	22
56	Norcepharadione B	*Fissistigma oldhamii*	22
57	Fissistigamide A	*Fissistigma oldhamii*	23
58	Fissistigamide B	*Fissistigma oldhamii*	23
59	Fissistigmine	*Fissistigma oldhamii*	23
60	Pseuduvarine A	*Pseuduvaria rugosa*	24
61	Pseuduvarine B	*Pseuduvaria rugosa*	24
62	10,11-dihydroxy-1,2-dimethoxynoraporphine	*Xylopia parviflora*	25
63	(+)-isocorydine a-N-oxide	*Miliusa velutina*	26
64	10-hydroxyliriodenine	*Miliusa cf. banarea*	27
65	1,9-dihydroxy-2,11-dimethoxy-4,5-dihydro-7-oxoaporphine	*Miliusa cuneata*	28
66	Artabotrine	*Artabotrys zeylanicus*	29
67	Artabotrysine	*Artabotrys spinosus*	30
68	Artabonatine C	*Artabotrys uncinatus*	31
69	Artabonatine D	*Artabotrys uncinatus*	31
70	Artabonatine E	*Artabotrys uncinatus*	31
71	Artabonatine F	*Artabotrys uncinatus*	31
72	Lastourvilline	*Artabotrys lastourvillensis*	32
73	Artabonatine	*Artabotrys uncinatus*	33
74	Artabonatine B	*Artabotrys uncinatus*	33
75	3,9,11-trimethoxy-1,2-methylenedioxyl oxoaporphine	*Desmos chinensis*	34
76	Desmorostratine	*Desmos rostrata*	35

表 2 马兜铃内酰胺类生物碱及其来源植物

Table 2 Aristolactam alkaloids and their biological sources

编号 No.	化合物名称 Name	植物来源 Source	文献 Ref.
77	Enterocarpam-III	*Orophea enterocarpa*	36
78	stigmalactam	*Orophea enterocarpa*	36
79	griffithinam	*Goniothalamus griffithii*	19
80	goniothalactam	*Goniothalumus borneensis*	37
81	Oldhamactam	*Fissistigma oldhamii*	22
82	aristololactam A IIIa	*Fissistigma oldhamii*	22
83	aristololactam A II	*Fissistigma oldhamii*	22
84	goniothalactam	*Fissistigma oldhamii*	22
85	aristolactam F I	*Fissistigma oldhamii*	22
86	aristolactam F II	*Fissistigma oldhamii*	22
87	aristololactam B II	*Fissistigma oldhamii*	22
88	aristololactam B III	*Fissistigma oldhamii*	22
89	aristololactam GI	*Fissistigma oldhamii*	23
90	aristololactam GII	*Fissistigma oldhamii*	23
91	3,5-dihydroxy-2,4-dimethoxyaristolactam	*Dasymaschalon blumei*	38
92	10-amino-3,6-dihydroxy-2,4-dimethoxyphenanthrene-1-carboxylic acid lactam	*Dasymaschalon trichophorum*	39

表 3 原小檗碱类生物碱及其来源植物

Table 3 Protoberberinium alkaloids and their biological sources

编号 No.	化合物名称 Name	植物来源 Source	文献 Ref.
93	Corytenchine	*Annona cherimolia*	40
94	Isocoreximine	*Annona cherimolia*	40
95	(-)-pessoine	*Annona spinescens*	41
96	(-)-spinosine	*Annona spinescens*	41
97	Cerasodine	*Polyalthia cerasoides*	42
98	Cerasonine	*Polyalthia cerasoides*	42
99	(-)-discretamine	*Fissistigma glaucescens*	43
100	Fissisaine	*Fissistigama balansae*	44
101	Thaipetaline	*Fissistigama balansae*	44
102	Kikemanine	*Fissistigama balansae*	44
103	Columbamine	*Fissistigama balansae*	44
104	Dehydrodiscretamine	*Fissistigama balansae*	44
105	2,10-dimethoxy-3,11-dihydroxy-5,6-dihydroprotoberberine	*Miliusa cuneata*	28
106	(-)-attavenustine	*Artabotrys venustus*	45
107	Discretine N-oxide	*Desmos rostrata*	35
108	Dehydrocoreximine	*Xylopia parviflora*	46

(**116**)[14]、Annocherine B(**117**)[14]和 Cherianoine(**118**)[14];暗罗属(*Polyalthia*)的 Methoxypolysignine(**119**)[47];以及木瓣树属(*Xylopia*)的 Parvinine(**120**)[25]、Xylopinidine(**121**)[46]、*N*,*N*-dimethylanomurine(**122**)[46]和 N-methylphoebine(**123**)[46]。

1.5　吲哚类生物碱(ndole)

该类生物碱主要分布于暗罗属和紫玉盘属,迄今共发现 11 个,分别为吲哚类生物碱(3S)-2-Oxo-5,12-dimethoxy-3-hydroxy-3-methylbenz[f]indoline(**124**)[48];异吲哚类生物碱(5-methoxy-2-methylisoindolin-1-yl)(4-methoxyphenyl)methanol(**125**)[49];倍半萜吲哚类生物碱 Polysin(**126**)、Greenwayodendrin-3-one(**127**)、3-O-acetyl greenwayodendrin(**128**)、N-acetyl polyveoline(**129**)和 Polyveoline(**130**)[50];以及苯聚吲哚类生物碱 Uvarindoles A-D(**131** ~ **134**)[51]。

1.6　氮杂芴酮类生物碱(Azafluorene)

目前,主要从番荔枝科 5 种植物中发现 8 个该类生物碱,分别为:来源于 *Polyalthia longiflia* 的 Polyfothine(**135**)和 Isooncodine(**136**)[52];来源于 *Polyalthia debilis* 的 1-methyl-4-azafluoren-9-one(**137**)和 7-methoxy-1-methyl-4-azafluoren-9-one(**138**)[53];来源于 *Oncohtigma mnosperma* 的 Oncodine(**139**)[54];来源于 *Alphonsea monogyma* 的 6,7-dimethoxy-5-hydroxy-onychine noxide(**140**)[55];以及来源于 *Mitrephora diversifolia* 的 5,8-dihydroxy-6-methoxyonychine(**141**)和 5-hydroxy-6-methoxyonychine(**142**)[56]。

1.7　氮杂蒽醌类生物碱(Azaanthraquinone)

迄今为止,从番荔枝科 3 个属中共发现 5 个该类成分,分别是来源于哥纳香属植物的 *Goniothalamus laoticus* 的 Laoticuzanone A(**143**)、Griffithazanone A(**144**)、3-methyl-1H-1-azaanthracene-2,9,10-trione(**145**)[57]和 *Goniothalamus griffithii* 的 Griffithazanone A(**146**)[16],以及在 *Polyalthia suberosa* 和 *Annona atemoya* 都发现的 Kalasinamide(**147**)[58,68]。

1.8　氮杂菲类生物碱(Azaphenanthrene)

目前,只从 *Anaxagorea dolichocarpa*[59]中分离得到 3 个该类生物碱 Eupolauramine(**148**),Sampangine(**149**)和 Imbiline(**150**)。

1.9　嘌呤类生物碱(Purine)

目前,嘌呤类生物碱从 *Anaxagorea javanica*[60]中得到 2 个,分别是 4,11-dimethoxy-eupolauridine(**151**)和 2-methoxy-3-hydroxyeupolauridine(**152**);从 *Canaga odorata*[61]中分离得到 1 个,名为:Eupolauridine(**153**)。

1.10　嘧啶类生物碱(Pyrimidine)

目前,从植物 *Annona foetida*[61]中分离得到 2 个该类生物碱,分别为:*N*-hydroxyannomontine(**154**)和 Annomontine(**155**)。

1.11　吡啶骈香豆素类生物碱(Pyridocoumarin)

目前,只在 *Goniothalamus australis*[62]中发现 2 个该类成分,分别为:Goniothaline A(**156**)和 Goniothaline B(**157**)。

1.12　苯杂氮喹唑啉类生物碱(Benzoquinazoline)

目前,只在 *Annona squamosa*[63]中发现 1 个该类成分,名为:Samoquasine A(**158**)。

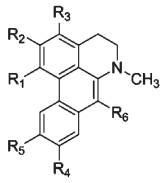
1.13　其它类生物碱

除了以上 12 类主要类型生物碱外,番荔枝科植物中还分离得到一些骨架较为新颖的生物碱,如 **159**、**161** 和 **162**。

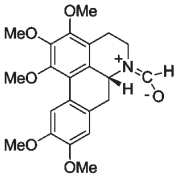
表 4　其它类生物碱及其来源植物

Table 4　Other alkaloids and their biological sources

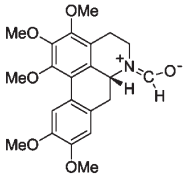
编号 No.	化合物名称 Name	植物来源 Source	文献 Ref.
159	Annosqualine	*Annona squamosa*	12
160	N-methyl-2,3,6-trimethoxymorphinandien-7-one	*Fissistigma oldhamii*	22
161	Cheliensisine	*Goniothalamus cheliensis*	64
162	Maingayinine	*Mitrephora maingayi*	65
163	Uncinine	*Artabotrys uncinatus*	31
164	Sampangine	*Canaga odorata*	66
165	Prolifine	*Saccopetalum prolificum*	69



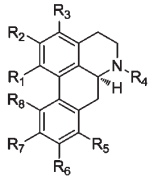
	R_1	R_2	R_3	R_4	R_5	R_6
1	OMe	OMe	OMe	OMe	OMe	OH
2	OMe	OMe	OMe	OMe	HCO	OH
20	OH	OMe	H	H	H	H
21	OMe	OMe	H	OMe	OMe	OH



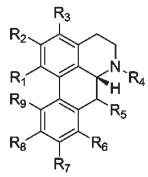
18a *Z*-form



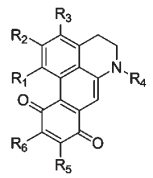
18b *E*-form



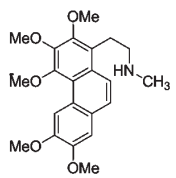
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
3	OMe	OMe	OMe	Me	H	OMe	OMe	H
11	OMe	OMe	H	Me	H	H	OMe	OH
16	OMe	OMe	H	Me	H	OMe	OMe	H
26	OMe	OMe	Cl	COOMe	H	OMe	OMe	H
27	OMe	OMe	OMe	COOMe	H	OMe	OMe	H
47	-OCH_2O-		H	H	H	OMe	H	OH
48	-OCH_2O-		H	H	H	OMe	H	H
49	-OCH_2O-		H	Me	OMe	OMe	H	H
50	-OCH_2O-		H	Me	H	OMe	H	H
51	OMe	OH	H	H	H	H	H	H
52	-OCH_2O-		OMe	H	H	OMe	H	OMe
53	OH	OMe	H	Me	H	H	OMe	OH
55	OH	OMe	H	H	H	OH	OMe	H
62	OMe	OMe	H	H	H	H	OH	OH
72	OH	OH	H	Me	H	OMe	OMe	H



	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9
8	-OCH_2O-		H	Me	H	H	H	H	H
28	OMe	OMe	H	COOMe	H	H	H	OMe	OH
36	-OCH_2O-		H	H	H	H	OMe	OMe	H
37	OMe	OMe	H	H	β-OH	H	H	OMe	OH
39	-OCH2O-		H	Me	=O	H	OH	H	H
40	OMe	OH	H	H	H	H	H	H	H
41	-OCH2O-		H	H	H	H	H	H	H
57	-OCH2O-		H	CONH2	H	H	OMe	H	H
58	-OCH2O-		H	CONH2	H	H	OMe	H	OH
74	-OCH2O-		OMe	H	α-OH	H	H	H	H
76	-OCH2O-		OMe	H	H	OMe	OMe	H	H



	R_1	R_2	R_3	R_4	R_5	R_6
23	OH	OMe	H	Me	H	OMe
43	-OCH_2O-		H	Me	OMe	H
44	-OCH_2O-		H	H	OMe	H



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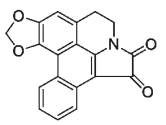

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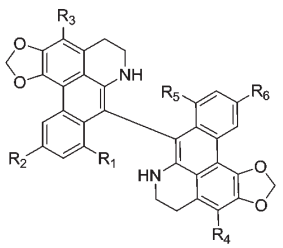
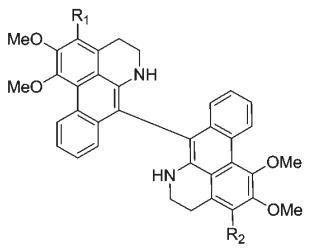
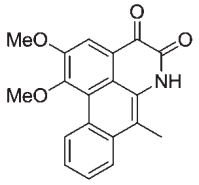




	R_1	R_2	R_3	R_4	R_5	R_6
29	H	H	H	H	H	H
30	H	H	H	H	OMe	H
31	OMe	H	H	H	OMe	H
32	H	OMe	H	H	H	OMe
67	H	H	OMe	H	H	H
71	H	H	OMe	OMe	H	H

	R_1	R_2
33	OMe	OMe
34	H	OMe
35	H	H



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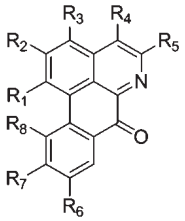
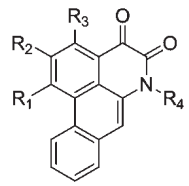
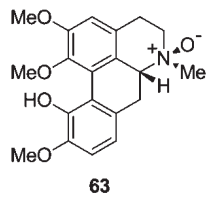


	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8
10	-OCH_2O-		H	H	H	OMe	H	H
14	OMe	OMe	H	H	H	OMe	OMe	H
22	OMe	OMe	OMe	H	H	H	H	H
23	-OCH_2O-		H	H	H	H	H	H
42	OMe	OMe	H	H	H	H	H	H
45	-OCH_2O-		H	H	H	OMe	H	OMe
46	-OCH_2O-		H	H	H	OMe	H	OH
59	-OCH_2O-		OMe	H	H	OMe	H	OH
64	-OCH_2O-		H	H	H	H	OH	H
65	OH	OMe	H	H	H	OH	H	OMe
68	OMe	H	H	OMe	OMe	H	H	H
69	OMe	H	H	OMe	OH	H	H	H
75	-OCH_2O-		OMe	H	H	OMe	H	OMe



	R_1	R_2	R_3	R_4
54	OMe	OH	H	H
56	OMe	OMe	H	H
60	OMe	OMe	NH_2	H
61	OMe	OMe	NH_2	Me
66	-OCH_2O-		H	OMe



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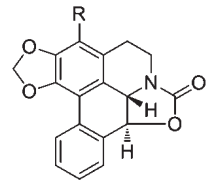
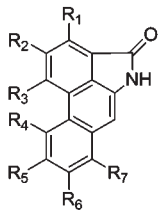
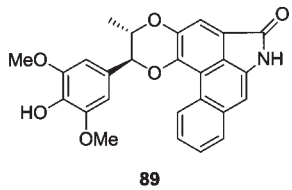


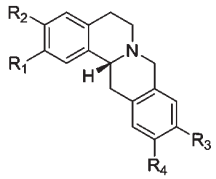
	R
70	OMe
73	H



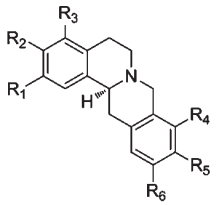


89

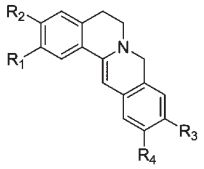
	R_1	R_2	R_3	R_4	R_5	R_6	R_7
77	OMe	OMe	OMe	H	OMe	H	H
78	OMe	OMe	OMe	H	OH	H	H
79	H	OMe	OH	H	H	H	OMe
80	H	OMe	OMe	H	H	H	OH
81	OMe	OMe	OMe	H	OH	H	H
82	H	OH	OMe	H	OH	H	H
83	H	OH	OMe	H	H	H	H
84	H	OMe	OMe	H	OH	H	H
85	H	OMe	OH	H	H	H	H
86	OMe	OMe	OMe	H	H	H	H
87	H	OMe	OMe	H	H	H	H
88	H	OMe	OMe	H	OMe	H	H
90	H	OMe	OH	H	OH	H	H
91	OMe	OH	OMe	OH	H	H	H
92	OMe	OH	OMe	H	OH	H	H



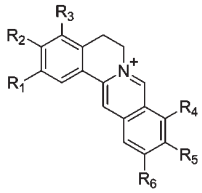
	R_1	R_2	R_3	R_4
93	OMe	OMe	OMe	OH
94	OMe	OH	OMe	OH



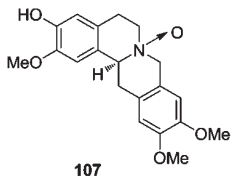
	R_1	R_2	R_3	R_4	R_5	R_6
95	OH	OMe	H	H	OH	OH
96	OMe	OMe	H	H	OH	OH
99	OMe	OH	H	H	OMe	OH
101	OMe	OMe	OH	OMe	OH	H
102	OMe	OMe	H	OMe	OH	H
106	OMe	OH	H	H	OH	OH



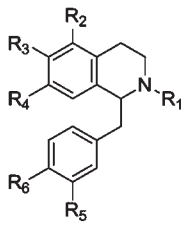
	R_1	R_2	R_3	R_4
97	OH	OMe	OH	OMe
98	OH	OMe	OMe	OMe



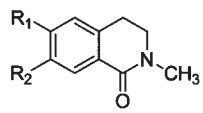
	R_1	R_2	R_3	R_4	R_5	R_6
100	OMe	OMe	H	OMe	OH	H
103	OH	OMe	OMe	OMe	H	H
104	OMe	OH	H	OMe	OH	H
105	OMe	OH	H	H	OMe	OH
108	OH	OMe	H	H	OMe	OH



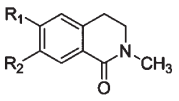
107



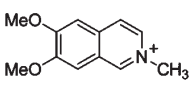
	R_1	R_2	R_3	R_4	R_5	R_6
109	Me	H	OMe	OMe	H	OMe
111	H	OH	OMe	OMe	H	OMe
120	H	-OCH_2O-		OMe	H	OMe



	R_1	R_2
110	OMe	OMe
114	OMe	OH



	R_1	R_2
110	OMe	OMe
114	OMe	OH



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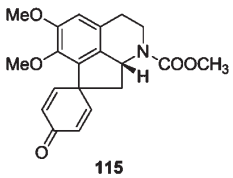

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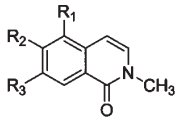
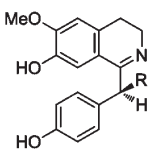
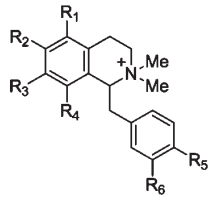


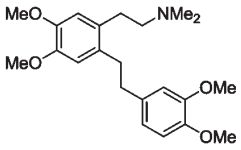
	R_1	R_2	R_3
112	H	OMe	OMe
118	OMe	OH	OMe



	R
116	OH
117	OMe



	R_1	R_2	R_3	R_4	R_5	R_6
121	H	OH	OMe	H	OH	H
122	OMe	OMe	OMe	H	OMe	H



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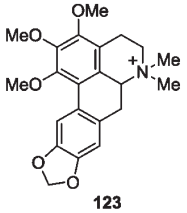

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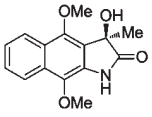

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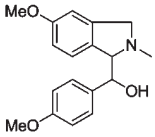

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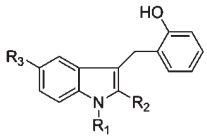
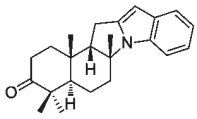


R_1	R_2	R_3



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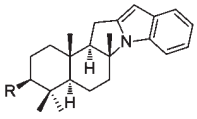
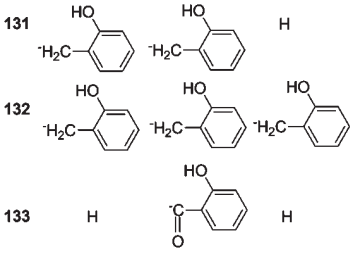
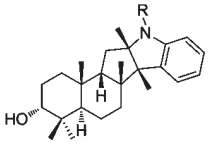


R

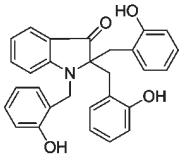


131	H
132	
133	H



	R
129	$COCH_3$
130	H

127	=O
128	CH_3COO



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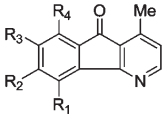
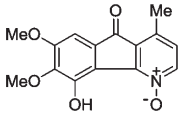


	R_1	R_2	R_3	R_4
135	H	OMe	OMe	H
136	H	OMe	OH	H
137	H	H	H	H
138	H	H	OMe	H
139	OMe	OH	H	H
141	OH	OMe	H	OH
142	OH	OMe	H	H



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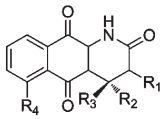
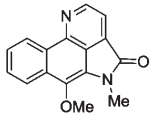


	R_1	R_2	R_3	R_4
143	α-OH	H	Me	OH
144	α-OH	Me	H	H
146	β-OH	H	Me	H



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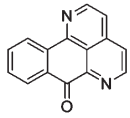

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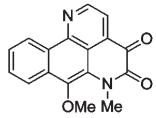

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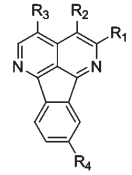
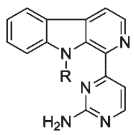
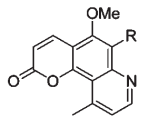


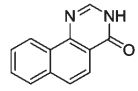
	R_1	R_2	R_3	R_4
151	H	H	OMe	OMe
152	OMe	OH	H	H
153	H	H	H	H



	R
154	OH
155	H



	R
156	OMe
157	OH



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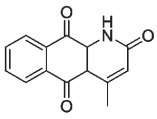

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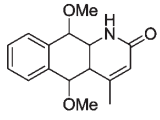

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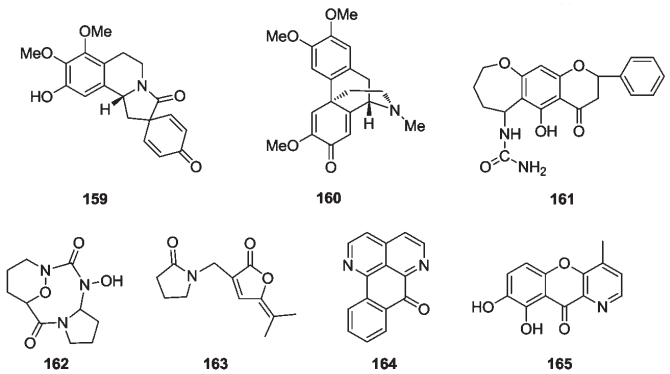

图 1 番荔枝科生物碱结构

Fig. 1 Structures of alkaloids from Annonaceae family

2 生物碱类化合物的生物活性

2.1 抗肿瘤活性

研究发现：阿朴啡类生物碱(-)-nordicentrine[17]、Pseuduvarine A[24]、Pseuduvarine B[24]、*O*-Methylmoschatoline[30]和 Desmorostratine[35]对 KB、NCI-H187、MCF-7、HepG2 和 HL-60 等肿瘤细胞系表现出良好的细胞毒活性。从澄光花属植物 *O. enterocarpa* 中得到的马兜铃内酰胺类生物碱 Enterocarpam-III 和 stigmalactam[26]对 HCT15 具有显著的细胞毒活性；而从皂帽花属植物 *D. blumei* 中得到的该类生物碱 3,5-dihydroxy-2,4-dimethoxyaristolactam[44]对 P-388、KB 和 ASK 三种肿瘤细胞系具有较好细胞毒活性。另外，氮杂蒽醌类生物碱 Laoticuzanone A[57]对 KB 和 HeLa 肿瘤细胞系也具有明显的细胞毒活性。此外，顾正兵等人[64]从云南西双版纳产的景洪哥纳香中分离得到一个新型生物碱 Cheliensisine，其结构中含一被取代的尿素基团，在植物中极为少见，经体外测试，显示有一定的抗肿瘤活性；从鹰爪花中分离得到的 α,β-丁烯酸内酯类生物碱 Uncinine[31]对 Hep G2 和 Hep 2,2,15 显示了显著的细胞毒活性。蒙蒿子属植物 *A. dolichocarpa* 中的氮杂菲类生物碱 Eupolauramine 和 Sampangine[32]对 K562 细胞具有良好的细胞毒活性，并呈现剂量依赖性，IC_{50}分别为 18.97 和 10.95 μg/mL。

2.2 抗寄生虫活性

据报道：从番荔枝属植物 *A. foetida*[11]中分离分离到的嘧啶类生物碱 Annomontine、*N*-hydroxyannomontine 和阿朴啡类生物碱 *O*-methylmoschatoline、Liriodenine 具有抗利什曼虫活性。从假鹰爪属植物 *D. rostrata*[35]分离到的小檗碱类生物碱 Discretine *N*-oxide、Discretine、Dehydrodiscretine、从银钩花属植物 *M. diversifolia*[56]中分离得到的氮杂芴酮类生物碱 5-hydroxy-6-methoxyonychine、从暗罗属植物 *P. debilis*[15]中发现的双阿朴啡类生物碱 Bis-7,7′-dehydro-8,8′-dimethoxyanonaine 和 Bis-7,7′-dehydro-10,10′-dimethoxyanonaine 具有显著抗疟原虫活性。此外，从暗罗属另一植物 *P. suaveolens*[50]中分离得到的吲哚类生物碱 Polysin 对布什锥虫的磷酸果糖酶具有竞争性可逆抑制作用，其他同类物 Greenwayodendrin-3-one、3-*O*-acetyl greenwayodendrin、N-acetyl polyveoline 和 polyveoline 则显示出选择性抑制布什锥虫某些糖解酶的活性。

2.3 抗炎活性

胡立宏等人[22]研究发现：瓜馥木属植物 *F. oldhamii* 中的阿朴啡类生物碱 Oxodiscoguattine、Oxocalycinine、Calycinine 和马兜铃内酰胺类生物碱 Aristolactam F II 具有良好的抑制刀豆球蛋白诱导的 T 淋巴细胞和脂多糖诱导的 B 淋巴细胞的增殖活性。而从该植物中分离得到的另外两个马兜铃内酰胺类生物碱 Aristololactam GI 和 Aristololactam GII[23]则具有显著抑制脂多糖诱导的小鼠巨噬细胞 RAW264.7 释放 IL-6 和 TNF-α 的活性。

2.4 抗血小板聚集活性

研究发现，阿朴啡类生物碱 7-hydroxy-dehydrothalicsimidine[7]、Thalicsimidine[7]、Norpurpureine[7]、Lirinidine[7]、N-methylasimilobine[7]、Oxopurpureine[10]、Oxonuciferine[10]、Oxoglaucine[10]、(+)-predicentrine[10]、Thalbaicalidine[10]、Thalicpureine[10]、Dehydrolirinidine[10]和 7-hydroxy-dehydroglaucine[10]可显著抑制由胶原蛋白和花生四烯酸引起的血小板聚集；其中，7-hydroxy-dehydrothalicsimi-

dine[7]、Thalicsimidine[7]、Norpurpureine[7]、Lirinidine[7] N-methylasimilobine[7]、Thalicpureine[10] 和 Dehydrolirinidine[10]还可抑制由血小板活化因子和凝血酶引起的血小板聚集。

2.5　其他活性

从白背瓜馥木(*F. glaucescens*)[43]中分离得到的原小檗碱类生物碱(-)-discretamine 具有非竞争性抑制血管的 α-肾上腺素受体和 5-HT 受体作用。而独山瓜馥木(*F. cavaleriei*)[49]中吲哚类生物碱(5-methoxy-2-methylisoindolin-1-yl)(4-methoxyphenyl)methanol 可显著抑制血管新生,有望开发为抗肿瘤制剂。另外,从 *Annona squamosa*[67]中得到的三个生物碱 Lanuginosine 、(+)-O-methylarmepavine 和 N-methyl-6,7 dimethoxyisoquinolone 显示剂量依赖性免疫刺激活性;其中 N-methyl-6,7dimethoxy-isoquinolone 在 0.3 mg/kg 口服剂量下活性最高,可显著促进 BALB/c 模型鼠脾 T 细胞和 B 细胞增殖,上调 $CD4^+$、$CD8^+$、$CD19^+$细胞因子。

3　小结

生物碱作为天然产物中活性较好的一大类成分,一直以来都是国内外学者研究的热点领域。番荔枝科植物资源丰富,生物量可观,其中存在的生物碱,不仅结构类型多样,而且活性也很广泛。随着分离技术不断提高及药理研究的继续深入,无论从经典化合物的活性再评价,还是新化合物的发现及活性探讨等方面,番荔枝科植物都值得我们进一步的开发和研究。

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